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Growth and Development of Children in Human Isolates

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I. PREFACE

Studies on growth and development of children occupy a considerable part of the contents of journals devoted to human biology. The ontogeny of man has been, figuratively speaking, minutely examined under a magnifying glass. Thus thousands of articles have appeared in print, covering various aspects of the subject, from the standpoint of genetic-environmental influences, such as ethnic origin, racial intermixing, family structure, population structure, diseases, twins, child-parent relationships, sex, age, social origin, psychological state, economic status, nutrition, society, migration, urbanization, climate, topography, geography and numerous other factors. The methodology of evaluating human ontogeny has improved over time, and so also have the statistical tools which assess the effects of various genetic-environmental factors on the growth process.

And yet, one aspect of the subject seems to have been overlooked, namely, the connection between the genetic structure of the population and development of the child. It is indeed a fact that the four major tomes in the field, which comprise landmarks in the study of human development and which summarize most of the publications on growth, namely, the books by Tanner (1962), Eveleth and Tanner (1976), Johnston et al. (1980), and Faulkner and Tanner (1986) make no mention whatsoever of this topic, which would seem to testify either to the difficulty of undertaking such a study and/or a lack of suitable investigational models at the time.

In the present study, we shall concentrate on two central aspects of inbreeding, namely: (a) methods used by anthropologists and biologists to measure the degree of inbreeding; and (b) the possible consequences of inbreeding in a population on child growth.

First, however, a fairly extensive review of the relevant literature will be presented.

Structure of the population from a genetic standpoint

Broadly defined, population structure deals with the relationships between the gene and the frequency of the genotype in particular populations (Relethford, 1980). Such relationships are reflections of the social structure with its multifarious aspects (e.g. economy, religion, etc.) and each deviation from the panmixia is a side-effect of these social aspects. Various models have here been designed to describe populations, as indicated below.

(1) The Genealogical model was developed by Wright (1921) and pertains to intermarriage of relatives either by chance inbreeding (for example in cases of small populations), or by non-random inbreeding (endogamy and the like). This model is known as a "Path Coefficient" and its main measure is the Inbreeding Coefficient F. The larger the value of F, the smaller the frequency of heterozygotes and the higher the frequency of homozygotes in the population. A Hardy-Weinberg equilibrium in a population is attained only when F=0.

(2) The Partitioned model, developed by Wahlund (1928), demonstrates that division of a population into sub-populations which randomly interbreed will itself lead to a deviation from the genotypic relationship of Hardy-Weinberg in the total population. This phenomenon, usually designated the "Wahlund Effect", is tantamount to inbreeding within the sub-populations. Wahlund demonstrated that the increase in homozygotes owing to sub-division of a population is on the order of the variance of the gene frequency within the subdivisions.

(3) The Hierarchical model, also developed by Wright (1943, 1965, 1973), attempts a merging of the two aforementioned models in order to incorporate various hypothetical situations in populations, such as non-random inbreeding in large populations, random inbreeding in sub-populations with mating by chance, and further secondary division of a population into randomly inbreeding sub-populations. Thus a more generalized model would encompass most accountable hypothetical situations beyond the two mentioned. The hierarchical model is characterized by a series of parameters known as "Wright's F-statistics", and assumes that a number of sub-populations may interlink by a branching process and that the interrelations between such sub-populations are historical. In other words, the implication is that all sub-populations derive from a common founding population.

(4) The Spatial model (Yasuda and Morton, 1967) is a conglomerate of models intended to provide answers to questions left unresolved by the other models. It is called "spatial" because the model depends on geographic isolation, albeit other factors which lead to isolation cannot be excluded (e.g. religious and social customs, social class, etc.). The most familiar models in this spatial

conglomerate are: a) Wright's "island" model; b) "Isolation by distance" model; and c) "Migration matrix" model(s). The first two were proposed by Wright (1943, 1951, 1965), the third by Cannings and Cavalli-Sforza (1973). Wright's models have undergone various expansions which need not be dealt with here.

Factors which seem to us highly significant in influencing the genetic structure of the population being studied are: (1) the effective population size, and (2) the manner in which mating partners are selected, the so-called Mating Types. Both of these factors can be measured by the genetic variability in the population. As already mentioned, it was Wright who coined the concept of F as the Coefficient of Inbreeding, defining it as the probability that two alleles at each given locus of an individual will be identical owing to a provenance from a common ancient ancestor. In a population of a finite size, even if the choice of a mate is random, the increase of homozygotes will be noticeable.

In the absence of migration and mutation in a population, genetic drift will lead to an increased number of homozygous individuals in an increasing number of loci, more than would be found in a large, randomly inbreeding population. Inter alia, this will result in recessive traits showing up more frequently, and in retardation of growth and diminution in body size with inbreeding.

Inbreeding and morphometric traits in man

The connection between inbreeding and morphometric traits is one of the biological problems that is still unclear. Prominent among the first to collect data on the depressive effect of inbreeding on growth were Neel and his co-workers (1949), Sutter and Tabah (1952) and Sutter (1958). Neel et al. studied for many years the impact of the atomic bombing of Hiroshima and Nagasaki on the Japanese people, delving concurrently into basic problems of that society, e.g. intermarriage and inbreeding level, and their effect on various biological variables. The first pertinent article on the subject was by Neel et al. (1949). Subsequently Morton (1955) investigated the effect of inbreeding on the weight of neonates; he found that a 10% increase in inbreeding resulted in an average drop of 43 grams in weight of the newborn. In a later study, Morton (1958) examined possible links between inbreeding and the duration of the gestation period, as well as the influence of inbreeding on bodily stature, body weight and chest circumference in the same Japanese children at birth and at 8-10 months of age. He found that inbreeding had no effect on length of gestation or head circumference, but that it did significantly decrease newborn body weight (120 gm/10% F) and newborn body length (2.8 mm/10% F).

In 1960 appeared the book by Falconer on quantitative genetics in which there is an attempt to build a model depicting the connection between inbreeding and body size. Falconer's working formula is based on expressing in percent the ratio 10 bF/outbred mean, which designates the extent of change in the mean value of a certain variable upon 10% increase in the coefficient of inbreeding. The term bF is a component of the vector of the regression coefficient of those measurements which typify the growth process on the inbreeding coefficient, i.e., bF is the regression coefficient on F of such measures as weight, stature, etc. Attempts of Falconer to apply his model to laboratory animals, and attempts of other investigators to apply the model to human populations (e.g. Schork, 1964) have yielded only partial agreement. As Schork (1964, p.298) points out:

> *Concerning the growth data, these results indicate that a 10% increase in inbreeding would decrease weight only by about 1% and head and chest girths would be changed even less.*

Most papers that have appeared in the 1960's (Slatis and Hoene, 1961; Barrai et al., 1964; Schork, 1964; Schull and Neel, 1965) have propounded that the mean weight at birth of neonates to parents who are first cousins, is lower, albeit not significantly,than the mean weight of neonates of non-related parents. Schork (1964) pointed out that his findings, based on 230 Japanese children from consanguineous marriages (part of a large sample of 2314 children), supported the conclusions of Morton (1955) in manifesting a suppressive effect of inbreeding on rate of growth, which was taken as the difference in measures at birth and 9 months later, in body weight, head circumference, and chest circumference. It should be emphasized, however, that Schork's (1964) results were not statistically significant. Indeed he sums up his findings in the following words:

> *Although statistically significant results were not obtained in considering inbreeding effects for the growth variables investigated, this is not to be considered as indicating that the effects of inbreeding on growth are nonexistent. While the results show that inbreeding does not greatly affect these growth measures, there is a consistent pattern of retardation in growth and diminution in size in the inbred group* (p.298).

Schork's conclusions may have been influenced by the studies of his colleague Komai (1963) who carried out a parallel investigation on elementary school children in Japan. Komai did report a small, and statistically significant, suppressive effect of inbreeding on morphometric variables such as stature, weight, shoulder breadth, chest circumference, etc.

Another study, by Barrai et al. (1964), unlike those previously mentioned which were all on young children, was carried out on a population of adolescents in Northern Italy. The sample involved 35,000 individuals of which 1556 were from provenances in which inbreeding was known to be prevalent. This study examined the influence of inbreeding on only two features, namely, stature and chest circumference. A suppressive effect of inbreeding was found only in chest circumference.

The study of the two American geneticists Schull and Neel (1965) on Japanese populations, perhaps more than any other, has made its imprint on the connection between inbreeding and morphometric traits, as well as the association between inbreeding and psychotechnic, psychological and some other traits which are outside the scope of the present study. They showed a generally small (ca. 0.5%) but significant suppressive effect of inbreeding on bodily dimensions (10 anthropometric traits). To quote Schull and Neel:

> *Though statistically significant and undoubtedly real, the effect is modest, and amounts, on the average, to a depression of less than 2% of the outbred mean per 10% inbreeding* (p.210-211).

Numerous subsequent studies by these authors and their collaborators became offshoots of the aforementioned pioneering research.

Of interest also is that Schull and Neel's findings indicated that the influence of inbreeding is generally greater for the behavioral than for the body size variables. We also learn from their study that investigations suggesting a possible influence of inbreeding on growth and development were initially actually undertaken by Japanese workers in the mid-fifties who reported a clear tendency for diminution of body dimensions as a result of inbreeding (Ichiba, 1953, 1954; Shiroyama, 1953).

In brief, there is general agreement as to the effects of inbreeding on morphometric traits, although the extent of the impact is still debated. Thus Hulse (1958) reported a significant effect of endogamy on body weight and stature, the offspring of exogamous marriages being on average taller by about 2 cm than the offspring of endogamous marriages. This study was carried out on a rural population in Switzerland. Hulse defined endogamy as marriage between individuals of the same village and exogamy as one between individuals from different villages. Steinberg (1963) likewise reported a significant `inbred' depression of about 60 mm/10% F in stature among males of the Hutterite group in the USA and Canada. Mange (1963), in his doctoral dissertation, considered the various effects of inbreeding on stature and weight. For stature Mange reported:

> *Thus a male whose parents were first cousins (F'_0=62 X 10^{-3})* is expected to be (0.014)(62)=0.9 inch shorter than a male whose parents were not related (F'_0=0). A female so inbred would be expected to be 1.9 inches shorter. The genetic mechanism by which this effect occurs might be in the*

corresponding increase in homozygosity which accompanies inbreeding (p.54).

For body weight Mange also observed that:

> *With no apparent explanation, at all, is the highly significant effect of the inbreeding coefficient of the father on the weight of both males and females. This effect amounts to -0.24 pound per unit of F'f on sons' weights, and -0.23 pounds per unit of F'f on daughters' weights* (pp.55-57).

In a subsequent summarizing article, Mange (1964) claims that the findings of Schull (1962) on 151 Japanese children from Hiroshima and Nagasaki, albeit not statistically significant, nevertheless show a distinct tendency towards an inverse correlation between inbreeding and morphometric traits. He also restated his findings of the previous year, perhaps more effectively, to wit:

> *The multiple regression analysis, by sex, of height on the inbreeding levels of an individual, his mother, and his father indicated that a first cousin marriage, say, would produce sons who were, on the average, about two cm shorter than non-inbred males; daughters from first cousin marriage would be about five cm shorter than non-inbred females* (p.131).

By the end of the 1960's, another comprehensive study in this field made its appearance, that of Krieger (1966, 1969), whose findings were based on a sample of 3465 children from Northern Brazil. In Krieger's investigation, unlike that of Mange, the effect of inbreeding on body height and weight was not statistically significant. According to Krieger, the inbreeding depression is very tightly linked with dominance, hence, for additive loci, no inbred effect can be detected with regard to the mean phenotypic value (Krieger, 1966, p.2). This would explain the fact that for a trait such as stature, no depressive effect of inbreeding was detected. As for body weight, Krieger (1966, p.27) argues that the environment has a central role in its definition and that the available investigative methods are incapable of isolating and separately assessing the effect of inbreeding on it.

According to Krieger, the statistically significant results obtained by Mange (1964) on the depressive effect of inbreeding stemmed from the fact that Mange incorrectly assumed an identical environment for consanguineous families but not for non-consanguineous families. In the same context of environmental effects, Krieger also refutes the statistically significant results obtained by Hulse (1958).

The beginning of the 1970's marked the appearance of a new series of articles, some supporting and some refuting in one way or another the correlation between inbreeding and morphometric traits. An interesting study in this series was that of Wolanski et al. (1970) which examined the influence of internal migration of Polish populations on the development of their children in the post-WWII era. One of the pertinent findings of this study was that a definite increase in stature occurred in children, with increased distance between birthplace of their parents. Wolanski and associates reasoned that this finding was not linked to the bodily metric traits of the parents, nor to variables such as father's or mother's age or the differences between these ages, nor to economic or social factors, but rather to inbreeding.

The same year also marked the appearance of an article by Neel et al. (1970) on the Japanese child population of Hirado Island, among whom the inbreeding effect seemed negligible:

There were no significant effects from consanguinity or inbreeding (p.286).

The ongoing "controversy" regarding effects of inbreeding on morphometric traits is summarized in a paper by Martin et al. (1973). Here we read that:

Results of various human population studies to date have indicated small effects, if any, of inbreeding, and conflicting estimates of the strength of the genetic component in continuous traits. This may reflect the true estimation or may reflect deficiencies in the type of data available (p.581).

The study of Martin and his associates dealt with S-leut populations in the USA and Canada, and as noted above, they stress the inability to define precisely the F-range, especially because of the paucity of information on the early ancestry of the investigated social unit. Yet their results, at least for some of the S-leut groups, were positive. They affirmed that:

In general the effect of inbreeding on S-leut anthropometric measurements involves a decrease in skeletal measurements and an increase in fatty measurements (p.590-591).

Indeed the authors seem to cast doubt on the significance of their own findings, remarking that:

Many small but significant changes were found with F, but the biological meaning of these is debatable (p.592).

In the mid-1970's and there after, this topic of the relationship between inbreeding and morphological traits seemed largely to disappear from the literature, albeit an occasional paper appeared, pointing, for example, to a correlation between inbreeding and blood pressure, blood pulse and hematocrit (e.g. Barbosa and Krieger, 1979), but none dealt directly with the subject of an association between inbreeding and morphometric traits.

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*F'_0 = Inbreeding coefficient for the offspring based on pedigree which generally had no ancestry omission back to the second cousin generation.

The Present Study

A primary goal of the present study, as previously indicated, was to evaluate the influence of inbreeding, as well as other possible factors, on the physical development of children within the Bedouin society. Hence the present study comprises the following main components:

a) The first part conveys information on the genetic structure of a Bedouin tribe, expressed mainly as the probabilities of kinds of mating of individuals within the population. The stochastic process here is a derivative of the cultural structure into terms and numbers pertaining to effective size of the population, frequency and nature of consanguineous marriages, sex ratio and age structure, social and geographic isolation, etc. Four main topics are considered, as indicated below.

The first deals with the history of the Bedouin tribes. On the basis of archaeological evidence, we delve into the geographic and ethnic origins of the various Bedouin tribes in South Sinai, and attempt to determine who were their founders, and from whence they arrived. Herein the possibility of a Founder effect is also evaluated.

The second main topic examines various cultural aspects and deals extensively with the tribal infrastructure and social components of which it is comprised. Mating patterns and rates of migration are here emphasized, and the definition and the significance of kinship are considered.

The third topic is related to the demography. Information is provided on patterns of mortality and fecundity, sex ratio, family size, tribe size, polygamy and other variables. The demographic evolution of the Bedouin tribes over time is considered.

The fourth and final topic is a summary of what seem to us the factors liable to influence the genetic structure of the Bedouin population. Here we define the infrastructures of the Bedouin tribes with respect to nuclear biological unit, the social unit within which most marriages take place (i.e., the sub-tribe, tribe, or conglomerate of several tribes). For each of the social units we also compute the corresponding F value.

b) The second part of our study considers, first, the growth-development of Bedouin boys vis-à-vis other comparable child populations. We present data also on the differences in child development within social sub-units of the same tribe. Here we also relate various factors which may be responsible for morphologic variability, e.g. topographical environment, (elevation), diet, ethnic origin, inbreeding.

c) The third and final part of the study explores the feasibility of a tribal morphologic identity and the main morphometric variables which could characterize such. In addition, attention is devoted to the relationship between the historical and biological evidence presented in the present study.

The present study is of the cross-sectional type. A longitudinal study of growth in the children was not feasible because of:

a) frequent movements or migrations of families in South Sinai; and

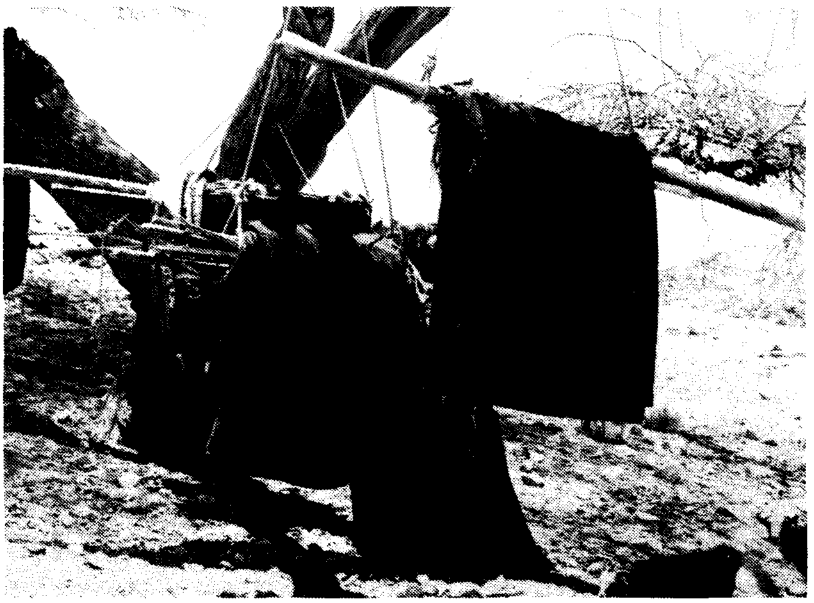
b) the political instability of the region, and hence, uncertainty as to time available for our study.

We believe that even a cross-sectional study of growth and development is perforce closely linked to biological, cultural and economic considerations.

Bedouin camps where children were examined

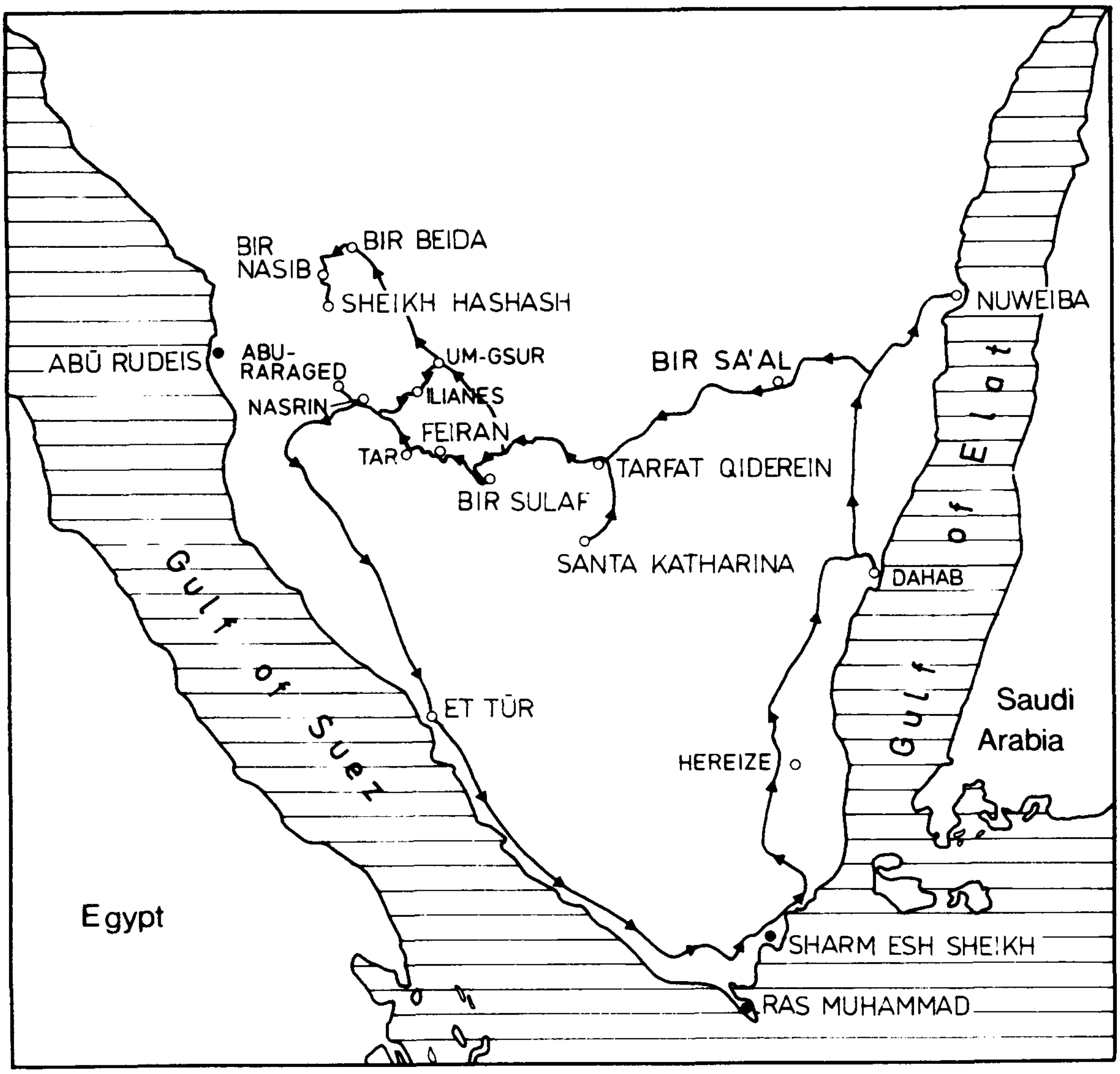
Measurements took place at 17 sites within the territorial limits of each of the following South Sinai tribes (see Fig. 1): Gebeliya tribe at Santa Katharina, Tarfat Qiderein, and Feiran; Gararsha tribe at Um-Gsur, Ilianes and Feiran; Aleigat tribe at Bir-Beida; the Hamada tribe at Bir-Nasib and Sheik Hashash; Haweitat tribe at Wadi Tar; Sawalcha tribe - Abu-Raraged and Nasrin; Ahali Et-Tur and Beni-Wassal tribes at Et-Tur and El-Wadi; Muzeina tribe at Hereize, Dahab, Nuweiba and Bir Sa'al; Awlad Said tribe at Bir Sulaf.

Each station was visited three times in the course of the study at intervals of approximately every half-year, from 1978-1980.



Winter tents hanged on the *Acacia* tree

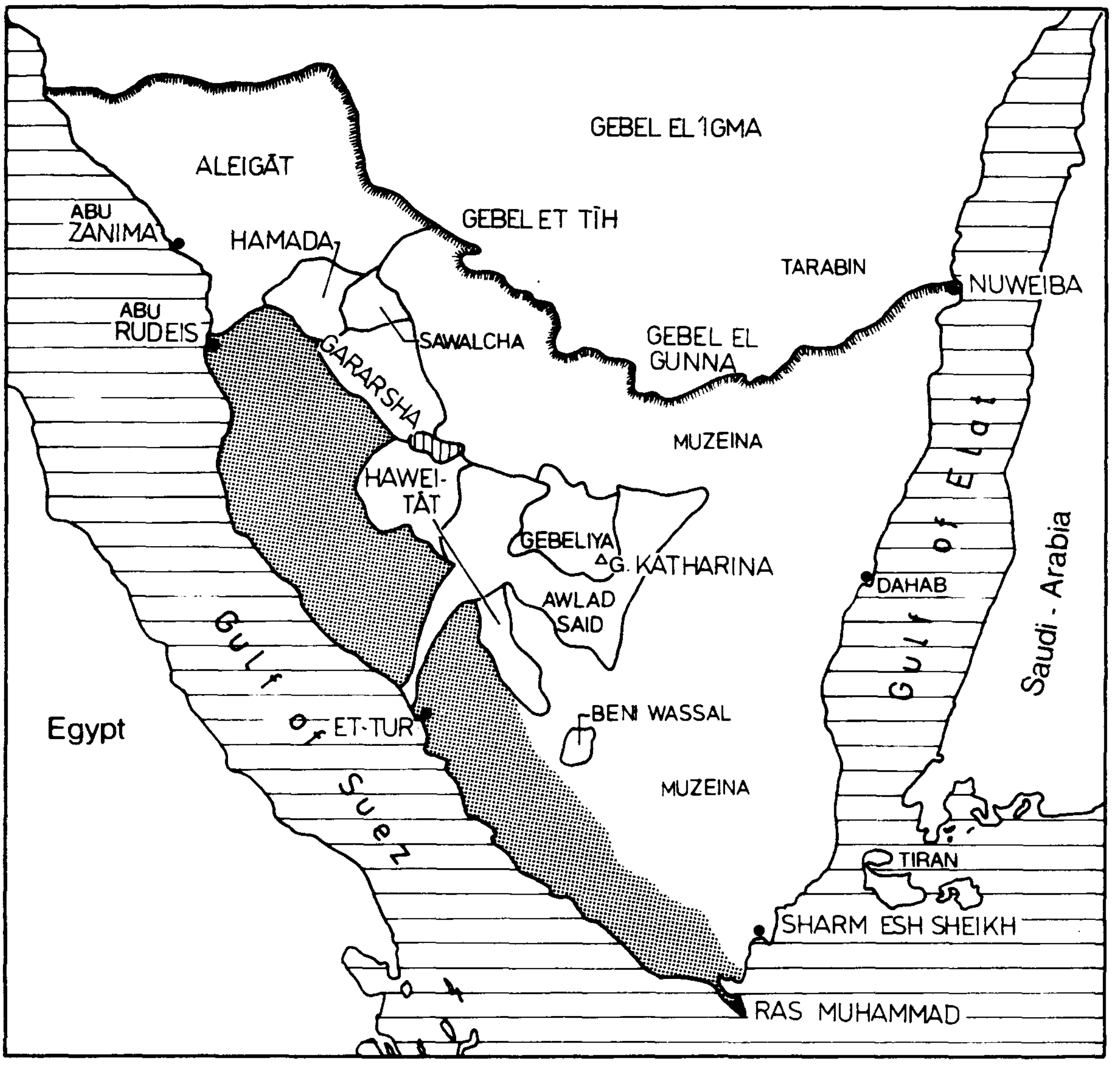
FIGURE 1: Population Centers in South Sinai Where Children Were Examined



II.THE POPULATION EXAMINED

Throughout the South Sinai peninsula are scattered 10 Bedouin tribes (Fig. 2), a total of about 10,500 individuals . Three of these tribes not dealt with here either because their numbers were very small (Beni-Wassal and Ahali Et-Tur) or because they were a small fraction of a much larger tribe inhabiting the central part of the Sinai (Tarabin). The seven major tribes of the region are united under a single administrative body known as "Towara".

FIGURE 2: Territorial Distribution of the Bedouin Tribes in South Sinai



Stippled area - demarcates the most arid zone in the Sinai, not claimed by any tribe.

Most of the tribes originally came from the Arabian peninsula, although a few are linked traditionally to Egypt and North Africa, and one derives partly from the southeastern part of the European continent. All the Bedouins of South Sinai are Moslem and make a living primarily from labor outside their territorial base in industrial areas in Israel and Egypt, as well as from raising sheep and camels, fishing, smuggling, and engaging in a primitive type of agriculture.

The main features of the Bedouins in South Sinai are:

(a) Isolation. Topographic barriers, such as the Tih escarpment in the north, the Gulf of Elat in the east, the Gulf of Suez in the west, and the Red Sea in the south, coupled with efforts of the tribes themselves to retain their cultural uniqueness, have ensured virtual biological isolation of the tribes from the surrounding societies.

(b) Mating Patterns. Consanguineous marriages, especially between first cousins are preferred within the Bedouin population of South Sinai. Thus in decreasing order of preference in selection of a mate is the extended family (first cousins) or Hams (blood feud group), clan, or blocks of extended families (social units among Bedouins which have no precise anthropological term; among settled Arabs they are known as "khamulas"), sub-tribe and tribe.

Marriages outside the tribal frame are very limited, as will be noted subsequently.

(c) Uniform Environment. The Bedouin residents of South Sinai live in an environment which is uniform in many respects, to wit: an arid climate; an economy primarily based on "outside" labor and traditional occupations, as noted earlier; education which comprises, at best, two or three years of elementary schooling; health care which includes medical services provided from 1967 to 1982 by the Israeli civil administration, prior to which there was reliance only on traditional tribal medical practices.

The Bedouin population in South Sinai lacks any social or religious stratification, thus being largely egalitarian.

(d) Population Size. Most of the tribes in South Sinai number between 500 and 1000 members, thus comprising relatively small social groups. Prior to the Israeli presence in 1967, the various tribal infrastructures tended to be even smaller, being delimited largely by the nature and "carrying capacity" of the area. Improvement in socioeconomic conditions and health status generally after 1967 led to increases in population size.

(e) Political Instability. In the first half of the present century the area of South Sinai passed through many conquests - by Turks, British, Egyptians, Israelis, Egyptians again, Israelis again, and most recently Egyptians for the third time. The penultimate shift of power to Israeli jurisdiction, commencing in 1967, brought about large changes in the social, medical, economic and cultural infrastructures of the Bedouins. This latter upheaval had a direct as well as an indirect bearing on the lives of the Bedouins, initiating a shift to better living standards heretofore not known to them. In many respects the new standards reshaped Bedouin ways of living, thinking, and working (see Marx, 1974, 1984; Pervolotzky and Pervolotzky, 1979).

(f) Tribal Population. The Bedouin individual is born into a certain tribal framework to which he remains firmly linked throughout his/her life. This framework or infrastructure, albeit devoid of military, judicial, or any other official or authoritarian backing, does provide for the personal, economic and legal safety of its members. The individual member, in turn, bears a responsibility towards his/her group, based on an `honor system' rather than on any codified or organized set of rules.

The number of boys examined in the present study, by tribal group and age, is given in Table 1.

TABLE 1 Number of South Sinai Bedouin boys examined, by tribal group*, and total number of boys, by age.

Tribe	No. of boys examined	Age	Total no. of boys examined
Gebeliya	72	4	10
Sawalcha	12	5	43
Hamada	27	6	105
Aleigat	39	7	103
Beni-Wassal	6	8	76
Muzeina	267	9	41
Haweitat	31	10	40
Gararsha	73	11	48
Awlad Said	26	12	46
Tarabin**	10	13	51
Total	563	Total	563

* The Ahali et-Tur tribe is not presented, but is included in the description of history of south Sinai bedouin tribes.

** Most of the tribe is located in the central and northern parts of Sinai.

Tests And/Or Examinations

Measurements (1-9) taken by anthropometer, unless otherwise specified, were:

1) Stature: The vertical distance from the horizontal standing plane to vertex. The examinee stands with heels together, body erect and head facing to the

front in the Frankfurt plane. The measuring instrument is against the body of the examinee, with the horizontal arm of the instrument resting against the head.

(2) Suprasternal height: The vertical distance from the horizontal standing plane to the lowest point in the suprasternal notch.

(3) Iliospinal anterior height: The vertical distance from the horizontal standing plane to the most projecting median point of the upper anterior iliospinal level.

(4) Tibial height: The vertical distance from the horizontal standing plane to the inner top of the tibial condyle.

(5) Acromial height: The vertical distance from the horizontal standing plane to the low end of the outermost extremity of the acromion process.

(6) Radial height: The vertical distance from the horizontal standing plane to the outer upper limit of the radial bone.

(7) Styloradial height: The vertical distance from the horizontal standing plane to the lower external limit of the radial bone. (8) Dactylion height: The vertical distance from the horizontal standing plane to the bottom end of the dactylion.

(9) Sitting height (1) The distance from the horizontal sitting plane to the top of the head. The examinee sits on a bench, body erect. Head is in the Frankfurt plane. The anthropometer is held vertically and in contact with the back [see trait "32" - sitting height(2).

(10) Foot breadth: Measure of the widest part of the foot. Measurement made by sliding caliper.

(11) Foot length: The distance between the heel and the tip of the longest toe. Measurement made by sliding caliper.

(12) Head length: Maximum length, in the sagittal plane: glabella-occipital diameter of the vault. Measurement made by spreading caliper.

(13) Head breadth: Maximum breadth. Measurement made by spreading caliper.

(14) Bizygomatic breadth: The maximal distance between zygomatic arches. Measurement made by spreading caliper.

(15) Bigonial breadth: The maximal distance between the external aspects of the angles of the mandible. Measurement made by spreading caliper.

(16) Total facial height (nasion-gnathion): The distance from the center of the nasal root to the underside tip of the chin. Mouth must be kept closed in normal occlusion. Measurement made by sliding caliper.

(17) Upper arm skinfold: A skinfold is taken in the median back part of the arm in a straight line with the elbow. The fold must be vertical. Measurement

made by special spreading caliper of a constant pressure (Lange skinfold caliper).

(18) Subscapular skinfold: The skinfold is lifted from underneath the angle of the scapula. The fold must be vertical. Measurement made by special spreading caliper of a constant pressure (Lange skinfold caliper).

(19) Biacromial breadth: The distance between the external edges of the acromial process. Measurement made by spreading caliper.

(20) Biiliac breadth: The distance between the most prominent median points of the frontal upper projections of the ilium. Measurement made by spreading caliper.

(21) Chest circumference: The horizontal girth of the chest at the end of a normal expiration. Measurement taken at the height of the nipples at right angle to body axis. Measurement made by measuring tape.

(22) Body weight: Boy is clad in shorts only.

(23) Grip strength of left hand: Examinee grabs the measuring instrument (Jamar adjustable dynamometer; Asimow Engineering Company) with left hand and presses as strongly as he can. The pressure must be continuous. Examinee is allowed two attempts, of which the highest reading is taken into account. During the gripping action the free hand is held behind the body.

(24) Grip strength of right hand: As described for left hand.

Derived measurements

(25) Total arm length: The difference between the acromial height (5) and the dactylion height (8).

(26) Upper body height: The difference between the stature (1) and the suprasternal height (2).

(27) Upper leg length: The difference between the iliospinal anterior height (3) and the tibial height (4).

(28) Upper arm length: The difference between the acromial height (5) and the radial height (6).

(29) Lower arm length: The difference between the radial height (6) and the styloradial height (7).

(30) Hand length: The difference between the styloradial height (7) and the dactylion height (8).

(31) Trunk length: The difference between the suprasternal height (2) and the iliospinal anterior height (3).

(32) Sitting height (2): The difference between the stature (1) and the iliospinal anterior height (3). Attention should be drawn to the difference between this variable and the similar-sounding, but directly measured sitting height.

Indices

(33) The ratio of weight to stature cubed: weight(gr)x100 /stature(cm)^3

(34) The ratio of weight to stature squared: weight(kg)x100 /stature(cm)^2

(35) The ratio of total upper arm length to stature:
total upper arm length(cm) x 100/stature(cm)

(36) The ratio of sitting height to stature: Sitting height(cm)x100/ stature(cm)

(37) The ratio of foot breadth to foot length:
foot breadth(cm)x100/ foot length(cm)

(38) The ratio of head breadth to head length:
head breadth(cm)/head length(cm) x 100

(39) The ratio of body breadth at shoulder level to the body height:
biacromial breadth(cm)x100/height(cm)

(40) The ratio of body breadth at waist level to stature:
biiliac breadth (cm)x100/stature (cm)

(41) The ratio of chest circumference to stature:
chest circumference (cm)x100/stature (cm)

(42) The ratio of weight to stature: weight(kg)x100/stature(cm)

Other

(43) Body surface area: 0.425 weight(kg) x 0.725 height(cm) x 71.84 (After Harisson et al. 1977)

(44) The ratio of body surface area to weight: body surface area(cm)/weight(kg)

(45) The ratio of weight to body surface area: weight(kg)/body surface area(cm)

(46) Energy intake per defined activity*: KJ = 0.047 x weight(kg) + 1.02

Measurements, usually taken in a vacant classroom or a clinic room, were made solely by a member of the anthropological team. Each measurer was assisted by a colleague who recorded the results. Measurements were taken on the left side and in the morning hours. Before measuring, a questionnaire was filled out for each child. Questions included vital statistics (immediately confirmed by the teacher or a local person familiar with the data needed). Special emphasis was given to the study of the genealogy of the examinee, given by his parents or one of his relatives. On completion of the measuring, each child was palmprinted and fingerprinted (Kobyliansky et al 1983,1986), then asked to provide saliva samples (Kobyliansky et al 1983); finally a gypsum imprinting of his dentition was taken (Raviv 1986, Menula 1986, Rubin 1987, Hershkovitz et al 1992, 1993, Ben David-Kobyliansky 1992)..

Demographic Questionnaire

The demographic data here presented have been collected largely by our own research team. Pertinent data from other studies, however, have also been included. The latter are from Muhsam (1966), Publication of the Central Bureau of Statistics, 1980, "Causes of Death in 1978", and Pnina (1978), on the Bedouins of the Negev; Ben-David (1978), Baily and Peled (1974), on the Bedouins of Sinai; and demographic data on the Bedouins of Sinai collected by the Ministry of Interior and compiled into the booklet "Distribution of the Population in the Territories" (West Bank, Gaza strip and Sinai peninsula) published in 1980.

(1) Adult questionnaire

In the course of the present study, more than 600 Bedouin adults (mainly males) were interviewed. For each, a detailed "curriculum vitae" form was filled out by the interviewer who spoke Arabic and was familiar with Bedouin customs and culture, thus minimizing "fake" answers, misunderstandings, or "leading questions". The questions were:

1. Names of person, father and grandfather
2. Name of tribe
3. Name of sub-tribe(s)
4. Name of extended family
5. Age of person examined
6. Birthplace
7. Marital status
8. Age of spouse
9. Number of children, their sex and age
10. If married to more than one woman, their ages and number of children by each spouse
11. Number of brothers and their ages
12. Number of sisters and their ages

(2) Children questionnaire

Children were also questioned. Their answers to the interviewer`s queries were confirmed by conversation with teacher or caretaker in the school. At times we relied also on information provided by adults of the tribe that were present during the child's interview. The questions put to the surveyed children (mainly boys) were:

1. Name of child, of father and of grandfather
2. Name of tribe
3. Name of sub-tribe

4. Name of family/extended family
5. Place of residence
6. Age
7. Names of brothers and their ages
8. Names of sisters and their ages
9. If there is more than one wife of the father, their names, age and the names of all their children
10. Did he have siblings in the school, or siblings who were also participating in the present study.

(3) <u>The Hams (blood feud group) records</u>

In the course of our investigation we traced more than 55 genealogical lines (about 3,000 individuals). These lines went back five generations, in some cases even seven and eight generations. Our recording included all data on "blood ties" in genealogical depth, and these data were verified by other individuals within the clan. Owing to the judicial significance of the blood feud group (see chapter on "Social Structure"), each Bedouin knows the group to which he belongs, and there was no problem in his response on this score, yet verification was deemed desirable. Most of the genealogies were taken by S. Levi who for many years had been engaged in the study of the Bedouins and their culture, and which helped to check the accuracy of the responses.

We may note that practically the only reliable sources for demographic data that proved useful in solving biological questions that arose in the course of the present study were the genealogical trees of the blood feud groups.

Two additional comments are in order. First, the data gleaned from the children's questionnaires are somewhat selective in that they derive from information obtained from males only, and only of families with at least one male child whose age was at least 5 years at the time of the research. Hence families that were childless or families having daughters only are not adequately represented in our sample. Second, our demographic data on the Bedouins of South Sinai were compared only with pre-1948 data on Bedouins in the Negev, thereby excluding possible effects of cultural changes in the demographic makeup of the Israeli Negev Bedouins following the establishment of the State of Israel. Since growth and development of children largely depends on parents and society, the possible influence of both factors is presented and discussed in the next chapter.

III. HISTORY, CULTURE AND DEMOGRAPHY

Any study of the genetic structure of a population must deal also with cultural variables (Dobzhansky and Boesiger, 1983). Hence the cultural variables of the Bedouin tribes are evaluated according to the following three main aspects:

a) The historical aspect: An attempt is made to arrange the tribes in groups according to their countries of origin and their demographic histories.

b) The cultural aspect: Here we examine the effects, on the genetic makeup of the population, of factors such as mating patterns, immigration of new groups in a tribe's territory and their incorporation into the framework of the established tribes, and emigration from a tribe.

c) The demographic aspect: Size and composition of the population is evaluated, e.g. ethnic origin of various social components, and distribution by age and sex. Separate computations are made for each tribe and in some cases even for small sub-divisions such as sub-tribe, clan, etc. Also considered are rates of fertility and mortality, sex ratio, polygamy, and other variables.

A. HISTORY

Narrative Evidence Of The Origin And Relationships Between South Sinai Bedouin Tribes

The history of the South Sinai Bedouin tribes has yet to be fully clarified. The most reliable sources are probably the weekly reports of the Head of the Santa Katharina monastery in South Sinai. These reports, which have been written virtually ever since the foundation of the monastery at the end of the 6th century (Tsafrir, 1970), have never been made available for scientific scrutiny, owing to opposition of the local monks. Consequently the main source of information on the history of the South Sinai tribes has perforce been the accounts of ethnographers and anthropologists primarily in the previous century (Burckhardt, 1822; Robinson, 1841; Stanley, 1864), as well as "tales" related by the Bedouins themselves, especially those by Sheikh Muhamad Mardi Abu-Le'ham of the Gebeliya tribe (1979, personal communication). The historical and social descriptions presented herein are, however, based primarily on studies by two Israeli investigators, namely, Joseph Ben-David ("The Bedouin Tribes in South Sinai", 1978) and Shabtai Levi ("Medicine, Hygeine and Health among the Bedouins of South Sinai", 1978; "The Bedouin Family in South Sinai", 1979; "Faith and Ritual among Bedouins of South Sinai", 1980).

The southern Sinai peninsula, although a desert area with harsh topographic conditions was inhabited by human populations even in early pre-historic time, according to the archaeological evidence (Bar-Yosef, 1980). Thus, large settlement sites were found in South Sinai in the Neolithic era (8000-5500 B.C.E.; Bar-Yosef, 1981, 1987), through the Chalcolithic era (4000-3150 B.C.E.; Oren, 1987), as well as in the early Bronze Age (3150-2200 B.C.E.; Beit-Aryeh, 1980), the Byzantine period (324-640 C.E.; Tsafrir, 1970; Finkelstein, 1980), and the early Arab period (640-1291 C.E.; Sharon, 1987). Since the Moslem conquest of Sinai (621 C.E.), Bedouin tribes from the Arabian peninsula began a constant infiltration into South Sinai and in the course of time they either displaced or absorbed the native pagan populations known in the literature by the name "Saracens" (Tsafrir, 1970). In view of the fact that ingress or egress of tribes into or out of South Sinai was a relatively rapid process, and the written testimonies date mainly from relatively recent times, it is uncertain which were the first Bedouin tribes to settle in South Sinai after the Moslem conquest and why they disappeared subsequently (Levi, 1987). Ben-David (1978) does note that one of the first tribes to settle in the region was the "Beni-Suleiman" tribe which achieved ascendancy about 700 years ago. Robinson (1841) also mentions this tribe as one of the early ones in the region and conjectures that it should probably be regarded as a relic of the ancient Saracen population. Burckhardt (1822, p.558), who travelled in the Sinai in the early 19th century, claimed that he encountered traces of this tribe near Et-Tur. He further notes (p.559) that this tribe settled in all of South Sinai following the first Moslem conquests in 638 C.E. but was decimated by the Sawalcha and Aleigat Bedouin tribes which invaded South Sinai from Egypt.

The tribes presently found in South Sinai are the Gebeliya, Sawalcha, Hamada, Aleigat, Beni-Wassal, Muzeina, Haweitat, Gararsha, Awlad Said and Ahali et-Tur. Among the first to arrive were probably the Hamada and the Beni-Wassal tribes (Arensburg et al., 1979). Some consider the Beni-Wassal tribe an offshoot of the Hamada tribe which split off as a consequence of an intratribal clash (Ben-David, 1978). The Bedouin version of the latter has it that the Beni-Wassal clan or khamula (number of extended families that share a common ancestor) joined forces with the Sawalcha tribe in a battle against the Aleigat tribe, but after the Sawalcha were defeated, an armistice agreement included a clause demanding the expulsion of the Beni-Wassal from the mother tribe (Hamada) and their transfer to the territory of the Muzeina tribe, an ally of the Aleigat in the aforementioned battle. Our own opinion is that the Beni-Wassal and the Hamada are probably distinctly separate tribes; they may have had some familial ties in the past but were never a single tribe.

There is evidence in South Sinai (e.g. the graves of sheikhs, palm tracts, etc.) which clearly indicates that the Beni-Wassal tribe was in the not very distant past one of the largest and strongest in South Sinai (Arensburg et al., 1979), whereas the Hamada tribe was always a small group adhering to fixed habitats and apparently never departing from them. Ben-David (1978) prefers the first version, namely, the one regarding the Beni-Wassal clan (khamula) of the Hamada and offers in support of this preference the fact that even now members of the Beni Wassal tribe are few in number in the South Sinai, being "imprisoned", as it were, in the area of Wadi Taiman which is in the territory of the Muzeina tribe.

The Hamada tribe is probably the most ancient of the current South Sinai tribes. Various traditions link this tribe with the departure of the Israelites from Egypt, claiming that members of this tribe descended from remnants of Pharaoh's army that survived at the Red Sea, becoming slaves of the Israelites during their sojourn in the Sinai desert (Ben-David, 1978; also S. Levi, 1980, personal communication). This "legend" is probably sheer fancy but does suggest the large span of time this tribe has spent in South Sinai. The territorial origin of the Hamada tribe is uncertain. Ben-David (1978) and also Levi (1979, personal communication) maintain that the Hamada probably came from the Arabian peninsula.

The Beni-Wassal tribe is thus a territorial contemporary of the Hamada tribe. The former is mentioned as a small tribe by both Burckhardt (1822) and Robinson (1841). These authors, incidentally, do not mention the Hamada tribe at all. Burckhardt (1822, p.558) notes that the Beni-Wassal tribe originated in the Barbary region (Saudi Arabia) and numbered only 15 families, some of which lived in Upper Egypt. According to Ben-David (1978) it appears that the Beni-Wassal tribe came from Hadhramaut at the southern edge of the Arabian peninsula. One Bedouin saga relates that when Muhammad brought the Islam religion into the Arabian peninsula, the Beni-Wassal tribe at first remained uninvolved, but when its members saw Muhammad win victory after victory they joined him and therefore were called the "Wasali", meaning, "late-joiners". Even today the Beni-Wassal tribe possesses palm trees at Nuweiba and Dahab as well as at Et-Tur, Wadi Thiman and Wadi Isla (see Figs. 1 and 2), which reflects on the original large territorial range of this tribe.

Among the first tribes to settle in South Sinai, the most prominent one was the Sawalcha tribe. According to Burckhardt (1822):

> *The Szowaleha...are the principal tribe, and they boast of having been the first Bedouins who settled in these mountains, under their founder Ayd, two of whose sons, they say, emigrated with their families to the Hedjaz....*(p.557).

This tribe settled in West Sinai and also in various parts of the high mountain area, engaging mainly in commerce and the transport of pedestrians from Egypt to the Santa Katharina monastery. For a long time the Sawalcha were regarded as the most important and strongest of the South Sinai tribes. Thus Robinson (1841) wrote:

> *The Sowalihah, the largest and most important of all the divisions of these Arabs, and comprising several branches which themselves constitute tribes...* (p.197).

It seems reasonable to assume that the three abovementioned tribes (Hamada, Beni-Wassal and Sawalcha) reached the Sinai between the 8th and 13th centuries (Arensburg et al., 1979). S. Levi, in a personal communication (1979), and Arensburg et al. (1979) maintain that the second wave of Bedouin migration to reach South Sinai (probably between the 13th and 14th centuries) comprised mainly tribesmen of the Ayede and Nefeat. But these tribes did not become acclimated in South Sinai and left the region for Egypt. There are still sites, such as the graves of sheikhs (e.g. that of Sheikh Suleiman, a Nafai of the Nefeat tribe at the mouth of the Meghara-Mukattab wadi or that of Sheikh Saleiman abu-Khijle el-Ayede of the Ayede tribe at Wadi Sakhab) or palm trees like those at Bir Iqna whose original owners were of the Nefeat tribe, which point to the presence and territorial distribution of these two tribes in the past. Some entire families of these two tribes, however, remained in South Sinai, attaching themselves to other tribes but still continuing to retain their original identity (e.g. the family of Ibrahim al Ayede, presently of the Awlad Said tribe).

At the end of the 14th century there was increased migration of Bedouin tribes into South Sinai. The first to arrive then was the Aleigat tribe. According to Ben-David (1978), this tribe came from Ullah, a region and city to the northwest of Khedjaz (Saudi Arabia). Levi (1987) believes that the name of the tribe, when broken into the syllables "Alei" and "gat", implies those who came from the East. The penetration of new tribes into South Sinai that began in the 13th century provoked resistance from the "veteran" tribes in the region, especially the largest of these, namely, the Sawalcha tribe. Thus Bedouin legend tells about a major battle between the Sawalcha and the Aleigat, the outcome of which was the basis for renewed territorial partition of South Sinai among the tribes. The legend is cited in various versions by numerous investigators (Ben-David, 1978). We present it here in abbreviated form because of its importance to an understanding of the historical processes in the region. Thus, according to Ben-David (1978):

> *Shepherds of the Aleigat tribe were accustomed, during periods of drought, to infiltrate into the territory of the older tribes in Sinai in order to obtain pasture for their flocks. These invasions met with disfavor by members of the Sawalcha tribe who one day decided to set an ambush for the Aleigat shepherds. Thus the invading shepherds were set upon by the Sawalcha tribesmen, massacred, and their herds of goats and camels taken*

as spoil. The Aleigat tribesmen then rallied their brethren still residing in Egypt and aid was not far in coming. One dark night, the reinforced Aleigat troops reached the Sawalcha camp (situated near the Watah Pass) and slaughtered every member of that camp. These two events brought about prolonged conflict between the two tribes, and only a treaty made between the Aleigat and the Muzeina finally enabled these two tribes to overcome the Sawalcha tribe and demand a new territorial partition of South Sinai (p.28).

Ben-David (1978) contends that the mentioned battle took place probably in the middle of the 14th century (1338-39). We think that the battle occurred somewhat later, about the end of the 14th or beginning of the 15th century. Our assumption is based on the fact that the Muzeina tribe, which was allied to the Aleigat in the battle, numbered at that time only several dozen individuals and was just starting its settlement in the region. It seems to us unlikely for a tribe in this "beginning" state to join forces with either of the combatants, nor would its joining one or the other side likely affect the outcome of the contest in view of its very small size.

Burckhardt (1822) presents a different view, that the Muzeina tribe was the "cause de combat" in that four families of this tribe arrived from Saudi Arabia (according to Burckhardt these originated from Khedjaz where they constituted a part of a larger tribe, the "beni-Horeb") because of fear of a vendetta, and sought to settle in South Sinai. At first they approached the Sawalcha and asked to join with them. The Sawalcha agreed but posed several conditions, some of which appeared degrading to the Muzeina (e.g. payment of a tithe, giving their women without reciprocity, etc.). Hence the Muzeina turned to the Aleigat tribe. The latter was only too happy to accept new partners and thereby strengthen its position in South Sinai, and so `signed' a "brotherhood treaty" with the Muzeina. This last step angered the Sawalcha and was the reason for the ensuing inter-tribal conflict which terminated in the heavy defeat of the Sawalcha.

Robinson (1841) writes about this same conflict thus:

The whole territory of the Tawarah originally belonged to the Sawalihah and Aleikat, and was equally divided between them; the former having possession of the western part of the peninsula, and the latter of the eastern. During a famine, a war arose between the two tribes, in which the former, in a night-attack near Tur, killed all but seven men of the Aleikat. To celebrate this victory, they assembled around the tomb of Sheikh Salih in wady Esh-Sheikh, and sacrificed a camel. Just at this time, seven men of the Muzeiny came to them from their country, Harb, on the road to the Hejaz, and proposed to settle with them in the peninsula on equal terms, *saying they had fled from home because they had shed blood, and feared the avenger. The Sawalihah replied that if they would come as serfs, they were welcome, if not, they might depart. They chose to depart, and on their way, fell in with the remnant of the Aleikat. Forming a league with these, they together fell upon the Sawalihah at night, as they were assembled among the Turfa-trees to feast upon the camel, and a great slaughter was the consequence. The war continued for many years, but at last peace was made between the contending parties by foreign mediation. The Aleikat now gave the Muzeiny half of their portion of the peninsula and of their general rights and admitted them to intermarriage* (pp.198-199).

Another version propounded by S. Levy (1979, personal communication) maintains that the "big battle" was in fact between the Hamada and Nefeat on the one side and the Sawalcha on the other. The assumption of this version is that at the time when the event supposedly took place the Aleigat tribe was still too small, and it is unlikely that it would challenge the Sawalcha tribe which was the strongest of the South Sinai tribes at that time. With time, however, as the Nefeat tribe left South Sinai, the Aleigat tribe supplanted it and invented the story of the battle.

In the present study, no attempt is made to select the most likely version of the battle, its outcome and consequences; rather the battle itself is used to illustrate demographic processes typical of the place and time, such as the infiltration of new tribes, changes in the ownership of territories, departure of tribes, etc.

The second wave of migration of Bedouin tribes into South Sinai commenced apparently at the beginning of the 15th century. The "veteran" tribes (e.g. Hamada, Beni-Wassal, Nefeat and Ayede) loosened their hold on the southern part of the Sinai peninsula, most of their members migrating into North Sinai and Egypt; an example are remnants of the Ayede tribe which are currently concentrated in the region of Port Toufik in Egypt. It is very likely that the departure of these tribes was neither rapid nor a single occurrence. Extended periods of drought may have led to occasional massive emigration from the Sinai, but infiltration of individuals from South Sinai into Egypt must have been a long and continuous process. We know that the Egyptians tried to prevent this process and that one of the major problems facing the first and succeeding Pharaohs was to contain this infiltration of desert dwellers into their settled country, but to no avail (Sharon, 1977). At that time, every piece of land vacated in South Sinai was immediately occupied by members of new tribes, so that there was no return of those which had left the territory.

The Muzeina tribe, since the 19th century, has become one of the most successful in South Sinai. Within a brief span of time it dominated all of southeastern Sinai, from Sharm-esh-Sheikh in the south to Nuweiba in the north. It penetrated to the northern sandstone regions (G'amlot Hemaier) and reached as far as the Et-Tih range, entering the high mountain region and occupying parts of the Tarfat Qiderein and Bir-Iqna ranges. To the west, the Muzeina tribe occupied the flats between the Gulf of Suez and the high mountain facing Et-Tur (Fig. 2).

Other tribes infiltrated the region as well as the Muzeina. Thus the Awlad Said tribe occupied the eastern and southern borders of the high mountain. The hold of this tribe in South Sinai was encouraged by the monks at the Santa Katharina monastery who allowed its members to cultivate the remote orchards of the monastery, particularly those in Wadi Isla, and to protect the Dir-Antush monastery at the foot of Gebel Umm-Gumar which was strategically situated to secure the supply and pilgrimage routes between Et-Tur and the mother monastery. Evidence regarding the geographic origin of the various clans (khamulas; groups of extended families) points to the fact that this tribe comprises a sort of conglomerate of families that had reached South Sinai at different times and had become organized into a new tribal infrastructure.

Burckhardt (1822) regarded this tribe as one of the clans of the Sawalcha and notes:

> *The Oulad Said whose Sheikh is at present the second Sheikh of the Towara Arabs...are not as poor as the other tribes, and possess the best valleys of the mountains* (p.557).

Also Robinson (1841) wrote similarly about the Awlad Said tribe. Another tribe settling in South Sinai at that time (14th century) was the Gararsha. Burckhardt (1822) assigns this tribe, as well as the Awlad Said, to the Sawalcha and comments:

> *The Korashy are descendants of a few families of Benei Koreysh, who came here as fugitives from the Hedjaz [Arabia], and settled with whom they are now intimately intermixed* (p.557).

The last tribe to settle in South Sinai was the Haweitat. This tribe receives no mention either by Burckhardt (1822) or by Robinson (1841). Field (1952), however, relates the story of this tribe as he heard it from Sheikh Musah Hussein Salem (of the Awlad Said):

> *...Long before the construction of the Suez Canal, the Haweitat moved westward from the Hedjaz passing into Sinai between Aqaba and Jebel Sharr, that is, along the Wadi Zoba. Before 1914 only about 5% of the Haweitat were in Egypt west of the Canal, and about 10% in Sinai under*

Saad Abu Nar. The remainder were under Alayan Abu Tugaiga, who was replaced by his nephew, Ahmed Ibrahim. The group in Egypt was at Juhur near Galiubiah under Abdul Kerim Shedid, who was succeeded by his son, Ismail Abdul Kerim Shedid. After the battle with Ibn Saud in 1932, the Haweitat streamed westward. About five thousand persons reached Egypt; about a hundred and fifty remained in Sinai (p.127).

Field continues recounting that he was witness to a land dispute between the Haweitat tribe and the more "veteran" tribes of South Sinai. In that instance, the South Sinai tribes (the Gararsha, Sawalcha, Awlad Said, Aleigat, Gebeliya, Muzeina and the Beni-Wassal) lodged a complaint before the Egyptian governor of Sinai who resided in El Arish. Even in present times, the South Sinai tribes are still trying to expel the Haweitat from their midst, refusing to grant its members grazing areas or water holes, as well as refusing to marry with them. Not surprisingly, when the Israeli regional authorities after 1970 wished to dig a well within the territory of this tribe, a delegation of all the Sheikhs of South Sinai petitioned the authorities that digging of such a well not be permitted because, according to them, the Haweitat tribe had no rights in South Sinai, that the latter was merely a visitor in the area (E. Bergman, I.D.F. officer, representative of the Governor of South Sinai in the High Mountain region 1976-1978; personal communication, 1979).

Thus far we have intentionally refrained from integrating the history of the Gebeliya tribe with the common history of all the other tribes, since the Gebeliya tribe, despite being one of the oldest and perhaps even the oldest in the region, is exceptional insofar as its history is concerned. On the beginnings of the Gebeliya, Burckhardt (1822) remarks:

To the true Bedouin tribes above enumerated, are to be added the advena called Djebalye, or the mountaineers. I have stated that when Justinian built the Convent [St Catherine], he sent a party of slaves, originally from the shores of the Black Sea, as menial servants to the priests. These people came here with their wives and were settled by the Convent as guardians of the orchards and date plantations throughout the peninsula (p.562).

Robinson (1841) presents a similar account but with an addendum of great significance to our study. The added information is that within the Gebeliya tribe in South Sinai there was a large group originally from Egypt. At present this offshoot of the tribe is known by the name of Awlad Gindi. According to Robinson:

When Justinian built the Convent, he sent two hundred Walluchian prisoners, and ordered the Governor of Egypt to send two hundred Egyptians, to be the vassals of the Monastery, to serve and protect it (p.200).

Also, according to Robinson (1841, p.200) and Nandris (1981, p.56), the evidence for the existence and complexity of the Gebeliya tribe already appears in the writings of Eutychius, Patriarch of Alexandria, in the 9th century. This Patriarch relates how the Pope's emissary was dispatched along with 100 males and their families from among the Byzantine servants, and another 100 families from Egypt, all of them sent to the Santa Katharina Monastery to guard it. The Gebeliya apparently assumed the Moslem faith at the time of the Caliph Abd-el-Malik (625-705), even though a few members continued to retain the Christian religion until the middle of the 18th century (Burckhardt, 1822, p.564). Nandris (1981) maintains that the population from which the first Gebeliya originated (the Vlah, as recorded in the writings of travellers and explorers) still exists under that name in southern Europe. He writes:

> *The Vlahs or Aromani of Greece are a Latin-speaking and Hellenophille people, related to the Rumanians* (p.57).

It is clear, then, that the first members of the Gebeliya tribe reached South Sinai in the 6th century and as a tribe has survived until the present. This remarkable survival as a cultural entity is attributable to two main factors, namely: (a) intensive economic support by the monastery authorities, which enabled them to withstand severe drought periods; and (b) cultural isolation from the rest of the South Sinai tribes.

Genetical Evidence Of The Origin And Relationships Between South Sinai Bedouin Tribes

According to the historical evidence, we believe that the tribes of South Sinai may be divided into four main biological units: the first includes the Sawalcha, Gararsha and Awlad Said tribes; the second, the Muzeina tribe; the third, the Aleigat and Hamada tribes; and the fourth, the Gebeliya tribe. The Haweitat, Beni-Wassal and Ahali Et-Tur are probably independent biological units. The regional origin of all these tribes, with the exception of the Gebeliya, according to most investigators, is the Arabian peninsula. Yet this view seems to us problematic, in that some of the South Sinai tribes did not arrive directly into Sinai from Saudi Arabia, nor did they arrive as a single homogeneous group. An example is the settlement of the Awlad Said tribe in the Sinai as reported by Ben-David (1978). According to this author, the Abu-Zohar clan was first to reach South Sinai from the Arabian peninsula, whereas the Abu-Alaj clan wandered in the North African dunes before reaching South Sinai from Tunisia. As for the Abu-Amar clan, this group reached South Sinai after a period of peregrination in Egypt and the Abu-Nakhila clan had previously wandered similarly in the Syrian desert. The Abu-Gass branch arrived in South Sinai following its sojourn in the

Hebron region south of Judea, and finally the Basharin clan had been initially in Sudan, and some even relate it to a population of slaves bought by the South Sinai tribes and subsequently set free (Ben-David, 1978, pp.19-21). Assuming this information is essentially reliable, it suggests the possibility that the various tribes had incorporated groups not originally present in the "mother" population. Hardly a tribe in South Sinai had not at one time or another assimilated extraneous families (see, for instance, Figs. 3 and 4, depicting the structure of the Muzeina and Gebeliya tribes).

There can be no doubt that slaves were brought to Sinai from the Sudan, about which we have written documentation.

> Thus "...*But poor as they are, some of them, especially the Gararsheh, possess Negro slaves who look after the camels*" (Palmer, 1871, p.84). And "...*Between three hundred and four hundred Negroes live in Sinai, the majority near Tor. Sheikh Eid commented that forty or more years ago, each big sheikh had Negroes as bodyguards and slaves*" (Field, 1952, p.129).

Such admixtures pose the question whether the individual tribes may be defined as homogeneous biological units. We attempt to answer this question subsequently. First, however, we shall examine the genetic evidence for the origin of, and the interrelations between, the various tribes.

The first studies to examine the frequency of genetic markers in some blood group systems, haptoglobins and transferrins, in Bedouin populations of South Sinai were carried out by Kaufman-Zivelin (1971) and Bonne et al. (1971). The data included the frequency of haptoglobin phenotypes in the Bedouin population of South Sinai, and are shown in Table 2. We should mention that: a) the calculations intentionally excluded immediate relationships such as son and father, siblings, and the like; b) the Aleigat tribe in the sample included also some members (31) of the Hamada tribe; and c)under the category of "Feiran" were included primarily three tribes, namely, Gararsha, Sawalcha and Awlad Said, and it is also likely that some individuals from the Gebeliya, Muzeina and the Haweitat were also represented in it.

Kaufman-Zivelin (1971) concludes that the Gebeliya tribe is distinct from the rest of the mentioned tribes because in it the frequency of the Hp1-1 phenotype is probably close to zero while the frequency of the Hp2-2 attains 63% and is greater than in the other tribes (see Table 2). As for the Hp2-1 heterozygote, the differences between the tribes are less marked. Calculation of the Hp1 gene frequency for the various tribes shows it to be lowest in the Gebeliya (0.19) and highest in the Aleigat (0.51). Kaufman-Zivelin (1971) also computed the observed frequency of the haptoglobin types versus the expected frequency according to the Hardy-Weinberg law for a panmictic population of unlimited size, and without selection, migration or mutations. She found that discrepancy between the observed and expected frequency occurred only in the Gebeliya tribe.

TABLE 2 Phenotype frequency of haptoglobins and of gene Hp1 in Bedouin populations of South Sinai, by tribe.

Haptoglobin phenotypes									
	Hp (1-1)		Hp (2-1)		Hp (2-2)		Total	Gene freq Hp1	S.E.
Tribe	N	%	N	%	N	%			
Muzeina	9	7.44	49	40.50	63	52.07	121	0.277	0.028
Gebeliya	-	-	41	36.94	70	63.06	111	0.185	0.026
Feiran*	12	13.48	45	50.56	32	35.96	89	0.388	0.036
Aleigat	21	26.58	38	48.10	20	25.32	79	0.506	0.040
Others*	0	23.26	37	43.02	29	33.72	86	0.448	0.037
Total	62	12.76	210	43.21	214	44.03	486	0.344	0.014

From Kaufman-Zivelin, 1971, p.20

* Included in this group are members of the Sawalcha, Gararsha and Awlad Said tribes

She likewise compared the frequencies of the three phenotypes between tribe pairs (Table 3) and clearly showed that the Gebeliya tribe differs significantly from all the other tribes and also that the Muzeina tribe differs significantly from the Aleigat. As for comparison of the Hp1 gene frequency in tribe pairs (Table 3), in all instances the differences in the gene frequency are statistically significant.

TABLE 3 Chi-square differences in phenotype frequencies of 3 systems: haptoglobin, ABO and P and Hp1 gene frequency between Bedouin tribe pairs in South Sinai.

TRIBE PAIR						
System	Gebeliya-Muzeina	Gebeliya-Aleigat	Gebeliya-Feiran**	Muzeina-Aleigat	Muzeina-Feiran	Aleigat-Feiran
Haptoglobin	9.67	44.78*	24.22*	20.56*	5.98	5.24
Hp1	5.50*	44.01*	20.40*	21.66*	5.75*	4.78*
ABO	36.17*	25.51*	36.14*	2.26	12.89	6.12
P	23.98*	1.07	0.13	12.37*	12.16	0.01

* Statistical significance = P<0.05

From Kaufman-Zivelin, 1971, pp.23-26

** Conglomerate of bedouins from different tribes, mainly Sawalcha and Awlad Said.

Comparison of ABO blood groups. Frequency of the ABO group genes in the various tribes is given in Table 4. As can be seen, the frequency of the q gene is high in the Gebeliya tribe relative to that in the other tribes , whereas in this same tribe the frequency of the p gene is comparatively low. Chi-square differences in the ABO system phenotypes between pairs of Bedouin tribes are considered in Table 3. Here also is seen the "exclusivity" of the Gebeliya from the rest of the tribes. It is also noted that the Muzeina tribe differs in the ABO context from the Feiran group.

TABLE 4 ABO gene frequency in various Bedouin tribes of South Sinai.

Tribe	No. of individuals	p	q	r
Muzeina	132	0.171	0.132	0.698
Gebeliya	112	0.123	0.255	0.621
Feiran	94	0.140	0.055	0.795
Aleigat	82	0.198	0.124	0.678

From Kaufman-Zivelin, 1971, p.25

The P blood group. The frequencies of the p_1 gene in the different tribes are: Muzeina=0.572; Gebeliya=0.309; Feiran=0.373; and Aleigat=0.366. It is here seen that the frequency of the p_1 gene is relatively high in the Muzeina tribe (0.57) compared to that in the other tribes (0.31-0.37). A comparison of the phenotypes in the P system (Table 3) reveals that the Muzeina tribe differs significantly from all the other groups.

Transferrin types. A total of 347 Bedouins (280 males and 67 females) were sampled for this typing, without regard to tribal assignation (Kaufman-Zivelin, 1971). The genetic type of transferrins revealed was TfCC, which in turn indicates the homozygote for gene TfC. Another study by Bonne' et al. (1971) corroborated the results of Kaufman-Zivelin. The frequency of the TfC gene in the combined samples was computed to be 0.999.

Kaufman-Zivelin, in her Bedouin study (1971), attempted to ascertain whether there was any correlation between the frequency of the Hp1 gene in the various tribes and its frequency in the geographic regions from which the tribes purportedly originated. Her data are presented in Table 5. The Hp1 gene frequency in the Muzeina tribe is, according to her data, similar to that in Arab and other Bedouin populations in Israel. In contrast, the Aleigat tribe resembles groups from Sudan, Uganda and Kenya, but manifests no similarity to Ethiopian or Egyptian populations in Hp1 gene frequency. The Feiran tribes (Gararsha, Sawalcha and Awlad Said) also resemble the Arab and Bedouin populations in Israel as well as Arab populations from Saudi Arabia. The Gebeliya tribe in South Sinai manifests a frequency of the Hp1 gene (0.18) that is much lower than usual in Europe (0.34-0.37) or, excepting Egypt (0.21), in Africa (0.40-0.63). Kaufman-Zivelin also addressed the question as to whether the Gebeliya tribe represents an amalgamation of African and European populations. She picked a large number of genetic markers whose frequency differs in African and European populations, and concluded that both African and European influences are discernible in their (Gebeliya) genetic systems and that deviation from the expected gene frequency, as presented by the two "mother populations", is putatively the result of selection processes or genetic drift. She also concluded that the Gebeliya is the only tribe that stands apart from all the other tribes in Hp1 and that a comparison of its frequency among the Bedouins in South Sinai and neighboring populations strengthens the assumptions regarding the geographic origins of the various tribes, as previously indicated.

TABLE 5 Frequency of the gene Hp1 among diverse groups in different geographic regions.

South Sinai Bedouin^	Hp1 Freq	Other Middle East	Hp1 Freq	East Africa	Hp1 Fre.	Asia	Hp1 Freq.	Europe	Hp1 Fre.
Muzeina (Arabia)	0.28	Bedouins (Israel)	0.34	Uganda	0.63	Iran	0.28	Greece	0.35
Gebeliya (Europe+ Middle East)	0.18	Arabs (Israel)*	0.35	Kenya	0.47	Hadhramaut (S.Arabia) Jews	0.21	Yugoslavia	0.37
Feiran (Arabia)	0.39	-	-	Sudan	0.50	Hadhramaut (S.Arabia) Arabs	0.47	-	-
Aleigat (Arabia)	0.51	-	-	Ethiopia	0.40	-	-	-	-
Total	0.34	-	-	Egypt	0.21	-	-	-	-

From Kaufman-Zivelin, 1971, p.29.

* Collected by different authors, mainly from Morant et al. 1971

^ Places in parentheses refer to geographical origin

TABLE 6 Frequency of various genes in the Bedouin population of South Sinai: Towara* and Gebeliya (Bonne et al., 1971, pp.400-406).

Gene	Towara	Gebeliya	Gene	Towara	Gebeliya
ABO system			Duffy system		
p^1	0.0405	0.1235	Fy^a	0.2689	0.2386
p^{int}	0.0156	-	Fy^b	0.3595	0.1662
p^2	0.1087	-	Fy	0.3715	0.5952
q	0.0936	0.2603			
r	0.7417	0.6163	Gm system		
MN system					
M	0.5173	0.6579	Gm^1	0.2379	0.2603
N	0.4827	0.3421	$Gm^{1,2}$	0.0344	-
JK system			$Gm^{1,10,11}$	0.0168	-
Jk^a	0.4788	0.3215	$Gm^{1,5,10,11}$	0.1557	0.3905
Jk^b	0.5212	0.6785	$Gm^{4,5,10,11}$	0.5552	0.3492
Rh system			Haptoglobin system		
$CDeR^1$	0.2607	0.2421			
CD^uer^{1u}	0.0046	-	Hp^1	0.4293	0.2105
Cder'	0.0046	-	Hp^2	0.5707	0.7895
$cDER^2$	0.0901	0.1684			
cdEr''	0.0139	-	Acid phosphatase system		
cD^uer^{ou}	-	0.0169	p^a	0.1332	0.0645
$cDeR^0$	0.1019	0.2601	p^b	0.8643	0.9355
cder	0.5243	0.3126	p^c	0.0025	-
P system			6-phosphogl. dehydrogenase system		
P_1	0.3746	0.2967	PGD^A	0.8508	0.9316
P_2	0.6254	0.7033	PGD^C	0.1468	0.0684
			PGD^H	0.0025	-
V system					
V	0.0407	0.0657	Adenylate kinase system		
v	0.9593	0.9343	AK^1	0.9751	0.9632
			AK^2	0.0249	0.0368
Kell system			Phosphoglucomutase (PGM_1) system		
KJs^b	0.1309	0.1794	$PGM^1{}_1$	0.8500	0.7579
kJs^a	0.0202	0.0654	$PGM^2{}_1$	0.1500	0.2316
kJs^b	0.8489	0.7552	$PGM^7{}_1$	-	0.0105

*All tribes of South Sinai excluding Gebeliya.

Contemporaneously with the study of Kaufman-Zivelin (1971), an extensive study by Bonne' and coworkers (1971) appeared on heritable blood factors in the Bedouin. In all, 297 individuals (280 males and 17 females) were examined (excluding family ties of the first order).

The sample was divided into four main groups, namely, Gebeliya (95), Aleigat (50), Muzeina (53) and the remaining Towara tribes (99). The main findings of that study are given in Table 6. The authors conclude that the Gebeliya tribe differs significantly from the rest in numerous genetic systems and that, with few exceptions, there are no significant differences between the other tribes. This is the reason why the data in Table 6 are given only for the Towara and the Gebeliya.

Bonne' et al. (1971) also note that:

> *In most systems the Towara tribes agree with what is known of other neighbouring peoples, and for the blood groups in the strict sense, they greatly resemble the Arabs of the Arabian peninsula. The main differences are the high frequencies of the Rh complex cde (r) and the genes K and* PGM^1_1*. The Jebeliya on the other hand, differ very markedly and significantly not only from the other Sinai Bedouins but from all other neighbouring populations... In general, the prominent negroid features observed in the Jebeliya call for a reappraisal of their historical and ethnic background* (p.407).

Yair Ben-David (Eugene Kobyliansky) and his associates (1983) examined the frequency of the T autosomal dominant gene among a number of Bedouin tribes (Table 7). The ability to taste the compound phenylthiocarbamide (PTC) is generally attributed to a dominant, autosomal gene, called T, whose recessive allele is t. Homozygote dominants (TT) and heterozygous (Tt) individuals are able to taste PTC whereas the recessive homozygote individuals (tt) are unable to do so.

TABLE 7 Frequency of gene T in Bedouin tribes of South Sinai.

Tribe	N	T
Gebeliya	92	.4583
Awlad Said	23	.4892
Muzeina	170	.3537
Hamada	23	.2482
Aleigat	46	.2482
Gararsha	68	.1775

From Ben-David et al., 1983, p.199

The statistical significance of the differences in this respect between the tribes is given in Table 8. The results show that the Gebeliya tribe differs significantly from all the tribes with which it was compared with one exception, the Awlad Said. The Muzeina tribe also differed from all the other tribes, without any exception. Furthermore, the high frequency of the T gene encountered in the Gebeliya tribe is typical also for many African societies (see Mourant et al., 1976).

TABLE 8 Chi square differences in frequency of gene T between paired South Sinai Bedouin tribes

Paired tribes	χ^2
Gebeliya-Muzeina	12.2***
Gebeliya-Hamada	6.6**
Gebeliya-Aleigat	13.1***
Gebeliya-Gararsha	26.3***
Gebeliya-Awlad Said	0.4
Muzeina-Hamada	9.3**
Muzeina-Aleigat	10.4**
Muzeina-Gararsha	21.3***
Muzeina-Awlad Said	10.3***
Hamada-Aleigat	1.1
Hamada-Gararsha	0.6
Hamada-Awlad Said	5.6*
Aleigat-Gararsha	0.6
Aleigat-Awlad Said	7.7**
Gararsha-Awlad Said	16.8***

From Y. Ben-David et al., 1983, p.58)

* 5% significance level

**1% significance level

***0.1% significance level

Significance of genetic studies. All the investigators of Bedouins whose studies on blood groups are here represented, emphasize that their material was problematic mainly because of the sampling procedure and size of sample, and caution against drawing broader firm conclusions. Nevertheless we believe such data can and should be considered, albeit with due caution, especially when correlated with other biological and morphological data. The biologic data that we have presented show that:

a) the Aleigat and Hamada tribes are related; in genetic systems like sensitivity to PTC, P blood group system and such, they show almost complete identity and can therefore be treated as one group;

b) the Muzeina tribe may be regarded as an independent biological unit because it does not show genetic proximity (albeit judged by blood markers only) even to the Aleigat tribe with which it purportedly had maintained marital relationships;

c) the Gebeliya tribe also appears to be an independent biological unit which, like the Muzeina tribe, shows little or no genetic relatedness to any of the other tribes in South Sinai. Unlike the Muzeina, however, it displays extreme variability in some of the genetic systems. This variability, or `instability', stems probably from the fact that previous field investigators failed to discriminate between the Awlad Gindi sub-tribe whose origin is probably Egyptian, and the other sub-tribes which originated from Bedouin tribes of the Arabian peninsula, perhaps even from surviving slaves brought by Justinian to the Santa Katharina monastery from Europe in the 6th century.

We should note that the biological data here presented concur in part with the socio-historical information available, as previously indicated.

The frequencies of the genotypes of the blood groups do not show any deviation from the Hardy-Weinberg law, with one exception, in spite of the fact that we are dealing here with small populations with non-random matings. The one exception is the Gebeliya tribe, although the reason for this is not clear. Why a "genetic balance", expressed by blood group systems, appears to be maintained within the South Sinai Bedouin groups, will be considered subsequently.

B. ETHNOGRAPHY

Social Structure

There are three large "social units" among Bedouins: a)"tribal suprastructure"; b)"tribal affiliation"; and c)"tribe". In the majority of Bedouin groups in northern Sinai and in Israel, the biological ties between and within the tribes find expression in the tribal suprastrucure organization. The tribes of South Sinai, however, diverge somewhat in this respect. While they all belong to one super-tribe organization (Safef in Arabic), known as the Towara ("Tor" in Arabic meaning a mountain, thus designating the topographic nature of South Sinai), the ties between the tribes are based mainly on common and defined geographic localization and not on any "blood" relationship such as is customary at the tribal suprastructure level in most Bedouin groups (Marx, 1974; Ben-David, 1978). Baily (1977, p.246) notes that *"the tribal suprastructure is the nationality of the Bedouins"*

The inception of most of the major Bedouin tribal suprastructures in Sinai and the Israeli Negev started with a limited number of tribes which initially consolidated in the Arabian peninsula and then migrated north and northwest into settled land. In the course of this migration, moving from one region to another, the group of tribes assimilated local families, factions and at times even entire tribes, to form an expanded tribal suprastructure. The founding of the majority of large tribal suprastructures of Bedouins in Sinai and the Negev was in the Arabian peninsula. For example, the Jabrat tribal suprastructure originated in the Lif Wadi in the Hejaz district, Arabia (Muhsam, 1966), whence it migrated through the Arava to Sinai, reaching the coastal area near El-Arish. A large faction of this tribal suprastructure continued its migration into the boundaries of Israel.

The Tarabin tribal suprastructure originated in the Turaba region in the center of the Arabian peninsula (Muhsam, 1966) and commenced its migration into Sinai later than did the Jibarat, although its route largely coincided with that of the Jibarat. Actually, the Tarabin, owing to its large size, started "pushing" small tribes belonging to the Jibarat in the direction of Israel, ultimately displacing the tribes of the Jibarat from their residence in the El-Arish region.

The Azazme tribal suprastructure originated in north Hejaz, Arabia (Muhsam, 1966) and reached its present location in the Israeli Negev by coming directly through the Arava and North Sinai. The Tayaha tribal suprastructure also originated in the Arabian peninsula. It settled first in Central Sinai and later various tribes of this tribal suprastructure penetrated into North Sinai and the Israeli Negev. The Towara suprastructure, which includes most of the Bedouin tribes of South Sinai, unlike the other large tribal suprastructures was formed by a conglomerate of discrete tribes with no genealogical or historical ties between them. The Towara in South Sinai had been organized to form a united body, powerful enough to counterbalance the other tribal suprastructures, especially the Tayaha which sought to encroach on its living spaces. However, apart from the latter common purpose, the Towara exerted no influence on occurrences between and within tribes in the South Sinai.

In South Sinai there also exists a "framework" of tribal affiliation or alliance, which is an organization between tribes within the tribal suprastructure. A similar organization exists also among the Negev Bedouins. Baily (1977) called the latter organization "El-Baten" or the El-Fahed". In the South Sinai affiliation, the ties between tribes are primarily on a socio-political level; in the Israeli Negev affiliation, however, the ties are essentially blood relationships, through a common ancestor. According to Baily (1977), the role of the latter tribal affiliation is to form a framework for social intercourse, such as inter-tribal marriages, or cooperation in pilgrimages to the graves commonly considered holy, usually tombs of sheikhs known for their "supernatural" powers, and also for economic cooperation (particularly in smuggling activities). The South Sinai tribal affiliations are called after the leading tribe in the group: the Sawalcha affiliation includes also the Awlad Said and Gararsha tribes, and the Aleigat affiliation includes also the Muzeina and Hamada tribes. The Gebeliya, Haweitat and Beni-Wassal tribes are not included within either coalition. The present tribal affiliations are not completely parallel with the biological units determined earlier on the basis of the different historical background of each tribe.

The third-ranking social unit from the standpoint of size is the tribe, or El-Ashira. According to Baily (1977) a tribe forms in one of two ways: 1) A sub-tribe increases in size and demands independence from the mother tribe in order to advance its special interests; 2) A certain group assimilates other groups and together these come to comprise a tribe. Marx (1974) has this to say about the Israeli Negev Bedouin tribe:

> *The most extensive political group at present is the tribe (ashira; plu. ashair) and the sub-tribe (ruba; plu. rub'oa). The tribe was formerly the group that made battle. Today it is the administrative unit. At the head of such a group stands an elected leader, called the Sheikh...the Sheikh is now the primary mediator between the sub-tribes and the authorities - a fact which lends him considerable power...the tribe also had an appreciable degree of continuity, and this is apparent from the fact that this is the smallest group in the customary genealogies which describe the relationships between all the tribes of the tribal suprastructure. The tribe is not a group possessed of land properties and its boundaries are not so clearly demarcated as those of branches, but generally one can say that the groups which comprise the tribe own adjacent lands which are utilized as areas of grazing* (p.58).

According to Kapra and Bar-Yosef (1978):

> *The tribe is the unit which guards the grazing land and the water sources needed for its sustenance against the other tribes. Hence the affinity of the Bedouin for his tribe, which safeguards his life and actual survival in the desert* (p.109).

It would seem that both these definitions, taken together, epitomize the role of the tribe in the general Bedouin society. The tribes of South Sinai, however, differ in important respects from the tribes of the Negev or North Sinai. Marx (1974), for instance, notes that the typical Bedouin tribe in the Negev includes individuals from different ethnic, geographic and economic backgrounds whom he assigns into three categories: a) Bedouins who dominate the tribe, albeit not always the majority in the tribe, and who consider themselves Arab; b) the group of Fellahin, a derivative term for those living in cultivated regions on the outskirts of the desert; c) the groups of slaves (Ab'ad), descendants of Negro slaves formerly the property of Bedouins.

Among the tribes of South Sinai the above division does not exist, and although elements of the last two categories occur within the various tribes, their relative numerical strength within the tribe is negligible. Too, each social framework within the Bedouin society in South Sinai is a biological entity.

The social structures of the Muzeina and Gebeliya tribes have been methodically studied by us, and we shall therefore refer to them in our presentation of the various social units of which the tribe is comprised, and of the biological ties between these units.

The tribe, for which the accepted Arab term in South Sinai is "qabila", is composed of several sub-tribes for which the Arab term is "ruba", meaning a quarter; this etymological division of four is really fictitious because each tribe is composed of a different number of rubas (Muhsam, 1966; Marx, 1974). The ruba (here also alternately termed a sub-tribe) is composed, according to Baily (1977) of:

> *groups of Hams [`blood feud' group], the majority of which are related to a common ancestor in the distant past, more than five generations ago; the makeup of the ruba is not static; groups may join it or leave it, according to their interests* (p.245).

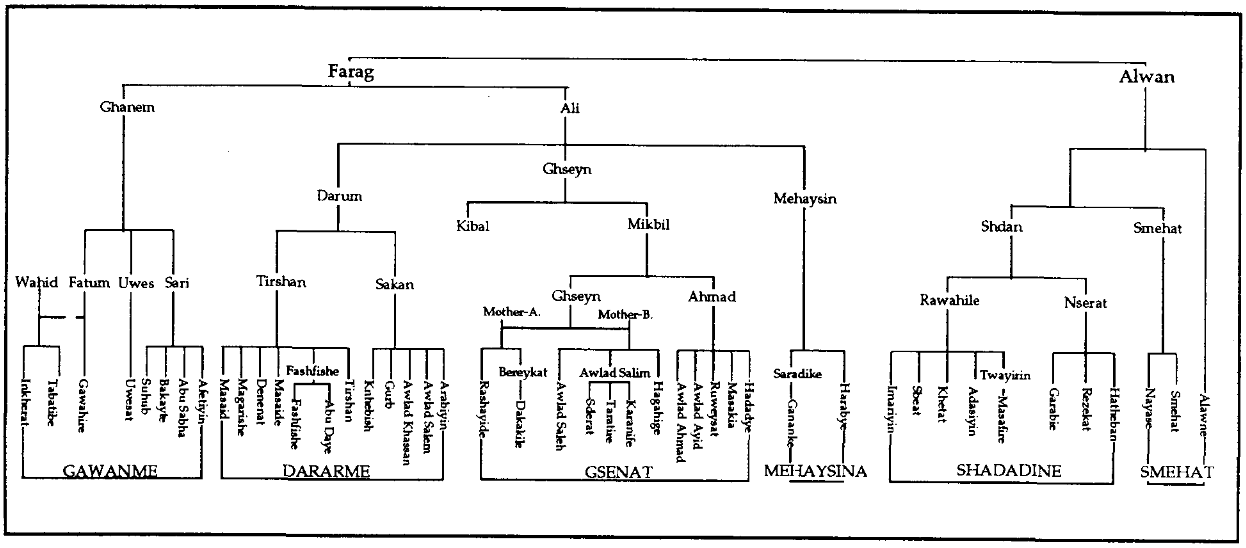
Marx (1974) comments on the rubas of the Negev tribes thus:

> *The largest ruba in the tribe is in most cases also the most aggressive, and from it is elected the Sheikh, or head of the tribe. The latter lends the ruba great influence, both in its internal tribal policies as well as in its dealings with the authorities. Thus, usually, the ruba of the Sheikh has more land than the other rubas and this enables it to attract to itself numerous affiliates and thereby become much larger than the other rubas* (pp.59-60).

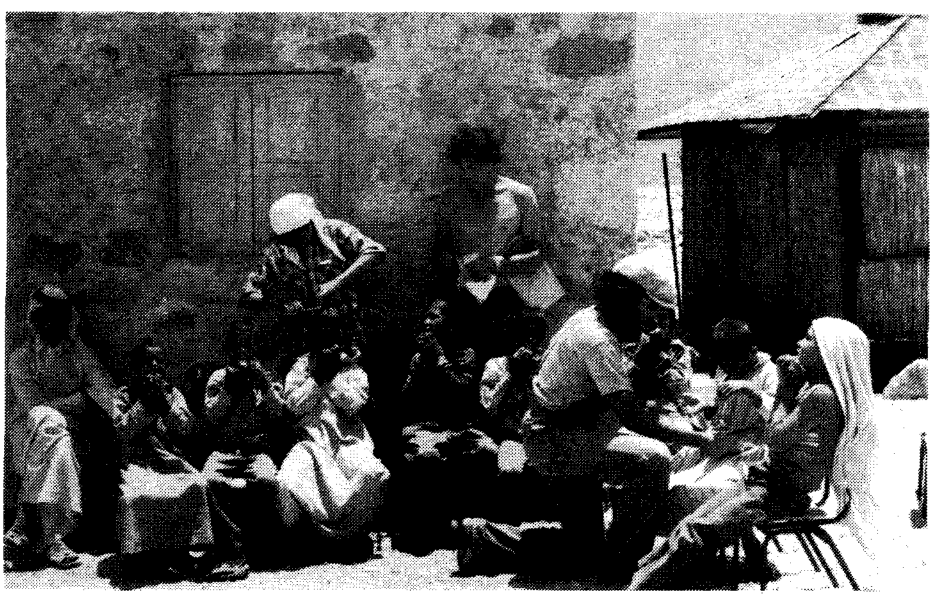
In the same connection, Kapra and Bar-Yosef (1978) note that

> *the ruba comprises a `pressure' group of families and units having common interests and standing together against groups of opposed interests within the same tribe* (p.109).

FIGURE 3: Genealogical Tree of the Muzeina Tribe*



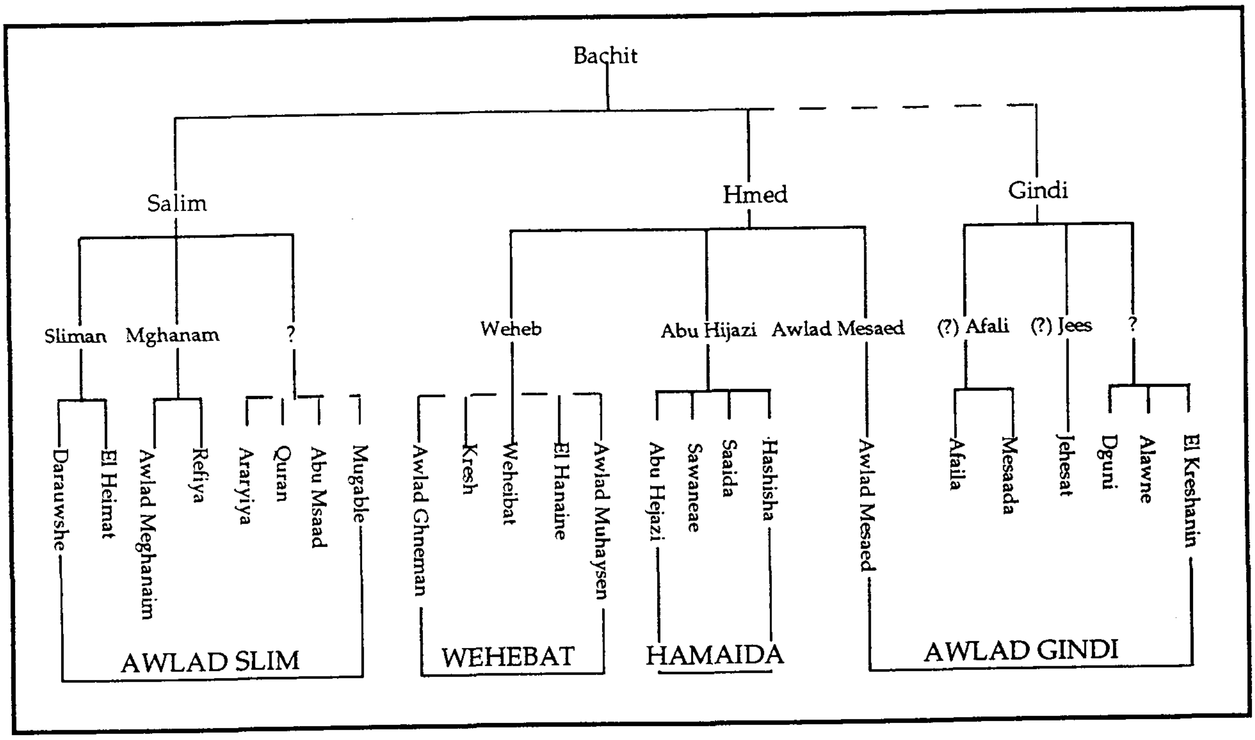
* The Muzeina tribe is comprised of six sub-tribes (horizontal names, bottom), four of which are organized within the Farag clan and two in the Alwan clan (horizontal names, top). The numbers of extended families (vertical names) varies greatly between sub-tribes. Some sub-tribes include also assimilated families (dashed lines).



Prof. Ben David and his research assistants taking dental casts from Bedouin children in Dahab.

In the tribes of South Sinai, as we shall see, the ruba is a well-defined biological unit, in the Muzeina tribe headed by a Sheikh or by an Omdah (another term for a tribal leader, identical in all respects to sheikh) in the Gebeliya tribe. Within the Muzeina (Fig. 3) we distinguish six sub-tribes, namely, the Gawanme, Dararme, Gsenat, Mehaysina, Shadadine and Smehat, all apparently deriving from the same founding ancestor. In the Gebeliya (Fig. 4), however, we find only four sub-tribes, namely, the Awlad Salim, Wehebat, Hamaida and Awlad Gindi, of which only the last does not relate directly to the tribe's genealogy.

<u>FIGURE 4</u>: Genealogical Tree of the Gebeliya Tribe*



* The Gebeliya tribe is comprised of 4 sub-tribes (horizontal names, bottom), three of which have a common ancestor (Bachit). The Awlad Gindi is an affiliated sub-tribe.

Muhsam (1966) in his extensive study of Bedouin tribes in the Israeli Negev notes that:

> *There are 93 tribes in the Beersheba Sub-District; these tribes are grouped into seven wider units called gabail (singular: gabila). Each tribe is composed of several sections called ruba. Most of the individual families forming a ruba belong to one clan or `hamula', only some of the larger rubas are divided into several clans. But in all cases, the ruba is distinguished by the fact that most of its members are related to one*

another by descent. The unrelated families in a ruba arose from tenants who, by marriage with members of the ruba, and by the acquisition of land, became themselves members of the ruba. It may be pointed out that individual families of various rubas within the tribe may be related to one another by kinship (p.25).

Muhsam's comments on the Negev Bedouin are applicable also for the majority of the South Sinai tribes insofar as the sub-tribe (ruba) is concerned.

Each sub-tribe or ruba is composed of several clans (khamula) which usually stem from a common ancestor. The Dararme sub-tribe of the Muzeina tribe is comprised of two clans - the Tirshan and the Sakhan (Fig. 3), whereas the Gawanme sub-tribe of the same tribe comprises four clans, three of which, the Sowariya (Sari), Fatiyma (Fatum) and Gwesat (Uwes), claim a common ancestor whereas the fourth, Wahid, derives from ancestors which became affiliated to the Gawanme sub-tribe. The clan has no clear-cut designation in the Arab language and the best one can do is employ the term Far'a or khamula, a term not prevalent among the tribes of South Sinai. The clans themselves are made up of smaller social units, namely, the "extended families", or in Arabic the Aeila. At times, the concept of a `father-house' substitutes for the concept of an extended family.

The extended Bedouin family is a social suprastructure whose actual existence and role are the subject of controversy among various investigators. For instance, Baily (1977, p.243) writes that the extended family is composed of a male, his wives and all his children, including the married sons and their wives. He further notes that:

this framework exists only when the father of the family is successful and prosperous, thereby exerting his authority on his sons even after they had married.

Kapra and Bar-Yosef (1978), on the other hand, define the extended Bedouin family as:

This is actually an extended economic suprastructure (meaning broader than the mere family) whose limits are not fixed. It usually includes family relatives and affiliate neighbors which maintain extensive or limited economical relations ranging from a full sharing in all incomes and expenses to a common ownership of a certain piece of property (p.109)

The Sakan clan (Dararme sub-tribe of the Muzeina tribe) is composed of five extended families, namely, the Khnebish, Gurb, Awlad Khassan, Awlad Salem and Arabiyin. The Mghanam clan (Awlad Salim sub-tribe of the Gebeliya tribe) is comprised of two extended families - the Awlad Mghanaim and the Refiya.

The social structure of the extended family is made up of a variable number of biological families; in Arabic these are called Beit. Marx (1974), writing on the Negev Bedouin family states:

> *The group within whose framework the economic activities take place is mostly the family, whether in its limited or extended form* (p.57).

In this connection Kapra and Bar-Yosef (1978) write on the South Sinai Bedouins that:

> *The basic economic unit in every Bedouin society is the limited family comprised of a male, his wives and his unmarried children. This is an economic framework within which each member of the family plays a certain role. The father is the leader of the family upon whom rest the duties of provision and security. The mother is responsible for all other tasks, i.e., housekeeping, raising of the children and upkeep of the family livestock* (p.109).

Baily (1977, p.243) assigns two roles to the Bedouin family in general, namely, (1) to constitute an economic framework within which the Bedouin man organizes his estate, with himself serving as "foreman" while his wife and children supply the "manpower". The wealth of the Bedouin is dependent on the success of this unit or framework. And (2) to constitute a framework for the production of male progeny that can serve as the enforcers in any blood feud.

The genealogical ties between such biological families are unravelled with the aid of the Hams records (see next chapter for details). The extended family is thus the framework that supervises the daily routine, migratory activities, and lodgings. The nuclear family, a more basic unit, is also the elementary socio-economic unit within the Bedouin society, but the lowest supervisory framework is the extended family.

The advantage of the extended family as the supervisory framework within the tribe is emphasized by Ben-David (1981) thus:

> *The fact that the extended family comprises a single migratory unit provides an economic advantage for both animal husbandry and horticulture, for these tasks cannot be undertaken by a single person. Moreover, nowadays the young of the family hire out for pay and are thus absent from their home for prolonged periods of time. It is the family elder, remaining in the encampment, who protects the children and tends to the livestock* (p.29).

All the Towara tribes have incorporated "external" families in the course of their history.

The Muzeina tribe (Fig. 3), according to our data, contains six incorporated or adopted families, although there may be one or two more. The assimilated families in the Muzeina tribe are the :

a) Tabatibe and Inkherat (sub-tribe Gawanme), which are believed to be descended from a common Muzeina ancestor but not from one of the original founding fathers of the tribe;

b) Hadadye (sub-tribe Gsenat), a family whose founder originally was from the Saradga tribe in North Sinai who married a woman of the Muzeina and preferred to remain in the Muzeina tribe;

c) Hagahige (sub-tribe Gsenat) who descended from the Beni-Wassal tribe that became affiliated with the Muzeina;

d) Twayirin (sub-tribe Shadadine), originating in Saudia; and finally

e) Adasiyin (sub-tribe Shadadine) who are considered to be Tarabins who have retained their integrity within the framework of the Muzeina tribe.

It should be noted that entry of a "foreign" family into the Muzeina tribe must be by common consent of all the clans.

The Hams are frequently regarded as part of the social structure of the tribe, much the same as the ruba, the extended family, and the like. In our opinion, the Hams is mainly a judicial body , albeit based on biological ties between its individual members, and not a tribal social body such as previously described. According to Ben-David (1981) the Hams and the extended family are two congruent frameworks:

> *The `Aeila' is the framework of the extended family. Its members are endowed with greater degrees of identity and consolidation than in all the frameworks above it, and it is also characterized by the consanguinity of its members. The members of an extended family are descended from a common grandfather or at least a common great-grandfather, that is, their common ancestry traces back to three or four generations. Therefore they must belong to the same Hams* (p.29).

The Muzeina tribe. Confusion in priority of publication that often happens when a number of investigators study the same subject at the same time, has happened to us with respect to the South Sinai tribes. Thus Ben-David's (1981) monograph entitled "Gebeliya - a Bedouin Tribe in the Shade of a Monastery" has introduced the history of the Gebeliya tribe before we were able to publish our own account on the same tribe. Therefore we shall concentrate in the present publication primarily on the social structure of the Muzeina tribe and shall touch upon the Gebeliya tribe only when necessary.

Sources. The social structure of the Muzeina tribe in all its intricacies is not known even to many of the elder members of the tribe. One may find a person within this tribe who knows only about the origin of the population adjacent to him (e.g. the extended families in his own sub-tribe) and another who can provide details on the biological ties between the sub-tribes as well, although members of the latter type are very scarce and are found only among the elders. From various versions we have heard in the tribe, it is clear that there is no single or uniform account of the Muzeina tribal genealogy. As might perhaps be expected, the more remote the required genealogy, the more varied the accounts of the informers. Yet the differences are not so extreme as to prevent the formulation of what appears to be an acceptable overall account of the genealogical tree of the Muzeina tribe. Once we had detailed information for all six sub-tribes separately, we could combine them into a composite picture, which is given in Fig. 3.

The genealogical map of the Muzeina tribe reveals that there are differences in the degree of esteem relegated to the various sub-tribes and even to some families within them. Thus the tribe divides into three main groups, namely, the Beni Ghanem (Gawanme sub-tribe), Beni Ali (Dararme, Gsenat and Mehaysina sub-tribes) and Beni Alwan (Smehat and Shadadine sub-tribes).The largest and strongest of the three is the Beni Ali. Following is the Beni Ghanem, whose eponym was purportedly the cousin of the founder of the first group (see Fig. 3). At the bottom of the hierarchy are the Beni Alwan , who are indicated in the genealogical map as descendants of the founding father Aliyan (Alwan), brother of Farag the founding father of the Beni Ali and Beni Ghanem.

Regarding the hierarchy between the sub-tribes of the Gebeliya tribe and its significance (which also applies to the Muzeina sub-tribes), Ben-David remarks (1981):

> *As in the intertribal relation, where each tribe claims, for one reason or another, ascendancy over the other tribes, so also in the Gebeliya tribe, a particular sub-tribe will claim ascendancy over the other sub-tribes* (p.32).

The large territorial spread of the Muzeina tribe (Fig. 5) enables it to control five main living resources, to wit:

a) grazing land around the high mountains and the open plains of 'Ein Khudrah (Gawanme territory), Bikat Baraka (Gsenat and Gawanme territory), Ilu-el-Agramiya (Mehaysina territory) and part of the ramlot sandstone area (Shadadine territory);

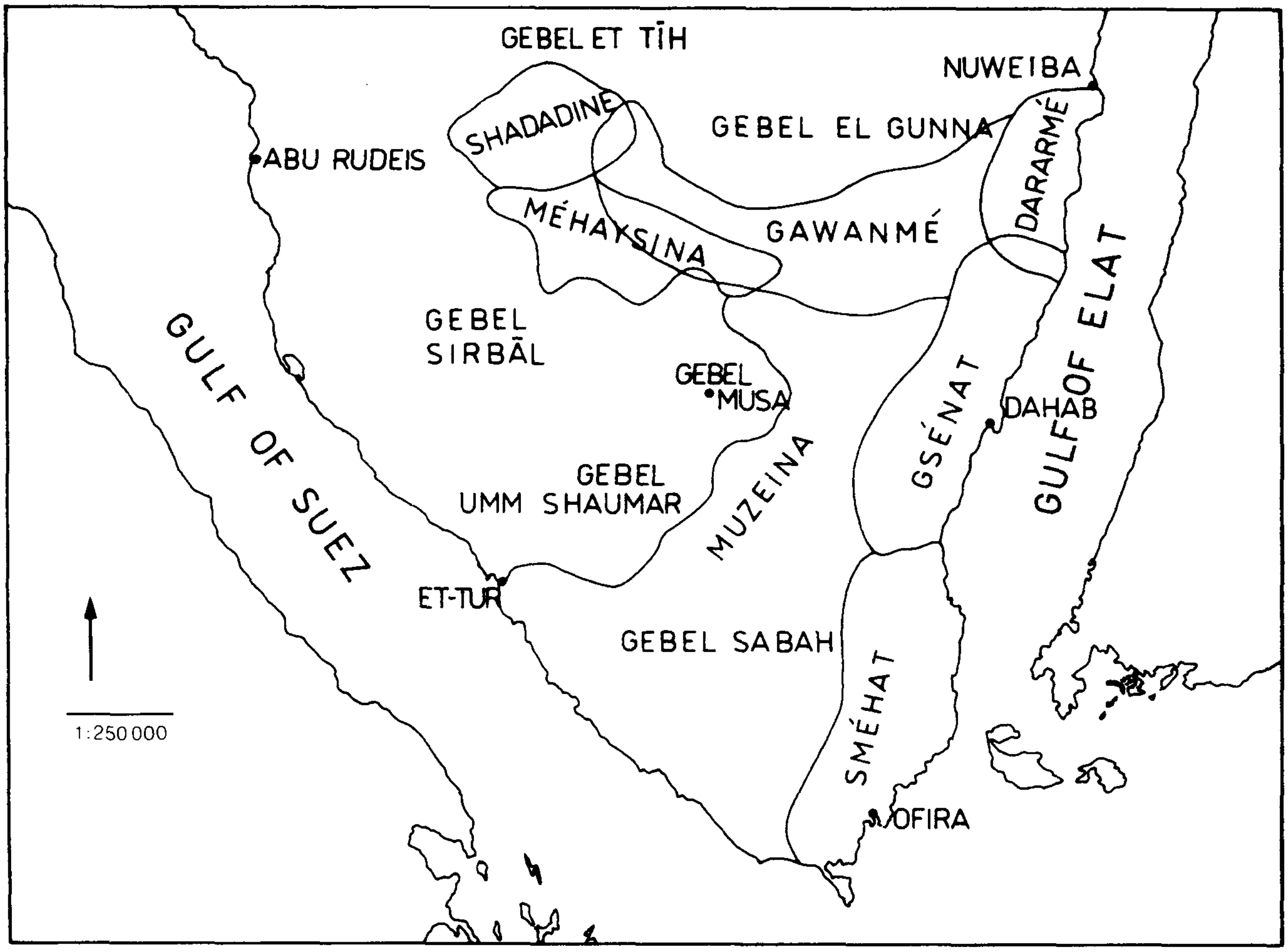
b) fishing regions along the Gulfs of Elat and Suez;

c) `smugglers' trail'.All the smuggling routes from Saudi Arabia and Jordan to Egypt pass through the territory of this tribe and consequently cooperation and consent of the tribe is mandatory;

d) proximity to urban settlements which provide job opportunities;

e) majority of tourism into South Sinai, excluding the pilgrims, must pass through the territory of the tribe.

FIGURE 5: Territorial Distribution in South Sinai of the Muzeina Sub-tribes.



Needless to say, these great economic advantages deriving from the territorial hold of the tribe have rendered it the strongest and largest of all the South Sinai tribes. The Muzeina sub-tribes Gsenat and Dararme reside along the Gulf of Elat and their borders extend eastwards from Nuweiba in the north to Ras et Tantur in the south and westwards, from the region of 'Ein Khudrah in the north to Gebel Feirani in the south. The Dararme have settled mainly at Neviot (Nuweiba) and emerge for spring grazing into the wadis that open into their territory, such as the Sa'ada, Samaghi, Hibeig and Rasasa. The Gsenat reside at Dahab and set out for grazing into the wadis of Umaiyed Dahab, Kenai and others. The Mehaysina reside partly in the region of Dahab and Nuweiba but mainly in the region of Ein-el-Akhdar. The Gawanme hardly have any contact with the Gulf of Elat, being scattered along Wadi Sa'al up to Sheikh Faranji. The Shadadine locate to the south of Gebel Raqaba and Zibalia and in the wadis of

Ma'in and Agir; a small faction of this sub-tribe is encountered in Wadi Nasb as an enclave within the territories of the other sub-tribes and an additional faction is concentrated at Dahab. The Smehat are settled along the southern coast of the Gulf of Elat (Fig. 5).

The "Hams"
A basic tool for studying marriage patterns among the Bedouins of South Sinai

The Hams, or blood-feud group, as a social unit has been mentioned previously. A fuller discussion of the scope of this social unit follows. The infrastructure which serves as a foundation for the evaluation of marital patterns within the Muzeina tribe is the Hams. The Hams in all Bedouin societies of the Near East is in fact a judicial framework which encompasses all the descendants of the single founding father as far back as five generations (Fig. 6). Kapra and Bar-Yosef (1978) note that:

> *The hamula or Hams is a group which, according to the Bedouins, protects the life, integrity and property of the individual from possible harm incurred by others. What characterizes this framework is the collective responsibility which activates the males of the group to punitive measures. Thus, once a member of the group is harmed, the other members of the Hams must punish every male member of the Hams responsible for the injury. The Hams includes all the progeny of the ancestor that had lived five generations ago, whence the origin of the name Hams which literally means `five'* (p.109).

On the same subject Marx (1974) comments

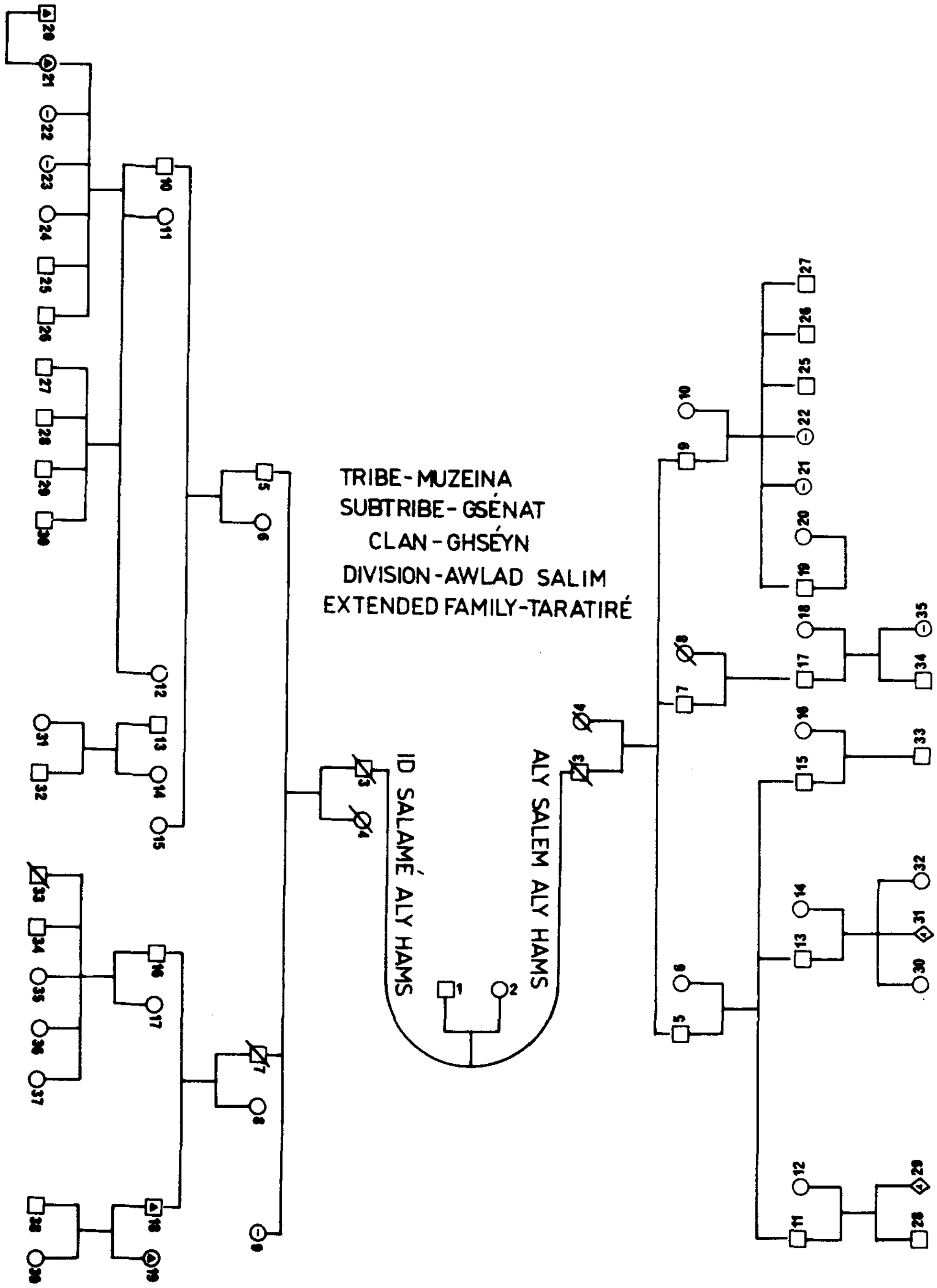
> *The term Hams (five), does not in fact refer to a recognized social group, i.e., the Khamula, but merely to those males in it who derive from a common ancestor that had lived five generations previously* (p.59).

And according to Ben-David (1981):

> *The Farah is sometimes identical to the Hams framework, which is a basic protective framework concerned also with the settlement of blood feuds. The Hams contains within itself all the progeny of a great-great-grandfather (tracing back to five generations). One cannot imagine the existence of a Bedouin who does not belong to a particular Hams, for then he would be exposed to mortal danger, to property damage and to dishonoring of his family without his being able to protect himself or give battle. Therefore, the more males a Hams contains, the stronger it is* (p.28).

There is consensus among the majority of investigators that the Hams framework includes all the descendants of a common ancestor that lived five generations previously (Fig. 6). It is only in the sixth generation that the Hams (blood feud group) undergoes subdivision into sub-units.

<u>FIGURE 6</u>: A Scheme Describing the Process of Splitting of a Hams. All the living members appearing in the genealogical tree comprise a "Blood Feud Group". The members of the next generation will already form two such groups, that of Id Salem Aly and Aly Salem Aly- An Example from the Muzeina Tribe.



The probands are marked with triangles.

The number of new sub-units that arise depends on the number of ancestors living in the second generation. Thus if there was only a single ancestor in the second generation, there will be no splitting and all the individuals of the sixth generation will still belong to the same "blood feud" group. When there are two ancestors in the second generation, there will arise two separate blood feud groups in the sixth generation. The number of blood feud groups in the seventh generation will depend on the number of ancestors in the third generation, and so on. Each generation counts back five generations and all individuals tracing back to this genealogical depth are members of the same blood feud group.

The branchings from the fifth generation on have an additive nature, that is, the number of branches increases from generation to generation. Yet, when an individual from the early generations fails to sire at least one son, his blood feud group becomes extinct.

Reasons for Hams (blood feud group) Divisions

One of the most interesting questions is why blood feud groups consist only of members who are related through a common ancestor who lived no more than five generations ago. It may be assumed that the larger the blood feud group, the greater the security of its members. Then why limit its size? The general response given to this question among the Bedouins of South Sinai is, first, that it is almost impossible to memorize all the descendants of more than five generations, as well as all the genealogical ties among them; and second, that it is impossible to have control or influence over large numbers of individuals scattered throughout a large area.

We suggest an additional reason for the division of the Hams, namely: an economic one - several of Bedouin families usually camp together. The basis for such organization is their Hams or extended family affiliation. Since the potential number of families which may camp together is limited by those related within five generations, the camps are relatively small, usually between 3-7 tents. Therefore, over-exploitation of grazing areas and water sources is avoided, new families are forced to search for new living areas, and hence enlarge the territiory of the tribe, and the limitation of camp size helps ensure its mobility in a nomadic lifestyle. Another interesting aspect related to the formation of small inbred groups is its biological advantage. Shmalghousen, already in 1946, claimed that isolates play a major role in evolution, and that under panmictic conditions, it is very difficult to preserve advantageous gene combinations. Positive combinations can increase in number and be preserved only in small populations with high consanguinity. Social behavior that encourages inbreeding, leading to the formation of autonomic groups, serves as one of the most important mechanisms which reduce panmixia. According to the same principle, disadvantageous combinations are very quickly eliminated from the group. Hence, the process of Hams division and social behavior which encourages marriages within certain groups ensures the continuity of the isolated nature of the Bedouin, with all the biological advantages derived from this situation.

Intra-Group Marriages: Endogamy

In analyzing the biology of a population, one needs to take into account the social effects inherent in the selection of a mate. According to Ben-David in this regard (1978):

> *By Bedouin laws in South Sinai, it is the inalienable right of a man to marry his cousin, that is, the daughter of his uncle on his father's side...this custom is ancient and its purpose is to safeguard the familial nature of the tribe as well as its unity* (p.123).

Similarly Perevolotzky (1979) comments that:

> *Bedouin law and tradition recognize the right of priority (`abda') which a man has on his female cousin* (p.56). And according to Levi (1979):
>
> *Marriage into the family is still predominant in Bedouin society. The rule is that a girl is intended for her male cousin on her father's side* (p.56).

Marriage of first cousins is required in most Bedouin societies of the Middle East and is based on both economic and social considerations. The main purpose of such marriages is to enhance the power of a group within the tribe. The concept of "power" has two primary connotations in the Bedouin society, the first of which is property (camels, herds of sheep and goats, etc.) and the second is numerical strength of the group. Since, however, marriages of first cousins are not always possible for lack of a partner, the tendency is to select a mate who is as closely related as possible to the father's family. This tendency is clearly evident from Table 9.

The preference of consanguineous marriages within the society stands in stark contrast to customs in other societies, where intermarriages of relatives below the rank of third cousins are, for example, forbidden by the Catholic faith (Masterson, 1970). According to data presented by Muhsam (1966) on Bedouin of the Israeli Negev, 97.6% of marriages occur within the framework of the tribal suprastructure; in the South Sinai, according to Nir's data (1987) it is 97%, and according to our data, 96.5% (average for all ten tribes). In the Negev Bedouins, 86.1% of the marriages are within the framework of the tribe, wherease in the South Sinai Bedouins (average, all tribes together) this value is 92% according to our data (97% in the Muzeina tribe!), and 86% according to Nir (1987). Data provided by Marx (1974) reveal that among the Bedouins of the Negev the number of individuals marrying within the blood feud group attains at times 60%, a "high" not encountered among the Bedouins of the Sinai. Marx, however, distinguishes between the various marital patterns on the basis of socio-economic considerations whereas we do so on the basis of biological considerations. For example, we rate marriages according to genealogical depth of the common ancestor of the couple, i.e., first cousin marriages - two generations, etc.

TABLE 9: Frequency of marital patterns within the Muzeina tribe in the last four generations.

	Generation[1]							
	G_{12}		G_{13}		G_{14}		G_{15}	
Marriage within:	n[2]	%	n	%	n	%	n	%
Hams	n.d.[3]	n.d.	n.d.	n.d.	8	3.8	43	14.6
Extended family	n.d.	n.d.	15	18.3	43	20.5	60	20.4
Clan	2	6.3	24	29.3	96	45.7	99	33.7
Sub-tribe	n.d.	n.d.	4	4.9	27	12.9	25	8.5
Tribe	2	6.2	7	8.5	23	10.9	44	15.0
Tribal supra-structure	n.d.	n.d.	2	2.4	7	3.3	10	3.4
Unknown	28	87.5	30	36.6	6	2.9	13	4.4
TOTAL	32	100	82	100	210	100	294	100

[1] G_{12} - great-great-grandfather generation

G_{13} - great-grandfather generation

G_{14}- grandfather generation

G_{15} - parents generation

G_{16} - the present generation. Since it is comprised mostly of children and youth, it is not represented in the table.

[2] n = number of families examined

[3] n.d. = no data

Hence, different categories of marital patterns are incorporated by Marx into the framework of the blood feud group, which accounts for the high frequency of marriages within this framework. According to Marx (1974) the rate of intermarriages between first cousins on the father's side among the Negev Bedouins is 11.7%. This value is close to what we encountered among the Sinai

Bedouins. Nir (1987) mentioned a lower frequency of first-cousin marriages among South Sinai Bedouins (8%). Nevertheless Marx (1974) notes that:

> *to my mind, one cannot talk about the existence of endogamy among the Negev Bedouin. Endogamy is predicated on intermarriage within a defined social group...in the Bedouin society, apart from the taboo on incest, there is no law that commands marrying within or outside a particular group* (p.187).

Marx proceeds to show that some three-fifths of all possible intermarriages do take place between cousins, and he notes that this is a very high rate considering all the expected obstacles and strictures (e.g. the desire of young people to choose their own mates). According to the data of Schull and Neel (1965) on various population groups within the Japanese society which encourage inbreeding, the percentage of consanguineous marriages of various sorts ranges from less than 2% to a high of 31%; first cousin intermarriages ranged from less than 1% to 15%. When we compare these latter data with those cited for the Bedouins, we realize that the Bedouin tribes which have so high a frequency of consanguinity constitute an unusually good research model for evaluation of the relationship between endogamy in small groups and biological variables in the group.

C. DEMOGRAPHY

The demographic data collected by various investigators relating to historical periods of the Bedouin tribes in South Sinai are generally rough estimates. The first orderly census was made only in 1968 by the Israeli authorities, and even the data of this census could not be fully reliable. The difficulty in taking an adequate Bedouin census resides in the structure of the their society, their way of life, and their beliefs. In this connection Muhsam (1966, p.9) wrote:

> *With respect to the Arab nomads, the Bedouins, it is widely agreed that their pride and illiteracy, their suspicion and extravagance - and the very combination of these contradictory characteristics - make it almost impossible to enumerate them.*

According to the available historical demography of the South Sinai (e.g. Burckhardt 1822, Shoucair 1916, Murray 1935, Field 1952, Baily and Peled 1974, Ben David 1978, Nir 1987) it seems that over a period of more than 150 years (1800-1968), the Bedouin population in South Sinai merely doubled in size. This rate of increase, albeit a rough estimate, probably reflects the population change for all the tribes combined. Clearly in the course of this long period probably some tribes enlarged numerically, others declined, and still others that remained virtually unchanged in size. Such disparities among the various tribes are dependent not only on biological factors, such as fertility and mortality, but also and perhaps even primarily on emigrations of parts of tribes outside the territory of Southern Sinai, mainly to Egypt. The reasons for such migratory movements from South Sinai could be episodes of drought and famine, outbreaks of plague, and/or greater economic opportunities elsewhere. Consequently the formulation of growth curves for the combined Towara tribes in South Sinai that would presumably demonstrate demographic changes in time, can have little or no meaning.

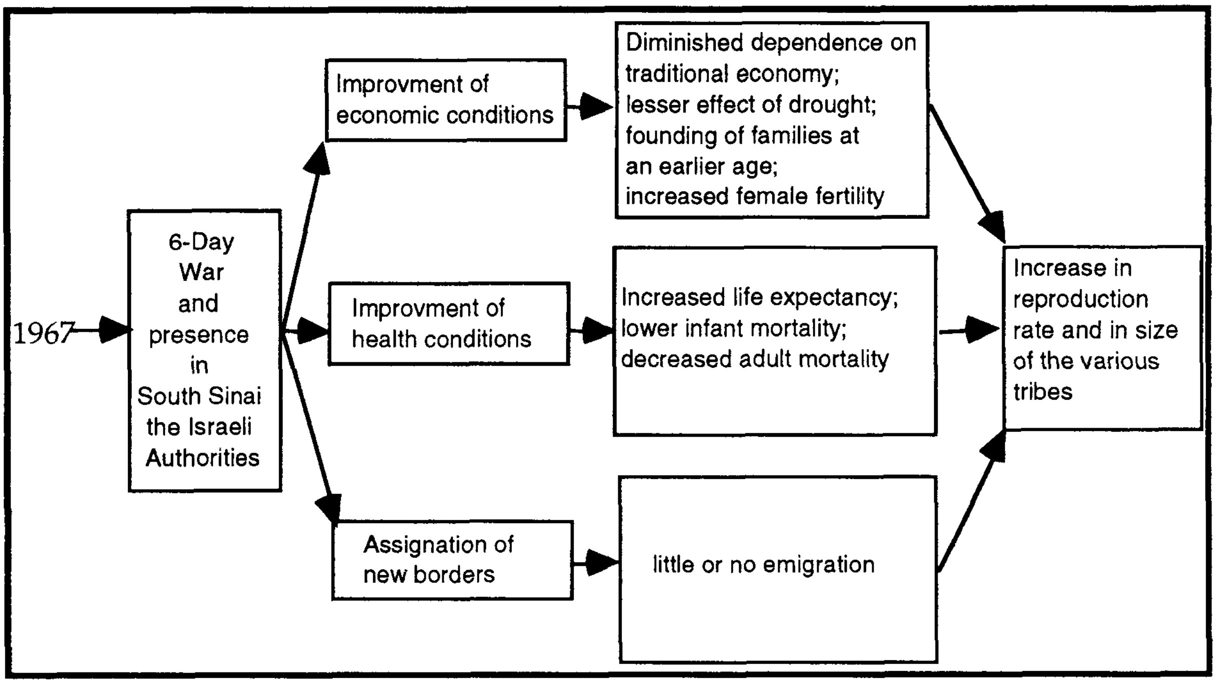
What one can say on the basis of the historical demographic data (see Nir 1987) is that three trends are suggested: first, that there are/were tribes which are/were continuously in the process of diminishing (e.g. the Sawalcha); second, that there are/were tribes that retained relative stability in size (possibly with a slight tendency to diminish), e.g. the Aleigat, Hamada and Beni-Wassal; and third, that there are/were tribes in relatively rapid stages of enlargement (e.g. the Muzeina and Gebeliya). For some of the tribes the demographic trend over time is simply not clear owing to a paucity of data (e.g. the Awlad Said and the Gararsha). To illustrate the changeable nature of the demography of the South Sinai tribes, we resort to the following exponential model:
$N_{(t)} = N_{(o)}\, r^{n-1}$, where $N_{(t)}$ = current population size, $N_{(o)}$ = past population size, r = rate of reproduction, and n = number of generations. If $N_{(t)}$ = 5358, the total number of Bedouins in South Sinai in the late sixties (according to a military census taken by Ben-David, 1978) and $N_{(o)}$ = 4000, the corresponding total in the early 19th century (according to Burckhardt, 1822), the growth rate of the population, comprising of the birth rate plus total immigration minus the death rate and emigration, will be: $r_1 = Ln[N_{(t)} / N_{(o)}]/t = Ln[5358/4000]/146 = 0.00200$. Thus, the entire Bedouin population of South Sinai would have increased during the past 146 years by 0.2% annually, and at this rate it would have taken them 244 years to double their population. The reasons for such a low growth rate, it may be worth repeating, are emigration, high infant mortality, outbreaks of intertribal homicide, disease, etc. Population growth rates, however, changed drastically from the sixties onward. Assuming $N_{(o)}$ = 5358 as estimated by military census for 1968 (Ben-David, 1978), and $N_{(t)}$ = 10, 663 (Nir 1987) by census for 1979, then the growth rate becomes r_2 = 0.0625, or an increase of 6.3% per year during this period, in contrast to the previous growth rate of only 0.2% annually. At this new growth rate the population would double itself in less than 20 years. Indeed Nir (1987) recently remarked that in 14 years of Israeli presence in South Sinai, the number of offspring doubled in Dahab, one of the major settlements of the Muzeina tribe.

If we compute the growth rate for each tribe separately and for two periods of time, namely, from 1935 to 1968, which we may designate as the pre-Israeli period, relying on 1929 data (Murray, 1935) and on 1968 data by Ben-David (1978), and from 1968 to 1979 which is conveniently designated the Israeli presence period, as per data based on two censuses carried out by the Israeli Defense Forces (IDF), we get a clear-cut and continuously increasing trend from 1929 to 1968 in the Gebeliya tribe, a slight increment in the Awlad Said, and a trend to decline in size in the Aleigat and Sawalcha tribes. In 1968 and there after, however, there was a distinct increase in population in all four tribes (Nir 1987).

The demographic differences between the Gebeliya and the Aleigat, besides those related to reliability of the census, stem from the change in the political status of South Sinai, starting in 1967. Until that year there had been substantial emigration of residents from South Sinai in the direction of Egypt, mainly members of the Sawalcha, Aleigat and Gararsha tribes (Ben-David, 1978; Arensburg et al., 1979). Since the natural growth rate in most tribes could not overtake the emigration rate, these tribes dwindled numerically. Following the Arab-Israeli 1967 (6-Day) War, the border between Egypt and South Sinai was sealed by Israel, the Bedouin emigration rate dropped to almost zero, and the tribes began to increase in size again. Factors contributing to renewed population growth among the Bedouin tribes as a result of the Israeli presence were clearly: a) improved local economic conditions, which in turn meant better nutrition and probably implied enhanced fertility and prolongation of the fertile period, lowered infant mortality and increased life expectancy; and b) improvement in the available medical services, which meant the diminution and control of former diseases and reduced mortality due usually to viral infections, especially in infants.

A diagram indicating the factors responsible for the demographic changes that occurred in South Sinai since 1967, is given as Fig. 7.

FIGURE 7: Flow Chart Demonstrating the Main Factors Associated with Demographic Changes in South Sinai After 1967.



Demography In The Social Frameworks Of The Bedouin Society (Tribal Suprastructure)

The social frameworks of the South Sinai tribes have already been discussed with respect to their ethnographic relevance. In the present section the emphasis is placed on demographic considerations.

The large tribal suprastructures of the Negev are the Tarabin (25 tribes numbering 33,062 individuals) and the Tayaha (29 tribes numbering 27,063 individuals). Compared to these groups, the South Sinai Towara tribal suprastructure is rather small, the maximum estimation in 1976 being about 10,000 individuals in 10 tribes.

The growth rate of a tribal suprastructure per year between 1929-1968 was about 0.9% (based on the data appearing in Table 10). It should be emphasized, however, that this growth rate is valid only for the period to which the data refer and does not represent a fixed value extending back into the historical past. Furthermore, this growth rate does not represent only the mean fertility and mortality in the population of a tribal suprastructure but also refers to assimilation into or departure from it of families, clans and sometimes entire tribes.

TABLE 10 Numerical growth and rate of growth of the Towara tribal suprastructure in South Sinai in the early 20th century compared to other tribal suprastructures of Bedouin tribes in the Negev.

Tribal Supra-structure	Numerical growth		Population growth rate per year (%) 1931-1946
Sinai/Years	**1929**	**1968**	**r**
Towara	4864[1]	6,888[2]	0.9
Negev[3]/Years	**1931**	**1946**	**r**
Azazma	8,661	16,505	4.3
Tarabin	16,330	33,062	4.7
Tayaha	14,163	27,063	4.3
Hanajira	3,756	7,281	4.4
Ijbarat	4,432	8,274	4.2

1.Murray (1935).

2.Levi (1970) from Nir, 1987

3 Muhsam, 1966 - data for Negev Bedouins

In the Towara tribes in South Sinai the number of individuals ranges between 151 and 1099 per sub-tribe. In the Muzeina, for instance, the Mehaysina is the smallest sub-tribe, with 261 members, while the Dararme is the largest, with 785 members (Table 11).

The number of extended families also differs among the tribes. In the Muzeina tribe we counted 45 extended families (see Fig. 3) whereas in the smaller Gebeliya tribe there were 24 (see Fig. 4).

There are extended families which number scores of members, at times upwards of 100 individuals, whereas very small extended families may be comprised of few individuals, sometimes even less than 10.

In the South Sinai tribes the number of nuclear families per tribe ranges from 88 in the smallest tribe, namely the Haweitat, to 880 in the largest tribe, the Muzeina; the number of families per sub-tribe ranges from 71 in the smallest sub-tribe of the Muzeina to 267 in the largest sub-tribe of this tribe (see Table 11).

It may be noted that in the extended family of the Muzeina tribe, one distinguishes on the average 3-4 separate blood feud groups, in extreme cases only one blood feud group or as many as ten blood feud groups. According to data presented by Ben-David (1981), the Gebeliya tribe averages 5-6 blood feud groups per extended family.

TABLE 11 Number of Bedouin families and individuals in the Towara of South Sinai in the early 1970's, by tribe and sub-tribe[1].

Tribe[2]	Sub-tribe	No. of individuals	No. of nuclear families
Ahali et-Tur	n.d.	183	56
Awlad Said		746	253
	Zehairat	419	144
	Awamrah	327	109
Gebeliya	n.d.	1155	349
Haweitat	n.d.	258	88
Hamada	n.d.	427	126
Muzeina		2886	880
	Dararme	785	267
	Gerabat	319	102
	Tsakhana	697	189
	Mehaysina	261	74
	Gawanme	277	71
	Shadadine	547	177
Aleigat		2213	585
	Awlad Salim	755	199
	Aleigat Et-Tur	151	48
	Zmiyalin El-Baara	1099	275
	Zmiyalin et-Ramla	208	63
Sawalcha	n.d.	401	119
Gararsha		1121	328
	Netsayirat	187	52
	Netsayira	491	132
	Awlad Badar	443	144

1 According to Baily and Peled (1974)

The data are not identical with our own. The same is true also for the division into clans. However, these are the only demographic data published for the number of individuals and families in the sub-tribes of South Sinai.

2 Beni Wassal not included

n.d. = no data

Distribution Of The Bedouins By Age And Sex

Despite the major censuses taken in the Sinai in 1968 and in 1975-6 by the Israeli authorities, there are no exact data on the age distribution within the Bedouin tribes of South Sinai. The demographer Muhsam (1966), who studied the demography of the Negev Bedouins, states in this connection:

> *The main reason for these difficulties lies in the fact that the Bedouin themselves do not know their age. In the present study it was therefore attempted to relate as far as possible the year of birth of a person to any major event of known date; but this attempt succeeded only in very rare cases. Furthermore, even if a Bedouin knew his own age and could be persuaded to communicate it to an enumerator who had previously gained his confidence, he would remain most reluctant to let the enumerator know the age of other members of his family, in particular of his wife and his daughters* (p.37).

Admittedly, Muhsam's comments refer to 1966, and pertain to demographic data collected 20 years previously, but in many respects they are still applicable. Thus Ben-David (1978), who presents the data of the 1968 Bedouin census in South Sinai, clearly notes that various portions of the age pyramid appear "abnormal" insofar as a "normal" human population is concerned. He cites, as an example, the very low rate of mortality among individuals ranging from 15 to 44 years of age, and believes that this is a distortion attributable to incompleteness of the census. The age pyramids for Bedouin groups from the Sinai, according to Ben-David, and from the Negev according to Muhsam, show that a major part of Bedouin in the South Sinai (44%) and in the Negev (49%) is concentrated in the low age group of 0-14 years (see Table 12). The same trend is true also in Arab villages in Israel (Muhsam, 1966). On the other hand, in European populations for the years 1930-1939, a period comparable to that during which Muhsam collected his data, the proportion of this age group in the total population is about one-third of the population, e.g. some 30% among the Italians, 32% in Poland, 35% in Rumania. In some European populations the percentage of this age group is even smaller, comprising an average of one-quarter of the population, e.g. 24% in France, 24% in England, 23% in Germany. In the U.S.A., the proportion of this age group, 0-14 years, is approximately 30%. In the Indian sub-continent it is 25%. In Egypt it approaches 39% and in South American countries it is about 37% (Jong, 1972).

In the South Sinai and Negev Bedouins, after age group 0-14 the relative proportion of each age group diminishes drastically (Table 12), a trend in contrast to that of corresponding age groups in other populations. For instance, in the

Israeli population, according to data of the Central Bureau of Statistics for 1978, about 13% of the males and females occur within the age group of 45-59 years whereas among the Sinai Bedouins the equivalent percentage is only about 6% and in the Negev Bedouins it is even less, only about 4%. The males of 60+ years in the South Sinai and Negev Bedouin populations comprise only 2.0-2.7% while in the Israeli male population they are 12.3%. Relatively much fewer South Sinai Bedouins live to old age, probably due to their harsh environment.

TABLE 12 Percentage distribution of the Bedouin in South Sinai[1] and the Israeli Negev[2], by age and sex .

Age group	Males		Females		Both sexes		sex ratio	
	Sinai	Negev	Sinai	Negev	Sinai	Negev	Sinai	Negev
0-14	23.1	25.0	20.8	24.5	43.9	49.5	111	102
15-29	10.7	11.1	9.2	11.1	19.9	22.2	116	100
30-44	9.8	8.2	9.9	7.8	19.7	16.0	99	105
45-59	7.9	4.2	4.6	4.0	12.5	8.2	172	105
60+	2.7	2.0	1.3	2.1	4.0	4.1	207	95
TOTAL	54.2	50.5	45.8	49.5	100.0	100.0	118	102

1 Ben-David, 1978

2 Muhsam, 1966

Bodenheimer (1958) claims that from the biological viewpoint a population is divisible into three fixed age groups, namely, the pre-fertile, fertile, and post-fertile periods. In the "young" populations in general the age distribution yields a pyramid in which a relatively large number of individuals are both in the pre-fertile and fertile stages, a situation that prevails among the Bedouins of the South Sinai. Such a structure of the total age pyramid may suggest a rapid rate of reproduction of a population. Yet this possibility is abrogated among the Bedouins by factors such as a short average life expectancy, frequent migrations, and other causes which we shall elaborate on subsequently.

Fertility Patterns

Jong (1972) has observed that:

There are no more important social or biological events in personal history than birth and death, and there are no aspects of human behaviour *more significant for the survival of a society than fertility and mortality patterns* (p.32).

We now consider these social-biological events among the Bedouins. There are a number of indices, reflecting fertility in a population which can be used in comparative studies. In western societies the calculation of such indices is a relatively simple matter. For the nomad Bedouin society, however, the formulation of fertility indices is a complex and complicated task which can at best yield an estimate rather than a precise value owing to incomplete information. The three indices which we applied to the Bedouin society were:

(a) Crude Birth Rate (CBR), or number of births per 1000 individuals of a population per year. This is of course a relatively crude index which is not sensitive to changes in the age and sex group structure within the population.

(b) General Fertility Rate (GFR), which is an index of the number of births per year per 1000 potentially fertile females (15-45 years old). This index is sensitive because it takes into account the sex and age composition of the population.

(c) Total Fertility Rate (TFR), which is an estimate of the number of children which a group of 1000 women could potentially produce if they all lived through their reproductive years.

Computation of CBR. The number of individuals in the Muzeina tribe, according to a 1976 census, was 3000. Of this total, 44% were children 0-14 years old, or 96 at each age, assuming approximately an equal number of children having been born each year. This number would of course represent only the children surviving. If we now add to this number the mortality rate among children in their first year, which reaches 18.8% (Table 13), then we obtain 118 children per annum. Dividing this number by the population size, we obtain as CBR approximately 38.7 live progeny per 1000 individuals of population. Ben-David (1978), who made an analogous computation for all the Bedouin tribes of South Sinai, based on the data of the 1968 census and on a mortality rate approaching 45% (of all children from 0-14 years), obtained also a CBR of 40 live births per year per 1000 individuals. According to our data, a rough estimate of the CBR for the Bedouin population in South Sinai in 1980, the time of our survey, was approximately 38 live births per 1000 individuals.

Computation of the GFR. The number of males to females in the Muzeina tribe was 1650 vs. 1350. Of the latter, 513 (38%) were women in the potentially fertile ages of 15-45 years. Therefore the GFR value is 228.9, estimated as annual birth rate (122) divided by number of fertile women (533) multiplied by 1000.

TABLE 13 Number of living, and deceased children after first year of life at various age intervals of mothers in the Muzeina tribe, 1980*; both sexes, based on 97 families.

	Age group of mothers						
	15-19	20-24	25-29	30-34	35-39	40-44	Total children
Number of children							
Living	10	72	50	81	44	75	332
Dead	1	5	11	20	16	24	77
Total born	11	77	61	101	60	99	409
Percent dead	9.1	6.5	18.0	19.8	26.7	24.2	18.8

*Reported by fathers.

Computation of the TFR. This index was computed by summing the age-specific fertility rates for all ages and multiplying by the range into which the ages are grouped. The estimated value for the TFR among South Sinai Bedouins was 6980.

We find that the fertility rates (DBR, GFR, TFR) in the Bedouin society of South Sinai are relatively high compared to those in populations of industrialized countries, but are comparable with those in neibouring Arab countries, or third world countries (Table 14).

TABLE 14 Fertility rates in South Sinai Bedouin society compared to those in other populations*.

	Fertility indices		
Population	CBR	GFR	TFR
Sinai Bedouin	38.7	228.9	6980
Saudi Arabia	42.3	180.7	5824
Israel	27.9	121.0	4101
Kuwait	40.3	174.2	5207
China	39.3	156.6	4926
Mexico	45.0	196.7	6268
Belgium	17.0	75.3	2565
Poland	26.3	103.1	3324

*All data are from Jong (1972, pp.40-45), except for Sinai Bedouin

CBR=crude birth rate; GFR=general fertility rate; TFR=total fertility rate

The fertility in the Bedouin society, on the basis of the data presented in Table 15 shows that by the time of menopause (age 45+) the Sinai Bedouin woman has had an average of 5.5 living children, the Negev Bedouin woman, 5.80 children, and the Arab village woman, 6.04 children.

The average fertility period of the South Sinai Bedouin female is about 18 (range 16-44 years), with overall fecundity of almost seven children (Table 15). The average birth interval of a married Bedouin woman in South Sinai is 2.4 ± 0.4 years. In the Bedouin populations of the Negev, the duration of the fertile period in women is 18.6 years, live births occur every 2.5 years, and the overall fecundity is 7.5 children per woman (Muhsam, 1966). Thus, it seems that the fertility indices in the

TABLE 15 Mean number of living children per family, compared with total births in Bedouins of South Sinai compared with like data among Bedouins in the Israeli Negev and Israeli Arabs.

Age of mother	South Sinai Bedouins[1]		Negev Bedouins		Arab villages[2]	
	Living children	Total births/ mother	Living children	Total births/ mother	Living children	Total births/ mother
15-19	1.42	1.54	1.52	1.67	1.36	1.59
20-24	2.32	2.47	1.88	2.27	2.30	2.96
25-29	2.94	3.46	2.95	3.60	3.70	4.97
30-34	4.26	5.10	3.98	5.09	5.10	7.15
35-39	5.50	6.98	4.47	6.16	5.78	8.26
40-44	n.d.	n.d.	5.80	7.53	6.04	8.78

1 Data for the South Sinai Bedouins are organized and analyzed according to fathers' questionnaires

2 Data from Muhsam, 1966

Bedouin society remain high throughout all age groups till almost the end of the fertile period. From a demographic standpoint, the Bedouin society in this respect belongs to the category of "Broad-peak Type" (Jong, 1972).

We also found that among young Bedouin fathers (21-35 years), the mean marrying age had been about 20 years, and in later age groups (36-45), it was about 26 years, calculated according to the age of the first child). These data suggest a change in the marrying age of males after the year 1967, during the Israeli presence in the territory.

Apparently a more rapid accumulation of property occurred after 1967 which enabled earlier marriage by South Sinai Bedouins, and conseqeuntly a greater mean number of children per family.

Mortality Patterns. Regrettably, we were unable to compute any mortality indices (Crude Death Rate and Infant Mortality Rate) that could be comparable with those for other groups. From 55 families, where the mothers were relatively young (15-29 years) 13 reported on at least one dead child, with the number of boys almost double the number of girls. In 42 families where the mothers were much older (35-44 years), 35 families already reported on at least one dead child in the family, the ratio between male and female remaining the same.

The mortality curve for the Bedouins in South Sinai, like that for many other populations, is U-shaped. Thus, among the Bedouins the mortality rates in the low age groups (0-14 years) are exceptionally high, but thereafter (15+ years) the rates decline rapidly, remaining relatively low till the end of the third decade of life when they rise sharply again albeit not to the same extent as in the early ages.

Generally the mortality patterns for males and females are not identical in most regions. For instance, in the "advanced" countries at present, male mortality rates exceed the female rates. In many so-called developing countries, however, female mortality rates still exceed that of the males (Jong, 1972). Bedouin society, the male mortality rate exceeds that of the females. Ben-David (1978) claimed that in the older age groups (45 years and over) the situation is reversed.

Regulation Of Fertility

In the following we shall attempt to review the main factors which, we believe, influenced fertility in the Bedouins of South Sinai. We shall also present the primary demographic data linked with these factors.

Some major factors which affect fertility are assigned into two groups:

a) Biological factors such as general health status, certain genetic diseases, sterility, period of lactation and length of the reproductive period.

b) Social factors such as age at marriage, divorce, absence of mates, death of mate, remarriage, polygamy, religion, use of contraceptives, abortions etc..

In the present study we concentrated mainly on social factors although the biological factors are also considered.

a) Biological factors

The state of health among South Sinai Bedouins has until recently received relatively little attention (Levi, 1978). Nonetheless, the available data suffice to emphasize how important this factor was in regulation of Bedouin population size in South Sinai before 1967. Major plagues, about which we have the testimony of travellers as well as an abundance of native folklore (Levi, 1987), accounted for a very slow total increase of population in time, even diminishing it markedly at intervals. Infants who became ill or mothers who contracted a postpartum infection, were in most cases doomed to death. The harsh living conditions - cold winters in a wind-exposed tent, and hot summers with little shelter, coupled with a meager and inadequate diet, rendered the population, particularly the young, prone to numerous diseases. Undoubtedly, poor nutrition and harsh living conditions also induced lengthening of the lactation period in women, and hence the overall fertile span was shortened (Frisch, 1977).

Traditional folk medicine could provide little of the medical needs, relying as it did mainly on magic, cauterization and use of herbal concoctions (Ring et al., 1983; Nathan et al., 1982). Regrettably, we lack valid data on morbidity rates and causes among the Bedouins of South Sinai. Examination of some medical records in the clinics of Dahab and Santa Katharina did not supply us with adequate information.

b) Social factors

The replies to a questionnaire among the South Sinai Bedouins indicated that the mean marrying age was about 23 years for a male and 17.5 years for a female. Nir (1987) found that the marrying age for females ranged from 16 to 18 years, and for males between 23 and 25 years in this same population. According to Muhsam (1966), among the Negev Bedouins, some 50% of the men were married by the age of 20 and 75% were married by age 24 (mean 22.4 years); among Negev Bedouin women, 50% were already married by age 17 and 80% were married by age 19 (mean 18.4 years).

The age difference between South Sinai Bedouin males and females at the time of marriage was between 2-6 years; for Negev Bedouins it was about 4 years (Muhsam, 1966). Yet there are some males who marry at a relatively advanced age, and sometimes they do so with young women despite the general social disfavor of marriages between an older man and a young woman. Thus Ben-David (1978) notes,

> *The marriage of young women by old or mature men is not a daily occurrence because the Bedouin are alert to the fact that `abandoning a young maiden in the hands of an elder of dubitable fecundity' (to use their words) is rather unesthetic* (p.124).

Of interest is that relatively few males (less than 4%) marry women older than themselves.

The early marrying age of females in the Bedouin society theoretically enables them to produce more progeny during their fertile period. There is some question as to whether a correlation exists between marrying age (except in later years), either of males or females, and fertility (Revelle, 1968). Most studies, however, suggest that there is no such correlation (Benedict, 1972). The reason for these may be due to the different "type" of social population structure.

In regard to polygamy, by Moslem law each Bedouin male can marry up to four women. Yet a Bedouin man with three or four wives is rare (Muhsam, 1966). On the basis of genealogical records, we found varying rates of polygamy throughout the studied generations, with a general trend towards diminution of the polygamy rate in time. We have also found, as expected, that frequency of polygamy increased with the husband's age. The mean rate of polygamy obtained for the total population, based on questionnaire data, was 15%, which is close to that computed from genealogical trees - 12.1% (Table 16).

Ben-David (1978) reported 17% polygamous families in the South Sinai bedouins. Nir (1987), on the basis of 1900 families, reported a 12.25% polygamy rate: 10.15% husbands with two wives, 1.68% with three wives and 0.42% with four wives, and maintained that only sheiks or wealthy and well-known men possessed more than two wives. Nir also gives the rate of polygamy in the various tribes: Aleigat 21.3%; Haweitat 12.9%; Gebeliya 7.5%; Sawalcha 21.1%; Awlad Said 11.1%; Hamada 5.5%; Gararsha 15.0%; and Muzeina 8.6%. The general trend from these data is that the larger the tribe the less the frequency of polygamous families. i.e., 8.6% within the Muzeina (3056 members) vs. 21.1% in the Sawalcha (401 members). Levi (1979) notes that of 81 examined polygamous families, 67 were bigamous, 10 trigamous and 4 quadrigamous.

Taking all the Negev Bedouin tribes together, the mean percentage of polygamous (actually bigamous) husbands in the late 1940's was 7.7, with a range of 4.4-15.5% (Muhsam, 1966). Marx (1974) who also worked on the Bedouin of the Negev, has maintained that polygamy is relatively rare among Bedouins, citing 9.2% for the Abou-Juoad tribe of the Negev, emphasizing that among the Sheikhs, polygamy was not uncommon, especially when compared to the overall Bedouin population in the Negev. It must be emphasized, however, that all these percentages represent marital status at a single point in time. Thus a Bedouin who may be polygamous, could divorce a wife and revert to monogamy, and later marry another woman and become polygamous again. Hence polygamy among Bedouin men may be regarded as a "flexible" state. For instance, although the rate of polygamy never exceeds 15% at any one time (Ben-David, 1978; Levi, 1979; Nir, 1987; and present study), according to our questionnaire, almost 35% of married males over the age of 45 reported having children from at least two women.

In the South Sinai the mean age at which the Bedouin males acquire a second wife is 31 years. Muhsam (1966) estimates this age for Negev tribes as 35.8 years. He further calculates the mean age difference between a husband and his second wife to be 14.5 years, and the age difference between the first and second wife, about 10 years. The demographic data in this respect, for both Negev and South Sinai Bedouins, are quite similar, so that the Bedouin male is likely to be some 11-14 years older at the time of his second than at his first marriage and usually his second wife is a woman not much older than was his first wife at her marriage.

Muhsam (1966) found that in polygamous marriages, only 80% of the husbands were older than their first wife whereas in monogamous marriages the corresponding value was over 90%. He attributes these findings to the fact that in many cases Bedouin males were required to marry the widow of their deceased older brothers. Such `forced' marriages could lead to a situation where the first marriage of a younger brother might well be with an older woman, and consequently "trigger" the young brother to acquire a second, youthful wife.

Levi (1979) maintains that the primary advantage of polygamy is that it enables the male to produce many offspring, thus enhancing the "physical" strength of the family. Muhsam (1966), on the other hand, claimed that polygamy lends an economic benefit to the Bedouin male in that it enables him, in times of drought and aridity, to split up his herds and send them to different watering holes, each under the responsibility of one of his wives.

TABLE 16 The average percentage of polygamous families in two last parent generations (G14; G15) of South Sinai Bedouins[1](based on 287 families, Muzeina tribe).

Generation[2]	Hams	Extended family	Clan	Sub-tribe	Tribe	Tribal supra structure	TOTAL
G14+G15	0(8)[3]	5(58)	9(120)	4(31)	8(30)	5(9)	31(256)
% Polygamous	0.0	8.6	7.5	12.9	26.7	55.5	12.1

1 According to tribal social structure of South Sinai Bedouin Hams blood feud group records

2 G14=grandparents; G15=parents

3 Numbers in parentheses refer to total number of families per social unit of the tribe.

We found a negative correlation between husband and wife kinship and polygamy, namely, the closer the kinship between husband and wife, such as being first cousins (marriages within the Hams), the less the likelihood that the husband would acquire an additional wife (Table 16). We cannot yet offer an explanation for this fact; the implications of this observation will be considered subsequently.

Fertility in polygamous families: An important albeit controversial issue is whether polygamy exerts an effect on the fertility of an individual woman. Theoretically, these should have no effect for according to Bedouin tradition, a husband with more than one wife must share his nights equally among all his wives, each night with only one wife, without favoring one wife over another.

Second marriages ,however, frequently result from inability of the first wife to produce many, or any, offspring. Benedict (1972) cited such "reasons" for the inverse correlation between polygamy and fertility. Most investigators concerned with the question, concur that polygamy is negatively correlated with fertility (see Benedict, 1972). The fact that the large study of Nag (1962) on factors influencing fertility in non-industrialized societies in various countries, fails to find any correlation between polygamy and fertility, is attributable generally to the manner in which Nag carried out his comparisons, namely, that he compared polygamous and monogamous societies whereas he should have compared polygamous and monogamous women of the same society. Indeed most studies done in the latter fashion (e.g. that of Dorjahn, 1958, and also the present study) reveal an inverse correlation between polygamy and fertility. However, the observed results are not statistically significant and therefore perhaps should be regarded with caution.

It is of interest that Muhsam (1966) noted that in Negev Bedouin polygamous families, sterility occurred more among first wives than in the monogamous families. However, his data also indicated that the percentage of infertile second wives was greater than that among first wives in polygamous families, something we did not encounter among the South Sinai Bedouins.

A further significant finding by us was that among the South Sinai Bedouins polygamous marriages were less fecund than monogamous marriages. Thus we found, on the basis of Hams records of 12 families that the average number of living children per wife in a polygamous family was 3.5 (the same for first and second wife). According to our questionnaire data (based on 15 polygamous families), the average number per wife was 4.0 (for both the first and second wife). In the monogamous family,however,the average number of children per wife was 5.5. Hence the disparity in fertility between monogamous and polygamous families, relating to live progeny is on the order of about a 36% differential. According to the data of Muhsam (1966, p.93), the difference was even greater in this regard, 32%, assuming no difference in child mortality within the two groups and that the age distributions of the wives in the two groups are comparable.

Divorce: By divorced individuals we here mean those who were married but then separated without having remarried by the time of our survey, and who retained custody of the children (the relevance of the latter criterion will be discussed later). The act of "divorcing" is prevalent in Bedouin society, yet is not reflected in the demographic data (Ben-David 1978). Levi (1979) noted that in a sample of 70 Bedouin families from South Sinai, he encountered 17% of remarried women, and he suspected that this percentage must even be as high as 30% in other parts of the Sinai where economic conditions were less stable. According to Ben-David (1978), among South Sinai female Bedouins aged 15-39 there were hardly any in a "divorced" status, whereas at age 40 and over the average was 5.3%. Among the Negev Bedouins, according to Muhsam (1966), the percentages for the corresponding age groups were 0.46% and 0.72%. Two main reasons account for the "disappearance" of divorcees from statistical tables, based on official population censuses. First, a divorced woman, if still considered to be in her fertile period, soon finds another husband because of a great paucity of women in the South Sinai Bedouin society; each woman who becomes "available" is virtually immediately `abducted' by one of the males in the tribe. Second, divorced women return to their parents' house, if they do not remarry, and receive anew the status of a daughter. In such cases, the head of the family, when queried by census takers, declares the divorced daughter as merely his daughter without giving her past marital history. The divorce rate generally becomes higher, albeit very minimally so, starting in the older age groups (40+ years), when the women are past their fertility period.

There is a tendency among most investigators to link marital instability with low fertility (Benedict, 1972). In this connection it is noteworthy that marriages in the Bedouin society are rather unstable. While the right of divorce is given to both husband and wife, the woman needs to apply to the judicial authorities of the tribe and to justify her request for divorce, whereas the man can "expel" the wife relatively easily, without explanation and usually without "legal" hearings. All he must do is exclaim, *I now divorce thee!* (Levi, 1979).

The reasons for divorce in Bedouin society are numerous, for example including infidelity, delinquency in housekeeping, infertility. Recompense to the woman divorced is negligible, yet is fixed and inherent within Bedouin law. Children, if there are any, will always be granted to the husband.

There may be a relationship between frequency of divorce and the desire of an adult male to have children. Thus a man who does not have children with a first wife will divorce her, or take a second wife, and if the second wife does not conceive, he may also divorce her, and remarry a third or even a fourth time. Hence, if the fault for infertiity does not reside in him, he will ultimately succeed in having offspring. A Bedouin man without children is considered "as good as dead", for he is then cast to the fringes of society, his influence in the social framework of the tribe becomes minimal, and his physical and economic safety become dependent on others.

Widowhood. Widowers or widows are designated as individuals who had been married but lost their mate by death, did not remarry, and were acting as head of a family.

In South Sinai Bedouin society, as is the case for the Negev Bedouins, the rate of widowhood increases in the age groups. From 0.0% in the Sinai Bedouin (less than 0.1% among the Negev Bedouin), at the age group of 15- 19 years, to 4.2% (7.3% among the Negev Bedouin) at the age group of 50-59. In both the South Sinai Bedouins and the Negev Bedouins, the number of widowers is relatively small compared with the number of widows (Muhsam, 1966; Ben-David, 1978). The latter attributes this to the fact that the widowed male does not long remain widowed, that he attempts to accumulate the financial means for obtaining a new wife, regardless of his age, and especially if he has children by the deceased wife. In contrast, a mature widow, that is, one past her fertile period who usually also lacks property, has less chance of remarrying.

Looking at the social aspect of widowhood on a global scale, they range from total prohibition of remarriage, for example the widow in certain Indian societies, to compulsory remarryiage with an obligation of the new husband to impregnate the widow in some African societies (Benedict, 1972). The Bedouin society inclines more toward the latter, demanding that the fertile widow remarry and return to the reproductive pool of the society. Thus most widows in the South Sinai Bedouin society do remarry; indeed the younger they are at widowhood the greater their chances for a rapid remarriage.

Contraception and Abortion. In the Bedouin society, as in other societies, there are various techniques for preventing conception, most of them based on imbibing herbal concoctions (Benedict, 1972).

Levi (1979) mentions three main traditional contraceptive techniques among the South Sinai Bedouins: 1)an abundant consumption of cowpeas; 2)drinking tea containing carnation thorns for 40 days; and 3) drinking water heated by a hot iron twice daily, preferably in the morning. The validity of these methods has never been examined by medical researchers and their utility is doubtful. With the entrance of Israel into the region in 1967, there has been an increase in the use of contraceptive pills.

It is noteworthy that it is usually older wives who have given birth to several children who are the ones generally using contraceptive measures, and not young wives without, or with only a few, children. The method of coitus interruptus is prevalent in many simple societies as a contraceptive measure (Benedict, 1972) but apparently is rarely practiced among the South Sinai Bedouin.

Abortions are condoned in Bedouin society only in special cases. Levi (1979) mentions two important instances where abortion may be carried out, first, in cases where a Bedouin wife becomes pregnant by another man while her husband is away; and second, in cases where young girls have had pre-marital sexual relations leading to pregnancy and are liable to be condemned to death by members of their own family unless abortion is performed. We doubt that the two mentioned factors cited by Levi significantly affect the fertility rate in Bedouin society, and in any case, no information is available regarding the rates of abortion among South Sinai Bedouins.

The technique of abortion among the South Sinai women, according to Levi (1979, p.23), is a mixture of various herbs, leaves, roots and stones, ground and mixed with water which the woman drinks until she aborts.

Usually, however, undesired pregnancies find their solution by having the responsible male by custom virtually "forced" to marry the pregnant female.

In sum, contraception and abortion were not effective in preventing the fertility potential in South Sinai Bedouin society. Factors that until recently prevented substantial growth of the population have been primarily malnutrition and poor health. A paucity of physicians and lack of medical care on the one hand, and poor economic conditions on the other, led to a very high mortality of infants, at times almost 25% according to our data and 45% according to Ben-David (1978, p.120). At present, a lack of physicians and adequate medical care still prevail, yet the ancient and still prevalent linking of family size with prestige promotes maximal reproduction under existing circumstances.

Curtailment in growth of the Bedouin society is thus dependent largely on external factors. The present social and economic infrastructure is conducive to propagation and therefore one may expect the Bedouin population to grow at an accelerated rate until new restraining factors arise.

Sex Ratio

The ratio of males to females in a generation is a vital measure of the demographic composition in a population. The average sex ratio of human births is approximately 105 (Cavalli-Sforza and Bodmer, 1971). Data on the sex ratio in the South Sinai Bedouin population in the 1960's and 1970's have been provided by Ben-David (1978, p.116). According to his data, unusual phenomena occur, the sex ratio changing dramatically with the age (Table 12). The mean sex ratio for all age groups combined was 118.3. According to Nir (1987), the sex ratio for the South Sinai Bedouins, all ages, was 109.

Ben-David has noted that the sex ratio among Sinai Bedouins differed completely from that reported in the literature, especially for Western societies, where the number of males is larger at birth but equals the number of females at about age 5, and thereafter diminishes with age relative to the number of females.

The data collected by us pertaining to sex ratios are similar to those obtained by Ben-David. From Hams (blood feud group) records we learn that in the parent generation (G15, ages ca. 18-44 years), the sex ratio average was 128.1 and in the offspring generation (G16, ages ca. 0-17 years) it was 106.9 (Table 17). The differences in sex ratio between the two generations (G15 and G16) may at least partially be attributed to an artificial disappearance of females from the Hams records in the fifteenth generation, i.e., those who did not reach adulthood and marry. According to Bed-David's (1978) data, the sex ratio in the G16 generation was 111.0, and in G15, 108. In our study we tried to overcome the tendency of the Bedouins to "eliminate" females from their reports, as already mentioned by Muhsam (1966), Ben-David (1978) and Nir (1987), by cross-checking the data with different resources.

Thus, the high male/female ratio referred to by Ben-David for Bedouin tribes of South Sinai is supported also by our data.

The data on sex ratio among Bedouins of the Negev prior to Israel statehood, according to Muhsam (1966), indicated a mean of 102 in favor of males for all age groups combined. The sex ratio in infancy (0-1 year) was 106.

In the Jewish population of the 70's, (based on the 1978 census), the changes in the sex ratio values with age are almost the inverse of those for the South Sinai Bedouin population. The sex ratio at birth was 105.9.

TABLE 17 Mean number of children per family and sex ratio in parental (G15) and offspring (G16) generations in accordance with relatedness of the parents.

Social group	Parent Generation (G15)					Offspring Generation (G16)			
	N*	$\overline{X}$	S.E.	Sex ratio	Percent childless families**	N	$\overline{X}$	S.E.	Sex ratio
Hams	6	3.50	0.88	128	16.7	28	2.67	0.36	110
Extended Family	34	3.73	0.39	122	15.0	46	2.84	0.25	115
Clan	94	4.34	0.23	117	4.0	72	3.31	0.21	105
Sub-tribe	26	3.61	0.40	146	7.1	15	2.66	0.52	85
Tribe	23	0.82	0.39	167	4.2	29	3.75	0.38	107
Tribal Super-structure	6	4.50	0.99	121	0.0	-	-	-	-
TOTAL	189	4.0	-	128.1	6.9	190	3.1	-	106.9

* N = number of families

** Data not given for G16 generation as reproductive period has not yet ended

The factors that could have been responsible for the great disparity between the sexes in the Bedouin population will now be considered.

Evolutionary explanation of sex ratio biases. The sex ratio, why more males than females are born and survive, or vice versa, in general has perplexed biologists even in previous centuries. Thus Darwin, in "The Descent of Man", devotes an entire chapter to this topic and to its link with natural selection. He wrote (Darwin, 1872):

> *I formerly thought that when a tendency to produce the two sexes in equal numbers was advantageous to the species, it would follow from natural selection, but I now see that the whole problem is so intricate that it is safer to leave its solution for the future* (p.611).

It is an axiom of evolutionary theory that parents will allocate resources to offspring of different sexes in order to maximize parental reproductive fitness. Three hypotheses have been proposed to explain parental predisposition: a) Fisher's hypothesis (Fisher, 1930) of equal parental investment at the end of the period of dependence; b) Trivers and Willard's (1973) hypothesis of parental predisposition depends of child sex, in terms of resources available to them and the effects of those resources on the offspring's reproductive success, and c) the hypothesis of local male/resources competition/enhancement, which stresses the contributions offspring make to the reproductive success of their parents and/or siblings and the reproductive costs imposed on parents and/or siblings by competition (Hamilton, 1964; Clark, 1978; Sieff, 1990). These hypotheses are not mutually exclusive and may apply simultaneously (Sieff, 1990).

Interestingly, it is indeed the above mentioned hypothesis which appear to offer the best explanation for the finding derived from the data of the Israeli Central Bureau of Statistics on Jewish and non-Jewish infant mortality (Zadka, 1978). Thus the mortality rates at the age of 0-6 days per 1000 live births in 1977 were 8.0 for Jews and 11.6 for non-Jews, whereas the mortality rates after the infants left the hospital, at age 1-11 months were 4.0 among Jews and 14.7 among non-Jews. Likely enough socio-economic reasons were largely responsible for the disparate rates at the later ages, albeit there might also have been a low "investment" in children in general as well as a preference for one of the sexes (males?) in particular. For example, in 1978, the live birth sex ratio for Jews was 105.9, and for non-Jews, 102.8 (Zadka, 1978). The sex ratio for infant deaths for ages less than one month was 141 for Jews and 117 for non-Jews; for infants 1-11 months, it was 120.0 for Jews and 103.8 for non-Jews (data calculated from special series No.638, published by the Central Bureau of Statistics, 1978). The low death sex ratio among non-Jewish populations indicates a slightly higher mortality rate among females.

Among the many variables associated with statistically significant biases in the human sex ratio at birth are war and post-war periods (MacMahon and Pugh, 1953); socio-economic status and conditions (Teitelbaum, 1970); relative ages of father and mother (Novitski and Kimball, 1958); family size (Jalavisto, 1952); inbreeding (Schull and Neel, 1965); as well as many others such as birth order, handedness of parents, smoking, and time of fertilization (for review see James, 1987). The magnitude of bias, however, is generally small. For example, the average sex ratio for women who smoke is 101.0, whereas that for offspring of non-smoking women is 103.3. In several traditional societies, a high sex ratio was found, e.g. 128 for Yanomamo infants (Chagnon et al., 1979) and 117 for the Cuirn foragers of Venezuela (Hurtado and Hill, 1987). This high sex ratio reflects secondary sex ratio rather than female-biased infanticide (Sieff, 1990).

Most of the above-mentioned factors (summarized by Teitelbaum, 1970; and recently by James, 1987; Blaffer Hrdy, 1987; and Sieff, 1990), although correlated with sex ratio, do not explain it. Recently Geodakyan and Geodakyan (1985), based on a large study on different species, proposed that intensive sexual activity of males, fresh sperm and aged eggs are factors leading to an increase in the number of males. Hence, in a population practicing polygamy even at low rates, as the Bedouins, the sex ratio is expected to increase: male sexual activity increases, while that of females decreases. It is interesting to note that many kings and sheiks who possessed large numbers of spouses had more sons than daughters. For example, Ramses II (1317-1251 B.C.E.), one of the famous Egyptian kings, had 74 wives, who gave him 111 sons and only 68 daughters.

Possible explanations for the high sex ratio among South Sinai Bedouins.

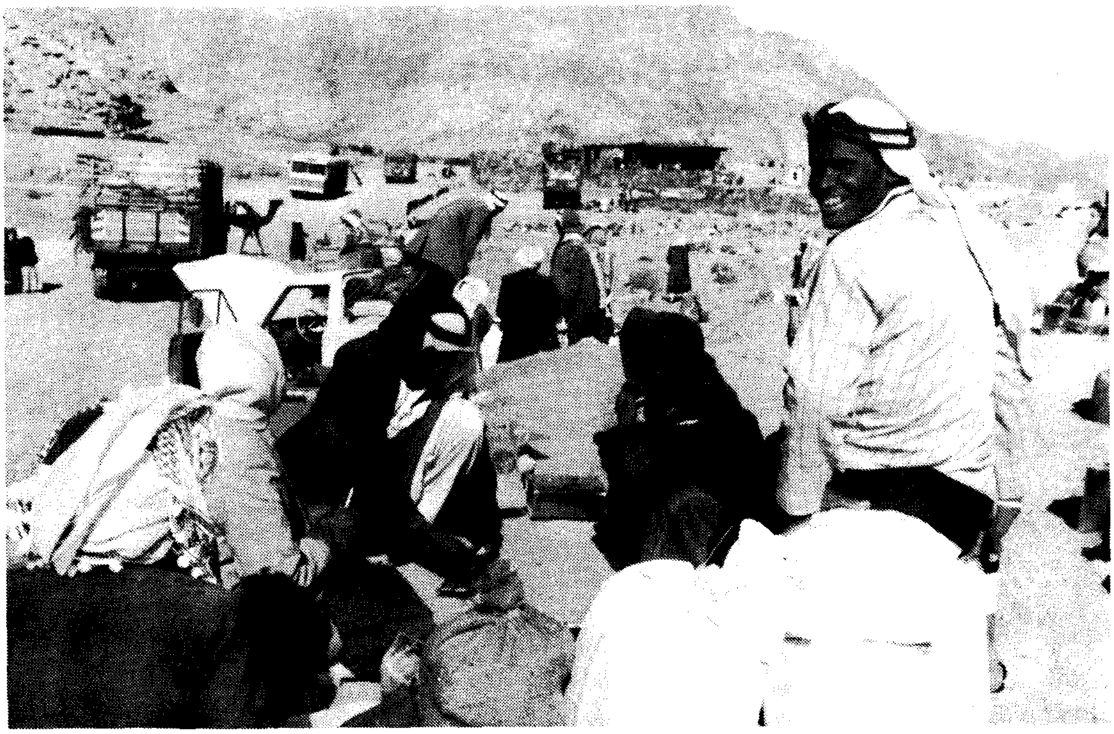
In our opinion the explanation for the high male to female sex ratio in the Bedouin population may reside mainly in its correlation with a) mating type of parents; and b) contribution of the male offsprings to family resources.

Consanguineous marriages. Evidence regarding the correlation between the sex ratio and marital pattern, that is, inbreeding and outbreeding, has been cited by a number of authors (Schull, 1958; Schull and Neel, 1965; Kirby et al., 1967). The first attempt to understand this correlation was made by Hook (1969). He formulated a theory which relies on the demonstration of various types of first-cousin marriages and is based on the concept of X-heterosis.

Hook and Schull (1973) assumed that if X-heterosis is significant, it should affect female mortality rate both during the gestation period and postnatally. They collected data on one of the islands of Japan (Hirado) and their findings, based on 565 married couples of first cousins, confirmed their basic assumption.

For the purpose of illustration, they present the following datum: the proportion of males and females among neonates born to the X-inbred parental group was 736 males and 661 females, resulting in a sex ratio of 111, and among neonates born to the X-outbred parents, 547 males and 611 females, or a sex ratio of 89. It follows that in a population such as the Bedouin, where first-cousin marriages have been preferred over many generations, the female offspring will be much more vulnerable than the male offspring due to the effect of X-heterosis. Looking again at the data appearing in Table 17 (for the 16 generation only, see next paragraph), we see that the most X-inbred groups in the Bedouin society (blood feud group or extended family, according to marital pattern) manifest a higher sex ratio (110 and 115, respectively) than do the more outbred groups (clan, sub-tribe and tribe with sex ratios of 105, 85 and 107, respectively). The data furnish us, albeit indirectly, with support for the noted trend. Thus the number of families in the parent generation (G15) with no children at all is higher in the X-inbred groups (blood feud group and extended families, 16.7% and 15%, respectively) than in the outbred groups: clan (4.2%), sub-tribe (7.1%), tribe (4.2%) and tribal suprastructure (0.0%) (Table 17).

It must be noted that the reliability of the information obtained for the different categories may be questionable, biased by the method of data collection, namely, by genealogical records. Young females can easilty disappear from records of past generations, especially if they were not married or died before marriageable age, thus significantly influencing the sex ratio (for this reason, the data on the sex ratio for the G15 generation which appear in Table 17, are suspicious, especially for remote tribal units such as the subtribe and the tribe). However, this is not the case for married males, who will always be included in such records. Therefore, we have taken the liberty of selectively using the data related to past generations.



Bedouins in Santa Katherina

IV. GENETIC COMPOSITION OF SOUTH SINAI BEDOUIN TRIBES

Effective Size Of The Population

Three major components are here considered when determining size of biological populations, , namely:

(1) Total number of individuals existing in a group at a given point of time;

(2) Breeding size, i.e., total number of individuals of the group in their potential reproductive period (15-45 years of age for female); and

(3) Effective size, meaning the total number of individuals in the population who mate and produce progeny.

The overall size of a particular population group is usually determined by a population census. From the standpoint of genetic drift, the overall population size is not relevant, but in terms of age and sex data available, it does enable one to compute what part of the population will directly transmit its genes to the next generation. If the overall size of the Muzeina tribe is 3056 individuals, and by Ben-David's (1978) age pyramid 39.6% of the population fall within the 15-45 years age group, which is the reproductive group in the tribe, then the size of the breeding group will be somewhat greater than 1200 individuals. Even if we assume that Ben-David`s age pyramid is not precise, we can still estimate the number of individuals in the breeding group by arbitrarily taking a third of the population. We should add that in "simple" societies the three reference groups, namely, the pre-reproductive, the reproductive and the post-reproductive (classification according to Bodenheimer, 1958), are unequal in size, with the reproductive group usually somewhat larger than the other two (Bodmer and Cavalli-Sforza, 1976, p.394). In an "ideal" population, the reproductive group is comprised of an identical number of males and females, size is constant throughout time, there is random mating, each male adult has only a single wife, and each individual of the parent generation produces an equal number of offspring. Only in such an "ideal" population are the size of the breeding group and the effective size of the population identical. In this case, the variance of the random deviation of gene frequencies is $q(1-q)/2N$, and the rate of decay is $1/2N$ (Li, 1968, p.320). In most human populations, including the Bedouin, such an ideal situation does not exist and therefore one needs to compute the effective size of the population.

In large populations, random variations in number of children produced by individuals with different genotypes have no significant effect on gene frequency; but in small populations such variations can have great significance with respect to gene frequency (Li, 1968).

Factors influencing effective size

The present chapter will deal with the wide gamut of factors which exert an influence on the effective size of the Bedouin population. Such factors include a) differential fertility, b) sex ratio, c) polygamy, d) temporary changes in population size, and e) inbreeding.

a. Differential fertility.

In the Bedouin groups, the `differential fertility' variable is a decisive factor in determining the size of Ne and has two different aspects, namely, 1) the differential fertility within a given Xi generation among Xnij generations, and 2) the differential fertility between generations Xni and Xnj which is the mean fertility of the population that changes from generation to generation. For the last two generations (G14&G15), one needs to take a high mean estimate of 4.0 children per family surviving to adulthood (it is not identical with the mean number of living children per family!), whereas for previous generations (G1-G13), based on the data of Ben-David (1978), the estimate would be 2.9 children per family.

b. The sex ratio

The efect of the sex ratio on the effective size (N_e) of a population comprising N_m+N_f inbred individuals can be calculated as follows:

1. $N_e=4N_mN_f/(N_m+N_f)$

Numerical inequality of the two sexes will thus invariably diminish the larger `breeding size' to a smaller `effective size'.

The ratio of males to females in the Bedouin population is the subject of controversy in the literature. According to Ben-David (1978, p.111), the mean sex ratio for the overall South Sinai Bedouin population (averaged for all ages) was 118; according to Nir (1987) it was 109. The ratio which we obtained from the Hams records is 128.1 for G15 and 106.9 for G16. In the age group of 15-44 the sex ratio according to Ben-David's data was calculated to be 108. As we have previously shown, sex ratio varied among generations, and under certain circumstances can reach high values. We here decided to use the lowest sex ratio values calculated by us as the representative sex ratio value in the `fertile age' group (15-44 years).

This of course minimized the effect of sex ratio on the effective size of the population, but put us on the safer side. This value will be the basis for all subsequent calculations of demographic parameters.

(N_m=number of males; N_f=number of females.), Kimura and Ohta, 1971, p.34

c. Polygamy

To our knowledge, there are no precise methods for assessing the effect of polygamy on N_e. Most investigators (e.g. Li, 1968; Kimura and Ohta, 1971) make do with the regular formula (No. 1) for computing the influence of the sex ratio on the effective size of the population.

A formula for calculating the effect of polygamy on N_e was proposed by Wright (1931). However, his formula fits only a situation where a husband has three wives. In the Bedouin population, it will be recalled, only a relatively small number of married males (about 1%) have three or more wives. Indeed in most of the polygamous families of the last generation, polygamous males have two wives (Levi, 1979; Nir, 1987). We concluded that perhaps the best way to introduce the effect of polygamy into computation of the Ne without overlooking men married to two women, is to adapt the differential fertility formula devised by Crow and Kimura (1970, p.351), and originally proposed by Wright (1931), which we did as follows:

(2) $N_e = (N\overline{K}-2)/(\overline{K}-1+V_k/\overline{K})$

where $\overline{K}$ = mean number of offspring per family, V_k the variance, and N the number of parents.

By this formula we can compute the N_e for two different N's, namely, N_f = the number of fathers and Nm=the number of mothers:

(3) $N_{ef} = (N_f\overline{k}_t - 2)/(\overline{K}\,t - 1 + vtt/\overline{k}t)$

(4) $N_{em} = (N_m\overline{k}_w - 2)/(\overline{k}w - 1 + vtw/\overline{k}w)$

where kt = mean number of children per father (formula 3), kw = mean number of children per mother (in polygamous families there will be a large disparity between

these two values), vtt = the variance in number of children per father (formula 3) and vtw = the variance in number of children per mother. After computing the N_{em} and N_{ef}, we introduced their numerical values into formula 1 so as to obtain the N_e of the tribe, including the effect of polygamy and sex ratio.

d. Changes in size of Ne in the early generations

In the course of the 16 generations through which the Muzeina tribe has existed as a defined and recognized social group, its effective size underwent frequent change. Regrettably little available information is extant on these changes, and therefore we have assumed a fixed average change per generation. The formula used to calculate the N_e of a tribe after t generations and with population sizes of $N_1, N_2 \ldots N_t$, according to Li, 1968, p.323, would be:

(5) $1/N_e = 1/t \times (1/Ne_1 + 1/Ne_2 + \ldots + 1/Ne_t)$

Thus, effective size of the group at any period in time will be the harmonic mean of the population effective sizes of different generations within the cycle.

To be sure, for a small number of generations and for significant size changes, the mean effective size does not reflect biological reality (see Li, 1968, p.323). However, since we here "used" population sizes in 15 generations, the distortion introduced into the calculation of the mean effective size for the Muzeina tribe might be smaller. In the absence of precise paleodemographic information on the size of the Muzeina tribe in previous generations, the Ne values for the preceding generation were obtained by the following procedure.

We first estimated the net reproductive rate (NRR), which is a measure of the ability of the population to renew itself (Hassan, 1981). The NRR can be here estimated either directly through Hams (blood feud group) records, or by various demographic variables. According to Ben-David's (1978) data, the average number of children surviving to adulthood in the preceding generations (G_1-G_{13}) was 2.9. Assuming a sex ratio of 107.8 for age group 15-44 years, the NRR should approximate 1.39. With the sex ratio around 108, the average number of women surviving to the age of child bearing was probably around 1.39. Hence, the rate of natural increase of population per generation, or Lotka rate (P), for the Muzeina tribe, assuming existing fertility rates continue, will be:

$P = (y \sqrt{R_0}) - 1 = 11.24$ (Hassan, 1981, p.139)

where y is the mean age at child-bearing age (19.6 years) and $R_0 = 0.39$ the excess of females beyond replacement. In such cases the population can grow at a rate of about 11.24 individuals per 1000 females per year.

The rate of population growth (r) is obtained from the equation: $r = Ln(N_2/N_1)/t$, where N_2 is the population size reached from an initial population N_1 after a particular time period (t). This equation can be simplified to: $r = LnR_0/t$. Given a generation span of 20 years (average age of marriages of male and female), the Muzeina tribe, with a NRR of 1.39, would increase at a rate of about 1.48% per year, or approximately 15 persons per 1000.

The relationship between population growth rate and doubling time (Dt) is expressed by the equation: $Dt = 0.6931/r$ (Hassan, 1981). For a growth rate of 1.48% per year, the doubling time would be 46.8 years.

According to the genealogical tree of the Muzeina tribe, it has been in existence about 16 generations as a recognized social unit, or some 320 years. The Muzeina could have doubled its size approximately 7 times at most during this period, given a generation span of 20 years. Knowing the annual rate of increase, the doubling time, the length of time the tribe has existed, and its size at present, we can calculate the size (N) of the tribe in previous generations (e.g., N_{16}=3000; N_{11}=750; N_6=187; N_1=46), and from that number - the effective size (Ne) at each generation.

It should be emphasized that intrapopulation growth from generation to generation is requisite for continuity of the effect of social and biological factors which mold the population into a certain genetic equilibrium. When this does not prevail, e.g. when there is a sharp decrease in population size as a result of an epidemic, the cumulative nature of the sample variance becomes disrupted, which can lead to changes in gene frequency to the point of abrogation of the previous effect. Once the population recovers, however, and starts growing anew, then the same factors will guide it to a new point of genetic equilibrium. The mean N_e which we computed for the last 15 generations is 56.8, which we assume is about the value of the Ne in the eighth generation of the tribe since its inception.

e. <u>Intragroup marriages or inbreeding level</u>

The nature of the mating patterns within a group is a further factor influencing Ne. In a population which encourages consanguineous marriages (e.g. first-cousins), such as the bedouin tribes of the South Sinai, the Ne will be smaller than that in a randomly breeding population of the same size. The reason for this size difference is that the probability for each man in the tribe to marry any one of the women of the tribe who are eligible for marriage is not equal, depending largely on the sizes of the different social structures.

Methods of computing the Ne of previous generations in a population are presented in Appendix 1.

Summary

In the present chapter we assessed the influences of various factors on the effective size of a population, more specifically, on the Bedouin Muzeina tribe. From a genetic viewpoint, we dealt with those factors which lead to disparity in gene frequencies in the group from one generation to the other owing to random deviation stemming from sampling errors. Such deviations are noticeable in small populations such as the Bedouin and can result in random fixation of the loci.

The rate of diminution in the genetic variability of small groups, which could also be called `the rate of loss of heterozygosity' or `the rate of fixation of the loci' (Li, 1968; p.323), is 1/2Ne per generation, where Ne is the effective size of the population. As a result of the aforementioned process, namely, the decline in genetic variability, the more time involved, the more would small isolated populations of equal gene frequency pull apart and diverge from one another, so that after a number of generations, they would become quite different in their genetic makeup even if environmental conditions remained identical (Li, 1968, p.324).

This type of differentiation between groups stems from random variation and from gene fixation also of a random nature and therefore neither has any adaptive significance.

However, the effective size (Ne) of the Muzeina tribe in the sixteen generation (846 members) is still large enough to comprise by itself a central factor in reducing the genetic variability of the tribe. In the next chapter we shall discuss another important mechanism (albeit fortuitous) which affects genetic variability in the Bedouin society.

Marital Patterns And Immigration Rate: Their Effect On The Coefficient Of Inbreeding (F)

By `immigration' we here mean the entry into the tribe in every generation of "foreign" women who in time produce offspring. The phenomenon of male migration is very rare and thus not considered in our forthcoming calculations. Women who emigrate out of the tribe or who enter it without producing progeny are excluded from this category.

Random breeding in small groups of N individuals results in a loss of heterozygotes at a rate of approximately 1/2Ne per generation, if we ignore the factors of immigration and selection. On the assumption of random union of gametes, the less the heterozygosity the larger the value of F per generation. All formulas cited are from Li (1968, p.305), except as noted otherwise. The increment in F is on the order of:

(6) $F_i = 1/2Ne + [(2Ne-1)/2Ne] \times F_{i-1}$

Immigration rate (M), on the other hand, will prevent the group from attaining homozygosity and will shift the gene frequencies of the group towards the mean value for the total population. In such a process the expression $S^2{}_q$ will diminish in the next generation to $(1-M)^2 S^2{}_q$ which will lead to a decrease in the value of F by the same proportion, owing to the ratio $F = S_q^2/\bar{q}(1-\bar{q})$.

In this new equilibrium, the value of F_{im} will now decrease owing to the intrusion of immigrants.

(7) $F_{im} = (1-M)^2 \times F_i$ (Wright, 1951)

In fact, formula (7) describes the basic relationships between the F and M values without the effect of selection.

Marital patterns constitute an important indicator as to how the genes are aggregated in the human genotype. Marital patterns are quite variegated in the various world populations. The reasons for such variability are apparently associated with biological, demographic, social, cultural and other factors.

As noted in the chapter on ethnography, in Bedouin society we recognize a number of marital "types" which, apart from their socio-economic implications, also have a fairly defined biological significance. It may be recalled that the marital "types" recognized thus far were based on the Hams (blood feud group), extended family, clan, sub-tribe, and tribal marriages. The main criterion used to define these marital "types" was the common biological background or depth of the two mates, i.e. the number of generations back to a common ancestor of the mates (Fig. 9). The manner in which we translate these marital "types" in biological terms is illustrated in three "schemes", first, the scheme of Hams of Haj Abdulla (Fig. 10); second, the private case of the Hamid Aiyed family (Fig. 11); and third, the "scheme" given in the first chapter (see Fig. 3).

We may consider immigration in Bedouin society on two different social levels, namely:

a. Women taken for marriage from outside Towara tribal suprastructure, and/or from outside her husband's tribe, but from one of the other Towara tribes;
b. Women taken for marriage from her husband's tribe.

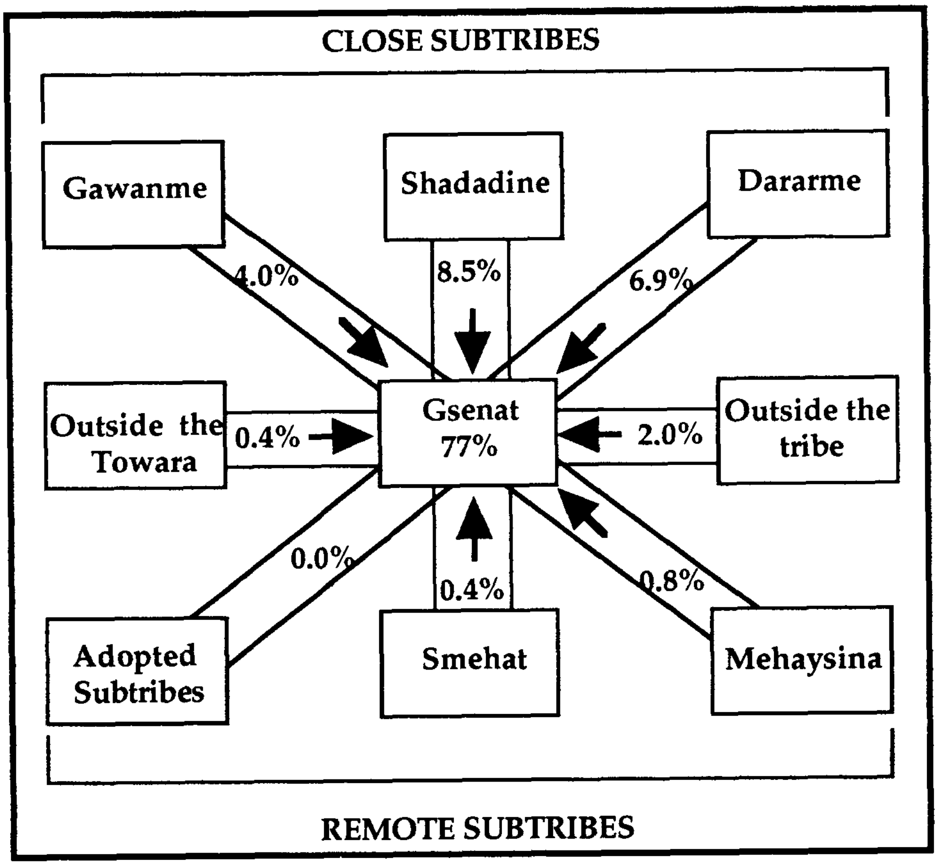
We emphasize again that the data presented herein pertain mainly to computations made for the current generation of the Muzeina tribe only; they do not necessarily reflect the situation prevailing in earlier generations.

a. <u>Marriages outside the tribe.</u>

Despite the numerous testimonies as to the entry of foreign families into the South Sinai Bedouin tribes (see chapter on Tribal Composition), there is little concrete evidence to this effect at present and even in the two preceding generations. The fact that the region of South Sinai is sealed by topographic barriers apparently has precluded regular traffic or communication with neighboring peoples. Thus only 0.4-2.0% of the marriages in the tribe were with women from outside the tribe (Fig. 8). Immigration from outside the Towara into the South Sinai bedouin tribes is extremely small (usually less than 0.5%).

Some tribes do display a stronger tendency to take a wife from outside their Towara tribal suprastructure (e.g. the Gararsha) than others (e.g. the Muzeina). Even within the tribe there are parts (e.g. the sub-tribes) which display different tendencies in this regard. The geographic location of a sub-tribe apparently plays an important role in this respect (Fig. 5). As mentioned, the Gsenat and the Dararme sub-tribes of the Muzeina tribe display such disparity. Thus the former, which lives in the center of the tribal territory, and has neighboring sub-tribes to the east, north and south, hardly accepts brides from outside the Towara, whereas the Dararme sub-tribe, which occupies the periphery of the tribal territory shows greater tendency for such marriages.

FIGURE 8 Women Exchange in Marriage Between the Gsenat Sub-tribe and Other Sub-tribes of the Muzeina Tribe in South Sinai*.



*The rate of "foreign" women entering the sub-tribe Gsenat is 23%; 77% are marriages with women from the same sub-tribe.

Nir (1987) presents somewhat different data in this matter, although he also emphasizes the significant trend for inter-tribal marriages. Nir claims that the rates of such marriages vary among the tribes: the Gebeliya tribe, for example, as a result of its origin and links with the Santa Katharina monastery, is regarded as a `foreign' tribe, and hardly absorbs women from other tribes of the Towara. According to Nir (1987) the Gebeliya is the tribe with the highest frequency of first cousin marriages and the least with outside tribe marriages (<1%). In contrast, the Awlad Said tribe accepts women from practically all the tribes of the Towara and at rates greatly exceeding those of the Gebeliya and Muzeina tribes combined. In the Muzeina tribe, according to our data, the rate of female inflow averages about 3% for each of the last three generations. Nevertheless there are differences also at the sub-tribe level.

b. Marriages within the tribe.

Undoubtedly genealogical ties between the sub-tribes exert a direct influence on the rate of female exchange between them, as illustrated in Fig. 8. First, we note that a large proportion of the females taken as wives comes from within the sub-tribe. For the Muzeina tribe the relevant percentage is approximately 77% (average for all sub-tribes) (G15, table 9). Of the remaining 23% of the marriages, only about 2.4% derive from other tribes or from outside the tribal suprastructure, the Towara, the remainder (20.5%) coming from neighboring sub-tribes. In the Gsenat sub-tribe, for instance (Fig. 8), 19.3% derive from related sub-tribes and only 1.2% from remote sub-tribes. These data suggest that at least in some cases the sub-tribe is the social unit, or alternately, a group of sub-tribes deriving from a common ancestor is such, as for example the Gsenat, Dararme, Shadadine and the Gawanme sub-tribes, all tracing back to an ancestor called `Farag'. Our next step is to try to reconstruct the geneological depth characterizing each type of marriage.

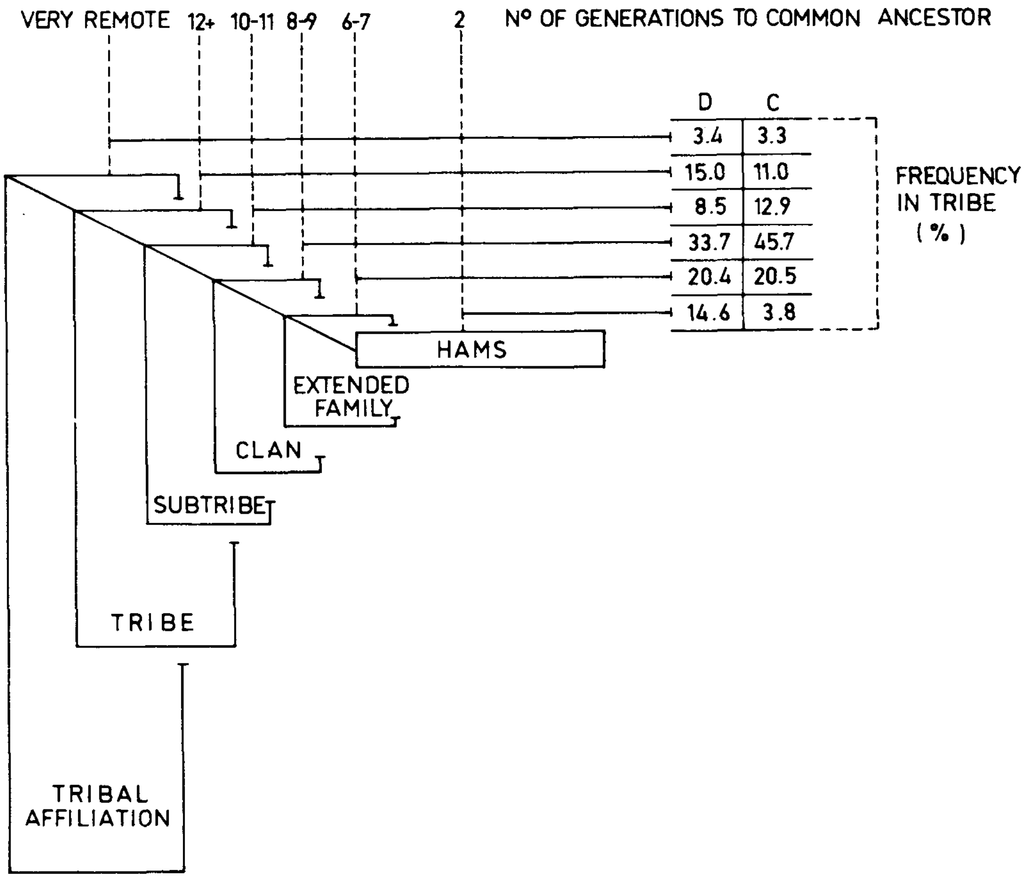
b.1. Hams (Blood Feud Group) Marriages

As noted in the preceding, these marriages are limited to marriages between cousins. Figure 11 describes several such possibilities, e.g. between individuals 1 and 2 who are first cousins, between individuals 1 and 3 who are second cousins, and between individuals 1 and 4 who are third cousins. Marriages between cousins are in most cases marriages with offspring of the father's brother, although there is evidence of other combinations as noted previously. A case in point of first cousin marriages is the one between Muhammed Abdalla Hamid (No. 34) and Mahmuda Saliman Hamed (No. 16) (Fig. 10). In such marriages, both partners need to be represented in the Hams records. *The genealogical depth ranges between two generations for marriages between first cousins to four generations for marriages between third cousins* (Fig. 11). Note that the most remote ancestor is Awad (Fig. 10).

b.2. Marriages in the Extended Family

Here we are dealing with marriages between two individuals of the same family, e.g. between individuals 1 and 5 in Fig. 11. Thus in the marriage between Awad Abdalla Hamed (No. 27) and Hamda Aid Gabali (No. 28) (Fig. 10), the bride comes from a Hams which genealogically belongs to the same family to which the groom's blood feud group belongs (the Breykat). *The common genealogical* *depth for the married couple reaches down to 7 generations.* The remotest ancestor is Breykat (Fig. 11).

FIGURE 9: Number of Generations of the Mates from a Common Ancestor in Various Types of Marriages

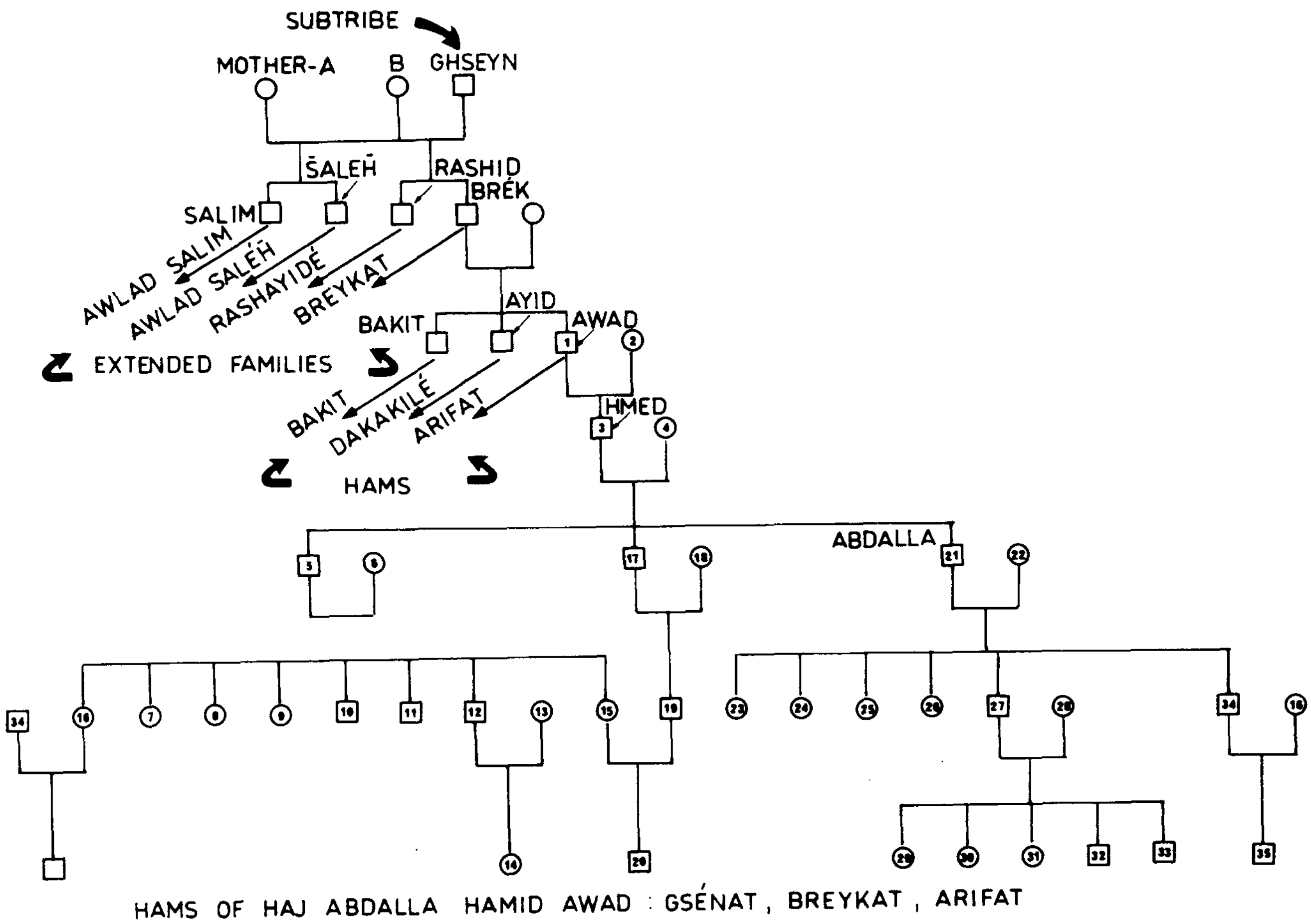


*Marriages outside tribal affiliation not included.

b.3. Clan Marriages

Clan marriages are between individuals belonging to two different families related by a close genealogical tie, for example, a marriage between individuals belonging to families sharing a common ancestor. Thus for the common ancestor Ghse'yn we have the following families: Rashayide, Breykat, Awlad Saleh, Awlad Salim and Hagahige (Fig. 3). Another example is marriage between individuals belonging to families originating from the common ancestor Sari; such families are the Suhub, Bakayte', Abu Sabha and Afe'tiyin (Fig. 3). As observed in Fig. 11, we are dealing with a marriage between individuals 1 and 6. To use a real case which appears in Fig. 10, we take the marriage of Hamid Suleiman Hamid (No. 12) (El-Atrash) to a woman (name not given) who derives from the Rashayide' family (No. 13). *The common genealogical depth for this couple is 9 generations* and their most ancient ancestor is Ghse'yn (Fig. 10).

FIGURE 10: The Origin of the Hams of Haj Abdallah Khamid Awad and its Place within the Genealogical Tree of the Muzeina Tribe



Mates discussed in text

34 = Muhammed Abdalla Hamid

16 = Mahmuda Saliman Hamed

27 = Awad Abdalla Hamed

28 = Hamda Aid Gabali

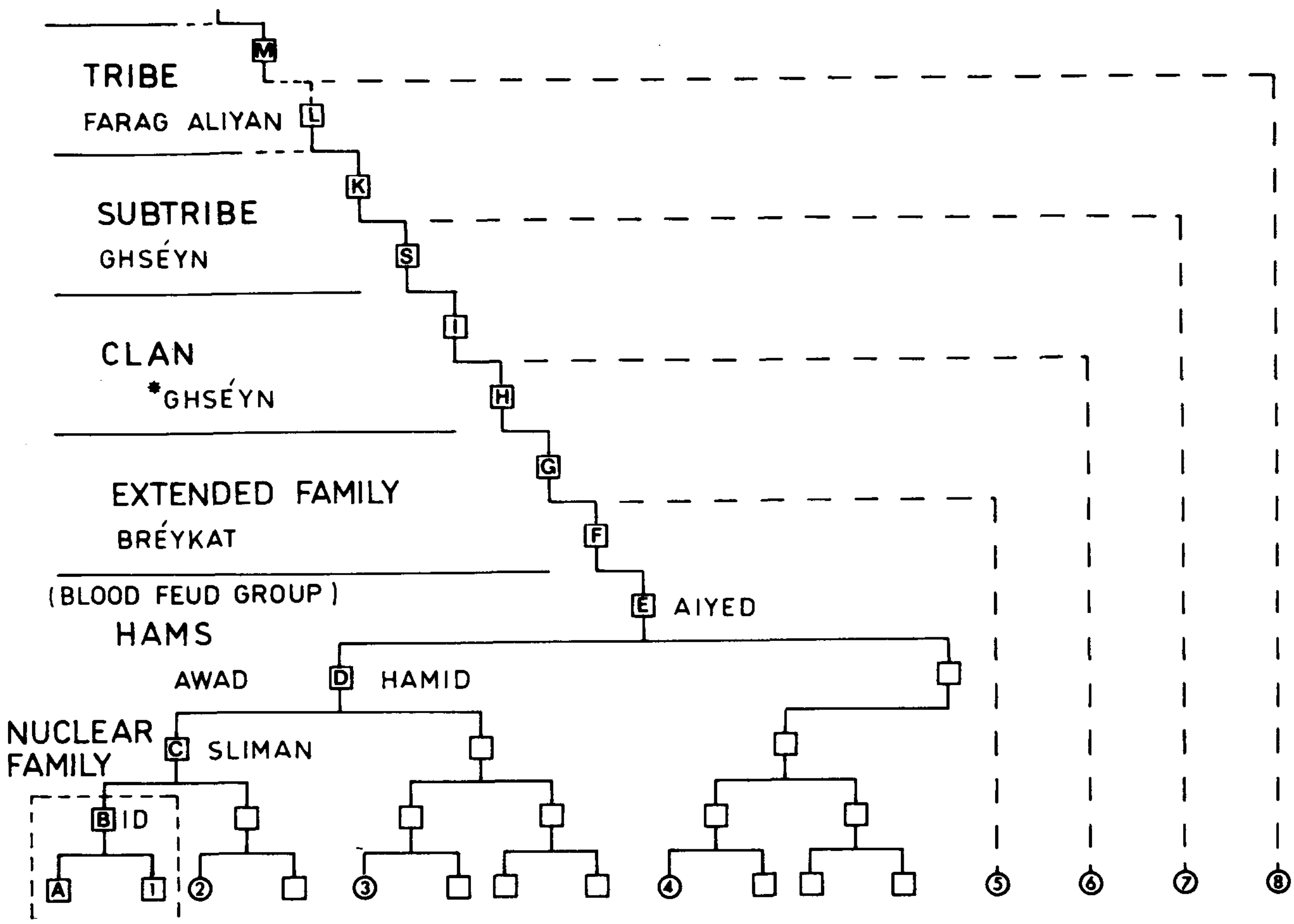
12 = Hamid Sulliman Hamid

13 = a woman derived from the Rashaide

21 = Abdalla Hamid Awad

22 = Gabaliya Saliman A'oula

FIGURE 11: The Genealogical Depth of the Various Marriage Types in the Hamid Aiyed Family.



* One of Ghse'yn's grandsons whose descendants form part of the Gsenat sub-tribe (see Fig. 3).

A - M = Ancestors and their place within the social framework of the Muzeina tribe

1 = Ego

2- 8 = Potential wives for marriages and their genealogical relation to Ego

b.4. Marriages in the Sub-tribe

We here consider marriages between individuals of families that belong to the same tribe, and are genealogically linked through one of the two sons of the tribal founder, either Farag or Alwan (Fig. 3). Such, for example, is the marriage between individual 1 and 8 in Fig. 11, or the marriage between Abdalla Hamid Awad (No. 21) of the Breykat family and Gabaliya Saliman A'ouda (No. 22) of the Shadadine sub-tribe and the Twayirin family (Fig. 10). *The genealogical depth common to these two marrying individuals ranges between 10 and 12 generations* (Fig. 11).

In sum, as noted in the preceding, a precise schema which describes the structuring and development of the tribe from its inception to the present enables one to trace the common "biological" background of each marrying couple. The only information needed to ascertain the genealogical depth of parents is the name of the extended family from which a wife derives.

Method Of "F" Computation

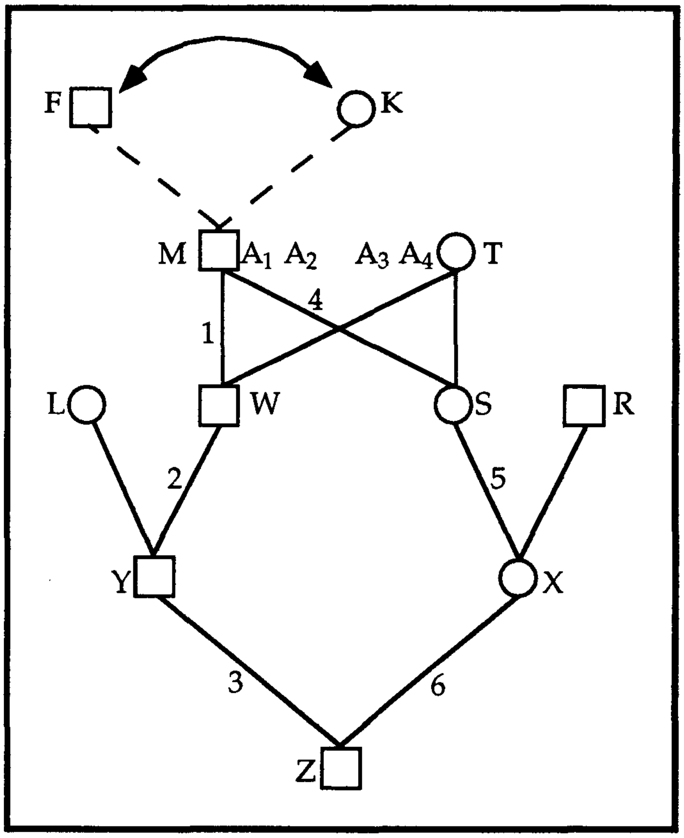
Path Analysis

This technique, first proposed by Wright (1921), enables one to compute a coefficient of inbreeding, once we know the biological relationships between parents. This coefficient is the correlation between uniting gametes and is computed by assigning a value of 1 to gene "A" and a value of zero to its allele "a" (or, in fact, any arbitrary value). The correlation is usually designated by "F" or "f". According to Wright's model, if n and n' are the number of generations in the pathway tracing back to a common ancestor of both parents of individual Z, then:

$$F=\sum_{i=1}^{n} (1/2)^{n'+n+1}$$

The idea behind this system is illustrated in Fig. 12. Here we can see the links of the descendant (Z) to earlier common generations. When both parents are first cousins, the probability that gene A1 will get to descendant Z via the parents in pathways 1, 2 and 3 is $(1/2)^3$. The same probability exists also for pathways 4, 5 and 6. Hence the probability that descendant Z will be homozygous for gene A1 is $[(1/2)^3 \times (1/2)^3] = 1/64$. The probability that he will be homozygous for one of the four genes represented in the autosomal locus of the parents will therefore be: $4 \times 1/64 = 1/16$. In societies where there is a long chain of arranged marriages tracing back to a depth of many generations, it is possible that in individual M the A1 gene is already in the homozygous state. Consequently, in every calculation of F, one needs to take into account also the F values of the preceding generations. The fact that M himself in Fig. 12 is already a product of a long line of marriages within very small groups, increases the probability that S and W will receive genes which are identical by origin from M by a factor of $F_A/2$. Therefore all the marital loops linked to a common ancestor require multiplication by a factor of $1+F_A$*.

FIGURE 12: Genealogy of Inbred Individuals Originating from One Family (mates F and K)



The Contribution of Marital Patterns in the Tribe to the F Value in the Present Generation

We recognized five different Fxe_i's in the South Sinai Bedouin, one for each conjugal type, thus: Fxe_1 for marriages within the Hams (blood feud group); Fxe_2 for marriages within the extended family; Fxe_3 for marriages within the clan; Fxe_4 for marriages within the sub-tribe; Fxe_5 for marriages within the tribe. On the basis of the structuring of marital patterns in the tribe, we computed for each Fxe_i the genealogical distance, in generations, between the parents and their common ancestor.

The genealogical depth of the Muzeina tribe is estimated to be about 16 generations. We further assumed that the parental pairs on which there is no genealogical information, distribute proportionally into our five recognized marital categories; these comprise about 4.4% in the 15 generation according to the Hams blood feud group records (see Table 9). The computation of the suitable Fxe_i was done according to the formula:

$$Fxe_i = PFxe_i + \sum_{i=1}^{n} [(1/2)^{n'+n+1}]/100 - u$$

where P is the proportion of the particular marital pattern within the total marital patterns in the sample, and u is the percentage of cases per generation of parent pairs for which no adequate genealogical data were available to us. The final value of Fxe is obtained by combining all the computed Fxei values:

$$\overline{Fxe}=\sum_{i=1}^{5} Fxe_i$$

(The data on which the computations were made are given in Table 9.)

Computation of Various Fxe_i

Marriages within the Hams (blood feud group) (Fxe_1).

This category includes four main marital types. Marriages between first cousins are marriages to the children of the father's brother or those of the mother's sister. Of the total marriages within the blood feud group recorded from our genealogical trees (for the Muzeina only), 58.5% were marriages with offspring of the father's brother and only 18.8% with offspring of the mother's sister. This datum reflects the trend of cousins for marrying the children of the father's brother, but is not entirely free of error because the Bedouins are reticent about reporting marriages with the offspring of the mother's sister as marriages between cousins. For the same reason, there is in fact some question about the true marital rate of first cousins within the tribe. According to the studied genealogical trees, first-cousin marriages (of both types) probably do comprise about 77.3% of all marriages in the Hams. Second-cousin marriages account for about 15.1%, and third-cousin marriages some 2.0%. Marriages between relatives of two different generations are about 5.6%. It should be noted that the greater the genealogical depth, the greater the error in the estimates of the frequency rates of the marital types.

The contribution of different marital types within the Muzeina and their frequencies within the population to the Fxe_i value are: First-cousin marriages: $(1/2)^5$x0.773 = 0.024156; Second-cousin marriages: $(1/2)^7$x0.151=0.001179; Third-cousin marriages: $(1/2)^9$x0.02=0.00003906; Cross-generational (uncle-niece) marriages between relatives: $(1/2)^6$x0.056= 0.0008749, with a combined value of 0.026248.

Since in the Muzeina tribe marriages within the Hams are only 14.6% of all marriages, the relative contribution of this marital pattern to the F value of the population is Fxe_1 = 0.026264x0.146 = 0.003834.

Marriages within the extended family (Fxe_2).

The common genealogical depth for a pair of parents extends to 6-7 generations. We elected to use the latter datum albeit significantly reducing the obtained F values. The frequency of this marital type accounts for 20.4% in the 15 (parent) generation (Table 9). Thus, $Fxe_2 = (1/2)^{13} x\ 0.204 = 0.0000249$

Marriages at the clan level (Fxe_3).

The genealogical depth here is 8-9 generations and the frequency of this marital type is 33.7% (Table 9) . Hence, $Fxe_3 = (1/2)^{17} x\ 0.337 = 0.0000026$

Marriages within the sub-tribe (Fxe_4).

The genealogical depth amounts to 10-12 generations: frequency 8.5%. Thus: $Fxe_4 = (1/2)^{21}\ x\ 0.085 = 4.0531\text{-}08$

Marriages within the tribe (Fxe_5).

The genealogical depth exceeds 12+ generations: mean frequency is 15%. Hence, $Fxe_5 = (1/2)^{25} x\ 0.15 = 4.4703\text{-}09$

Overall Contribution of Marital Patterns to Coefficient of Inbreeding (Fxe) in the Parent (fifteen) Generation

The overall value of $F\bar{x}e_{1\text{-}5}$ obtained by us (0.0038615) comprises almost entirely (96.3%) the effect of first-cousin marriages. The contribution of all the other marital patterns to the value of $F\bar{x}e$ is negligible (3.7%). All these $F\bar{x}e$ values refer of course to one generation only, for when inbreeding processes are allowed to carry into a greater depth of generations the contribution of the other marital patterns to the overall $F\bar{x}e$ value also increases. It may be noted that the obtained value is probably lower than the true value owing to the probability of inaccurate information provided on cousin marriages with offspring of the mother's sister, as previously observed.

Contribution of Tribal Marriage Patterns in Earlier Generations to Value of Fxe

The use made of the Hams (blood feud group) records to compute the Fxe for earlier generations poses two main problems:

a)The deeper one delves into early generations (i.e., 1st, 2nd...,15th generation), the smaller the value of the expression n'+n+1, the latter indicating the number of individuals participating in the inbreeding loop linking all the common ancestors of individual Z. Therefore, the composition of the tribe, as described in the present study (Fig. 3) indicates a fixed situation for a given unit of time. The further back we proceed in the number of generations, the more distorted becomes the structure of the tribe as we recognize it, and the marital patterns may assume a genealogy entirely different from that shown in Fig. 3.

b)The frequencies of the different marital types are, inter alia, a function of group size. In a sample of 60 cases of cousin marriages within the Muzeina tribe, we found that 53% occurred in blood feud groups numbering in excess of 60 individuals, 31.6% in blood feud groups of 40-60 individuals and only 15% in blood feud groups of up to 40 individuals. Furthermore, in blood feud groups of less than 30 individuals cousin marriages were extremely rare. There is a clear correlation between Hams (blood feud groups) size and frequency of cousin marriages, but demographic reconstruction of the past history of the Hams did not enable us to evaluate fluctuations in population size or in the Hams size and therefore we must assume a fixed mean growth rate for all earlier generations. Consequently, we will consider the number of individuals in the Hams, in each generation, as stable, and the rates of marriages between cousins will be also estimated as stable since the number of cousins for each individual remains fixed in every generation.

In order to optimally compute the overall coefficient of inbreeding for the South Sinai Bedouin society (F), after 15 generations, we took into account the following possible variables:

Fxi = the inbreeding coefficient per generation.

Fxe = contribution of the breeding patterns to the coefficient of inbreeding.

Fin = the influence of the genetic drift (depending on size of the Ne).

Our final working formula, based on Li (1968) became:

$F = [Fxi_{16}(1+F_A)] \times (1-M)^2$

There are three main parameters which contribute to a determination of the F value. These are: the inbreeding coefficient for the present generation (Fxi_{16}); the contribution of earlier generations to the final inbreeding coefficient ($1+F_A$) and the effect of immigration during the last generation $(1-M)^2$. The estimated F value is **0.09802**. It is noteworthy that both Fxi_{16} and F_A include the following variables: breeding patterns; genetic drift; differential fertility; and the sex ratio and extent of polygamy. The computation procedure for F can be found in Appendix 2.

Imigration rates affecting the F value in South Sinai Bedouins

Since the tribe is the biosocial unit with which we are primarily concerned, it was deemed worthwhile to ascertain the effect which an average 3% migration rate per generation would have on the F value. The formula chosen for this purpose (after Li, 1968, p.305) takes into account both the effect of inbreeding as well as that of genetic drift (formula 8). Thus, the F value for the entire Muzeina tribe, when Ne=846 and the migration rate is 3%, will be:

$F = (1-M)^2/[2Ne-(2Ne-1)(1-M)^2]=(1-0.03)^2/[1692-(1692-1)(1-0.03)^2]= 0.009315$

The value of F for groups of related sub-tribes (super sub-tribes) that have a common ancestor within the Muzeina tribe, when Ne=564 and the migration rate is 6%, would then be: F = 0.00684.

And similarly, the value of F for the sub-tribal framework (Ne=141, migration rate = 23%) would be: F =0.005137.

The largest F value obtained was for the tribal framework. Hence, we shall employ the tribal framework as the intersocial unit. Yet the fact that the F values for the other two frameworks are not much lower also suggests other possibilities. The relationships between the migration rate on the one hand, and the effective size of the population on the other, are such that a rise in heterozygosity within the first two sub-units, namely, the sub-tribe and the super-sub-tribe (stemming from an increased migration rate) is greater than the rise in homozygosity within the same groups, owing to reduction in their effective size.

Summary

The discrepancy between the value of F for the 16th generation only (F_{16} = 0.004297) and the one obtained for all generations together ($F_{1\text{-}16}$=0.09802) illustrates why F values computed for different human societies are relatively small. Up to the early 1970's, the highest F value computed for a human population (F=0.043) was that for the Samaritans by Bonne' (1963). Numerous studies (e.g. Salzano, 1972, on nine tribes of American Indians and Eskimo populations) along the same line have led investigators to the conclusion that this value (0.043) was about the upper limit of F possible in human populations. Subsequently, however, it was found that the upper limit can be somewhat higher (F=0.050; Katayama et al., 1981). Among the many studies of the topic, the one by Spielman et al. (1975) is especially relevant to our present study, for the values computed by those investigators for American Indian populations took into account past biological processes. Spielman and his associates noted that in such a computation the value of F can turn out to be much higher than one might suppose. According to these authors:

> *...it is difficult to escape the conclusion that except at loci with very high heterozygosity maintained by selection, identity by descent from ancestral alleles in Amerindians founders for a pair of randomly chosen alleles in a contemporary Amerindian tribe should be no less than **0.3** and may well be greater than **0.5*** (p.367).

Their value is manifestly higher than obtained by us, but if we take into account that the duration of the formation of Indian societies in America is vastly longer than that of the Bedouin tribes in the Sinai, the higher value is understandable.

Genetic Composition And F Values In The Bedouin Society Vis-A-Vis The Known Gene Frequency

Here we shall attempt to ascertain the high value of F in the South Sinai Bedouin society on the basis of the evidence available pertaining to the various gene frequencies.

Mathematical manipulations in population genetics usually presuppose that the entire population is a single panmictic unit, that is, that the choice of a mate from among the total population is a random process. This assumption, however, as noted in the preceding (see chapter on Marital Patterns), is inapplicable for the South Sinai Bedouins as well as indeed for much larger populations since they generally split up into a number of sub-populations due to various factors such as geographic location, topographic barriers, religion, economic status, etc. (Wahlund, 1928).

The first important contribution to a mathematical consideration of a "splitting" in populations insofar as a local differentiation of gene frequency is concerned, was made by Wright (1940, 1943, 1951). Wright developed a series of F coefficients for split populations and demonstrated their interrelations (Wright, 1965). Assuming that a total population (T) is divided into isolated sub-populations (S), the inbreeding coefficient for individual "I" comparable to the total population (T) is obtainable from the formula $F_{IT} = F_{ST} + (1-F_{ST})F_{IS}$ (Kimura and Ohta, 1971, p.118) where F_{IS} is the inbreeding coefficient for the individual relative to the sub-population to which he belongs and F_{ST} is the inbreeding coefficient of his sub-population relative to the total population. Thus F_{ST} is the correlate between random gametes taken from the same sub-population. In terms of a panmictic index, P=1-F, the relationships can also be expressed by: $P_{IT}= (P_{IS} \times P_{ST})$. (Kimura and Ohta, 1971, p.118) Because the inbreeding coefficient can be interpreted as the probability that two homologous genes in united gametes are the result of a common ancestry (Malecot, 1948), it is important to derive the formula in reference to such a probability. Crow and Kimura (1970) have indicated that the term P_{IT} (or $1-F_{IT}$) represents the overall probability that two homologous genes in individual I are not identical owing to a derivation from a common ancestor. The term P_{IT} is equal to the product of the two probabilities P_{IS} and P_{ST}, the first of which is the probability that two homologous genes in individual I are not identical by origin relative to the number of sub-populations (S). The second is the probability that two homologous genes picked at random from a sub-population S are not identical by origin. From these definitions it is clear that F_{IS} reflects the influence of local matings (such as consanguineous marriages) within sub-populations S, whereas F_{ST} reflects the influence of a genetic drift on the differentiation in the gene frequency among sub-populations.

It should be noted that F_{ST} will never equal zero even were matings in each sub-population to be completely random.

The inbreeding coefficient is readily computable if we know the frequencies of the various genes in the sub-populations. According to Wright (1943), if the mean and variance of the frequencies of a given allele in the sub-populations are $\overline{P}$ and S_p^2, respectively, then $F_{ST}=S_p^2/[\overline{P}(1-\overline{P})]$ (Kimura and Ohta, 1971, p.120).

This formula of Wright's was subsequently broadened by Nei (1965) to encompass also systems of multiple alleles, as follows: $F_{ST}=-S_{jk}/\overline{P}_j\overline{P}_k$ where S_{jk} is the covariance of the frequencies of the alleles k and j while $\overline{P}_j$ and $\overline{P}_k^{jk}$ are the mean frequencies.

The application of these formulas to the Bedouin population of South Sinai is dependent on two requisites: a)that all the tribes under consideration be derived from the same population; and b)that we have on hand reliable data on gene frequencies in each tribe.

The first condition or requisite holds true for some of the Bedouin tribes, that is, for the tribes that derive from Saudi Arabia (see chapter on "History of the South Sinai Tribes"). The second condition is also fulfilled albeit the quantity of data available is limited and based mainly on the studies of others: Kaufman-Zivelin, (1971) on types of haptoglobins and transferins in the Bedouin population of South Sinai; Bonne' et al. (1971) on heritable blood factors; and Ben-David (Kobyliansky) et al. (1982) on the sensitivity to Phenylthiocarbamide (PTC) tasting among South Sinai Bedouins.

We could calculate the F_{ST} values between two tribes, the Muzeina and Aleigat, for two systems, namely, the P (blood group) and the Hp (haptoglobins). Also calculable for four tribes (Muzeina, Aleigat, Gararsha and Awlad Said) are the F_{ST} values for an additional system, the T (Phenylthiocarbamide); and for two tribes (Muzeina and Aleigat) we could calculate the F_{ST} values for a multiple allele system, namely, the ABO blood group.

a. Comparison of the blood group P

The genetic marker P represents one of the blood groups. It is a two-allele gene (P_1 and P_2) of which the P_2 is dominant. Computation of the F_{ST} for the frequency of this gene is given below.

F_{ST} value between the Muzeina and Aleigat tribes for system P (blood group):

Gene	Muzeina	Aleigat	$\overline{X}$	S.D.	F_{St}
P_1	0.572	0.366	0.469	0.146	0.085

b. Comparison of the frequency of the Hp1 gene

The haptoglobins (Hp) are glycoproteins present in the serum which are capable of binding hemoglobin (Hb). All the haptoglobin types designated Hp1-1, Hp2-1 and Hp2-2 derive from a pair of autosomal alleles Hp1 and Hp2. The F_{ST} computed from these is given below.

F_{ST} value between the Muzeina and Aleigat tribes for system Hp1 (haptoglobins):

Gene	Muzeina	Aleigat	$\bar{X}$	S.D.	F_{St}
Hp1	0.280	0.510	0.395	0.163	0.111

c. Comparison of the T gene frequency (sensitivity to phenylthiocarbamide)

In the case of the T gene we had data from two additional Bedouin tribes (Awlad Said and Gararsha) whose origin was close to that of the first two (Muzeina and Aleigat), and therefore we could compute the F_{ST} of four tribes .

F_{ST} value between the Muzeina, Aleigat, Awlad Said and Gararsha tribes, for system T (phenylthiocarbamide):

Gene	Muzeina	Aleigat	Awlad Said	Gararsha	$\bar{X}$	S.D.	F_{St}
T	0.354	0.248	0.458	0.178	0.317	0.136	0.085

d. Comparison of the gene frequency in the ABO system

Since definite identification of the phenotype A intermediate is questionable, we resorted to three alleles only, namely, p, q and r. The various computations were made from the formula of Nei (1965) for a multiple allele system. Owing to the complexity of the system and of the computation technique, which differs slightly among investigators, we have used the method of Thoma (1970).

For systems of single alleles (P_1, Hp1, T) we computed the χ^2 values from the test of Snedecor and Irwin (1933). Thus $\chi^2 = (\bar{p}-p_i)^2 2n_i/\bar{p}(1-p)$ where p_i = the frequency of the gene in a given group, $\bar{p}$ = the mean i weighted frequency of the same gene, and n = size of the sample.

For the multiple allele system (ABO) we computed the χ values from the formula by Thoma (1970): $\chi^2_{(k-1)} \cong KV^o_p \cong V'p$

The χ^2 values obtained for single allele systems all show significant differences between the Muzeina and Aleigat tribes for P_1 and Hp1, and between the Muzeina, Aleigat, Awlad Said and Gararsha tribes for T (Table 18). The values obtained for the multiple allele ABO system are given in Table 19.

TABLE 18 Intertribal differences in frequencies of genes P1, Hp1 and T by the χ^2 method.

System	P1	Hp1	T
c^2	14.34	23.37	24.58
P	<0.001	<0.001	<0.001

TABLE 19 Differences in the ABO system between the Muzeina and Aleigat tribes.

	Gene		
	(p)	(q)	(r)
Muzeina	0.171	0.132	0.698
Aleigat	0.198	0.124	0.678
$\overline{X}$	0.185	0.128	0.688
n	107	107	107
V^0	0.0001793	0.000016	0.00010
V'	0.0007812	0.000559	0.00112
V	-0.0006091	-0.000543	-0.00102

Since all the observed genetic variances (V^0) between the Muzeina and Aleigat tribes are significantly smaller than the sampling variances (V'), it is clearly pointless to compute the χ^2 values, for the common variances and the different F_{ST} values. Thus we are in a situation where, in the single allele systems, there is a significant difference between the tribes while in the multiple allele system there is no significant difference. Perhaps the difficulty here stems from the fact that we have chosen to use the ABO system which is known to be a problematic one in identifying differences between ethnic groups (Kobyliansky and Livshits, 1983). Yet, on the basis of the results obtained with the systems of single alleles, we can pose the question: "What are the factors leading to differences in gene frequencies between tribes?" There are two possible answers to this question, namely: (a)genetic drift, and (b)selection.

To ascertain which of these two alternatives was applicable in our case, we examined the relationship between the observed variance and the expected variance with regard to the inbreeding coefficient F_{ST}. We reasoned that if the observed variance is greater than the expected, then it is probably selection which acted to bring about the intertribal differences in allele frequencies because only selective forces could throw the system out of balance. On the other hand, if we find that the observed is less than the expected, we must attribute the difference in gene frequencies among the tribes to random processes, such as genetic drift.

Our results show that the observed variance of F is $S^2_{obs.}$= 0.0002176, whereas the expected variance of F was $S^2_{exp.}$= 0.005836. The computation was by the formula $S^2_{exp.}=2\overline{F}^2_{ST}/(n-1)$, where F_{ST}= the mean F value for the three systems and n-1= number of populations (according to Lewontin and Krakauer, 1973). The ratio S^2obs./S^2exp. amounted to 0.037285. Insofar as this ratio showed the same distribution as did the ratio χ^2/df (Lewontin and Krakauer, 1973), we computed the corresponding value (0.037285) for the χ^2 distribution (26.82). It was statistically significant ($p<0.001$), which indicated that the observed ($S^2_{obs.}$) heterogeneity was significantly lower than the expected heterogeneity ($S^2_{exp.}$). Consequently we may conclude that differences in gene frequencies among the tribes are probably due to random processes, and that the selection factor is little if at all responsible for the intertribal differences. Hence, perhaps we should not expect to find in it adaptive differentiation among the Bedouin in its various zones. It seems reasonable to assume that any selective pressures would be virtually identical for all the sub-groups in South Sinai. Li (1968) and Thoma (1970) report that an adaptive differentiation can only occur in broad geographic regions, such as the various European countries. Yet, Kobyliansky and Livshits (1983) have shown that in small, isolated Jewish groups such as the Samaritans, the Karaites or the Habbanites, selection was the main factor responsible for differences in their gene frequencies, of the ABO system. But these groups differ from the Bedouin tribes in that the former are small groups originally geographically very remote from one another, e.g., the Samaritans in Israel, Karaites in Iraq, and the Habbanites in Hadramaut (a costal region of South Arabia), each also very different in environment and socio-economic circumstances. In short, they are not a suitable model for comparison with the Bedouins of South Sinai.

Population genetic structure models: their implementation to the south Sinai Bedouins.

To gain insight on the link between social and genetic components in the South Sinai Bedouin population, we could have employed existing models in the literature, but none of them appeared applicable to the Bedouin society.

The two main models for the study of population structure, proposed by Wright (1951), are known as the "Island Model" and the "Isolation by Distance".

In the former, the general population is comprised of a series of sub-groups with an effective size (Ne) in each of which the matings are random. This model assumes that individuals in the population are replaced as a single unit at a rate of M per generation and that the migrants stem randomly from the general population without any tendency for them to come from neighboring groups. The second model assumes that the general population distributes uniformly over a wide territory, with the parents of each individual surveyed being taken at random from a limited geographic area. The main variable in the latter model is "Size of Neighborhood" which is in fact the effective size of the population in the specific area from which the parents came (Mn).

In view of our knowledge of the Bedouin of the South Sinai region (see chapter on Ethnography), it is clear to us that the prerequisites for the use of one or the other of Wright's two models are not fulfilled. Models similar to those of Wright have been suggested by Malecot (1948, 1967). In his model one would expect that individuals living adjacently will be more similar genetically than individuals living far apart. The main parameter in Malecot's model is the "Coefficient of Kinship", which is the probability that two homologous genes, picked at random, from two different individuals, will be identical by descent. As we have seen, geographic distance is not always the leading factor in the selection of a mate among adjacent bedouin tribes (although it does in certain cases), but rather the historical relationship plays a much more important role. Consequently the model of Malecot is also not applicable here.

Another model for the study of populations has been proposed by Kimura (1953), namely, the "Stepping-stone Model". This model, in which the general population is divided into a number of separate population units (similarly to the "Island Model"), is actually an amalgamation of the two models proposed by Wright, but the exchange of individuals takes place only between adjacent settlements. Kimura and his associates added further mathematical elaborations to their basic model (Kimura and Weiss, 1964; Weiss and Kimura, 1965), but even these do not render their model suitable for our Bedouin population study.

Thus, to illustrate the problems or difficulties in using such a model as the "stepping-stone" for the Bedouin society, let us take the simple case of the one-dimensional "stepping-stone" with a finite number of groups arranged linearly. The Muzeina tribe is adjacent to both the Aleigat and the Gebeliya tribes. By the "stepping-stone" model, the Muzeina tribe should exchange individuals with the other two tribes at a rate of M_1 per generation, so that $M_1/2$ will be the proportion of exchanged individuals between adjacent tribal pairs per generation unit. The trouble is, however, that in Bedouin society there is not always a connection between geographic proximity and exchanges of population, as indicated previously.

Neither do improved models of the "stepping-stone" type, such as that by Maruyama (1970), known as the "Circular stepping-stone Model", suit the purposes of the present study.

Effect of inbreeding on population demography and child development

a. Survival Factors (Fertility and Mortality)

Having computed F (0.09802) for the South Sinai Bedouin, we next attempt to learn, from the data available in the literature, what may be the direct and/or indirect influence of such an F value on the health of the population.

Schull (1972) distinguishes between the influence of inbreeding (the effects on offspring number and kind which results from a parent being the product of a consanguineous marriage) and consanguinity (the effect of consanguineous marriage on the number and kind of offspring born to such a marriage) in a population. Based on a previous extensive study involving more that 10,000 families in Japan (Schull et al., 1970), Schull writes (1972):

> *No effect of paternal inbreeding was observed, but neither parental inbreeding nor consanguinity could be shown to exert a significant effect upon the frequency of stillbirths* (p.158).

Yet, in an earlier study (Schull and Neel, 1965), it was found that the risk of death or disease was greater among the children of consanguineous marriages than among children whose parents were not related.

Findings regarding fertility are more clear-cut, for here the overall number of pregnancies and of newborns increased significantly with consanguinity (Schull, 1972). However, the "net fertility" (i.e., total live births minus non-accidental deaths prior to age 21) does not increase significantly if one takes into account factors such as socio-economic status and religious affiliation of the parents. Quoting from studies carried out on various Japanese populations, Schull (1972) summarizes the topic of mortality and inbreeding (consanguinity) as:

> *...mortality in the first twenty years of life increases about 0.5 percent per percentage foetal inbreeding (consanguinity), and by a lesser amount as a function of maternal inbreeding* (p.158).

b. child development

The influence of consanguinity and parental inbreeding on behavioral and constitutional traits of child development, has been studied first on Japanese groups (Schull and Neel 1965; Neel et al., 1970a,b).

Results of these studies have failed to show:

...any clear effect of parental inbreeding on such diverse indicators of possible effects as physical development, systolic and diastolic blood pressure.......eye and ear diseases, visual accommodation, visual and auditory acuity, intelligence, school performance (Schull, 1972 p. 158).

On the other hand, consanguinity was found to have some influence on child growth and development, albeit minor and only in some respects. Thus Schull (1972) wrote:

...all of the metrics of physical and mental growth and development were depressed with consanguinity. The effects, though demonstrated, were small, amounting to at most a few percent of the mean of the outbred children (pp.158-159).

It may be noted that the effect of inbreeding has been evaluated in many controlled experiments on animals. Spuhler (1972) may be cited in this regard:

...the two most important observed consequences of inbreeding in experimental and farm animals are (1)the reduction of the mean phenotypic value shown by characters connected with reproductive capacity or physiological efficiency, and (2)the increase in uniformity, or reduction in variance, about the mean phenotypic values within an inbred line (p.166).

Food support received by South Sinai Bedouin From Welfare agency

V. GROWTH AND DEVELOPMENT OF BEDOUIN CHILDREN (BOYS) IN SOUTH SINAI

Age Determination

Age determination in the Bedouin population was from the start a complex task. As noted previously, there is no orderly recording of age among the South Sinai Bedouins. Our estimate of chronological age was based on the following criteria:

1) age given by the child himself; 2)age given by the child's teacher; 3) age given by the child's parents.

Hence, in the absence of reliable, recorded information, we had to rely primarily on biological criteria which we compared with the verbal information. The biological criteria were skeletal maturation and dental development, which are considered below.

Skeletal Development

Age estimation by skeletal development is based on the fact that the skeletal system passes through fixed stages in the course of development (Roche,1980).

The technique employed by us was radiography of the bones of the wrist, the palm and the fingers in order to assess their stage and development. The literature, to be sure, contains additional criteria on other regions of the body (Akerlund, 1918; Pyle and Sontag, 1943; Elgenmark, 1946; Harding, 1952). Our technique, first used by Pryor (1907) and Rotch (1908, 1909), was selected because of: (a)A single roentgenogram of the hand (wrist, palm and fingers) provides information at one swoop on the largest number of bones and therefore should increase precision of the final result; and (b)the order of ossification of these bones is relatively fixed (Yarbrough et al., 1973).

Age "identification" was by the "Atlas Method", that is, we compared the X-ray picture of stages of hand development in Bedouin children with those appearing in the radiogaphic atlas of Greulich and Pyle (1959) which is generally considered one of the most reliable (Roche, 1980). We calculated the developmental age for each wrist bone separately; the mean of all the "separate ages" was regarded as the "age" of the subject examined. Our preference for this method (see Roche, 1980) stems from the assumption that radiography of a single bone is less likely to provide as good an estimate of a subject's age since rate of ossification of the bones in the wrist, palm and digits differs among individuals (Todd, 1937; Garn and Rohmann, 1960).

A major drawback of the method used, from our standpoint, is the premise on which it is predicated, namely, that every child undergoes a fixed succession of changes in bone shape throughout his growing years. Moreover, the atlas was primarily designed for children in the U.S.A. and we cannot be sure that it is applicable also for Bedouin children.

Teeth eruption as criterion for child physical maturation

Development and eruption of the teeth is also an index of physical maturation that can be used to about the age of 18-20, in conjunction with other indices of physical maturity, e.g. secondary sexual characteristics. In the absence of suitable radiographic means for checking stage of tooth eruption, we opted for the clinical approach, that is, emergence of a deciduous or permanent tooth in the mouth cavity (Demirjian, 1980).

Stages of tooth eruption have been thoroughly investigated in relation to age, race, sex, socio-economic status, nutrition, etc. (see extensive review by Demirjian, 1980). Some of these variables clearly affect the time of tooth emergence (Voors and Metselaar, 1958; McGregor et al., 1968; Brook and Barker, 1972; Bambach et al., 1973; Garn et al., 1973; Mukherjee, 1973; Trupkin, 1974; Delgado et al., 1975).

Because the present study refers to males only, we cannot assess the possibility of sex-linked dental emergence in the Bedouin. We may note, however, that most investigators hold that there is no significant difference between the sexes regarding the time of dental emergence (e.g. Falkner, 1957; Roche et al., 1964; Billewicz et al., 1973).

Gypsum (Alginate) impressions of the upper and lower dentitions were made on each Bedouin child, and dental age was based on examination of these casts. We chose the dentition of the lower jaw as the primary representation of each dental system (eruption usually earlier here than in the upper jaw) and gave preference to the right side in the estimation of age. We should note that the correlation between right and left sides in stage of tooth eruption is high (Rubin, 1987; Ben-David (kobyliansky) et al. 1991).

We relied on two sources for dental age determination, namely, Schour and Marsler (1940) and Brothwell (1963), although it must be noted that stages of tooth eruption in both sources were based on European populations. To what extent the data may not be applicable to the Bedouin, is a moot point.

Correlations between different methods of age "identification".

Pearson's coefficient of correlation was used to determine the relationships between the three "methods" of determining age, namely, chronological, skeletal, and dental (Table 20).

TABLE 20 Evaluation of Pearson's correlation coefficient vis-à-vis the three methods for determining age.

Ages	Chronological age	Dental age
Dental age	r=.898	-
	n=315	-
	p=.001	-
Skeletal age	r=.852	r=.818
	n=266	n=176
	p=.001	p=.001

We ascertained whether the value of the coefficient of correlation between the results of the three methods used to estimate age in the Bedouin group was statistically significant by use of Student's t-test. We also computed the partial coefficient of correlation between ages in order to evaluate the correlation between skeletal and dental age when chronological age is held constant. Finally, using a linear equation, we carried out a prediction of age from the three methods.

Results and Discussion

Comparison of the mean values of age distribution by the three methods (Table 21) shows that the highest mean of the total age distribution is obtained for the chronological age distribution.

TABLE 21 Age determination according to the specified criteria.

Variable	No. of cases	Mean age	Standard deviation
Chronological age	612	8.66	2.67
Dental age	318	8.36	2.40
Skeletal age	269	8.08	2.50

This finding is in line with the results of other studies (Prahl-Andersen and Roede, 1979) which show that chronological age, particularly in boys, precedes the biological age. The value of the coefficient of correlation between dental and skeletal age is relatively high but still lower than the values of the other two coefficients of correlation measured (Table 20). All the coefficients were statistically significant.

The skeletal age is well predicted from both dental and chronological age whereas the chronological age is predicted at a high level of accuracy only from the dental age (Table 22). The latter probably occurs because children of different ethnic groups but identical in chronological age may differ in their stages of skeletal and sexual development (e.g. Meredith, 1969; Malcolm, 1970). Rates of maturation are undoubtedly affected by factors such as heredity, socio-economic and nutritional status, nosology, climate, etc. (Eveleth and Tanner, 1976). These factors are not always considered separately in order to assess the effects of each on skeletal maturation. Indeed, because of the desert nature of the biotopes of Bedouins, studies on the possible effect of climate on growth is of special interest.

It has been suggested, albeit without convincing verification, that a tropical climate per se is a retarding factor on skeletal growth (Mills, 1937, 1950). In this regard, experiments on laboratory animals have yielded conflicting results (Barnett and Coleman, 1959; Lee et al., 1969); while studies on children in the USA, checking whether growth was correlated with season of the year, have yielded negative results (Sawtell, 1929; Reynolds and Sontag, 1944; Dreizen et al., 1959). In any case, poor nutrition and health in the Bedouin society are highly related to growth and development.

If one keeps chronological age constant and computes the correlation between skeletal and dental age, a relatively high value for partial correlation obtains, to wit, $r_{xz(y)}=0.94$. Also relatively high is the proportion of the predictive variance from the true variance: 80% from chronological age to dental age, 72.4% from chronological age to skeletal age, and 66% from dental to skeletal age. Moreover, the "b" values in the regression equation for predicting chronological from skeletal age and chronological from dental age, are practically identical whereas the "a" values show a relatively large variance, more than a year (see Table 22). These results appear somewhat contradictory to findings of other investigators (e.g. Prahl-Andersen and Roede, 1979).

According to our results (comparison of "a" and "b" values in the regression equations), it would seem that (1) when the chronological age variable is held constant, the skeletal and dental systems apparently develop at about the same rate; and (2) there is a difference between the latter systems of about one year. This one year difference is retained for at least the age interval of 6 to 12 years.

TABLE 22 Single-variable prediction of age by linear equation in Bedouin boys.

		Regression constants	
Dependent variable (Y)	**Independent variable (X)**	**Intercept (a)**	**Slope (b)**
Dental age	Skeletal age	a=.722 S.E.=.403 p=.037	b=.887 S.E.=.047 p=.00001
Chronological age	Skeletal age	a=.654 S.E.=.292 p=.013	b=.879 S.E.=.033 p=.0001
Chronological age	Dental age	a= 1.252 S.E.=.206 p=.00001	b=.855 S.E.=.023 p=.00001
Skeletal age	Dental age	a=2.177 S.E.=.366 p=.00001	b=.752 S.E.=.040 p=.00001
Skeletal age	Chronological age	a=1.778 S.E.=.264 p=.00001	b=.824 S.E.=.031 p=.00001
Dental age	Chronological age	a=.430 S.E.=.227 p=.209	b=.942 S.E.=.026 p=.00001

Our above-cited results do not conform with those of Steel (1965), Lacey (1973) and Demirjian (1980). They suggest that the maturation processes of the dental and skeletal systems are based on different genetic factors, as well as being independent of one another, and that even identical environmental factors may affect these processes differently.

In the present study, the relatively high correlation between dental and skeletal age seems due largely to:

(a) The limited age range (5-13 years). During earlier, and later, developmental phases (e.g. 0-5 and the pubertal years), the growth rates within and between the systems occasionally change. Our computation therefore relates only to the "less problematic" portion of the growth curve, therefore perhaps accounting for our larger correlation between the dental and skeletal systems.

(b) Possibly there is a genuine reduction of variance between the age distributions based on skeletal and dental criteria. This reduction could stem from enhanced selection pressures resulting both from size of the group and the nature of its breeding patterns as well as from environmental pressures.

There may also be a stronger selective pressure towards rapid skeletal development in Bedouin children because in tribal societies there is a clear advantage in good walking ability even at an early age whereas in the dentition, the pressure towards rapid development is less urgent; the suckling period often lasts till a relatively advanced age (2.5 years). The above argument is as yet only suggestive.

The above-cited factors may account for the intra-group Bedouin variability being, at least for part of the variables, smaller than that expected when compared with data from Western societies, and which in turn would lead to an increase in the values of the coefficients of correlation.

Developmental Differences Between Bedouin And Other Children

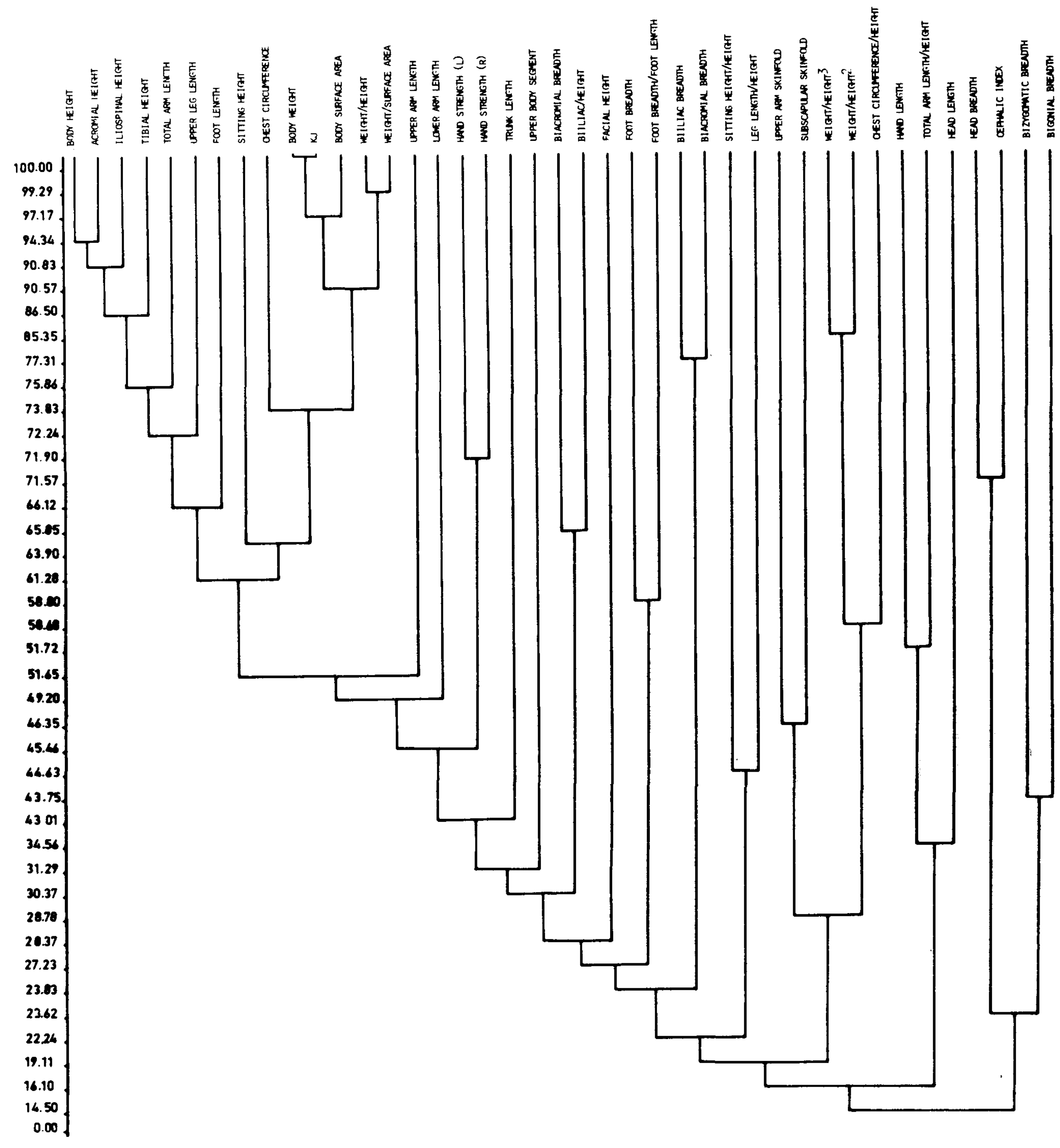
For purposes of comparison, we used growth rate data obtained from Muzeina boys only. The Muzeina tribe was chosen because of its relative homogeneity and good numerical child representation.

The usual standard for comparing physical development of different groups of children is chronological age. The manner in which we defined chronological age for Muzeina and other bedouin children, however, perforce differed in this respect, since exact age was not known and had to be estimated. Another problem is the definition of age categories. We defined age within the range of 5.5-6.4 years as age group 6, 6.5-7.4 years as age group 7, etc. When we compared literature data on children whose age group categories differed from ours, their mean values were calculated; for example, values of anthropometric traits were averaged for given age groups 6.5 and 7.5 to compare with values of our age group 7. Since our Bedouin samples are numerically inadequate for ages 14-18, we limited our discussion to the 5-13 years age range, except in the case of height and weight development. Our consideration of the 14-18 year range was necessary in order to more fully understand the developmental processes of Bedouin boys compared to those of others.

Certain landmarks, and measuring techniques, may differ according to the text followed (e.g. Martin and Saller, 1957 vs. Tanner, 1964). In the literature on child growth, not every investigator has indicated the measuring techniques employed. In this regard, we have appended a relevant comment next to "problematic" characters in our study. Historically there has been an effort to standardize landmarks.

The need to include as many anthropometric traits as possible for comparison forced us, owing to the wide range of morphometric traits used in growth studies, to resort to a relatively large number of growth studies on different populations.

FIGURE 13: Cluster Analysis of the Morphometric Traits of Boys 5-13 Years Measured in the Present Study: the Muzeina Tribe*.



* Figures on vertical axis are correlation coefficients x 100 Based on correlation matrix of morphometric traits. All ages were united after normalization by age in each age group.

Thus, for example, the European continent is represented by a wide array of populations, e.g. Russian, French, Polish and English (see Appendix 3). Consequently for some traits the European population is represented by Polish children while for other traits, English children are the subjects.

We decided to use a wide array of morphometric traits representing every region of the body, despite the fact that some are intercorrelated (Fig. 13) and therefore probably provide similar information. This was done because of the sizeable differences among various studies in number and kinds of the investigated traits. Our problem here was that if we reduced to ten or five the number of traits to be presented, we increased the risk that the particular traits considered would not be represented in many of the studies with which we intended to compare our results.

A number of traits deemed especially significant will now be considered, with following, the Muzeina boys compared to boys of other groups of like ages.

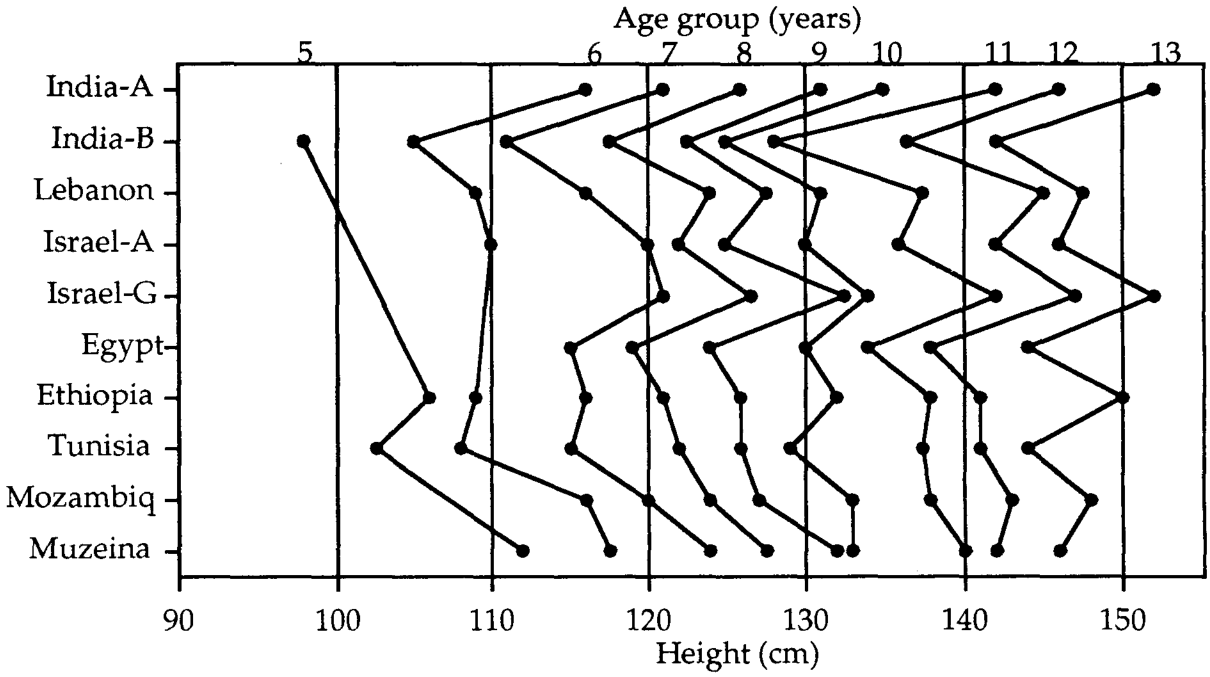
Stature

Body height and body weight appear to be two primary traits indicative of the general growth processes.

In average stature, boys of the Muzeina Bedouin, compared with Indian and Mediterranean boys, appear taller in the early years (ages 6-9), about the same at ages 10-12, and shorter at age 13 years. The same tendencies prevail also in a comparison of Muzeina boys with European, American and African groups (Fig. 14-16). Eveleth and Tanner (1976) discuss the differences in height attainment between children of Indian, Mediterranean and Western European parents. According to these authors, Indian children 2-10 years old are taller than European children of the same age. After the age of 10, height increment in the former is at a slower rate and they are now shorter than either their European or American counterparts.

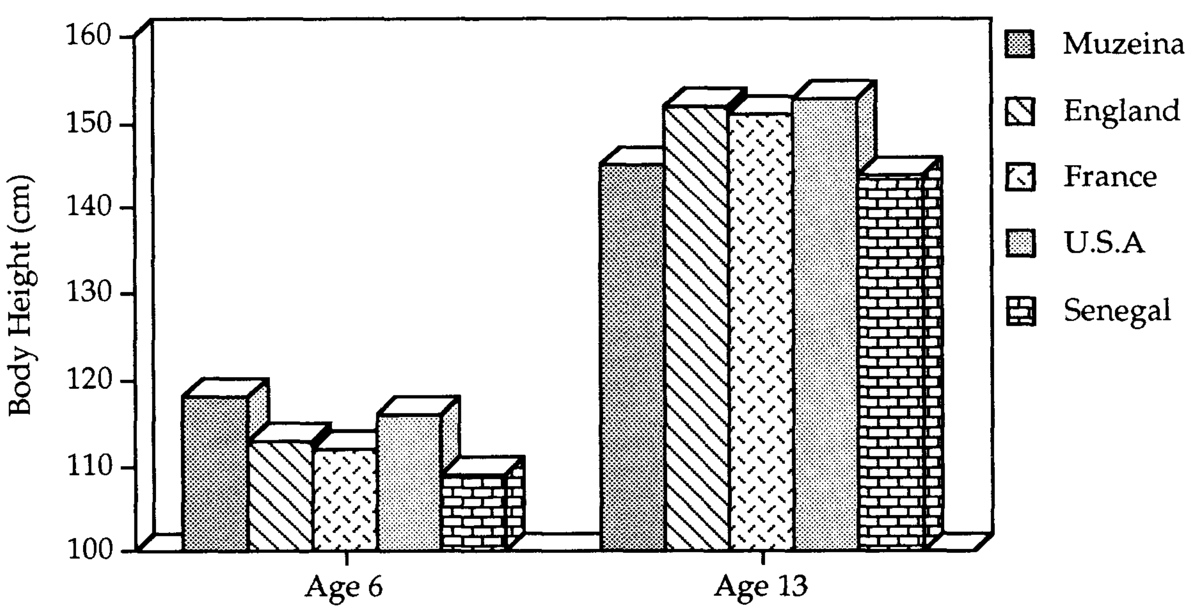
The Muzeina boys compared with children in Israel (see Fig. 14) are exceeded in average height by the Jewish children at age 9, but the Israeli Arab children attain the mean stature of Muzeina boys only at age 12 and do not exceed them even at age 13.

FIGURE 14: Stature of Muzeina Boys Aged 5-13 Years Compared With That of Boys of Indian, Mediterranean and African Populations*.



*Note: for explanations of population references see Appendix 3.

FIGURE 15: Mean Stature of Muzeina Boys at Ages 6 and 13 Years Compared With That of Boys of Comparable Ages in Mediterranean, European, American and African Populations.



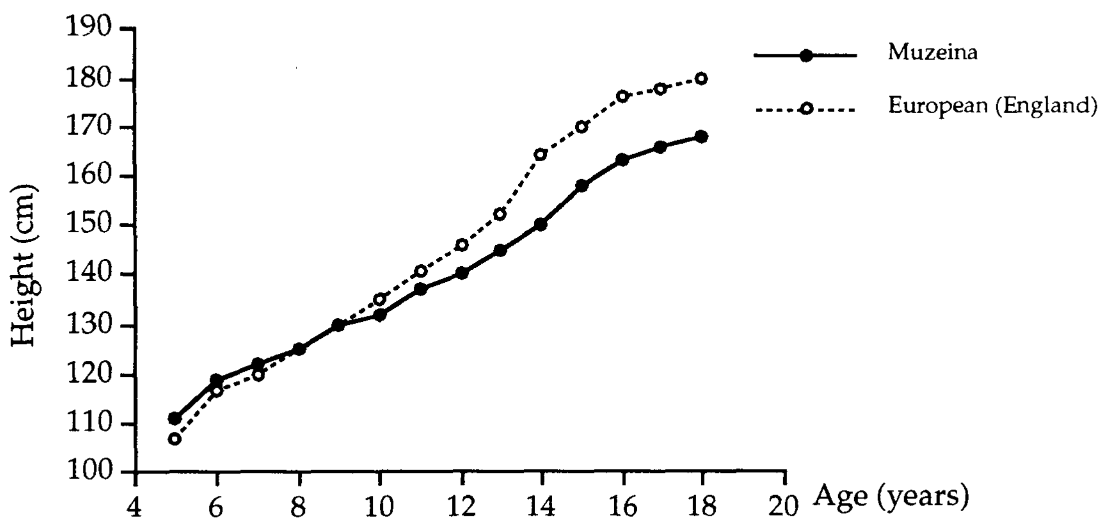
Note: For explanations of population references see Appendix 3.

A very similar picture is obtained for the Muzeina children when compared, for example, to English children (Fig. 16).

In order to overcome problems related to the effect of inaccurate age determination and small sample sizes in some groups on growth rate values, we employed the "smoothing" technique. This method "moderates" the curve but makes it more reliable than that obtained directly from the actual growth data. Also, the occurrence of peak height velocity of the adolescent spurt in height of the Muzeina boys is based on the interpretation of cross-sectional rather than longitudinal data. Hence, for the sake of comparability, all other data used for comparison were also from cross-sectional studies and were "smoothed".

Growth rates in stature of Muzeina and Egyptian boys show an essentially similar trend, that is, a gradual drop in the rate of development from age 6 up to age 10-11 and subsequently an increase to age 15 (Fig. 17). In Indian children there is a sharp decline in growth rate between the ages 6-10, and afterwards, a sharp increase to age 12. The growth rate remains relatively high for Indian children until the age of 15, when it begins to decrease sharply (Fig. 17).

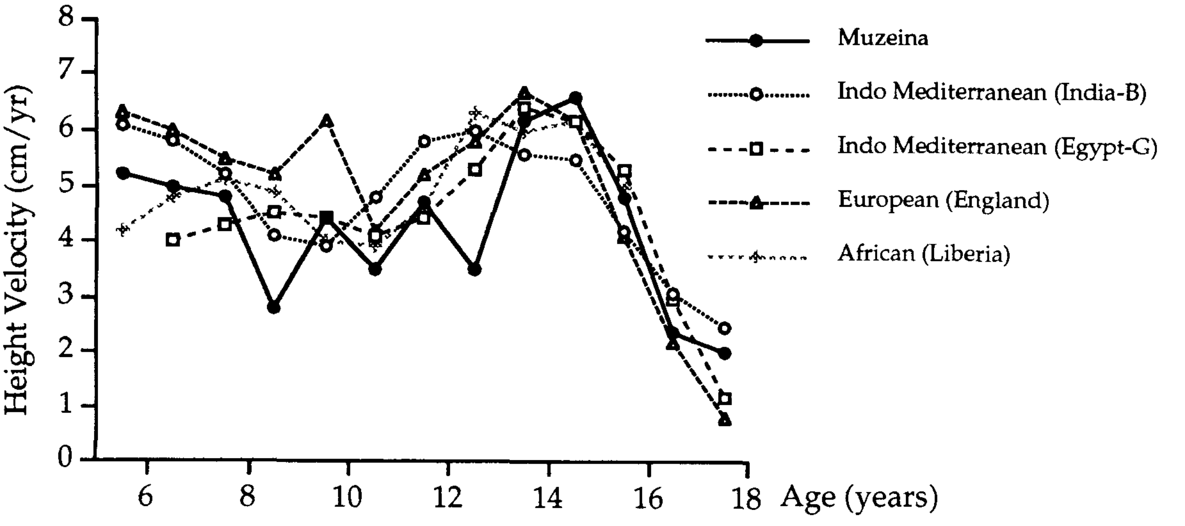
FIGURE 16: Mean Stature of Muzeina Boys Compared With That of London Boys, by Age; Data "Smoothed".



Note: For explanations of population references see Appendix 3.

The peak velocity of the adolescent spurt in height seems to occur later in Muzeina boys than in the London and Egyptian boys (Fig. 17). The magnitude of the peaks, however, appears to be equal for all three groups. From the age of 5 years (and possibly earlier) until the end of the spurt, Muzeina boys have a height velocity smaller than in London boys, but similar to that of Indian and Mediterranean (Egyptian) and African (Liberia) boys (Fig. 17).

FIGURE 17: Velocity of Growth in Stature in Bedouin Boys From South Sinai (Muzeina Tribe) Compared With Boys From Egypt, India, Europe (England) and Africa (Liberia), 6-18 Years of Age; Data "Smoothed".



Note: For explanations of population references see Appendix 3.

One of the central questions that arises from the data presented thus far is whether the observed difference between the growth curves of Muzeina boys and those of children of some Indian, Mediterranean, European and African populations, stem from the relative paucity of late-maturing children in the Muzeina sample. If so, then possibly the Muzeina curve reflects the influence of inadequeate sampling or is an artifact of the cross-sectional method rather than a genuine difference in the growth rate. Only a longitudinal study could fully resolve this question. However, since such a study is not feasible for nomad societies like the Bedouin, we have attempted another course, described below.

First we chose the mean height in the adult Muzeina male population (166.7 cm) as our point of reference (Monk, 1993). The initial parameter computed was the ratio (in percent), P_i between the mean height in each age group and the mean height in the adult male population ($\overline{X}$).

The P_i values for different ages are shown in Fig. 18, which indicates what percentage of the adult male stature each age group of the Muzeina tribe attains compared with like ratios in the corresponding age groups in other populations. Thus by age 5 the Muzeina children have already attained 68% of their ultimate adult average height (Fig. 18) whereas the Indian and English boys have attained 61% of this stature at the same age. At age 11, the Muzeina children have already attained 84% of their final height, compared with 80% for Indian children and 81% for English boys.

FIGURE 18: Percentage of Mean Stature of Adult Males Attained by Bedouin Boys From South Sinai (Muzeina Tribe), Europe (England) and India, Ages 5-18 Years.

Note: For explanations of population references see Appendix 3.

Heretofore we have compared several populations at comparable ages. However, since age determination of Bedouin children is not totally accurate, we have estimated an average P_i value by combining children of different ages into one age group, (e.g. from 5 to 11 years and from 5 to 13 years). We thereby obtained a new index (P_i) which indicates the mean distance of a certain child population from the height of the adult population. In this way we could evaluate the percentage (P_i) that the mean height of a given age group (A_i) comprises of the mean height of the adult population.

The data in Table 23 show that the overall boy population in the Muzeina tribe, ranging from 5 to 11 years of age, attains on the average 75.6% of the development of the adult population, more than any of the other compared groups. This clearly indicates that on the average, prior to their adolescent spurt in height, they already have less to attain than other populations in order to reach adult height. The differences between the Muzeina and European (London) boys, in mean percentage in the first age group (5-11 years) is 3.8%, which is reduced to 3.0% in the wider age group (5-13 years).

TABLE 23 Comparison of P_i values in stature among different boy populations[1], aged 5-11, and 5-13 years

	Population			
Parameters	**South Sinai Muzeina**	**India***	**Europe (England)**	**New Guinea (Kiapit)**
$\overline{X}$ (cm)	166.7	162.5	174.7	163.2
P_1 (%)	75.6	70.9	71.8	72.3
P_2 (%)	78.0	74.1	75.0	74.7

$\overline{X}$ = average height of adult males

P_1 = mean percent of average adult height for age group 5-11 years

P^2 = mean percent of average adult height for age group 5-13 years

*=Indian national

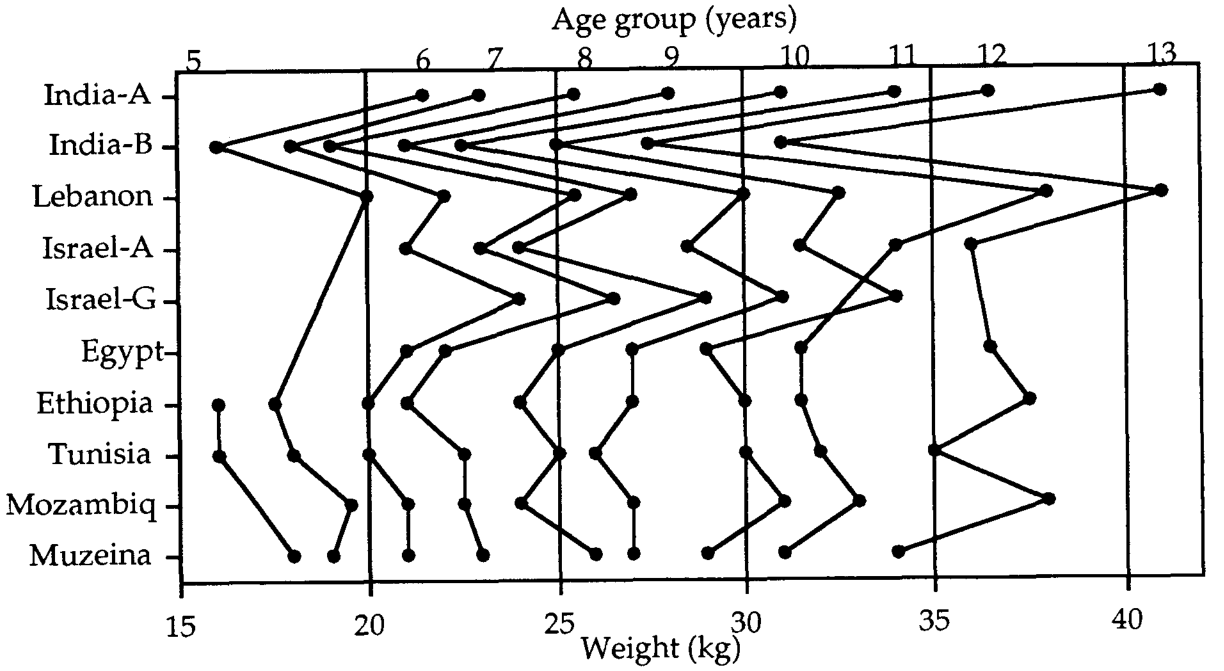
[1]= For explanation of population references see Appendix 3

Body Weight

Average weight of Muzeina boys aged 5-9 years is more than that noted for African (Mozambique, Tunisia, Ethiopia and Egypt) and Indian boys, and very similar to that of Israeli Arab boys. The Muzeina boys generally weigh less than boys of comparable ages in Lebanon, "high" Indian castes or Jewish children in Israel (Fig. 19). At ages 10-11 the Muzeina boys are almost identical in weight with children of the compared African populations and exceed in weight the Indian (National) boys (Fig. 19). Compared with boys of other countries at ages 6 and 13, respectively (Fig. 20), the Muzeina children show much the same mean weight at 6 years of age but definitely less at age 13.

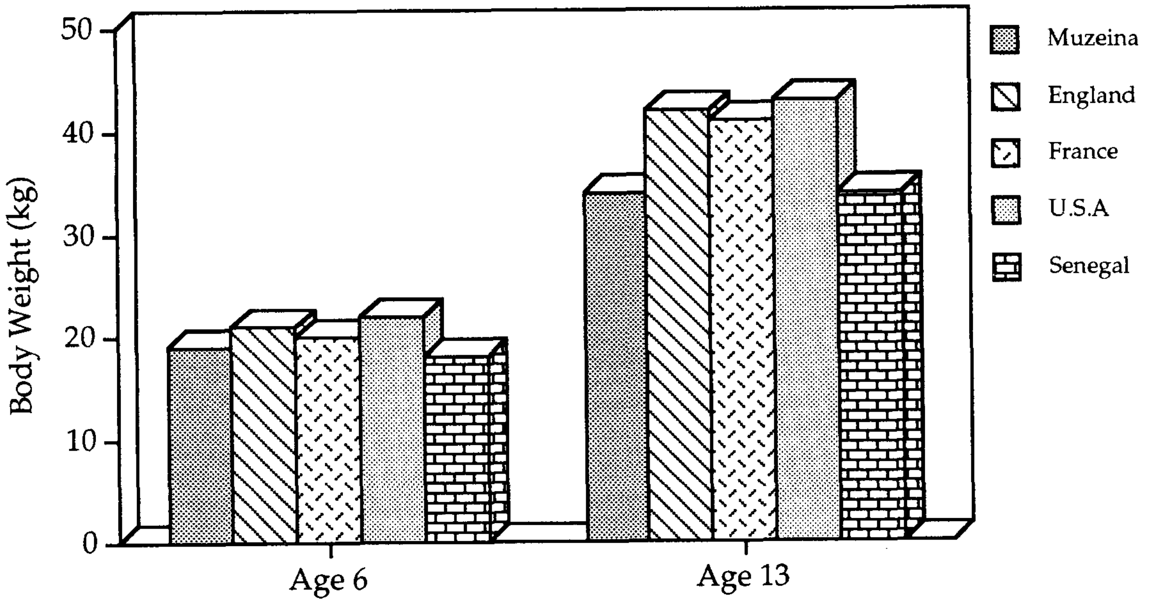
Jewish Israeli children at all comparable ages weight more than Muzeina children (Fig. 19, Israel-G). Arab Israeli children resemble in mean weight the Muzeina children in the 8-9-year age groups but subsequently weigh more. Comparison of the weight values between Muzeina and European (London) children from ages 5 to 18 is presented in Figure 21. This figure reveals that throughout their developmental period, the Muzeina children weigh less than do the English children and that their tendency to diverge from the mean weight of these children increases with age.

FIGURE 19: Mean Body Weight of South Sinai Muzeina Boys Compared With That of Boys From India, Mediterranean and African Populations, ages 5-13.



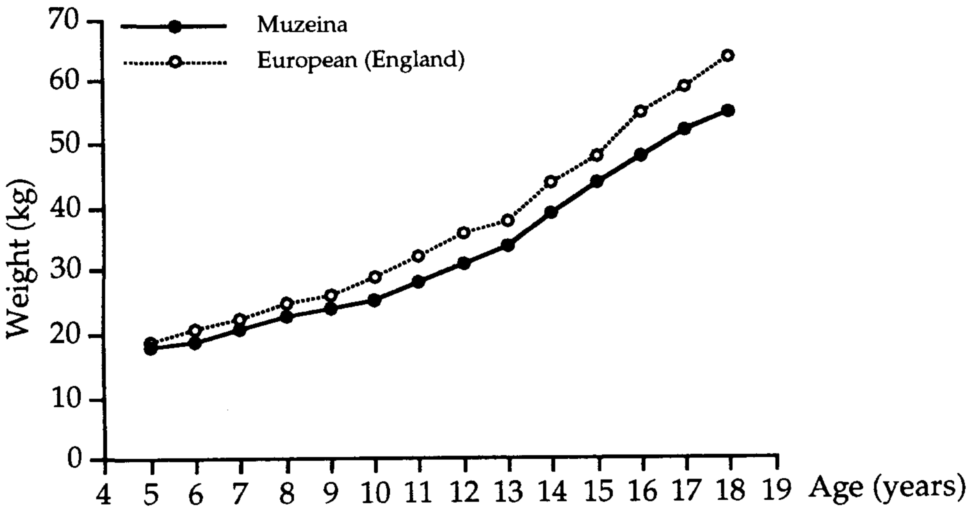
Note: For explanations of population references see Appendix 3.

FIGURE 20: Mean Body Weight of Muzeina Boys Aged 6 and 13 Years Compared With Children of Other Countries at Like Ages.



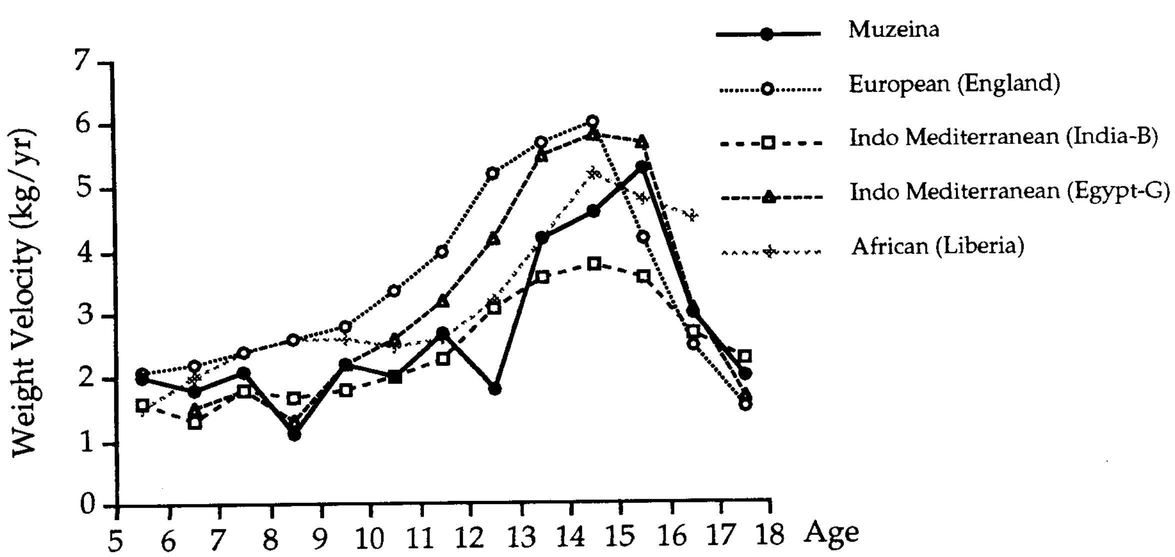
Note: For explanations of population references see Appendix 3.

FIGURE 21: Mean Weight of Bedouin Boys From South Sinai (Muzeina Tribe) and London, by Age; Data "Smoothed".



Note: For explanations of population references see Appendix 3.

FIGURE 22: Mean Annual Velocity in Weight of Boys between Ages 5-18 in South Sinai (Muzeina Tribe), Europe (England), African (Liberia), Egypt, and India; Data "Smoothed".



Note: For explanations of population references see Appendix 3.

Figure 22 depicts the annual rate of weight gain in Muzeina boys compared with that of boys from India and Egypt (all data "smoothed"). It is seen that up to age 10-11, the annual weight increment in the Muzeina boys increases steadily, reaching a peak between 14 and 16 years of age. The annual increment in weight among Indian children after age 11 is much less pronounced than that of Muzeina and Egyptian boys. Although the weight gain curves of Muzeina and Egyptian boys are very similar, it seems that Egyptian boys tend to grow faster and reach their maximum rate of weight increase a year earlier.

If we superpose the weight gain rates of Muzeina children at different ages on weight gain plots of European and African boys, we see (Fig. 22) that the weight gain curve of Muzeina children differs significantly from that for European (England) boys and is very similar to that of African boys (Liberia). From ages 11-14 years European (England) boys manifested a greater increase in annual weight velocity (average of 1.5 kg more per year).

In Figure 23 we learn that by age 5, the Muzeina children have attained 34% of their total weight development whereas Indian children of the same age have completed 31% and London children, only 30% of their total weight development. At age 13 the situation reverses in that the London boys have by then completed 67% of their weight development while the Muzeina children and the Indian children have completed only 64% and 65%, respectively.

If we estimate the average P_i values for ages 5-11, we see (Table 24) that insofar as weight gain (toward the adult mean), the Muzeina children precede the children from the Indian subcontinent, the European (English) children and also the children from the aborigine tribes of New Guinea.

Body weight related to stature is considered in Figure 24. It is seen here that Muzeina boys actually weigh less relative to their height than do English boys, but similar to Indian boys. The rapid height gain with age among Muzeina boys is not accompanied by a corresponding weight gain. Only up to age 9 are they taller than English children but weigh less at all ages (5 to 13 years).

TABLE 24 Comparison of P_i values in body weight among different boy populations, aged 5-11 and 5-13 years.

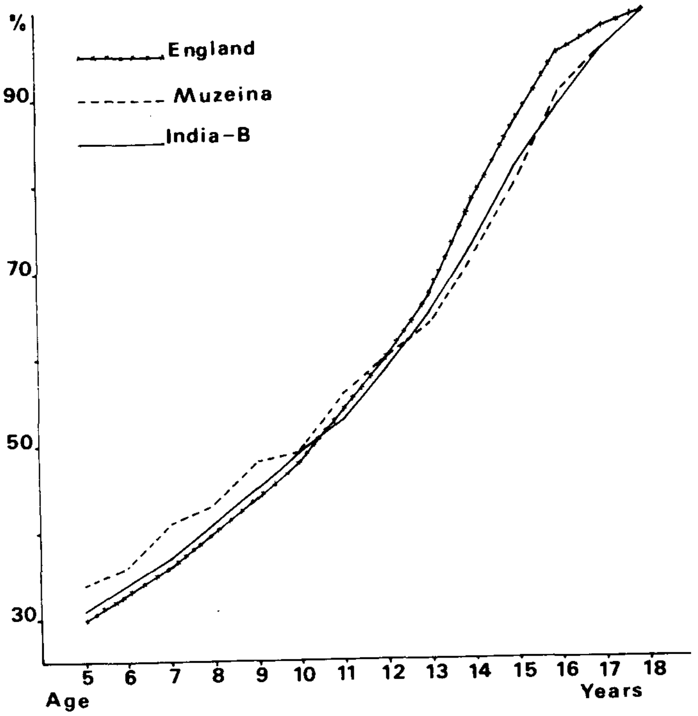
	Population			
Parameters	South Sinai Muzeina	India	Europe (England)	New Guinea (Kiapit)
$\overline{X}$ (kg)	53.3	46.5	63.0	53.5
P_1 (%)	43.7	41.4	40.7	40.4
P^2 (%)	51.2	46.0	45.0	43.6

$\overline{X}$= average weight of adult males;

P_1 = mean percent of average adult weight for 5-11 age group

P_2 = mean percent of average adult weight for 5-13 age group

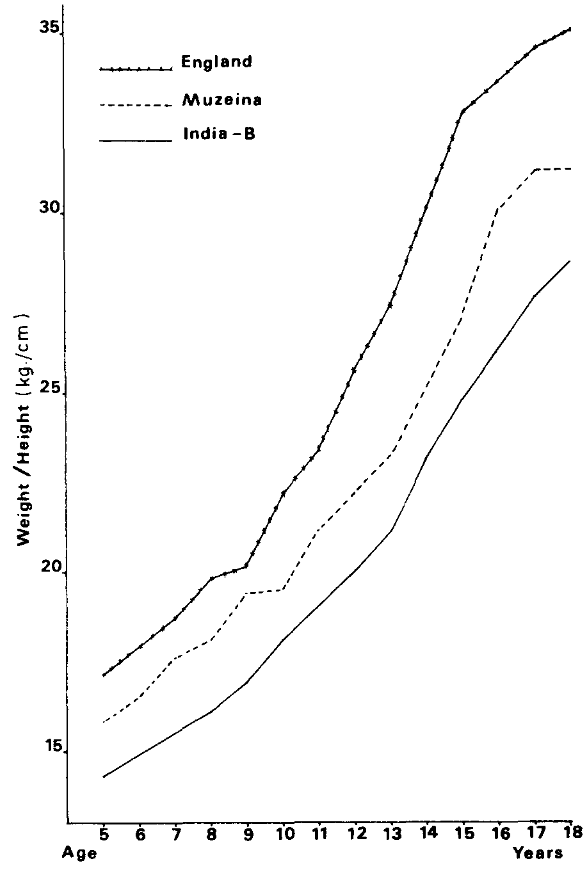
FIGURE 23: Percentage of Mean Male Adult Weight Attained by Boys From South Sinai (Muzeina Tribe), England, and India, at Annual Intervals, Ages 5-18.



Note: For explanations of population references see Appendix 3.

If we calculate a new parameter K_i ($K_i=P_i$ weight/P_i height), which generally expresses the ratio between weight and height development in relation to adult weight and height, we see that the K_i value for Muzeina boys at age 5 is 45.3 whereas in European children of the same age the ratio is 48.4. This may indicate a more balanced height and weight growth pattern at early ages in London boys, probably as a result of more favorable economic conditions which have a crucial influence on weight growth rate. At age 5 the Muzeina boy on average is taller by almost 3 cm (Fig. 16) than the London boy but weighs 1 kg less. At age 13, the K value for Muzeina boys is 73.6 whereas that for London boys is 76.3, thus suggesting the relationship between weight and height development in each is different. The London boy at age 13 is taller on average than the Muzeina boy by more than 7 cm and weighs 8 kg more. Indian boys at the same age have a K value of 74.7, very similar to that of Muzeina boys, although the former are shorter than Muzeina boys by 4.7 cm and weigh 3.7 kg less.

FIGURE 24: Ratio of Weight to Height in Muzeina Boys, 5-13 Years of Age, Compared with Like Data for Boys in England and India



Note: For explanations of population references see Appendix 3.

Head and Face

Between the ages of 5-13 years, head length in Muzeina children increases by about 10 mm, an addition of 5.9%. Head breadth increases during this interval by 5.8 mm, an addition of 4.3%. Clearly, the head increases more in length than in breadth, both absolutely and relatively. Hence the cephalic index decreases slightly between age 5 and age 13.

The rate of facial growth is not uniform in its various anatomical regions. The face broadens by a larger measure than does the head and changes shape from trapezoid to more hexagonal. These shape changes are due to the fact that the bizygomatic breadth increases relatively by a rate of almost twice that for the distance between the rami of the lower jaw (bigonial breadth) and almost three times that of the rate of expansion of the minimum frontal breadth. Between the ages of 5 and 13 facial height increases 17.1 mm, or 19.5%.

When we compare development of the face and head in Muzeina boys from South Sinai with that in children of Bedouin tribes from the Egyptian

Western Desert, or with Polish children, we note that the Muzeina have longer heads (Appendix 3).

The mean head length in Muzeina children between 6-7 years of age (the 6.5 age group) is 182 mm, while in Egyptian groups it ranges between 174.5 to 177.4 mm. In the Polish boys it is much smaller, attaining only 169.8 mm. Between 12-13 years of age (the 12.5 age group), the head length in the Muzeina group reaches a mean of 188.1 mm, in the Egyptian boys, between 182.2 mm and 183.4 mm, and in the Polish boys, only 175.5 mm. The gain in head length between the 6.5 and 12.5 age groups is 3.3% for the Muzeina society, 3.9% for the Egyptian and 3.3% for the Polish, that is, almost identical growth rates with the differences evident only in absolute terms. On the other hand, the head breadth in the Muzeina children is noticeably less than in the Polish boys, and markedly smaller than in the Egyptian boy sample (for population references see Appendix 3).

In all the groups compared, the cephalic index tends to decline with age. Yet there are considerable differences between the groups in the cephalic index (Appendix 3). The Muzeina boys show the lowest cephalic index when compared with Polish and Egyptian boys of comparable ages.

The fact that none of the compared groups shows very much change in this index with age suggests that shaping of the head is largely effected relatively early in life, before age 6. Furthermore, the data indicate a distinct difference in head shape in the three cited groups, mainly between the Muzeina and the Polish boys, the latter presenting a relatively short and broad head (brachycephaly) while the Muzeina have a relatively long and narrow head (dolichocephaly).

In facial structure, the Muzeina boys differ from the Egyptian and Polish groups, having shorter faces (Appendix 3). At 6.5 years the mean facial height is 96.5 mm for Polish boys, 98.3 mm for Egyptian boys and only 94.5 mm for the South Sinai Bedouin Muzeina boys. At 12.5 years of age, mean facial height is 107.3 mm for Polish, ca. 108.0 mm for Egyptian, and 103.5 mm for Muzeina boys; the relative increment in facial height from age 6.5 to 12.5 is 11.2% in the Polish boys, 9.9% in the Egyptian, and 9.5% for the Muzeina boys.

Mean facial breadth (bizygomatic) of the Muzeina children tends to be less than in the Polish boys but higher than that of the Egyptian boys (Appendix 3). Thus at 6.5 years the bizygomatic breadth attains a mean of about 114.4 mm in the Muzeina, 118.1 mm in the Polish, and 107.2-112.8 mm in Egyptian boys. In the 12.5 age group, the mean bizygomatic breadth is 123.0 mm in the Muzeina Bedouin boys, 125.6 mm in the Polish and 117.3-121.1 mm in two groups of Egyptian Bedouin boys; rate of increment in byzygomatic breadth in the Muzeina boys is 7.5%, 7.4-9.4% in the Egyptian groups, and 6.3% in the Polish boys.

The bicondylar breadth is not strictly comparable in the several groups owing to differences in measuring methods. However, the trends seem to be identical to those obtained for bizygomatic breadth.

We may conclude that facial breadth in the Muzeina boys tend to be considerably less than in the Polish boys but greater than in the Egyptian groups.

In sum, we note that:

a) In absolute terms, the head of the Muzeina children is long and narrow compared with the head of children in the European and Egyptian populations. The head length at age 5 reached 94.3%, and head breadth - 95.8%, of those values at age 13.

b) The face increased in different height measurements by 9-12% and in different breadth measurements by 6.9-11.6%. At age 5 the bizygomatic breadth achieved 89.6% of its size at age 13 and facial height reached 83.7%, whereas the head length at age 5 reached 94.4%, and head breadth- 95.8%, of those values at age 13. The Bedouins have a comparatively short and narrow face.

The Chest, Abdomen and Pelvis

The mean breadth of the body in the shoulder region, the biacromial distance, increased in the Muzeina boys between the ages of 5 to 13 from 23.6 cm to 30.8 cm, or 30.5%.

During the same age span, breadth of the body in the hip region, the biiliac distance, increased from a mean of 17.3 cm to a mean of 20.6 cm, a gain of 19.1%. Hence, between ages 5 and 13 the shoulders developed at a faster rate and to a greater extent than did the hip region. It should be pointed out that the measurement in the shoulder region, between the two acromial crests, is between two separate bones which are not directly linked to the axial skeleton, whereas the measurement in the lower pelvic region is between the two crests of the pelvic bones which are interconnected by an additional bone, the sacrum. Consequently the two measurements differ in that the first represents growth of osseous, muscular and adipose tissue, whereas the second is largely of osseous tissue only.

The increase in trunk length (suprasternal height minus anterior superior iliac spine height) is from a mean of 27.5 cm at age 5 to 34.6 cm at age 13, a gain of 25.8%. The increase in length of the trunk, head and neck combined, or "sitting height", is from a mean of 51.2 cm at age 5 to 62.6 cm at age 13, a gain of 22.3%. Height in the sitting position, measured as the distance from the top of the head to the sitting plane, between ages 5-13 increased from a mean of 61.2 cm to 75.8 cm, a gain of 23.9%.

Comparison between Muzeina boys and the children of various other ethnic groups (Appendix 3) reveals that the Muzeina children possess, up to age 9, a mean body girth in the shoulder region (biacromial breadth) which is larger than that in boys from India and Egypt, but is smaller than in London boys. After age 9, the biacromial breadth of Muzeina boys is larger than in Indian children, and smaller than in Israeli and London boys.

The biiliac breadth to age 9 is greater in Muzeina children than in Israeli or Egyptian boys, and remains large relative to Israeli children also at later ages. The Egyptian boys, on the other hand, equal the Muzeina from age 10 and in some cases even exceed them (Appendix 3).

The chest circumference in Muzeina boys up to age 7 is greater than in Indian, Israeli and English boys. At the ages of 8 and 9, this measure drops below the equivalent value for English children, is smaller than in Israeli children whose parents derive from East Europe (E.E.), but is similar to that of Israeli children born to Mediterranean parents (M.E.). After the age of 10 years both Israeli groups (E.E. and M.E. have a significantly larger chest circumference than do the Muzeina children (Appendix 3).

The mean sitting height in Muzeina children is smaller than in London and Israeli boys starting at age 8-9, but is larger than in the Indian or Egyptian boys at all ages (Appendix 3).

If we consider the biacromial breadth/Body height ratio (Appendix 3), we note that compared to Israeli, Egyptian and Polish children, the Muzeina Bedouin boys are narrow in the shoulders relative to their height (Appendix 3) and broad in the pelvic region relative to height only when compared with Israeli boys (Appendix 3). However, the Muzeina boys when compared with London boys, show lower biiliac/stature values at all ages. In both of the latter populations, this ratio decreases significantly with age; however, this ratio among London boys at 13 years of age is very similar to that of Muzeina boys at age 5! (Appendix 3). Moreover, the size of the biiliac/height ratio is reduced between ages 5 and 13 by 10.2% among Muzeina boys and by only 6% among London boys. The significance of this difference is that height gain in the Bedouin boys between ages 5 and 13 years is much faster than in the pelvic girth of the compared boys. The ratio of chest circumference to body height changes with age in the Muzeina boys, as well as in the other compared groups (Appendix 3). At ages 9 to 13, the Egyptian children have a small chest circumference relative to their height, the Bedouin Muzeina and Polish boys are about the same in this measure, and the Israeli children display a higher ratio of chest circumference to height at ages 10-13.

The Extremities

The upper and lower limbs are each composed of three parts: the upper limb has the upper arm, lower arm or forearm, and hand; the lower limb includes the thigh, lower leg or shank, and foot. Each segment has its own rate of growth, which changes with age. Thus, with changes in age, there are changes also in the proportions, both within and between the parts.

Upper Limb

Krogman (1972), commenting on growth of the upper limb in U.S. white children, notes that up to puberty the patterns of growth of the upper limb and its component parts are the same in boys as in girls. Subsequently, however, the growth rate in the males is greater than in the females. In American "White" children between the ages of 3 and 12 years, the upper limb grows at a rate of 2-3 cm per year. At puberty the rate increases and subsequently declines sharply.

According to Krogman (1972), the lengths of the upper arm and lower arm (forearm) are equal at birth. On maturation, after about age 18, the lower arm comprises only 75% of the length of the upper arm. A young child has a relatively long hand compared to length of the entire arm. The ratio of arm length to body length also changes with age. All these rates and ratios may differ in different ethnic groups (Krogman, 1972).

In the Muzeina boys, total arm length increased by 15.95 cm, or 32.7% between the ages of 5 and 13 years. Separately, the upper arm increased by 6.6 cm (32.9%), the lower arm by 5.6 cm (34.3%) and the hand by 3.8 cm (30.4%). Thus the forearm grows relatively more rapidly than the upper arm but remains smaller than the latter throughout the developmental period; both the forearm and the upper arm grow relatively faster than the hand between ages 5-13 years.

Relative to the upper arm, at age 5 the forearm length is 81.6% of the length of the upper arm, and remains much the same proportion at age 9 (82.1%) and at age 13 (82.5%). Hand length at age 5 reaches 63.2% of the length of the upper arm, at age 9 - 62.6%, and at age 13 - 62.0%. Compared to American and Israeli boys, the Muzeina have a longer upper arm and forearm at 5 to 8-9 years, but then the reverse occurs, the Muzeina boys manifesting a shorter upper arm and forearm. A similar process takes place also with the hand, except that here it commences at age 12 (Appendix 3). The Muzeina boys have a slightly longer upper limb relative to body length than Israeli boys (Appendix 3).

Lower Limb

Krogman (1972) has demonstrated that the upper limb, as the lower limb, develops at about the same rate in both sexes till puberty, whereupon the lower limbs of the male (all three component parts) become longer than in the females. He also found that growth of the thigh proceeds more rapidly than the lower leg, albeit the proportions of these two components are the same in different ethnic groups.

Development of the lower limb.

In the South Sinai Muzeina boys, between 5 and 13 years the total length of the entire lower limb increased 24.3 cm or 40.7%; 12.4 cm is contributed by the lower leg (measured by tibial height. However, growth rate of the lower leg is not uniform relative to growth of the entire limb. Thus at age 5 the lower leg comprises 48.1% of the total leg length, and at age 9 - 49.2%.

Our data indicate (Appendix 3) that until age 8, South Sinai Muzeina boys have longer legs (total length and segments) than do Israeli and American boys, although the American boys manifest more rapid leg growth at age 9 and after.

The ratio of total leg length to stature (Appendix 3) shows that up to age 9 the Muzeina boys have a longer leg relative to stature than Israeli boys but after age 9, the curves are much the same.

The Foot

The foot here receives a special chapter because of the importance we assign to its development in nomad and seminomad peoples. According to Krogman (1972), in European populations the length of the foot at birth is about 31% of the average in the adult male, and by age 10 reaches about 82%. Average length of the foot relative to stature at age 13 in males is 15.5%. While length and width dimensions of the foot differ among various groups, the width/length ratio appears to be relatively fixed.

In the South Sinai Muzeina boys between ages 5 and 13, foot length increases by 5.3 cm, or 29.0%, and in breadth by 2.0 cm (27.8%). Thus rate of growth was practically identical in both length and width between ages 5 and 13.

Growth in foot length and width of Muzeina boys, compared with like dimensions in Israeli Jewish boys, shows more rapid development in the former from 5 to 9 years, but the reverse afterward (Appendix 3). Average incremental growth in breadth is very similar in Muzeina and Israeli boys (Appendix 3). Consequently, the foot differs significantly in that the Muzeina boys acquire a foot "mold" which is broad relative to length, whereas the Israeli boys develop a foot which is comparatively narrow relative to its length (Appendix 3).

It is important to note, concerning foot development, that Bedouin children walk barefoot from early childhood whereas Israeli children wear shoes beginning approximately one year of age, a difference which probably affects both rate and pattern of development of the foot in each group.

Adipose Tissue

It is customary to suppose that circumferential measures (e.g. the chest) are influenced to a greater extent than other bodily measurements by involving more adipose tissue (Krogman, 1972). Yet differences in physical activity also affect development or non-development of adipose tissues. According to Krogman (1972), changes with age in the thickness of subcutaneous adipose tissues are of a rather fixed pattern, namely, rapid increase during the first year of life, followed by a decrease to age 8, followed again by a rapid upsurge, although there is marked variability in this pattern among different ethnic groups.

Our evidence for Muzeina boys (Appendix 3) indicates that their subcutaneous adipose tissue, measured by skinfolds, is considerably less than on boys from Israel or England, and appears to be about the same as in Egyptian boys. The noted differences are probably due to the disparity among the boys in both the amount and quality of the food consumed. When comparable measures in the increment of subcutaneous fat with age are made in Bedouin boys (Muzeina) and Egyptian boys, who are also deprived nutritionally, we find only slight differences between the two, possibly genetic in origin (Appendix 3).

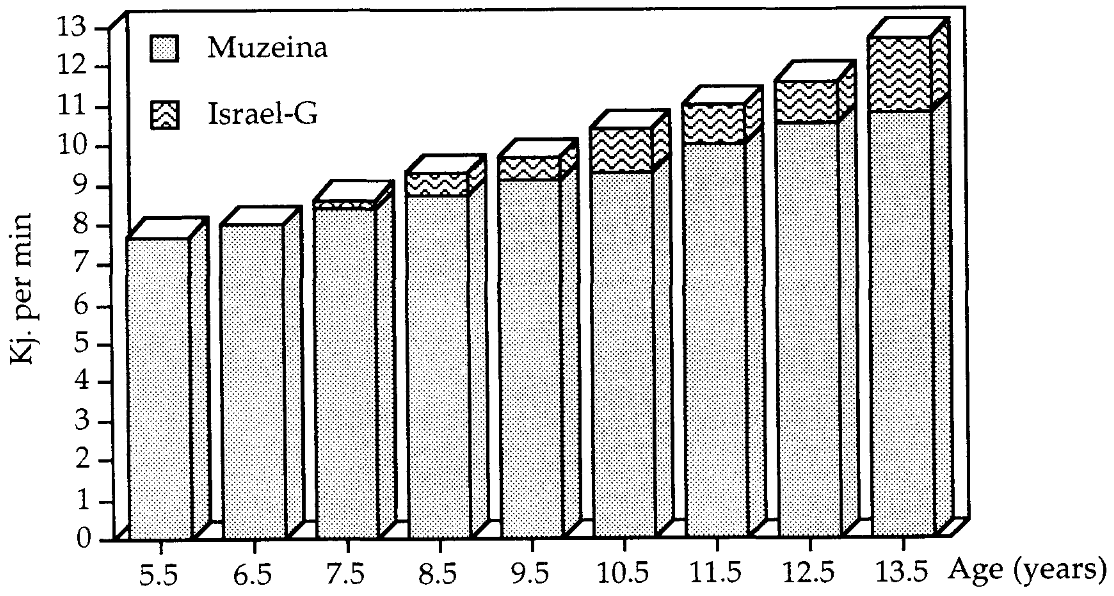
Energy Consumption

The Basal Metabolic Rate (BMR) can be expressed by various units, to wit: liters of oxygen consumed per minute, kilocalories (Kcal), kilojoules (KJ) per minutes or relative to body surface as Kcal or KJ per m^2. Due to objective difficulties in the course of our study, we were unable to obtain precise data on the oxygen consumption and lung volume of Bedouin children and therefore had to rely on kilojoules. The KJ unit is defined as the energy expended when 1 kg is moved a distance of 1 meter by 1 Newton. A Newton is the force which accelerates 1 kg by a rate of 1 meter per squared second (1kg by $1m/sec^2$). The energy unit in nutritional studies is usually the Kilocalorie (Kcal) which is equivalent to 4.185KJ. On occasion one finds in the literature the term Megajoules (MJ) which is equivalent to 10^6J.

Energy consumption by individuals is dependent on four interconnected variables, namely, age, level of physical activity, body size and composition, and environmental factors. Accordingly we selected an equation which enabled computation of the energy consumption per fixed activity (e.g. walking at a rate of 3 miles per hour) regardless of age or sex of the individual. The resulting equation is: $KJ/min = 0.197 \times weight + 4.284$ (from Harrison et al., 1977, p.401)

Comparing our results with those for Jewish boys in Israel (Fig. 25), we find that, except for ages 5 and 6 where we did not have data for Israeli children, energy expenditure for performing the aforementioned task for 1 minute is less in Muzeina Bedouin boys than in contemporary Israeli Jewish boys of the same age. This result suggests that lower mean body weight of the Bedouin boys is the primary factor which enables them to perform physical activities at a lower energy "cost".

FIGURE 25: Change With Age in Energy Expenditure Required to Perform a Defined Task, in Muzeina and Jewish Boys in Israel.



A word of caution is perforce necessary: in our formula, body weight is the only criterion or factor considered,which undoubtedly causes some bias in the obtained results.

To be sure, the existence of nomad or semi-nomad desert populations subsisting largely on grazing, primitive agriculture limited to constricted regions, and perhaps occasional "outside" work, is dependent on a precise balance between energy expenditure and the food resources available to the group (Harrison et al., 1977). Studies have shown that populations subsisting under severe environmental and/or economic conditions do not display a special physiological adaptation but rather a behavioral adaptation, meaning that the group generally refrains from "excess" activity, or any activity not vital for its existence, thereby limiting its energy consumption (see review by Lange Anderson et al., 1978). Our own experience with the Bedouin in South Sinai over the years confirms this finding.

There is need, also, to evaluate anew the appellation of nomadism, which has been attributed almost automatically to Bedouin populations. In this connection, Palmer (1871) more than a century ago remarked that the Bedouins were far from being the exclusive nomads depicted in numerous literary `romances'. He noted:

> *The idea prevalent in Europe of the nomad character of the Arabs is erroneous. They are generally described as wandering incessantly with their tents from place to place, but in reality no people wander less than the Bedouin, or are more attached to their native homes* (p.78).

Body Size and Shape

In addition to the usual measures by which shape is defined (e.g. ratio of limbs to torso, ratio of weight to stature, etc.), we used also two other working equations. The first computed body surface area by the DuBois formula:

$A = W^{0.425} \times H^{0.725} \times 71.84$ (Harrison et al., 1977, p.401)

where A = body surface area in cm^2; W = body weight in kg; and H = body height in cm. This formula was developed as European criteria and therefore tends to bias the results in favor of populations for which it was developed.

The association between body size and shape has been the subject of numerous investigations ever since publication of the Bergmann and Allen laws (1847, 1877). Later many anthropologists (e.g. Roberts, 1953) attempted to demonstrate that the laws stipulating that body size in warm-blooded animals of a particular species or subspecies usually increases with a drop in the temperature of their biotope (the Bergmann Law) or that there is an increase in the relative proportions of projecting organs, such as ears, tail, etc., with a rise in the ambient temperature (Allen's Law), are applicable also for humans. For example, an extensive study in the early 1950's by Roberts showed that the mean body weight to body surface area ratio in populations residing in warm regions is lower than in populations living in temperate and cold regions; furthermore, that the ratio of sitting height to stature diminishes with increase in temperature, that is, the lower limbs tend to become longer in the warm regions, and the trunk dimensions smaller in hot climates.

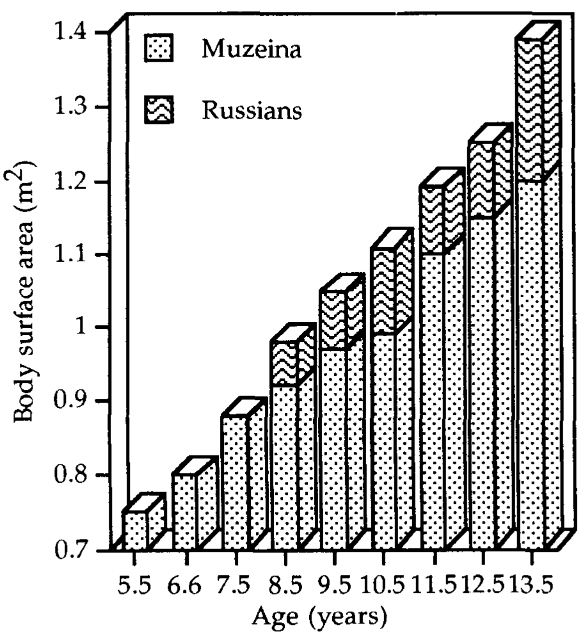
Most of the previous findings on the subject were assembled by Schreider (1951), who then demonstrated that the ratio of weight to body surface area diminishes as one proceeds from temperate to hot climates. He determined a ratio of 38 kg (body weight) to 1 m^2 (of body surface) in a French adult male population, 36kg/m^2 in an Arab population, 35kg/m^2 in a Somali population and 32kg/m^2 in an Indonesian population. Other investigators (e.g. Harrison et al., 1977) point out, however, that the correlation between body shape and temperature accounts for only 50-60% of the overall morphologic variability in a population and hence other factors should also be sought as responsible for the variability.

The data collected by us on South Sinai Muzeina boys on both body surface area as well as body surface relative to body weight, are shown in comparison with like measures in European children of Russian extraction in Figure 26a,b. It is evident from these figures that average body surface area in the Bedouin Muzeina boys is considerably smaller than in the European boys, and the ratio of surface area unit to weight unit is higher in the former (Fig. 27 a,b).

These results testify not only to absolute differences in weight and stature between the Bedouin (Muzeina) and Israeli and Russian boys, but also to a difference in proportionality, a fact apparent also in earlier data presented in this chapter.

FIGURE 26a: Body Surface Area in Muzeina Boys ComparedWith Russian Boys, Ages 5-13*.

FIGURE 26b: Body Surface Weight Area/ in Muzeina Boys Compared With Russian Boys, Ages 5-13*.



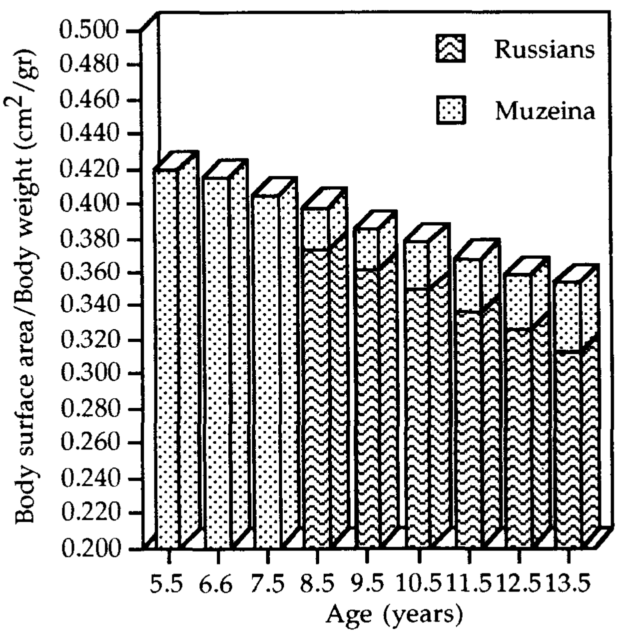


FIGURE 27a: Body Surface Area in Muzeina Boys Compared With Israeli Jewish Boys, Ages 5-13*.

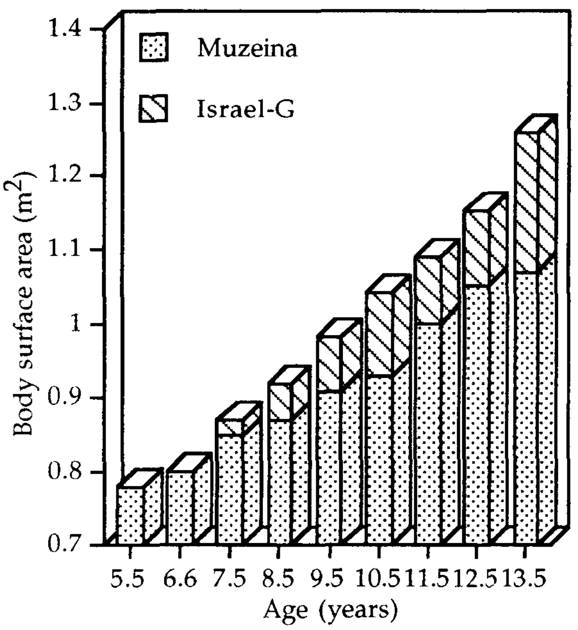
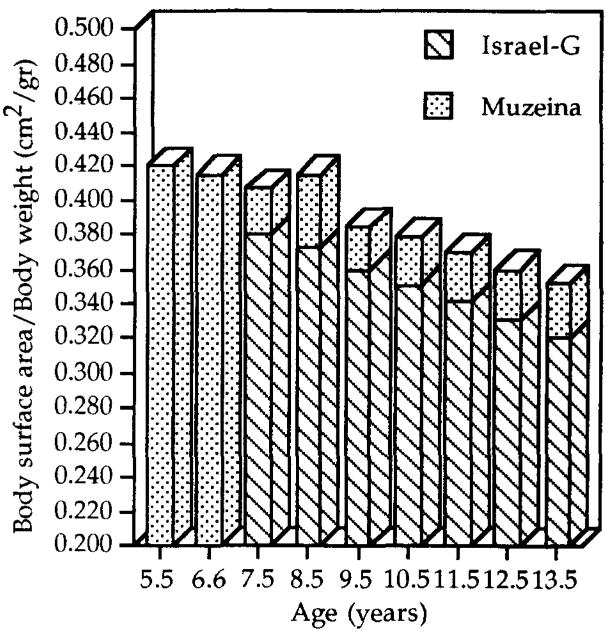


FIGURE 27b: Body Surface Area/Weight in Muzeina Boys Compared With Israeli Jewish Boys, Ages 5-13*.



*No data for age 5 and 6 years for Israeli and Russian children

In sum, Bedouin (Muzeina) boys, compared with Russian (Moscow) and Israeli boys, appear to have a narrower body relative to their stature, longer limbs relative to stature, a lower weight per unit of body surface area, and a smaller amount of subcutaneous adipose tissue. Perhaps such body features help to regulate the internal body temperature in regions of a warm climate, although there is controversy in the literature as to whether body size really contributes to the body's thermal regulation. Animal studies have shown that in warm climates the animals with a small body have advantages over large-sized animals in body thermal regulation. Riesenfeld (1981), for example, tested the tolerance of two types of rats to extreme heat and cold conditions with small-sized and large-sized representations. He reached the following conclusion (Riesenfeld, 1981):

Thus the present study confirms a functional correlate to Bergmann's ecological rule. Results obtained by this writer's previous study (Riesenfeld, 1980) further showed that the differences in temperature tolerance between Buffalo and Fisher rats are due to their differences in body weight and not any temperature-specific genetic differences. This follows from the fact that in both Buffalo and Fisher rats of both sexes, temperature tolerance is *significantly correlated with body weight or rather their weight to surface ratio...* (pp.96-97).

The conclusions drawn from these experiments designed to evaluate the correlation between body weight, race and climate in animals, seem consistent with those of similar studies on human populations, namely, that there is an inverse correlation between body weight and the ambient temperature, which would support the validity of the Bergmann Rule for human populations (Newman and Munro, 1955; Schreider, 1963; Roberts, 1973; etc.). Yet, diametrically opposite conclusions were drawn by Austin and Ghesquiere (1976), who observed groups of Bantu and Pygmies in Africa. According to these authors, small-bodied populations possess a lower tolerance to heat than do large-bodied populations. A year later, Austin (1977) underscored the limitations of such studies, using a computer simulation to prove his argument. He wrote (Austin, 1977):

The results do not fully support the concept, implicit in Bergmann's `Rule', that small body size is advantageous in warm environments...in hot humid conditions large body size is apparently more advantageous than small body size (p.116).

The experimental method and conclusions of the latter author have been severely criticized (see Riesenfeld, 1981, p.99). In sum, it would seem that matters as laid down in the Bergmann-Allen Rule are not as clear-cut or conclusive, especially for humans, as previously believed. The Bedouins have a body structure which apparently affords them advantages in severe desert climatic conditions. However, as indicated in a previous study of Bedouins in Israel (McCance et al., 1974), internal systems (e.g. the excretory system) in these individuals offered no special advantages over those extant in the "ordinary" population. The conclusion drawn by McCance et al. is that:

Physiologically speaking....Bedouin did not appear to be better adapted to life in the desert than other human ethnic groups (p.263).

Summary

In rates of development and general morphology, there are significant differences between South Sinai Muzeina, and some European[1] and American White boys.

Thus, up to age 9 Muzeina boys are taller than European boys but subsequently the latter exceed the Muzeina boys. A developmental spurt in Bedouin boys does occur almost at the same age as in European boys.

[1] European refers to boys from England (London), Poland, and to Israeli Jewish boys of European extraction.

At age 5, the Muzeina boys attain 68% of mean stature of the adult male population of the tribe, compared to 61% in the European boys considered, and at age 11 the Muzeina already attain 84% of the mean adult male stature versus 81% in the European boys.

In mean body weight, the Muzeina boys are lighter than their European counterparts, and with age this disparity probably increases. We may note that at age 5 the average Muzeina boy attains 34% of his weight at age 18, whereas the average European boy at the same age attains 30% .

Mean stature of the Muzeina boy at age 5 exceeds that of European boys by about 3 cm, but weight is at least 1 kg less. However, at age 13 the mean stature of European boys is greater than that of Muzeina boys by 7 cm and their mean weight by 8 kg.

In morphological structure there are sizeable differences between Bedouin (Muzeina) and European boys. Thus the Muzeina boys have a relatively longer head than European boys.

If we take into account the fact that mean head breadth in adult Bedouins is identical to that in European children at age 5-6, it is clear that a relatively narrow head is a general morphologic characteristic of the Bedouin population.

The face of Muzeina boys is shorter and narrower than that of the European boy at all ages. The rapid development in stature compared to the slow gain in width in the shoulder and pelvic regions in the Muzeina boys results in a pronounced ectomorphy type compared to that in European populations. As for proportions between the different parts of the upper limb, the Muzeina boys have a longer upper arm and forearm at age 5 to 8-9 years than European boys, but then the reverse occurs, the Muzeina boys acquiring a shorter upper arm and forearm. The same is true with the hand except that a reversal commences at age 12. Nevertheless, compared to European boys the Muzeina still have on average a longer upper limb relative to stature.

As for the lower limb, in the Muzeina up to age 9 it is longer relative to stature than in European boys, but subsequently this ratio equalizes in the two populations. The foot of the Muzeina boys is very different from that of the European boys at all ages. Basically the Muzeina have a foot which is broad relative to its length whereas in the European boys it is narrow relative to length (Appendix 3).

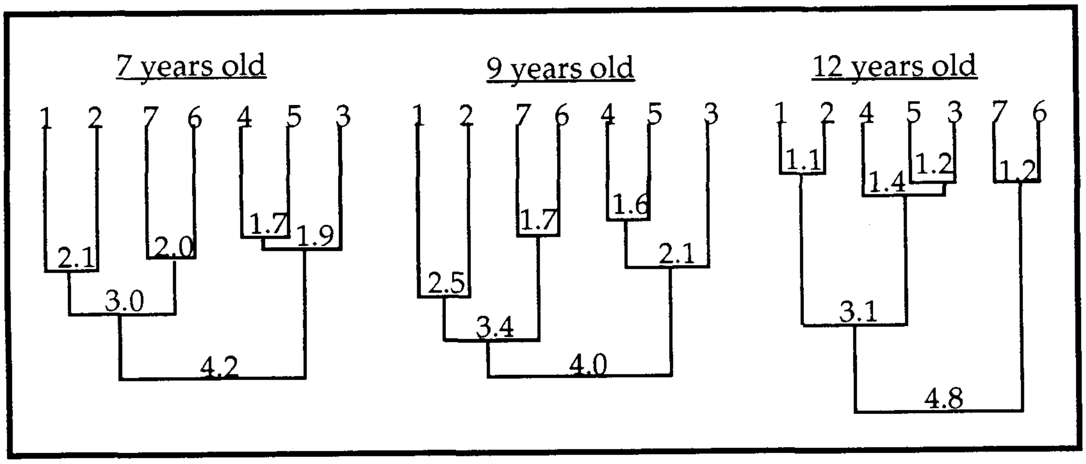
An additional morphologic `identifier' of the Bedouin Muzeina population is their amount of subcutaneous adipose tissue, which is very meager compared to that in the European populations and becomes even less with age. Body surface area in Muzeina boys was found to be greater relative to weight compared to that in European boys (Appendix 3).

Finally, we have also shown that, owing to their special body build the Bedouin children expend less energy than European children of comparable ages in performing the same physical tasks (e.g. walking).

__Changes In Morphological Resemblance Between Sinai, Egyptian And Israeli Boys With Age__

Thus far we have examined changes in single morphological traits with age, or have compared single traits between groups. We shall now look at overall morphological changes among Bedouin boys of South Sinai. Based on 8 morphometric traits - sitting height, biacromial breadth, arm length, stature, facial height and breadth, and head length and breadth - we calculated for ages 7, 9 and 12 years the morphological similarity and/or disparity between Mediterranean boys of different ethnic and geographical location, namely, those from South Sinai Muzeina and Gebeliya tribes, Egypt (Kenous, Arab-Nubian and Fededji) and Israel (parents born in the Middle East and in North Africa).

FIGURE 28: Morphological Similarity and Disparity Between Seven Different Groups of Boys at Ages 7, 9 and 12, Respectively (groups are indicated beneath).



1=Muzeina-S. Sinai 3=Kenous-Egypt 5=Fededji-Egypt 7=Israeli Jews (North African origin)

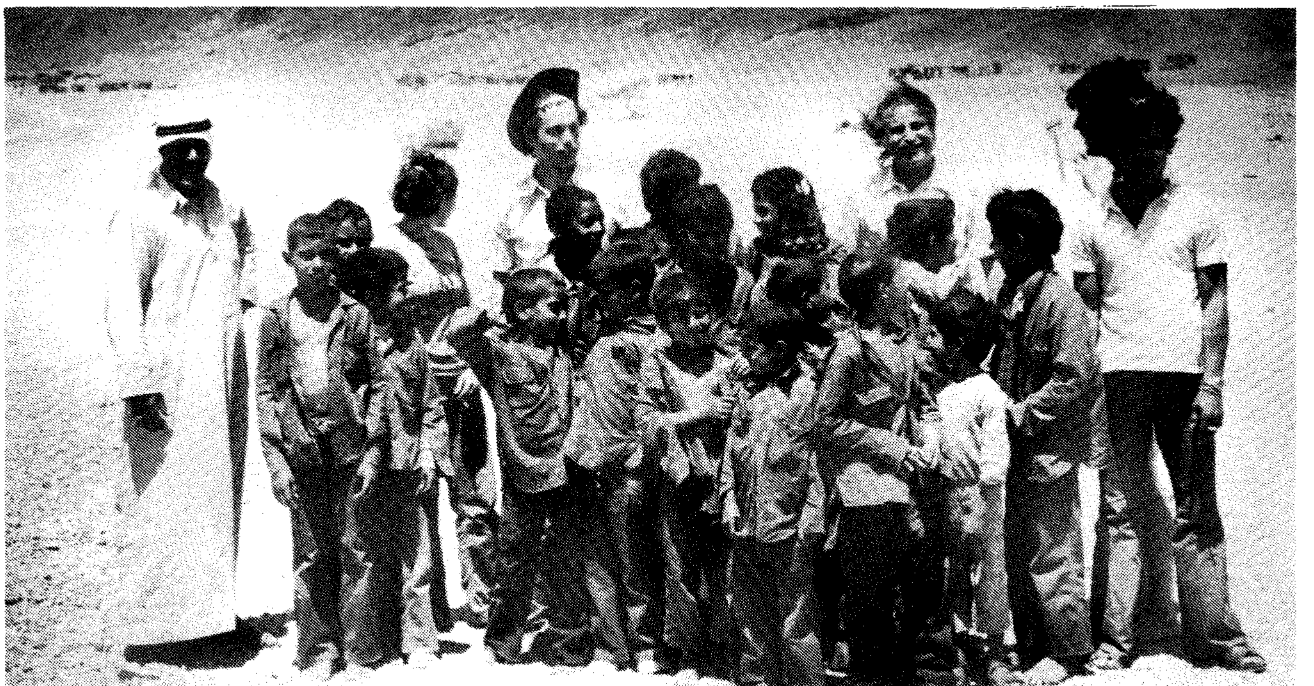
2=Gebeliya-S. Sinai 4=Arab Nubian-Egypt 6=Israeli Jews (Middle East origin)

* level of morphological association measured as Euclidean distances

Pairwise morphological associations among the groups were obtained by the Euclidean distance, according to Lalovel, (1980): $D=\sum_{k=1}^{n}(\overline{X}_{ik}-\overline{X}_{jk})^2$ where D is the morphological difference between two populations (i and j), $\overline{X}$ is the mean value of the kth trait in these populations, and n is the number of traits. Since many of the morphological traits could not be compared by their absolute values, all the traits were standardized by dividing each mean value by its standard deviation. Thus, $\overline{X}_i$ actually represents not the average, but rather $\overline{X}_i$/S.D. The results of the calculations were further subjected to cluster analysis (UPGMA Method), which in turn led to the construction of single dendrograms (Fig. 28). In these dendrograms it can be seen that: (a)clusters are organized in accordance with geographical location of the groups; and (b)level of morphological association between the groups changes with age.

The overall morphological similarity between South Sinai and Israeli groups decreases with age, the mean distances being 3.0 for age 7, 3.4 for age 9, and 4.8 for age 12. The similarity increases with age, however, between the Egyptian groups and South Sinai Bedouin boys (Fig. 28).

The above results seem to indicate that until age 9, South Sinai children develop, in general, very much like other Mediterranean groups, regardless of nutritional status and other environmental factors. After age 9, the influence of environmental factors apparently becomes more pronounced, resulting in changes in cluster order and an increase in morphological similarity between groups of the same geographical region.



Prof. Ben David (hat), Prof. Arensburg, S. Gur-Lavy and Fatchi (the Bedouin driver of the team).

VI. INTER AND INTRA TRIBAL MORPHOLOGICAL IDENTITY

Morphological Differences Between Children (Boys) Of Different Bedouin Tribes In South Sinai

In the preceding chapter we emphasized the differences in development between Bedouin boys in South Sinai (Muzeina tribe) and boys of other ethnic and geographic derivations. In the present chapter we shall deal primarily with two central questions, to wit:

(a) Are there morphologic and developmental differences between Bedouin boys of different tribes in South Sinai?

(b) Are there morphologic and developmental differences between Bedouin boys belonging to different sub-tribes of the same tribe?

We have arranged the Bedouin tribes of South Sinai in four groups as follows, according to their origin and ethnic background (see Chapter 1): Group 1, Gebeliya tribe (72 boys); Group 2, Muzeina tribe (269 boys); Group 3, Hamada and Aleigat (66 boys); Group 4, all other tribes (Beni Wassal, Haweitat, Gararsha, Awlad Said and Sawalcha) (158 boys).

We have concentrated mainly on comparisons between Muzeina and Gebeliya boys. In certain instances and mainly in the summarizing chapters, we shall incorporate all the other groups into the results.

In the first stage we carried out comparisons based on raw data, using a two-way analysis of variance where the two independent variables were age and tribal origin.

Results

The means and standard deviations of the distributions of traits in the four Bedouin groups are given in Tables 25 to 66. The differences between the Muzeina and Gebeliya tribes, as indicated in the two-way analysis of variance of the traits and indices are given in Table 67. The final results indicate that in 23 of the 41 traits, there were significant differences between the two tribes. In most cases, as we shall see shortly, the differences were in the breadth measurements or in the indices.

A measurement appearing with an asterisk means that the two tribes differ significantly in the measure. The large spurts in the mean values, as exemplified in the irregularities of the growth data (Tables 30-34; 38-40, 51-52), stem from the small sizes of the samples.

A few words of discussion on the interaction effect may be in order. Ordinarily, in a two-way analysis of variance, one attempts to ascertain the influence of the independent variables on the dependent one (while each time we activate one of the independent variables and keep the other fixed). From the independent variable designated "ethnic origin" we learned about the morphologic differences between the Muzeina and Gebeliya boys. Regarding the second independent variable, age, we assumed that since we were dealing with child populations, most of the traits would show significant changes with age; only 5 traits, most of which were indices rather than direct measurements, failed to show significant changes with age. These were the cephalic index, shoulder (biacromial) breadth/stature index, upper limb (total arm) length/stature index, foot breadth/foot length index, and subcutaneous adipose tissue in the upper arm. Hence we may assume that the body build type, or bodily proportions, are fixed already at an early age, generally 6 years or less. Important information is added by studying the influence of the interaction between both independent variables ("ethnic origin" and "age") on the morphological differences between the groups. In this case the differences are not linked to "ethnic origin" alone or to "age" alone but rather to a combination of both. In developmental terms what we get is not information on the intertribal differences in the trait averages but rather on intertribal differences in the rate of physical development in the tribes, a subject that will be dealt with subsequently.

Hence the pattern of growth between ages 5-13 years of traits which yield a significant interaction effect (age x tribal origin) differs among the tribes. Two traits, morphological facial height and ratio of sitting height to stature, manifested a significant interaction effect.

Head and Face (Tables 25-30)

The ratio between the length and width of the head, or cephalic index, is identical in the Muzeina and Gebeliya tribes, albeit the head in the latter tends to be somewhat narrower than in the Muzeina tribe (Head breadth *). The mean zygomatic face breadth is identical in both tribes. The face as a whole in the Muzeina becomes narrower (Bigonial breadth *) and longer (Morphological facial height *) (* significant difference $p<.05$).

TABLE 25 Mean head length (mm) in South Sinai Bedouin boys, by tribe and age.

TRIBE	Gebeliya		Muzeina		Hamada & Aleigat		Others**		TOTAL	
AGE	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
5	179.00*	8.48	178.94	6.60	175.66*	6.35	178.80	4.31	178.61	5.86
6	180.60	4.32	182.40	5.73	183.72	6.30	181.31	4.92	182.06	5.57
7	181.50	8.35	181.61	5.39	186.00	3.80	183.47	5.64	182.46	6.13
8	184.00	4.39	181.60	5.92	182.33	3.82	180.42	5.04	181.62	5.23
9	181.50	7.42	180.91	4.79	185.50*	2.12	182.75	3.57	182.00	4.81
10	186.00	8.80	185.81	5.43	183.00*	6.32	183.54	3.83	184.67	5.54
11	183.87	3.44	185.46	6.31	191.16	5.63	185.60	7.79	185.02	6.57
12	188.70	7.45	186.60	5.39	188.33*	6.50	189.25	4.53	188.15	5.62
13	186.16	8.44	189.54	5.45	186.27	6.26	187.00	5.39	187.36	6.14

TABLE 26 Mean head breadth (mm) in South Sinai Bedouin boys, by tribe and age.

TRIBE	Gebeliya		Muzeina		Hamada &Aleigat		Others**		TOTAL	
AGE	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
5	136.50*	6.36	134.57	3.70	135.66*	5.59	132.90	5.40	134.29	5.09
6	132.60	3.74	135.71	4.39	134.35	5.04	135.42	4.72	134.88	4.55
7	136.16	5.40	136.04	4.07	136.48	4.37	133.93	3.43	135.76	4.19
8	133.85	4.63	136.41	4.12	134.83	3.65	137.54	4.58	136.33	4.36
9	137.16	3.86	137.00	4.20	137.66*	7.63	134.83	4.56	136.34	4.51
10	136.60	8.26	140.00	3.79	135.00*	4.96	138.81	4.42	138.38	5.09
11	140.00	6.02	137.15	4.89	139.16	4.95	136.46	4.40	137.73	4.98
12	136.00	3.26	138.86	5.06	143.66*	1.52	136.87	5.89	137.81	5.16
13	137.16	3.86	140.42	3.97	137.90	5.57	138.66	4.18	138.90	4.46

* less than 5 cases

** Gararsha, Awlad Said, Sawalcha, Haweitat

TABLE 27: Cephalic index in South Sinai Bedouin boys, by tribe and age

TRIBE	Gebeliya		Muzeina		Hamada &Aleigat		Others**		TOTAL	
AGE	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
5	76.25*	3.05	75.34	4.49	77.36*	3.20	74.36	3.35	75.28	4.34
6	73.47	3.05	74.43	2.20	73.29	2.82	74.74	3.38	74.16	2.77
7	75.21	5.36	74.88	2.87	73.34	2.32	72.71	1.92	74.38	3.33
8	72.75	2.06	75.02	3.54	73.98	2.72	76.50	3.61	75.12	3.49
9	75.64	2.95	76.19	3.27	71.98*	2.72	73.83	3.57	74.94	3.42
10	73.72	4.96	75.41	3.39	73.85*	4.18	75.65	2.79	75.02	4.16
11	76.17	3.85	74.02	3.45	72.81	2.42	73.69	4.75	74.14	3.95
12	72.14	2.47	74.44	2.60	76.32*	1.84	72.34	3.10	73.28	2.96
13	73.78	3.41	74.10	2.96	74.04	2.03	74.21	3.12	74.19	2.84

TABLE 28 Mean bizygomatic breadth (mm) in South Sinai Bedouin boys, by tribe and age.

TRIBE	Gebeliya		Muzeina		Hamada &Aleigat		Others**		TOTAL	
AGE	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
5	111.00*	4.24	111.26	3.00	110.33*	2.52	110.70	4.03	111.00	3.22
6	113.30	2.41	113.22	3.84	112.94	4.82	112.83	2.86	113.09	2.63
7	116.58	2.51	115.52	3.64	114.00	4.64	114.53	3.14	115.26	3.54
8	116.86	2.48	116.75	4.69	117.50	2.59	117.00	3.19	116.78	3.80
9	117.50	3.78	117.50	3.48	116.00*	6.56	115.92	2.47	116.83	3.44
10	113.60	3.21	118.09	3.73	115.75*	5.74	119.36	3.93	117.52	4.33
11	120.75	3.99	120.23	5.55	120.83	4.62	119.00	3.46	119.98	4.36
12	119.90	3.63	121.87	6.15	124.00*	1.00	120.06	4.28	120.91	4.80
13	120.33	4.41	124.21	4.95	121.54	4.61	120.08	4.10	121.91	4.71

* less than 5 cases

** Gararsha, Awlad Said, Sawalcha, Haweitat

TABLE 29 Mean bigonial breadth (mm) in South Sinai Bedouin boys, by tribe and age.

TRIBE	Gebeliya		Muzeina		Hamada &Aleigat		Others**		TOTAL	
AGE	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
5	93.00*	9.99	96.26	6.04	95.67*	3.21	96.80	7.50	96.18	6.28
6	99.20	5.55	96.85	5.86	96.67	7.53	99.80	3.90	97.73	5.85
7	101.58	6.93	98.23	5.93	95.30	6.50	97.30	5.80	98.33	6.24
8	103.33	6.74	97.00	4.91	99.33	1.75	101.20	5.10	99.45	5.36
9	104.67	4.50	99.50	8.47	97.67*	1.53	102.00	3.50	101.18	6.07
10	97.80	7.29	101.36	7.21	7.00*	8.91	104.10	3.20	101.19	6.56
11	108.37	3.11	99.09	4.91	98.00	7.77	102.00	6.10	101.88	6.47
12	104.10	8.66	100.80	7.79	105.33*	5.77	104.40	5.70	103.16	7.18
13	101.33	10.2	102.93	6.57	100.70	6.04	102.70	5.10	102.16	6.43

TABLE 30: Mean morphological facial height (mm) in South Sinai Bedouin boys, by tribe and age.

TRIBE	Gebeliya		Muzeina		Hamada &Aleigat		Others**		TOTAL	
AGE	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
5	85.50*	2.12	87.67	3.12	90.00*	2.00	87.10	3.78	87.57	3.24
6	93.10	5.51	93.03	4.18	94.16	4.00	90.74	4.11	92.67	4.38
7	92.83	3.66	95.91	4.32	92.10	3.07	95.23	5.99	94.98	4.64
8	93.67	3.78	98.12	3.86	98.33	4.13	97.59	3.70	97.34	4.07
9	96.33	4.08	99.57	7.40	101.67*	4.04	97.54	5.22	98.47	4.83
10	98.40	2.41	100.54	6.45	97.75*	2.22	98.36	5.02	99.06	4.99
11	100.37	3.29	100.23	3.42	100.33	6.28	98.56	4.49	99.95	4.28
12	103.40	5.01	102.20	3.65	98.33*	1.53	102.82	5.15	102.51	4.48
13	96.83	1.94	104.78	5.01	106.73	4.47	104.08	6.11	104.18	5.77

* less than 5 cases

** Gararsha, Awlad Said, Sawalcha, Haweitat

The Trunk (Tables 31-40)

In the trunk, boys of the two tribes differ markedly.The Muzeina have a longer trunk [trunk length and sitting height (1)*] as well as broader shoulder and hip widths (biacromial and biiliac breadth *), . Also their chest circumference(*) is greater .

The differences in indices relating trunk breadth to overall stature were all statistically significant (Tables 38-40). In sum, both relatively and absolutely, the Muzeina children have a longer and broader trunk than do the Gebeliya children.

TABLE 31 Mean sitting height (1) (cm) in South Sinai Bedouin boys, by tribe and age.

TRIBE	Gebeliya		Muzeina		Hamada &Aleigat		Others**		TOTAL	
AGE	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
5	58.90*	5.23	61.16	2.56	61.76*	2.62	58.76	2.81	60.37	2.90
6	63.38	2.46	64.30	2.16	64.12	2.22	62.58	2.50	63.64	2.41
7	65.89	2.96	66.32	2.05	64.10	2.55	65.23	2.95	65.79	2.49
8	66.25	3.62	68.13	2.25	69.51	2.30	67.19	2.15	67.54	2.74
9	67.83	2.50	68.63	2.88	68.96*	0.25	68.86	2.90	68.61	2.64
10	70.10	1.71	69.80	3.34	68.10*	1.35	69.70	2.48	69.59	2.59
11	70.90	1.67	73.65	2.98	72.48	4.01	72.21	2.07	72.42	2.73
12	73.88	3.20	73.30	3.30	74.13*	3.05	73.07	3.71	73.40	3.33
13	72.05	1.89	75.78	3.06	75.30	3.01	74.46	3.63	74.80	3.20

Note: sitting height (1) - see Chapter on measurement methods.

TABLE 32: Mean biacromial breadth (cm) in South Sinai Bedouin boys, by tribe and age.

TRIBE	Gebeliya		Muzeina		Hamada &Aleigat		Others**		TOTAL	
AGE	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
5	23.10	0.14	23.64	1.13	24.43*	0.37	23.00	1.36	23.48	1.18
6	24.46	1.90	24.67	1.04	25.25	1.61	24.62	0.93	24.73	1.30
7	25.25	1.63	26.22	1.30	25.97	0.90	26.40	1.72	26.08	1.41
8	26.56	2.33	26.65	1.57	28.26	1.08	26.74	1.14	26.80	1.54
9	26.86	1.70	28.10	1.37	27.26*	1.15	27.17	1.48	27.49	1.48
10	27.14	0.76	27.61	1.56	28.32*	1.48	28.50	0.93	27.95	1.28
11	27.93	1.28	28.80	2.13	29.18	1.75	29.60	1.75	28.99	1.84
12	29.40	1.14	29.40	1.81	29.72*	0.57	29.86	1.70	29.59	1.56
13	28.78	0.90	30.84	1.36	31.90	1.63	30.48	1.62	30.76	1.70

* less than 5 cases

** Gararsha, Awlad Said, Sawalcha, Haweitat

TABLE 33 Mean biiliac breadth (cm) in South Sinai Bedouin boys, by tribe and age.

TRIBE	Gebeliya		Muzeina		Hamada &Aleigat		Others**		TOTAL	
AGE	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
5	16.25*	0.07	17.34	0.96	17.60*	0.40	16.33	1.27	16.98	1.11
6	16.81	1.03	17.88	1.13	17.87	1.32	17.06	0.72	17.53	1.15
7	17.95	0.69	18.41	0.96	18.49	0.89	17.90	1.18	18.25	0.99
8	17.66	0.37	18.85	1.20	19.16	1.19	18.40	1.24	18.56	1.21
9	17.66	0.69	18.90	0.95	20.16*	1.45	18.23	1.09	18.55	1.17
10	18.32	0.73	19.38	1.47	18.97*	0.68	19.46	0.98	19.18	1.15
11	19.01	1.18	19.75	1.74	20.43	1.45	20.14	1.06	19.84	1.41
12	19.92	1.24	20.56	2.07	20.63*	0.90	20.50	1.63	20.40	1.66
13	20.15	1.18	20.61	1.30	21.26	1.82	20.22	1.48	20.63	1.49

TABLE 34 Mean chest circumference (cm) in South Sinai Bedouin boys, by tribe and age.

TRIBE	Gebeliya		Muzeina		Hamada &Aleigat		Others**		TOTAL	
AGE	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
5	53.85*	0.21	56.04	2.32	57.20*	1.70	54.90	2.63	55.62	2.39
6	56.21	3.27	57.80	2.73	58.80	3.30	57.40	2.49	57.70	2.91
7	58.70	2.12	60.04	3.03	59.43	1.89	60.03	2.89	59.75	2.73
8	60.81	3.22	61.36	2.60	64.66	1.83	60.92	2.43	61.40	2.76
9	61.05	3.26	62.14	3.05	62.46*	3.46	61.69	2.43	61.82	2.81
10	61.60	2.74	62.76	4.40	64.25*	2.19	64.16	2.64	63.29	3.26
11	63.47	1.91	65.31	3.22	66.24	3.71	67.23	4.00	65.80	3.58
12	65.45	2.85	67.68	5.40	68.03*	2.61	68.72	4.09	67.60	4.34
13	66.56	2.83	69.29	2.61	71.90	3.57	70.07	3.44	69.83	3.47

* less than 5 cases

** Gararsha, Awlad Said, Sawalcha, Haweitat

TABLE 35 Mean trunk length (cm) in South Sinai Bedouin boys, by tribe and age.

TRIBE	Gebeliya		Muzeina		Hamada &Aleigat		Others**		TOTAL	
AGE	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
5	27.55*	3.32	27.45	1.70	27.63*	2.01	26.66	1.06	27.24	1.62
6	28.50	1.85	29.65	1.53	29.32	1.25	28.43	1.72	29.13	1.61
7	29.46	2.57	30.08	1.56	30.13	2.37	29.37	2.01	29.90	1.92
8	30.94	2.29	30.79	2.34	31.38	1.78	30.31	1.54	30.64	2.00
9	31.40	1.74	32.12	3.08	31.06*	1.68	31.04	2.11	31.52	2.43
10	32.72	1.50	31.93	1.99	31.65*	1.38	32.18	1.69	32.11	1.68
11	31.98	1.56	34.08	2.18	33.81	2.93	33.95	2.09	33.60	2.23
12	34.16	2.63	33.91	2.45	32.93*	2.00	33.48	2.15	33.71	2.28
13	33.66	2.07	34.63	2.08	34.90	1.49	34.43	2.38	34.44	2.02

TABLE 36 Mean sitting height (2) (cm) in South Sinai Bedouin boys, by tribe and age.

TRIBE	Gebeliya		Muzeina		Hamada &Aleigat		Others**		TOTAL	
AGE	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
5	50.65*	2.61	51.20	1.72	52.40*	3.16	50.57	2.12	51.09	1.98
6	53.31	2.76	54.13	1.77	54.38	1.57	52.73	2.03	53.72	1.99
7	54.77	3.03	55.27	2.35	55.71	2.94	54.58	2.72	55.15	2.58
8	56.55	2.95	56.23	2.86	57.90	2.62	56.16	2.03	56.28	2.65
9	57.45	2.46	57.71	2.97	57.86*	1.38	57.43	2.04	57.58	2.39
10	59.26	1.79	57.39	3.36	58.25*	1.59	58.89	2.11	58.33	2.55
11	58.83	1.87	61.54	2.20	61.06	3.63	60.58	2.45	60.61	2.57
12	61.08	2.80	61.27	2.93	60.03*	2.85	61.04	2.56	61.05	2.67
13	60.83	2.37	62.63	2.58	63.29	2.22	62.86	2.99	62.60	2.59

Note: sitting height (2) - see Tests and/or explanations chapter.

* less than 5 cases

** Gararsha, Awlad Said, Sawalcha, Haweitat

TABLE 37 Sitting height (1)/stature index in South Sinai Bedouin boys, by tribe and age.

TRIBE	Gebeliya		Muzeina		Hamada &Aleigat		Others**		TOTAL	
AGE	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
5	52.58*	2.35	55.23	1.23	55.40*	1.63	54.67	1.79	54.93	1.56
6	53.95	1.34	54.74	1.52	53.77	1.04	54.84	1.60	54.46	1.46
7	54.24	1.03	53.61	1.39	52.49	2.07	53.78	0.82	53.60	1.39
8	52.30	1.22	53.43	1.27	53.45	1.01	53.72	1.57	53.36	1.41
9	52.88	0.79	52.51	1.26	52.35*	0.34	53.40	0.72	52.89	1.01
10	52.55	1.03	53.48	1.63	52.02*	0.67	52.51	1.71	52.80	1.53
11	51.71	1.10	52.54	1.42	51.84	1.43	51.63	0.99	51.95	1.24
12	51.46	1.22	51.43	1.49	52.53*	0.46	52.08	2.19	51.75	1.69
13	50.59	0.72	51.73	1.13	50.93	1.35	51.13	1.43	51.16	1.26

TABLE 38 Biacromial breadth/stature index in South Sinai Bedouin boys, by tribe and age.

TRIBE	Gebeliya		Muzeina		Hamada &Aleigat		Others**		TOTAL	
AGE	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
5	20.66*	0.78	21.39	0.82	21.94*	1.26	21.39	0.96	21.40	0.89
6	20.79	1.03	21.00	0.69	21.16	0.92	21.57	0.59	21.15	0.79
7	20.78	1.10	21.19	0.96	21.21	0.25	21.83	1.06	21.25	0.98
8	20.87	1.63	20.96	1.02	21.71	0.66	21.45	0.68	21.20	0.97
9	20.93	0.85	21.40	0.94	20.69*	0.67	21.08	1.02	21.15	0193
10	20.34	0.43	21.17	0.60	21.63*	0.89	21.47	0.43	21.20	0.68
11	20.38	0.98	20.55	1.04	20.87	0.93	21.55	0.48	20.92	0.95
12	20.48	0.77	20.61	0.70	21.09*	0.78	20.95	1.10	20.73	0.87
13	20.21	0.59	21.05	0.63	21.44	0.54	21.16	0.53	21.05	0.66

* less than 5 cases

** Gararsha, Awlad Said, Sawalcha, Haweitat

TABLE 39 Biiliac breadth/stature index in South Sinai Bedouin boys, by and tribe age.

TRIBE	Gebeliya		Muzeina		Hamada &Aleigat		Others**		TOTAL	
AGE	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
5	14.53*	0.57	15.69	0.76	15.83*	1.41	15.19	0.99	15.47	0.92
6	14.30	0.60	15.22	0.87	14.97	1.03	14.93	0.84	14.99	0.89
7	14.79	0.70	14.86	0.74	15.10	0.50	14.81	0.80	14.86	0.71
8	13.90	0.80	14.82	0.89	14.58	0.69	14.70	0.82	14.66	0.85
9	13.79	0.77	14.39	0.55	15.30*	0.98	14.14	0.79	14.28	0.78
10	13.72	0.24	14.75	0.66	14.49*	0.49	14.66	0.67	14.49	0.67
11	13.87	0.92	14.08	0.86	14.63	1.14	14.34	0.77	14.21	0.88
12	13.86	0.42	14.39	0.95	14.62*	0.08	14.61	0.91	14.37	0.85
13	14.14	0.69	14.08	0.92	14.39	0.85	13.88	0.84	14.12	0.84

TABLE 40 Chest circumference/stature index in South Sinai Bedouin boys,by tribe and age.

TRIBE	Gebeliya		Muzeina		Hamada &Aleigat		Others**		TOTAL	
AGE	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
5	48.16*	1.94	50.75	2.19	51.53*	4.98	51.09	1.95	50.77	2.41
6	47.80	0.93	49.22	2.42	49.45	2.09	50.31	2.02	49.40	2.21
7	43.37	2.12	48.66	2.24	48.56	1.21	49.71	2.03	48.79	2.09
8	47.76	0.81	48.20	1.49	49.82	1.43	48.75	1.50	48.53	1.49
9	47.57	1.26	47.32	1.52	47.41*	2.60	47.90	2.67	47.58	2.00
10	46.17	1.67	47.92	2.08	49.06*	1.26	48.33	1.75	47.93	1.92
11	46.29	0.73	46.62	1.55	47.64	2.24	48.79	1.71	47.47	1.87
12	45.59	1.39	47.78	2.07	48.22*	1.15	48.73	2.04	47.66	2.18
13	46.73	1.50	47.31	1.61	48.73	1.56	48.11	1.24	47.82	1.57

* less than 5 cases

** Gararsha, Awlad Said, Sawalcha, Haweitat

The Limbs

In neither the upper limb (Tables 41-45) nor lower limb (Tables 46-49) was there any significant difference between the Muzeina and Gebeliya boys.

The Foot

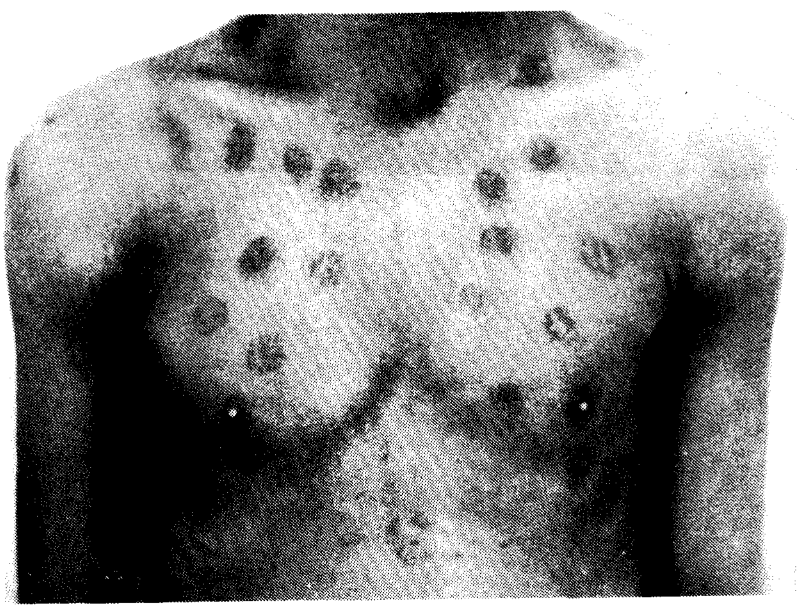
Mean foot length was the same in both the Muzeina and Gebeliya boys, but foot width was significantly greater in the Muzeina (Tables 50-52). Hence the ratio between foot length and foot width was significantly different, the Muzeina boys having feet broader both absolutely and relatively.

TABLE 41 Mean upper arm length (cm) in South Sinai Bedouin boys, by tribe and age.

TRIBE	Gebeliya		Muzeina		Hamada &Aleigat		Others**		TOTAL	
AGE	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
5	20.10*	1.13	19.89	1.53	19.60	2.85	18.96	1.60	19.60	1.64
6	20.93	1.39	21.08	1.84	21.02	1.09	20.50	1.27	20.90	1.50
7	21.96	0.97	21.89	1.69	21.85	1.02	21.70	1.35	21.87	1.45
8	22.90	1.93	23.31	1.93	23.33	1.69	23.16	2.78	23.16	2.22
9	22.36	1.43	23.57	1.92	23.03*	0.66	23.23	1.41	23.22	1.59
10	24.28	1.46	23.00	2.35	22.97*	0.09	24.32	0.94	23.67	1.69
11	24.53	0.86	25.74	1.49	25.23	1.75	24.83	1.50	25.10	1.46
12	26.62	1.50	26.20	1.51	25.26*	1.36	25.66	1.76	26.02	1.61
13	26.06	1.84	26.44	1.12	26.80	1.65	26.20	1.43	26.44	1.42

* less than 5 cases

** Gararsha, Awlad Said, Sawalcha, Haweitat



Cauterization, a popular 'medical' treatment among the Bedouins of South Sinai.

TABLE 42 Mean lower arm length (cm) in South Sinai Bedouin boys, by tribe and age.

TRIBE	Gebeliya		Muzeina		Hamada &Aleigat		Others**		TOTAL	
AGE	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
5	15.90*	0.42	16.24	1.62	16.86*	0.89	15.17	0.93	15.99	1.43
6	16.61	1.89	16.56	1.72	16.87	1.43	16.09	1.44	16.48	1.61
7	17.23	1.19	17.80	1.31	18.42	1.22	17.52	1.35	17.75	1.30
8	18.50	1.40	18.47	1.57	19.90	1.35	17.86	1.66	18.42	1.62
9	19.40	1.32	19.35	1.55	18.76*	0.32	18.66	1.15	19.05	1.31
10	19.96	0.72	19.40	1.82	19.25*	1.41	19.75	1.08	19.60	1.33
11	20.80	0.99	20.39	0.71	21.28	2.82	20.75	1.29	20.74	1.41
12	20.81	1.37	20.82	1.47	20.50*	0.78	20.85	1.21	20.81	1.28
13	21.05	1.24	21.82	1.43	22.58	1.06	21.89	1.42	21.92	1.34

TABLE 43 Mean hand length (cm) in South Sinai Bedouin boys, by tribe and age.

TRIBE	Gebeliya		Muzeina		Hamada &Aleigat		Others**		TOTAL	
AGE	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
5	11.90*	0.98	12.58	1.58	12.83*	1.40	12.63	0.75	12.57	1.32
6	13.02	1.14	13.38	1.21	13.18	1.37	12.83	0.97	13.15	1.17
7	14.08	0.87	13.86	1.15	14.38	0.82	13.92	0.84	13.97	1.01
8	14.18	1.70	14.50	1.31	14.30	1.11	14.14	1.20	14.27	1.30
9	14.12	1.26	14.75	0.71	14.83*	0.75	14.70	1.73	14.65	1.23
10	15.28	0.93	15.07	0.76	14.75*	0.56	15.34	1.11	15.16	0.89
11	14.73	1.15	15.81	1.63	16.86	0.93	16.00	1.12	15.82	1.39
12	16.13	1.19	15.92	1.02	14.23*	0.50	15.30	1.05	15.62	1.14
13	15.45	0.95	16.40	0.83	17.40	1.39	16.35	1.11	16.52	1.21

* less than 5 cases

** Gararsha, Awlad Said, Sawalcha, Haweitat

TABLE 44 Mean total arm length (cm) in South Sinai Bedouin boys, by tribe and age.

TRIBE	Gebeliya		Muzeina		Hamada &Aleigat		Others**		TOTAL	
AGE	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
5	47.90*	0.56	48.72	2.94	49.30*	4.47	46.75	2.60	48.15	2.94
6	50.44	4.08	51.03	2.75	51.10	2.44	49.36	2.53	50.51	2.83
7	53.30	1.58	53.52	2.27	54.65	1.90	52.82	2.93	53.50	2.29
8	55.58	4.20	56.11	3.00	57.53	3.63	54.73	3.39	55.62	3.40
9	55.11	3.11	57.67	3.30	56.63*	0.47	56.60	3.16	56.77	3.11
10	59.52	1.43	57.06	4.63	56.97*	1.41	59.42	2.41	58.28	3.33
11	60.07	1.79	61.94	3.78	63.38	4.35	61.59	2.55	61.66	3.19
12	63.56	3.39	62.44	4.03	60.00*	2.32	61.81	3.10	62.30	3.48
13	62.56	2.13	64.67	1.78	66.80	2.86	64.45	3.17	64.89	2.78

TABLE 45 Mean total arm length/stature index in South Sinai Bedouin boys, by tribe and age.

TRIBE	Gebeliya		Muzeina		Hamada &Aleigat		Others**		TOTAL	
AGE	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
5	42.83*	1.38	43.98	1.51	44.16*	2.70	43.47	0.98	43.78	1.46
6	42.84	1.53	43.43	1.41	42.87	0.99	43.24	1.49	43.23	1.36
7	43.38	1.31	43.39	1.52	44.30	1.32	43.65	1.61	43.54	1.47
8	43.84	1.41	44.12	1.52	43.49	1.23	43.64	1.18	43.87	1.34
9	42.95	1.48	43.90	1.24	42.99*	0.38	43.88	1.49	43.66	1.35
10	44.62	1.00	43.65	1.67	43.54*	1.68	44.76	1.47	44.18	1.54
11	43.83	1.56	44.18	1.40	45.30	1.16	44.34	1.39	44.33	1.41
12	44.25	1.14	43.80	2.13	42.52*	0.93	44.03	1.21	43.90	1.57
13	43.93	1.27	44.16	0.76	45.17	0.92	44.24	1.08	44.39	1.04

* less than 5 cases

** Gararsha, Awlad Said, Sawalcha, Haweitat

TABLE 46 Mean iliospinal anterior height (cm) in South Sinai Bedouin boys, by tribe and age.

TRIBE	Gebeliya		Muzeina		Hamada &Aleigat		Others**		TOTAL	
AGE	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
5	61.25*	2.33	59.58	4.35	59.23*	4.90	57.00	4.34	58,89	4.33
6	64.26	3.86	63.35	3.52	64.76	3.52	60.89	3.57	63.04	3.86
7	66.67	2.53	68.25	2.81	66.72	3.90	66.35	3.15	67.46	3.03
8	70.12	4.14	70.91	3.38	71.28	1.09	69.18	3.91	70.10	3.63
9	70.83	3.61	73.63	4.47	73.86*	1.90	71.50	3.58	72.41	3.92
10	74.18	3.70	73.21	5.22	72.65*	1.04	73.87	3.05	73.53	3.79
11	78.27	2.07	78.59	4.75	78.81	4.78	78.36	3.69	78.48	3.85
12	79.85	6.44	80.58	3.37	81.06*	2.84	79.22	4.30	79.94	4.43
13	81.56	2.72	83.84	2.80	84.25	4.02	82.80	3.89	83.46	3.54

TABLE 47 Mean tibial height (cm) in South Sinai Bedouin boys, by tribe and age.

TRIBE	Gebeliya		Muzeina		Hamada &Aleigat		Others**		TOTAL	
AGE	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
5	29.25*	1.90	28.68	2.44	28.66*	2.01	26.93	2.50	28.20	2.45
6	31.04	1.92	30.69	1.88	31.50	1.90	29.44	1.70	30.56	1.96
7	32.00	1.43	33.33	1.83	32.63	2.16	31.80	1.69	32.78	1.88
8	34.57	2.40	34.44	1.87	35.01	1.69	33.04	2.37	33.92	2.24
9	34.23	2.41	36.20	2.53	35.80*	1.90	34.74	2.08	35.31	2.36
10	36.26	1.09	36.17	2.94	35.37*	1.45	36.08	1.72	36.05	2.08
11	37.93	1.60	38.27	2.08	38.46	2.07	38.58	1.86	38.35	1.86
12	40.10	2.13	39.46	2.03	38.96*	0.66	38.54	2.42	39.22	2.18
13	40.46	1.03	41.12	1.27	41.74	2.08	40.51	2.32	41.07	1.84

* less than 5 cases

** Gararsha, Awlad Said, Sawalcha, Haweitat

TABLE 48 Mean upper leg length (cm) in South Sinai Bedouin boys, by tribe and age.

TRIBE	Gebeliya		Muzeina		Hamada &Aleigat		Others**		TOTAL	
AGE	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
5	32.00*	0.42	30.90	2.25	30.56*	3.16	30.07	2.24	30.69	2.23
6	33.22	2.07	32.65	1.90	33.26	1.85	31.52	2.12	32.48	2.15
7	34.66	1.49	34.92	1.79	34.09	2.00	34.55	1.95	34.68	1.79
8	35.55	1.87	36.47	2.09	36.88	0.98	36.00	1.93	36.18	1.93
9	36.60	1.72	37.43	2.16	38.06*	0.28	36.76	2.00	37.10	1.94
10	37.92	3.14	37.91	2.04	37.27*	0.81	37.79	1.76	37.78	1.96
11	40.33	0.89	40.96	1.82	40.35	2.85	39.78	2.39	40.31	2.07
12	41.66	2.24	41.12	1.84	42.10*	2.45	40.68	2.25	41.12	2.10
13	41.10	2.15	42.72	2.21	42.71	2.53	42.28	2.03	42.45	2.27

TABLE 49 Leg length/stature index in South Sinai Bedouin boys, by tribe and age.

TRIBE	Gebeliya		Muzeina		Hamada &Aleigat		Others**		TOTAL	
AGE	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
5	54.74*	0.33	53.73	1.38	53.03*	0.94	52.93	1.39	53.49	1.37
6	54.64	1.09	53.89	1.14	54.33	1.06	53.56	1.39	53.96	1.24
7	54.91	1.45	55.25	1.27	54.48	2.11	54.86	0.67	55.01	1.33
8	55.34	0.96	55.77	1.47	55.19	1.33	55.17	1.03	55.45	1.25
9	55.20	1.22	56.04	1.66	56.07*	1.13	55.44	1.25	55.68	1.40
10	55.57	1.28	56.03	1.71	55.50*	0.58	55.63	1.51	55.74	1.43
11	57.08	0.91	56.04	1.35	56.34	0.40	56.38	0.98	56.41	1.08
12	56.84	1.53	56.54	1.21	47.46*	0.68	56.46	0.97	56.63	1.17
13	57.27	1.51	57.24	1.05	57.08	0.89	56.84	0.78	57.13	1.02

* less than 5 cases

** Gararsha, Awlad Said, Sawalcha, Haweitat

TABLE 50 Mean foot length (cm) in South Sinai Bedouin boys, by tribe and age.

TRIBE	Gebeliya		Muzeina		Hamada &Aleigat		Others**		TOTAL	
AGE	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
5	18.45*	0.77	18.18	1.10	18.30*	0.88	17.66	0.74	18.05	0.97
6	18.97	1.14	19.10	0.94	19.47	1.17	18.66	0.80	19.02	1.05
7	19.83	0.70	19.94	1.03	19.75	0.80	19.70	0.81	19.83	0.93
8	20.13	1.32	20.59	1.13	21.35	0.60	20.24	1.13	20.45	1.17
9	20.71	1.06	21.34	0.89	21.56*	0.70	20.77	0.95	21.05	0.95
10	21.74	0.79	21.32	1.16	21.60*	0.68	21.67	0.97	21.55	0.96
11	21.91	0.45	22.38	1.26	22.90	1.77	22.68	1.09	22.47	1.18
12	23.15	1.00	22.94	1.48	22.36*	1.02	22.76	1.04	22.88	1.18
13	23.45	0.68	23.45	0.85	23.96	1.10	23.55	1.21	23.62	0.98

TABLE 51 Mean foot breadth (cm) in South Sinai Bedouin boys, by tribe and age.

TRIBE	Gebeliya		Muzeina		Hamada &Aleigat		Others**		TOTAL	
AGE	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
5	6.95*	0.77	7.06	0.33	7.10*	0.30	6.96	0.29	7.03	0.33
6	7.15	0.45	7.47	0.46	7.72	0.44	7.37	0.35	7.45	0.46
7	7.50	0.43	7.73	0.43	7.73	0.30	7.66	0.37	7.69	0.40
8	7.61	0.34	7.95	0.41	8.01	0.14	7.83	0.57	7.87	0.46
9	8.11	0.65	8.15	0.56	8.63*	0.35	7.83	0.35	8.07	0.52
10	7.90	0.48	8.17	0.51	8.10*	0.18	8.22	0.44	8.13	0.45
11	7.85	0.42	8.53	0.43	8.30	0.46	8.70	0.57	8.44	0.57
12	8.63	0.45	8.90	0.64	8.60*	0.26	8.72	0.40	8.75	0.50
13	8.78	0.51	9.02	0.45	9.22	0.30	8.83	0.38	9.01	0.44

* less than 5 cases

** Gararsha, Awlad Said, Sawalcha, Haweitat

TABLE 52 Foot breadth/length index in South Sinai Bedouin boys, by tribe and age.

TRIBE	Gebeliya		Muzeina		Hamada &Aleigat		Others**		TOTAL	
AGE	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
5	37.61*	2.63	39.04	2.75	38.82*	1.34	39.44	1.61	39.05	2.29
6	37.73	1.96	39.14	1.96	39.69	1.99	39.55	1.81	39.18	1.98
7	37.87	2.07	38.83	1.80	39.16	1.48	38.93	2.01	38.80	1.93
8	37.88	1.21	38.71	2.29	37.58	1.46	38.46	2.22	38.45	2.10
9	39.13	1.39	38.15	1.46	40.03*	1.37	37.74	1.35	38.33	1.51
10	36.36	2.28	38.31	1.12	37.51*	0.78	37.96	1.39	37.77	1.51
11	35.80	1.31	38.13	1.04	37.18	1.68	38.77	1.27	37.79	1.64
12	37.27	0.83	38.42	1.04	36.82*	0.64	37.81	0.99	37.81	1.05
13	37.43	1.28	38.57	1.10	38.21	1.14	37.56	1.55	38.04	1.30

Subcutaneous Adipose Tissue

In the upper arm and the subscapular area there were significant differences between the Muzeina and Gebeliya boys in thickness of the subcutaneous fat layer (Tables 53-54). Muzeina boys had more subcutaneous adipose tissue than Gebeliya boys, especially in the subscapular region .

TABLE 53 Mean upper arm skinfold (mm) in South Sinai Bedouin boys, by tribe and age.

TRIBE	Gebeliya		Muzeina		Hamada &Aleigat		Others**		TOTAL	
AGE	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
5	5.75*	1.06	5.57	1.80	4.38*	2.75	6.50	0.86	5.78	1.65
6	3.76	1.47	5.09	1.19	5.40	1.73	5.28	1.56	5.05	1.50
7	4.60	1.45	5.28	1.61	4.83	1.60	4.05	0.97	4.93	1.56
8	5.28	1.31	4.96	1.03	6.45	1.43	4.86	1.50	5.12	1.34
9	4.66	0.98	5.41	1.35	6.50*	3.53	4.57	1.61	5.03	1.55
10	4.96	1.57	5.24	1.59	5.40*	2.40	4.59	1.17	4.98	1.52
11	5.87	2.09	6.10	1.82	6.07*	1.37	4.93	1.96	5.60	1.91
12	5.80	2.03	5.41	1.92	4.66*	1.15	5.26	1.87	5.39	1.85
13	4.68	1.08	5.99	1.93	5.46	2.78	5.20	2.08	5.43	2.07

* less than 5 cases

** Gararsha, Awlad Said, Sawalcha, Haweitat

TABLE 54 Mean subscapular skinfold (mm) in South Sinai Bedouin boys, by tribe and age.

TRIBE	Gebeliya		Muzeina		Hamada &Aleigat		Others**		TOTAL	
AGE	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
5	3.85*	0.49	3.60	0.75	3.43*	0.92	3.37	0.64	3.53	0.70
6	2.94	0.50	3.96	1.36	3.75	0.69	3.48	0.68	3.64	1.04
7	3.58	0.47	3.96	0.95	3.25	0.48	3.43	0.57	3.72	0.81
8	3.78	0.31	4.46	0.90	4.70	0.78	3.30	0.44	3.94	0.89
9	3.51	0.84	4.22	1.09	4.00*	1.41	3.66	0.84	3.88	0.98
10	3.62	0.71	4.96	1.19	3.65*	0.43	3.35	0.46	3.94	1.04
11	4.28	0.94	4.66	1.04	4.25	0.95	3.73	0.71	4.18	0.94
12	4.10	0.53	4.56	1.03	4.00*	0.00	4.10	0.82	4.25	0.83
13	3.98	0.67	4.94	1.05	4.52	0.76	4.00	0.79	4.43	0.92

Hand Strength

There were no significant differences in hand strength between the boys of the Muzeina and Gebeliya tribes (Tables 55, 56).

TABLE 55 Mean hand strength (L) (kg) in South Sinai Bedouin boys, by tribe and age.

TRIBE	Gebeliya		Muzeina		Hamada &Aleigat		Others**		TOTAL	
AGE	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
5	8.50*	3.54	9.95	2.46	10.33*	3.51	9.50	2.07	9.76	2.40
6	11.78	3.19	11.76	2.15	11.76	1.85	10.28	2.52	11.35	2.37
7	14.33	2.64	13.80	2.23	13.67	2.78	14.06	2.86	13.90	2.41
8	15.14	3.08	14.43	2.37	15.83	2.23	14.59	2.04	14.64	2.37
9	15.67	1.97	16.00	3.37	16.00*	1.41	15.92	2.90	15.91	2.82
10	16.20	1.92	16.44	2.51	16.00*	2.16	16.60	2.72	16.39	2.33
11	16.50	1.60	16.92	2.27	19.00*	1.41	19.00	3.42	17.87	2.81
12	18.80	2.39	19.67	3.77	18.33*	1.53	18.47	2.76	18.93	2.96
13	20.50	3.45	19.42	1.78	20.50	3.41	20.08	2.19	20.19	2.71

* less than 5 cases

** Gararsha, Awlad Said, Sawalcha, Haweitat

TABLE 56 Mean hand strength (R) (kg) in South Sinai Bedouin boys, by tribe and age.

TRIBE	Gebeliya		Muzeina		Hamada &Aleigat		Others**		TOTAL	
AGE	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
5	8.50*	2.12	9.94	2.13	9.00*	3.46	10.00	2.45	9.79	2.27
6	12.67	3.54	12.31	2.65	12.70	2.49	10.65	1.93	11.97	2.67
7	14.58	2.61	14.11	2.31	14.00	3.64	14.50	2.56	14.23	2.49
8	16.00	3.56	14.25	3.00	16.33	2.73	14.73	2.37	14.78	2.86
9	14.50	1.38	16.78	3.40	16.00*	1.41	16.31	3.84	16.17	3.26
10	16.00	2.55	17.10	3.35	17.50*	2.08	16.70	4.03	16.83	3.23
11	17.75	1.75	18.64	3.04	19.50*	4.20	19.87	3.38	19.05	3.10
12	19.80	2.44	20.93	3.86	20.67*	1.53	20.00	2.45	20.31	2.91
13	20.67	3.39	21.50	2.91	21.50	3.41	21.67	2.96	21.63	3.27

The two tribes did not differ significantly in stature , or in other height dimensions. In contrast, there was a significant difference in weight (*) at all ages and in the ratio of weight to stature (*) .

TABLE 57 Mean stature (cm) in South Sinai Bedouin boys, by tribe and age.

TRIBE	Gebeliya		Muzeina		Hamada &Aleigat		Others**		TOTAL	
AGE	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
5	111.90*	4.94	111.84	5.60	111.63*	7.88	107.57	6.09	110.73	5.94
6	117.57	6.13	117.02	4.77	119.14	4.65	114.20	5.28	116.71	5.26
7	121.45	4.38	123.72	4.11	122.43	4.37	120.94	5.65	122.79	4.56
8	126.68	6.67	126.91	4.60	129.18	2.30	125.34	5.50	126.41	5.17
9	128.28	5.15	131.37	5.41	131.73*	1.30	128.93	4.73	130.32	5.09
10	133.44	4.46	131.93	6.55	130.90*	2.31	132.76	3.21	132.26	5.06
11	137.11	3.07	139.85	5.73	139.88	8.34	138.95	5.50	139.05	5.59
12	143.58	5.69	141.89	5.91	141.10*	5.40	140.27	6.37	141.63	5.95
13	142.40	2.65	146.21	4.25	147.88	5.54	145.66	6.48	146.12	5.19

* less than 5 cases

** Gararsha, Awlad Said, Sawalcha, Haweitat

TABLE 58 Mean acromion height (cm) in South Sinai Bedouin boys, by tribe and age.

TRIBE	Gebeliya		Muzeina		Hamada &Aleigat		Others**		TOTAL	
AGE	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
5	89.30*	5.23	86.73	5.41	88.03*	6.64	84.06	5.40	86.21	5.46
6	91.67	6.10	92.41	4.22	93.70	4.40	89.62	4.03	91.77	4.66
7	96.59	4.22	98.09	4.28	96.66	4.16	95.59	4.83	97.27	4.42
8	101.30	5.51	101.09	4.66	104.65	4.48	99.71	5.24	100.84	5.13
9	102.30	4.08	104.46	4.90	104.43*	1.35	103.08	4.71	103.60	4.44
10	107.16	3.69	104.02	7.45	102.85*	2.48	106.68	2.75	105.32	5.11
11	110.26	3.34	111.70	5.31	112.31	6.92	111.67	4.53	111.50	4.84
12	116.08	5.09	114.34	6.10	113.60*	4.08	112.67	6.28	114.05	5.83
13	114.71	2.15	117.51	3.85	119.15	5.72	117.43	5.63	117.65	4.83

TABLE 59 Mean upper body segment length (cm) in South Sinai Bedouin boys, by tribe and age.

TRIBE	Gebeliya		Muzeina		Hamada &Aleigat		Others**		TOTAL	
AGE	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
5	23.10*	0.70	23.75	0.99	24.76*	1.25	23.91	1.36	23.85	1.12
6	24.81	1.47	24.47	1.50	25.05	0.91	24.45	1.11	24.61	1.29
7	24.74	2.20	25.10	1.31	25.06	1.25	25.21	1.01	25.06	1.37
8	25.61	1.10	25.42	1.12	26.52	1.08	25.84	0.91	25.64	1.15
9	26.05	0.96	26.25	1.39	26.80*	0.69	26.38	0.92	26.31	1.08
10	26.54	0.66	26.00	1.44	26.60*	0.66	26.70	1.30	26.41	1.21
11	26.85	1.50	27.46	1.21	27.25	0.84	27.00	1.06	27.15	1.16
12	27.23	1.23	27.52	1.26	27.10*	0.85	27.55	1.09	27.44	1.14
13	27.16	0.80	28.00	0.97	28.36	0.95	28.43	1.10	28.15	1.10

* less than 5 cases

** Gararsha, Awlad Said, Sawalcha, Haweitat

TABLE 60 Mean body weight (kg) in South Sinai Bedouin boys, by tribe and age.

TRIBE	Gebeliya		Muzeina		Hamada &Aleigat		Others**		TOTAL	
AGE	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
5	16.15*	2.33	17.70	1.71	17.00*	1.00	15.95	1.93	17.12	1.87
6	17.90	2.36	19.30	2.03	20.21	2.89	17.86	1.19	18.95	2.27
7	20.45	2.03	21.87	2.28	20.83	2.53	20.62	2.88	21.37	2.42
8	22.57	3.64	23.05	2.74	25.66	2.06	22.10	2.15	22.85	2.80
9	22.91	4.27	25.54	2.87	23.50*	2.12	23.30	2.50	24.47	3.09
10	24.60	2.60	25.82	3.49	24.50*	2.27	25.45	1.57	25.40	2.75
11	26.25	2.13	29.77	3.75	30.37*	6.62	29.59	3.42	29.08	3.84
12	30.05	3.86	32.07	4.91	29.83*	2.75	30.14	3.44	30.85	4.13
13	29.38	2.88	33.97	3.43	34.77	2.68	33.04	5.21	33.38	4.04

TABLE 61 Weight/stature index in South Sinai Bedouin boys, by tribe and age.

TRIBE	Gebeliya		Muzeina		Hamada &Aleigat		Others**		TOTAL	
AGE	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
5	14.40*	1.44	15.80	0.92	15.24*	0.71	14.78	1.17	15.42	1.08
6	15.10	1.20	16.47	1.33	17.04	1.96	15.72	0.86	16.22	1.48
7	16.83	1.39	17.57	1.35	17.02	1.58	16.99	1.65	17.32	1.43
8	17.73	1.97	18.12	1.63	19.34	0.84	17.64	1.16	17.98	1.57
9	17.78	2.66	19.39	1.54	17.94*	1.67	18.05	1.57	18.74	1.82
10	18.44	1.96	19.46	1.88	18.69*	1.41	19.17	1.05	19.15	1.61
11	19.12	1.17	21.20	1.81	21.63*	3.09	21.24	1.75	20.85	1.96
12	20.88	2.09	22.42	2.72	21.11*	1.18	21.44	1.79	21.69	2.26
13	20.61	1.70	23.20	1.79	23.79	1.49	22.59	2.65	22.86	2.15

* less than 5 cases

** Gararsha, Awlad Said, Sawalcha, Haweitat

Relationship Between Size and Shape of Body (Tables 62-65)

There is a significant difference between the Muzeina and Gebeliya boys in the relationship between body size and shape. This fact became apparent in the preceding, where a relationship was found between the limbs and the trunk, and is corroborated in the significant difference in body surface area between the two tribes. Similar significant differences were recorded also regarding the ratio of body surface area to body weight (Tables 62-65).

TABLE 62 Weight/stature^3 index in South Sinai Bedouin boys, by tribe and age.

TRIBE	Gebeliya		Muzeina		Hamada &Aleigat		Others**		TOTAL	
AGE	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
5	1.14*	0.01	1.26	0.09	1.23*	0.20	1.28	0.09	1.26	0.10
6	1.08	0.05	1.20	0.10	1.20	0.10	1.22	0.12	1.19	0.11
7	1.14	0.10	1.15	0.08	1.14	0.06	1.16	0.07	1.15	0.08
8	1.10	0.06	1.12	0.06	1.15	0.04	1.12	0.08	1.12	0.07
9	1.07	0.10	1.12	0.07	1.04*	0.10	1.08	0.10	1.10	0.08
10	1.04	0.14	1.11	0.08	1.09*	0.04	1.08	0.07	1.09	0.08
11	1.01	0.03	1.08	0.04	1.11*	0.10	1.10	0.06	1.07	0.06
12	1.01	0.09	1.09	0.09	1.06*	0.03	0.09	0.09	1.07	0.09
13	1.01	0.06	1.08	0.05	1.11	0.06	1.06	0.07	1.07	0.06

TABLE 63 Weight/stature^2 index in South Sinai Bedouin boys, by tribe and age.

TRIBE	Gebeliya		Muzeina		Hamada &Aleigat		Others**		TOTAL	
AGE	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
5	1.28	0.07	1.41	0.06	1.37*	0.14	1.37	0.07	1.39	0.07
6	1.27	0.05	1.40	0.10	1.43	0.13	1.38	0.09	1.39	0.11
7	1.38	0.10	1.42	0.09	1.39	0.09	1.40	0.09	1.41	0.09
8	1.39	0.09	1.42	0.09	1.49	0.05	1.40	0.07	1.42	0.09
9	1.38	0.16	1.47	0.08	1.36*	0.13	1.40	0.11	1.43	0.11
10	1.38	0.16	1.47	0.10	1.42*	0.08	1.44	0.08	1.44	0.10
11	1.39	0.06	1.51	0.07	1.54*	0.13	1.52	0.08	1.49	0.09
12	1.45	0.12	1.56	0.15	1.49*	0.03	1.52	0.10	1.52	0.13
13	1.44	0.10	1.58	0.09	1.62	0.09	1.54	0.13	1.56	0.11

* less than 5 cases

** Gararsha, Awlad Said, Sawalcha, Haweitat

TABLE 64 Body surface area (sq cm) in South Sinai Bedouin boys, by tribe and age.

TRIBE	Gebeliya		Muzeina		Hamada &Aleigat		Others**		TOTAL	
AGE	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
5	7162.61*	670.16	7448.12	560.97	7310.94*	529.82	6924.91	627.97	7288.77	601.84
6	7783.02	726.45	7981.52	554.21	8251.89	721.59	7560.71	395.91	7896.18	621.71
7	8402.70	518.22	8741.86	546.79	8501.11	646.88	8405.28	766.07	8613.24	606.78
8	9031.41	950.81	9125.96	683.13	9572.95	337.90	8895.98	632.88	9056.31	710.86
9	9162.78	976.07	9775.94	737.68	9415.76*	339.53	9274.39	613.87	9538.56	755.05
10	9725.08	513.18	9865.27	903.99	9579.7*	494.41	9838.38	377.56	9807.46	678.97
11	10203.48	508.11	10927.88	897.06	10982.7*	1594.3	10838.84	821.79	10759.3	901.56
12	11167.84	880.55	11421.36	990.50	11002.3*	730.57	10999.49	858.03	11197.6	904.00
13	10998.53	596.61	11926.08	732.13	12039.11	558.16	11746.51	1132.1	11804.6	859.44

TABLE 65 Body surface area/weight (cm^2/gr) in South Sinai Bedouin boys, by tribe and age.

TRIBE	Gebeliya		Muzeina		Hamada &Aleigat		Others**		TOTAL	
AGE	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
5	0.445*	0.02	0.421	0.01	0.430*	0.01	0.436	0.01	0.427	0.01
6	0.436	0.01	0.415	0.01	0.409	0.02	0.423	0.01	0.418	0.02
7	0.412	0.02	0.403	0.01	0.410	0.01	0.410	0.02	0.406	0.01
8	0.403	0.02	0.398	0.01	0.383	0.00	0.402	0.01	0.399	0.01
9	0.404	0.03	0.384	0.01	0.401*	0.02	0.399	0.01	0.392	0.02
10	0.397	0.02	0.384	0.02	0.392*	0.01	0.387	0.01	0.387	0.01
11	0.389	0.01	0.368	0.01	0.365*	0.02	0.367	0.01	0.372	0.01
12	0.373	0.02	0.359	0.02	0.369*	0.00	0.366	0.01	0.365	0.01
13	0.375	0.02	0.352	0.01	0.346	0.01	0.358	0.02	0.355	0.01

* less than 5 cases

** Gararsha, Awlad Said, Sawalcha, Haweitat

Basal Metabolism

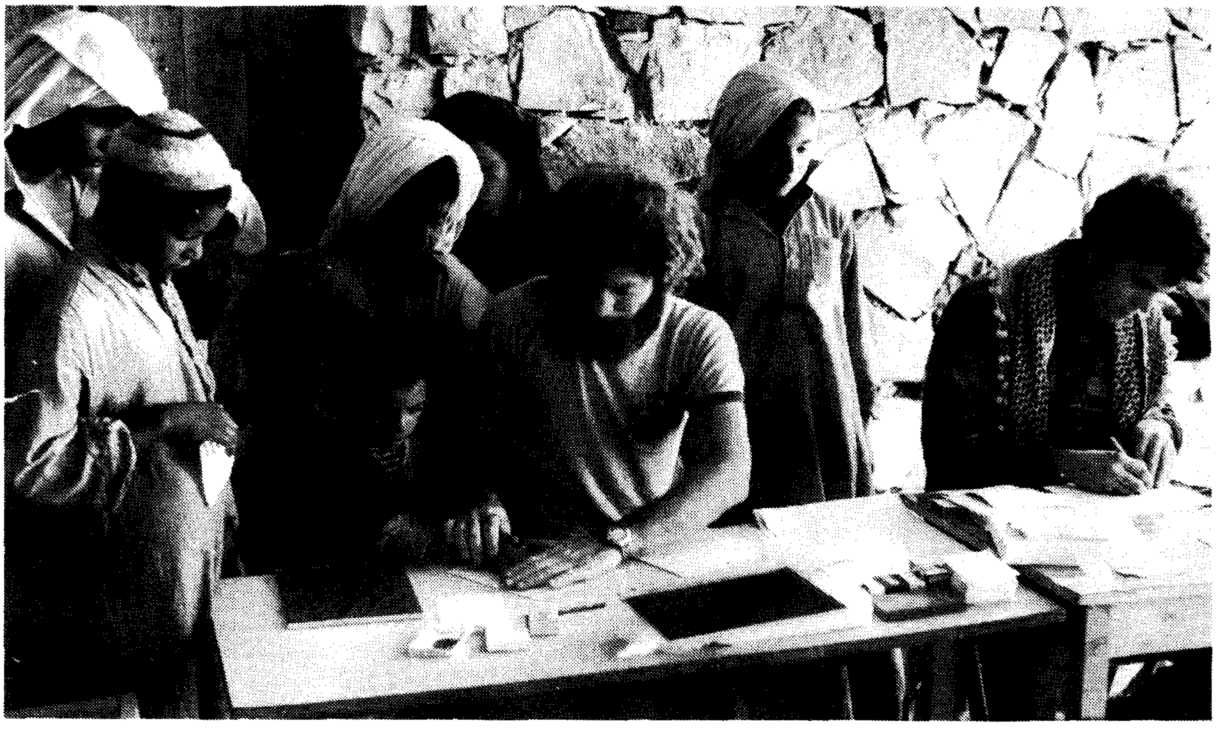
The Muzeina and Gebeliya boys differ significantly with respect to energy expenditure required to perform an identical task (KJ), as indicated below (Table 66).

TABLE 66 Energy expenditure required to perform identical tasks (Kj/min) in South Sinai Bedouin boys, by tribe and age.

TRIBE	Gebeliya		Muzeina		Hamada &Aleigat		Others**		TOTAL	
AGE	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
5	7.46*	0.45	7.77	0.33	7.63*	0.19	7.42	0.38	7.65	0.36
6	7.81	0.46	8.08	0.39	8.26	0.56	7.80	0.23	8.01	0.44
7	8.31	0.40	8.59	0.45	8.38	0.49	8.34	0.56	8.49	0.47
8	8.73	0.71	8.82	0.54	9.34	0.40	8.63	0.42	8.78	0.55
9	8.79	0.84	9.31	0.56	8.91*	0.41	8.87	0.49	9.10	0.61
10	9.13	0.51	9.37	0.68	9.11*	0.44	9.29	0.30	9.28	0.54
11	9.45	0.42	10.15	0.73	10.26*	1.30	10.11	0.67	10.01	0.75
12	10.20	0.76	10.60	0.96	10.16*	0.54	10.22	0.67	10.36	0.81
13	10.07	0.56	10.97	0.67	11.13	0.52	10.79	1.02	10.86	0.79

* less than 5 cases

** Gararsha, Awlad Said, Sawalcha, Haweitat



Dr. Hershkovitz (middle) taking fingerprints from Bedouin children.

TABLE 67: Comparison of morphological similarity and disparity between Muzeina and Gebeliya tribes by means of two-way analysis of variance, 41 traits; boys, 5-13 years.

TRAIT	Head length		Head breadth		Cephalic index		Bizygomatic breadth		Bigonial breadth		Morphological facial ht.	
Source of variation	F	Sig.	F	Sig.	F	Sig.	F	Sig.	F	Sig.	F	Sig.
Main effects	5.92	.001	3.62	.001	1.14	.337	19.11	.001	4.24	.001	29.80	.001
Age	6.57	.001	3.88	.001	1.05	.401	21.39	.001	2.67	.008	33.41	.001
Ethnic	0.05	.829	4.02	.046	1.38	.242	1.19	.277	10.14	.002	13.45	.001
2-way interaction												
Age-Ethnic	0.51	.841	1.36	.216	0.95	.479	1.146	333	1.719	.095	2.05	.041
Explained	3.37	.001	2.56	.001	1.05	.408	10.65	.001	3.055	.001	16.74	.001
TRAIT	Sitting height (1)		Biacromial breadth		Biiliac breadth		Chest circumference		Sitting height(2)		Trunk length	
Source of variation	F	Sig.	F	Sig.	F	Sig.	F	Sig.	F	Sig.	F	Sig.
Main effects	66.73	.001	49.54	.001	21.23	.001	39.81	.001	44.51	.001	27.15	.001
Age	4.90	.001	55.74	.001	22.97	.001	44.75	.001	49.79	.001	30.51	.001
Ethnic	8.89	.003	10.47	.001	22.36	.001	12.23	.001	2.51	.114	3.85	.051
2-way interaction												
Age-Ethnic	1.41	.194	0.98	.452	0.36	.939	0.21	.989	1.11	.357	0.84	.570
Explained	35.98	.001	26.69	.001	11.41	.001	21.18	.001	24.09	.001	14.77	.001
TRAIT	Sitting ht. stature		Biacromial breadthx100/ stature		Biiliac br.x 100/stature		Chest circumference x100/stature		Total arm length		Upper arm length	
Source of variation	F	Sig.	F	Sig.	F	Sig.	F	Sig.	F	Sig.	F	Sig.
Main effects	21.25	.001	2.93	.003	11.11	.001	9.55	.001	70.34	.001	40.65	.001
Age	21.42	.001	1.85	.069	8.11	.001	7.98	.001	77.91	.001	44.76	001
Ethnic	5.39	.021	7.88	.005	20.09	.001	10.38	.001	1.41	.236	0.42	.515
2-way interaction												
Age-Ethnic	2.16	.031	0.48	.871	1.49	.161	1.07	.384	1.18	.314	0.87	.539
Explained	12.27	.001	1.77	.032	6.58	.001	5.56	.001	37.79	.001	21.93	.001

Note: Sitting height (1) differs from Sitting height (2) - see tests and/or explanations chapter.

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Table 67: Cont.

TRAIT	Lower arm length		Hand length		Total arm length/stature		Iliospinal ant. ht.		Tibial height		Upper leg length	
Source of variation	F	Sig.	F	Sig.	F	Sig.	F	Sig.	F	Sig.	F	Sig.
Main effects	38.33	.001	23.03	.001	1.36	.206	95.77	.001	90.46	.001	85.21	.001
Age	42.36	.001	25.84	.001	1.50	.157	106.35	.001	100.42	.001	94.31	.001
Ethnic	0.25	.616	2.64	.106	0.75	.388	1.70	.194	1.50	.221	0.71	.399
2-way interaction												
Age-Ethnic	0.42	.910	0.91	.509	0.74	.660	0.69	.703	1.04	.403	0.79	.612
Explained	20.49	.001	12.62	.001	1.07	.386	51.02	.001	48.38	.001	45.48	.001

TRAIT	Leg length/ stature		Foot length		Foot breadth		Foot br. x100/foot l.		Upper arm skinfold		Subscapular skinfold	
Source of variation	F	Sig.	F	Sig.	F	Sig.	F	Sig.	F	Sig.	F	Sig.
Main effects	16.93	.001	62.59	.001	39.99	.001	3.95	.001	1.94	.047	5.68	.001
Age	18.49	.001	69.30	.001	44.80	.001	1.52	.150	1.76	.087	4.62	.001
Ethnic	0.18	.667	0.72	.396	18.17	.001	17.74	.001	4.73	.031	20.94	.001
2-way interaction												
Age-Ethnic	1.24	.276	0.47	.876	0.66	.728	1.13	.343	0.91	.510	0.77	.631
Explained	9.55	.001	33.36	.001	21.48	.001	2.62	.001	1.45	.113	3.37	.001

TRAIT	Hand strength (L)		Hand strength (R)		Stature		Upper body segment ht.		Acromial height		Body weight	
Source of variation	F	Sig.	F	Sig.	F	Sig.	F	Sig.	F	Sig.	F	Sig.
Main effects	34.55	.001	35.39	.001	138.74	.001	24.37	.001	95.77	.001	92.03	.001
Age	37.65	.001	39.07	.001	154.51	.001	27.08	.001	105.51	.001	103.49	.001
Ethnic	0.01	.940	0.51	.474	1.82	.178	0.79	.372	0.37	.545	23.58	.001
2-way interaction												
Age-Ethnic	0.38	.929	0.94	.486	0.92	.502	0.57	.798	0.76	.641	0.98	.449
Explained	18.47	.001	19.18	.001	73.88	.001	13.17	.001	51.06	.001	49.18	.001

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Table 67: Cont.

TRAIT	Weight x100/ stature		Body surface area		Body surface area/weight		Weight x100/stature^3		Kj	
Source of variation	F	Sig.	F	Sig.	F	Sig.	F	Sig.	F	Sig.
Main effects	60.85	.001	120.64	.001	47.53	.001	18.22	.001	92.03	.001
Age	67.77	.001	135.57	.001	52.24	.001	14.58	.001	103.49	.001
Ethnic	32.65	.001	14.67	.001	37.10	.001	26.82	.001	23.58	.001
2-way interaction										
Age-Ethnic	0.90	.513	0.84	.564	0.76	.637	1.41	.192	0.98	.449
Explained	32.64	.001	64.26	.001	25.52	.001	10.31	.001	49.18	.001

Detection of Morphologic Differences Between South Sinai Bedouin Boys of Different Tribes by ANOVA Standard Scores

Method

In the second stage of our comparison between the Muzeina and Gebeliya tribes, we converted all the numerical values, i.e. "raw scores", to standard scores and combined the different age groups. We did this in order to overcome the difficulty of obtaining valid statistical answers because of the small samples available to us, some of the age-tribal groups comprising less than 10 individuals. This statistical procedure was made available because the interaction: Age X ethnic origin, for most anthropometric measures was not significant.

A standard score (Z_i), it may be recalled, is the distance of individual X_i with respect to a particular trait from the mean distribution $\overline{X}$ for the particular trait within the population, given in units of standard deviation (S.D.). Thus $Z_i=(X_i-\overline{X})/S.D.$ We combined the boys of all tribes in each age group (5-13 years) and regarded them as a single sample. We then computed for this "sample" the mean and standard deviation, and calculated the standard score for each child in the expanded "sample". Subsequently we reassigned the children according to their tribal affiliation, and, based on their standard scores, computed the mean and standard deviation of each trait's distribution.

We then carried out a one-way analysis of variance where the independent variable was the tribe and the dependent variable was the mean distribution of each trait, in standard deviation units.

In addition, we examined the degree of relatedness between the Muzeina and Gebeliya tribes to the remaining tribes, utilizing the Scheffe Method for a one-way analysis of variance. This test divides the tribes into homogeneous groups by likenesses and differences of traits.

Results

Results of the analysis of variance, following standardization of the raw scores, are given in Table 68. The number of traits differing significantly between Muzeina and Gebeliya boys is 23 out of 41, identical to that obtained by a two-way analysis of variance of the "true" scores. The ranking of the trait means, and the discrimination between them performed by Scheffe's Method for the 4 Bedouin groups considered in Table 68, shows that for the 23 out of 41 traits that were found significantly different in the four groups, the Gebeliya group belongs to a subset which is different from that of the Muzeina subset. Furthermore, most of the trait means in the Gebeliya tribe are ranked lower than that of the Muzeina tribe. The morphologic uniqueness of the Gebeliya tribe is further emphasized by the fact that regarding 10 traits the Gebeliya children belong in a separate subset, i.e. their traits do not resemble those of any other group of children. In this respect, none of the other groups (Muzeina, Hamada + Aleigat, others) was found to belong to a separate subset, this for all 41 traits examined, i.e. no single morphological trait was unique to any of these groups.

The anthropological team of Tel-Aviv University with Bedouin children: left Prof. Arensburg, sitting Prof. Ben-David (Kobyliansky) and Rachel Nefesh (the nurse).

TABLE 68: Comparison of morphological likenesses and differences between the Gebeliya, Muzeina and four Bedouin tribes separately, by means of one-way analysis of variance based on 42 traits.

TRIBES	Muzeina-Gebeliya		Four tribal groups*		
TRAITS	F	Sig.	F	Sig.	Scheffe procedure subsets
Stature	2.45	.117	5.33	.001	I=4,1;II=1,2,3
Iliospinal ant. height	2.66	.103	5.38	.001	I=4,1;II=1,2,3
Tibial height	2.07	.150	7.99	.000	I=4,1;II=1,2,3
Acromial height	0.79	.372	3.36	.018	I=4,1,2,3
Sitting height (1)	9.75	.002	5.43	.001	I=1,4,3;II=3,2
Foot breadth	17.54	.000	8.98	.000	I=1;II=4,2,3
Foot length	1.00	.316	3.19	.023	I=4,1,2;II=1,2,3
Head length	0.04	.836	1.11	.342	I=1,4,2,3
Head breadth	3.86	.050	1.75	.155	I=1,4,3,2
Bizygomatic breadth	0.72	.395	1.31	.267	I=4,3,1,2
Bigonial breadth	8.28	.004	6.11	.000	I=3,2;II=2,4;III=4,1
Morphological facial ht.	10.92	.001	4.46	.004	I=1,4,3;II=4,3,2
Upper arm skinfold	3.88	.049	2.95	.032	I=1,4,2,3
Subscapular skinfold	18.36	.000	19.68	.000	I=4,1,3;II=3,2
Biacromial breadth	11.18	.001	7.79	.000	I=1;II=2,4,3
Biiliac breadth	27.42	.000	13.12	.000	I=1,4;II=2,3
Chest circumference	14.01	.000	9.18	.000	I=1;II=2,4,3
Body weight	22.87	.000	12.46	.000	I=1,4;II=2,3
Hand strength (L)	0.00	.982	0.36	.778	I=4,1,2,3
Hand strength (R)	0.47	.491	0.51	.672	I=1,4,2,3
Total arm length	1.97	.160	4.40	.004	I=4,1,2;II=1,2,3
Upper body segment length	0.87	.351	2.76	.041	I=1,2,4,3
Upper leg length	0.80	.370	2.86	.036	I=4,1,2,3
Upper arm length	0.45	.501	1.00	.389	I=4,1,3,2
Lower arm length	0.50	.478	3.93	.008	I=4,1,2;II=1,2,3
Hand length	1.84	.176	1.68	.169	I=1,4,2,3
Trunk length	4.18	.041	3.17	.024	I=1,4,3,2
Sitting height (2)	2.62	.106	2.50	.058	I=1,4,2,3
Weight x 100/Stature^3	28.26	.001	9.87	.000	I=1;II=4,2,3
Total arm length/Stature	1.21	.272	0.75	.520	I=1,2,4,3

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Table 68: cont.

Sitting height/Stature	4.93	.027	4.22	.005	I=3,1,4;II=1,4,3
Leg length/Stature	0.21	.643	2.87	.036	I=4,3,2,1
Foot breadth x 100/Foot length	21.09	.000	7.88	.000	I=1;II=3,4,2
Head breadth x 100/Head length	1.65	.200	1.69	.166	I=3,1,4,2
Biacromial breadth x 100/Stature	10.39	.001	14.31	.000	I=1;II=2,3;III=3,4
Biiliac breadth x 100/Stature	21.93	.001	8.53	.000	I=1;II=4,2,3
Chest circumf. x 100/Stature	11.79	.001	15.87	.000	I=1;II=2,3;III=3,4
Weight x 100/Stature	32.68	.000	14.21	.000	I=1,4;II=4,2,3
Body surface area	14.39	.000	9.41	.000	I=1,4;II=2,3
Body surface area/Weight	38.79	.000	15.73	.000	I=3,2,4;II=1
Kj	22.70	.000	12.41	.000	I=1,4;II=2,3

*1 = Gebeliya; 2 = Muzeina; 3 = Hamada and Aleigat; 4 = Beni-Wassal, Haweitat, Gararsha, Awlad Said, Sawalcha

Sitting height (1) differs from Sitting height (2) - see tests and/or explanations chapter.

Weight x 100/ $Stature^2$-was omitted from two way ANOVA

A Bedouin with his camels.

Morphological Differences Between Boys Of Sub-Tribes Within The Gebeliya And Muzeina Tribes

The morphological differences between boys in the sub-tribes were evaluated in two tribes. One of these tribes is the Gebeliya, for which there is clear-cut evidence that one of its sub-tribes (Awlad Gindi) is different from all the others in origin. The Awlad Gindi sub-tribe, as previously noted, came from Egypt whereas all the other sub-tribes (Wehebat, Hamaida and Awlad Salim - see Fig. 4) probably originated in the Arabian Peninsula. Hence one reason for differences in morphology of children within a tribe could be the fact that they belong to sub-tribes which initially came from different geographical regions. However, morphologic differences among children of the Muzeina tribe, which is a relatively homogeneous social unit compared to the Gebeliya tribe, could also stem from the nature of marital patterns in the group, namely a clear preference (about 75%) for marriages within the sub-tribe level, thus creating isolated social units within the broader tribal framework.

Morphological Differences Among Boys of Sub-tribes in the Gebeliya Tribe

The number of boys in the Gebeliya sub-tribes is very small, as indicated below:

Group No.	Sub-tribe	No. of Individuals	Common Ancestor
1	Awlad Gindi	19	Gindi (?)
2	Wehebat Hamaida Awlad Salim	36	Bachit

In order to detect morphological differences between boys of the Gebeliya sub-tribes, we had to overcome the problem of sampling limitations, stemming from the very small numbers in each age group within each sub-tribe. We therefore used the following statistical procedure:

a)"Standardization" process: For each trait, per each boy in the tribe, we calculated the relative standing with respect to the mean in that particular age group (standard score).

b) The sample: We divided the boys according to their sub-tribal affiliation.

c) Distribution of traits: For each sub-tribe, and each trait, we constructed a new distribution based on the standard scores of its children, regardless of age.

d) Measures of central tendencies and variability were calculated by means of condescriptive statistics (SPSS, 1975).

e) Significant differences between the means (Awlad Gindi vs. all other sub-tribes) were computed by a one-way analysis of variance (ANOVA).

Results

Of the 41 traits examined by the one-way analysis of variance following standardization of measurements, 16 were found to vary significantly between the Awlad Gindi boys and boys of the other subtribes (Table 69). The Awlad Gindi children were found to be broader in girth, heavier, and longer limbed, as well as having a broader head and a longer face. In trunk height, however, the Awlad Gindi boys resembled those of the other subtribes. Also the indices of the various bodily measures were similar in these two child groups (Awlad Gindi vs. other Gebeliya sub-tribes). Yet the body surface area and the caloric expenditure required to perform a defined task were greater in the Awlad Gindi boys.

The statistical non-significance of many of the differences in measurements among the sub-tribes is no doubt due, at least in part, to the small samples.

TABLE 69: Comparison of morphological likenesses and differences between the Gebeliya sub-tribes by means of one-way analysis of variance based on 41 traits.

	Awlad Gindi	
GEBELIYA SUB-TRIBES	Hamaida, Wehebat, Awlad Slim	
TRAITS	F	Sig.
Stature	6.88	.011
Iliospinal ant. height	7.14	.011
Tibial height	10.58	.002
Acromial height	7.98	.006
Sitting height (1)	3.30	.074
Foot breadth	1.18	.282
Foot length	4.88	.031
Head length	1.08	.301
Head breadth	4.49	.038
Bizygomatic breadth	2.42	.125
Bigonial breadth	0.12	.727
Morphological facial ht.	6.67	.012
Upper arm skinfold	0.84	.363

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TABLE 69: cont.

GEBELIYA SUB-TRIBES	Awlad Gindi Hamaida, Wehebat, Awlad Slim	
Subscapular skinfold	0.27	.603
Biacromial breadth	8.44	.005
Biiliac breadth	6.98	.010
Chest circumference	3.85	.055
Body weight	4.08	.048
Hand strength (L)	1.16	.285
Hand strength (R)	2.49	.120
Total arm length	4.59	.036
Upper body segment length	2.47	.121
Upper leg length	3.09	.084
Upper arm length	4.77	.033
Lower arm length	5.65	.021
Hand length	0.01	.925
Trunk length	0.99	.323
Sitting height (2)	1.24	.269
Weight x 100/Stature^3	1.57	.214
Total arm length/Stature	1.10	.298
Sitting height/Stature	2.05	.157
Leg length/Stature	0.67	.415
Foot breadth x 100/Foot length	1.27	.265
Head breadth x 100/Head length	0.14	.703
Biacromial breadth x100 /Stature	0.88	.352
Biiliac breadth x 100/Stature	0.11	.739
Chest circumf. x 100/Stature	0.00	.960
Weight x 100/Stature	2.37	.129
Body surface area	6.03	.017
Body surface area/Weight	1.38	.244
Kj	4.02	.050

Note: Sitting height (1) differs from Sitting height (2); see tests and/or explanations chapter.

The fact that for more than a third of the traits here considered there were significant differences between different groups of the same tribe points to the great importance of social structure when one carries out a biological investigation of any sort, probably even more so in studies of endogamic tribal societies.

Morphological Differences Among Muzeina Boys

A. Boys divided according to common ancestor

In order to detect morphological differences within the Muzeina tribe itself, we first divided the boys into three groups:

Group No.	Sub-tribe	No. of individuals	Common ancestor
1	Shadadine Smehat	37	Alwan
2	Mehaysina Gsenat Dararme	142	Farag-Ali
3	Gawanme	30	Farag-G'hanem

We then followed the same statistical procedure as in the Gebeliya boys, additionally applying the Scheffe method to rank all six sub-tribes according to mean values for each trait.

Results

Morphological comparisons: The comparisons of morphologic traits between Groups 1 and 2 (Table 70) show that boys of Group 1 differ from those of Group 2 in three traits (upper leg length, foot length and foot breadth) at a significance level of $p<0.05$ and in five traits at a significance level of $0.1>p>0.05$ (biiliac breadth, sitting height (1), iliospinal height, tibial height and hand length). Most of the statistically significant results pertain to measures of the limbs and trunk dimensions. These differences suggest that the boys of the Shadadine and Smehat (Group 1) differ in important respects from those of the Mehaysina, Gsenat and Dararme sub-tribes of Group 2.

Arrangement of Groups 1 and 2 according to mean values of traits shows that the boys of Group 2 (Farag-Ali descendants) manifest consistently higher values than the boys of Group 1 (Alwan descendants).

A comparison of children of Group 2 with those of Group 3 shows a significant difference ($p<.05$) in chest circumference, cephalic index, foot breadth, head length, trunk length and chest circumference/stature, and at the significance level of $0.1>p>0.05$ in body surface area/weight, foot breadth/foot length, sitting height (1)/stature, ponderal index and bizygomatic breadth. The differences between Groups 2 and 3 seem to center mainly in the trunk and head. Thus the boys of the Mehaysina, Gsenat and Dararme sub-tribes, compared with boys of the Gawanme have on the average a broader head in absolute terms, a broader head relative to head length, and a broader face, as well as a shorter trunk and a larger chest circumference relative to stature, and finally, more weight per unit of body surface area.

The comparison between Groups 1 and 3 shows that in chest circumference/stature, sitting height (1), hand length and upper leg length, averages differ between the groups at the significance level of $p<0.05$, and for leg length/stature, ponderal index and subscapular skinfold, at the significance level of $0.1>p>0.05$. Thus the differences between the boys of the Shadadine and the Smehat and those of the Gawanme are mainly in the trunk and lower limbs, with higher mean values in the former. The boys of Group 1 have a larger mean chest circumference relative to stature than those in Group 3.

TABLE 70:Comparison of morphological likeness and differences between the Muzeina sub-tribes by means of one-way analysis of variance.

MUZEINA SUB-TRIBES	Group 1*vs.Group 2		Group 3 vs. Group 2		Group 1 vs. Group 3	
TRAITS	F	Sig.	F	Sig.	F	Sig.
Stature	2.15	.143	0.01	.940	1.05	.308
Iliospinal ant. height	3.35	.069	0.03	.856	2.06	.156
Tibial height	2.99	.085	0.01	.892	0.21	.647
Acromial height	0.64	.424	0.92	.337	0.50	.479
Sitting height (1)	3.44	.065	0.87	.351	4.99	.029^
Foot breadth	4.54	.034^	4.96	.027^	0.06	.807
Foot length	4.59	.033^	0.96	.327	0.60	.440
Head length	0.10	.744	4.90	.028^	2.04	.157
Head breadth	0.22	.636	1.49	.223	0.32	.571
Bizygomatic breadth	2.29	.131	3.66	.057^	0.20	.651
Bigonial breadth	0.21	.642	0.01	.947	0.05	.810
Morphological facial ht.	0.23	.629	0.03	.844	0.04	.839
Upper arm skinfold	0.02	.871	0.08	.768	0.01	.893
Subscapular skinfold	0.66	.415	2.32	.129	3.26	.075
Biacromial breadth	0.54	.463	0.91	.340	1.74	.192
Biiliac breadth	3.86	.051^	0.43	.512	1.04	.309

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Table 70: cont.

Chest circumference	0.55	.458	5.80	.017^	1.93	.169
Body weight	2.32	.129	1.43	.233	0.01	.906
Hand strength (L)	1.58	.210	0.01	.987	0.75	.387
Hand strength (R)	1.31	.253	0.02	.876	0.53	.469
Total arm length	1.96	.162	0.01	.980	1.18	.280
Upper body segment length	0.62	.432	0.12	.722	0.55	.459
Upper leg length	5.05	.026^	0.31	.577	4.04	.048^
Upper arm length	0.03	.851	0.59	.442	0.27	.599
Lower arm length	0.29	.589	0.16	.684	0.57	.450
Hand length	2.92	.089	1.65	.200	7.32	.008^
Trunk length	0.18	.669	4.04	.046^	2.16	.146
Sitting height (2)	0.82	.366	2.06	.650	0.09	.754
Weight x 100/Stature^3	0.39	.531	2.98	.085	3.95	.051^
Weight x 100/ Stature^2	0.00	.965	1.46	.228	0.93	.337
Total arm length/Stature	0.00	.966	0.16	.682	0.13	.712
Sitting height/Stature	0.44	.508	2.92	.089	0.71	.402
Leg length/Stature	1.79	.181	1.05	.305	3.52	.065
Foot breadth x 100/Foot length	0.00	.967	2.93	.089	2.63	.109
Head breadth x 100/Head length	0.72	.397	5.32	.022	1.58	.213
Biacromial breadth x 100/Stature	0.87	.352	2.21	.139	0.23	.630
Biiliac breadth x 100/Stature	0.10	.744	0.00	.938	0.10	.753
Chest circumf. x 100/Stature	0.40	.523	8.23	.004^	8.35	.005^
Weight x 100/Stature	1.25	.264	2.69	.102	0.23	.626
Body surface area	2.50	.115	0.62	.431	0.22	.636
Body surface area/Weight	0.93	.335	3.07	.081	0.48	.488
Kj	2.29	.131	1.40	.237	0.01	.905

Sitting height (1) differs from Sitting height (2)- see tests and/or explanations chapter. Group 1: Shadadine, Smehat sub-tribes; Group 2: Mehaysina, Gsenat, Dararme sub-tribes; Group 3: Gawanme sub-tribe. ^ signification level $p<0.05$

These results suggest that the greater the genealogical distance between two sub-tribes, the more distinct and consistent are the metric differences between them. Thus we find that between the two groups farthest apart genealogically, Alwan vs. Farag-Ali descendants, the consistency of the results is most marked, whereas between the more related groups, Farag-Ali and Farag-G'hanem descendants, consistency is least in trait differences. Judging by these consistent trends, we are convinced that the few significant results obtained are not fortuitous, but rather imply general morphologic discrimination between sub-tribes.

A tendency towards morphological differences between the Gawanme children and those of the Mehaysina, Gsenat and Dararme may be noted. Here it is apparent that the Gawanme are descended from the ancestor Ali who is the brother of Ghanem, both of whom are the sons of Farag, a later genealogical split than the afore-mentioned (Alwan-Farag) but earlier than that of the Mehaysina, Gsenat and Dararme. By the same token, we can understand why so few traits serve to differentiate between children of the Gsenat, Dararme and Mehaysina, tribal groups descended from a common ancestor (Ghseyn) who live in territorial proximity and tend to exchange brides at a higher rate than in the other sub-tribes. The relatedness of the Smehat and the Shadadine is also understandable in the same context. The Smehat, in fact, was once an extended family within the Shadadine that moved out of the tribal centers and formed a separate sub-tribe.

That many of the mean differences in traits among the groups within the Muzeina are not statistically significant is probably due to the fact that the described social process that leads to sub-tribe formation does not necessarily create at the same time independent biological units. Nevertheless, the possibility also exists that inability to reveal morphological differences among the sub-tribes may be attributed to the small size of the samples and/or to the limited time interval elapsed since each sub-tribe began to act as an independent social and biological unit. Although the differences were generally not "significant", as noted, the directions of our results suggest that such processes (i.e., biological differentiation between the sub-tribes) probably do take place in the Bedouin society even within tribes that are considered homogeneous populations (e.g. the Muzeina tribe).

Definition of Tribal Morphologic Identity

There is scarcely any Bedouin of a tribe who will not brag that he can identify members of other tribes without undue difficulty.

While it is true that there are fine differences in behavior, apparel and language which can be of help in such identification, these apparently are not the only criteria upon which the Bedouin relies. His criteria, as reported by the Bedouins themselves, are rather "morphological" characteristics.

In the present chapter, the question of morphological identity attributed to the tribes will be examined.

We have attempted to differentiate the boys by tribe, by means of "discriminant analysis" of most of the studied anthropometric traits.

The Sample

At first we studied the morphological differences between the boys of the Gebeliya and Muzeina tribes. Subseqeuntly we included the boys of the Hamada-Aleigat and the "other tribes", i.e. the combined Gararsha, Awlad Said, Sawalcha and Haweitat. For each test we made two runs - one for F=1 and the other for F=4. As is known, a variable is a candidate for selection only if its partial F-ratio is greater than an arbitrary value assigned by the investigator. When F=1, the function will include all such variables whose contribution towards distinguishing between the Bedouin groups is above and beyond the separation created by prior variables in the function at a significance level defined as F>1.0. It follows that when the F value is low (F=1), more variables will enter the discriminant function than when the F value is high (F=4). In this manner we were able to manipulate the number of variables included in the functions and ascertain a low number of variables sufficient to yield a good discrimination between the various tribes.

In anthropology, discriminant functions are usually generated and used without reference to the level of chance classification - random results are assigned the value of 50% correct classification (in the case of two groups), and any results greater than 50% are usually considered to be due to the information contained within the descriptors (measurements). However, for a given number of individuals, the probability of fortuitously obtaining 100% correct classification increases as the number of features (d) increases from 1 to the number of individuals in the study (N) (Stouch and Jurs, 1985a,b). These classifications, while correct, are due only to artifacts of mathematics governing the process of generating linear discriminant functions (LDF). They are not due to any relationship between the individuals, and the resulting LDF will have no predictive ability beyond random guessing (Stouch and Jurs, 1985a,b).

Until recently, it was accepted that if the number of descriptors is kept below one-third the number of individuals used, the probability of complete separation due to chance could be kept low. The ratio of $N/d \geq 3$ was accepted as a minimum requirement (Stuper and Jurs, 1976; Varmuza, 1980). More recent studies (Stouch and Jurs, 1985a,b), however, have shown that at that ratio random classification results ranged around 90%. Even one descriptor for every ten individuals would yield random correct classification of about 75%. It was also found that unequal group sizes serves to increase correct random classification and that for any one value of the ratio N/d, the percentage correctly classified is the same regardless of the number of individuals used in the study.

a. Differences between children of Muzeina and Gebeliya tribes

Table 71 gives a summary of the stepwise procedure pertaining to differences between children of the Muzeina and Gebeliya tribes. Because of the small sample size, discrimination at the subtribe level was not applicable.

TABLE 71 Discriminant analysis stepwise procedure based on morphological traits: Muzeina vs. Gebeliya, F=1,4, boys 5-13 years.

Step	Entered	F to enter
1	Body weight/Stature^2	34.39*
2	Bigonial breadth	13.75*
3	Biiliac breadth	10.29*
4	Foot breadth/Foot length	11.70*
5	Sitting height/Stature	3.43
6	Foot breadth	1.71
7	Acromial height	2.36
8	Stature	2.2
9	Lower arm length	1.21

* Traits included within the discrimination function for F=4.

Bedouin children in Nuweiba

Although there is a clear tendency for discrimination between the Muzeina and Gebeliya, the overlap between them is considerable. The effect of this overlap becomes clear when we look at Table 72. It may be seen here that our classification procedure was able to correctly identify 77.7%-78% of these cases as members of the tribes to which they actually belonged.

TABLE 72: Percent of individuals correctly identified by tribal membership, for F=1 and F=4.

Group	No. of cases		Predicted group membership in:			
			Gebeliya		Muzeina	
	F=1	F=4	F=1	F=4	F=1	F=4
Gebeliya	60	62	(46)	(46)	(14)	(16)
			76.7	74.2	23.3	25.8
Muzeina	164	174	(36)	(36)	(128)	(128)
			22.0	20.7	78.0	79.3

Note: figures in parentheses are number of cases

Mean percent of grouped cases correctly classified: 77.7 for F=1 and 78.0 for F=4

b. Differences between the children of four tribal groups

Here, too, we carried out two separate runs, one for F=1 and the other for F=4. Table 73 summarizes the stepwise procedure for the 4 groups for F=1 and F=4.

It will be recalled that the discriminant functions are derived in such a fashion that the first provides maximal discrimination between the groups, the second separates them maximally in a 90 degree direction to the first, and so on. The net result is that the groups are separated as far as possible on the basis of data obtained from the original discriminant variables. The discriminant functions can be regarded as defining axes in a geometric configuration in which each case and each group center are points. The spatial orientation of these axes is basically random, except for the fact that they are arranged in a descending order of maximal discrimination. The axes may be rotated while we hold constant the relative positions of the individuals and the group.

TABLE 73 Discriminant analysis stepwise procedure based on morphological traits of South Sinai Bedouin boys, 5-13 years, by tribe; F=1: Gebeliya (1), Muzeina (2), Aleigat and Hamada (3), and all other tribes (4).

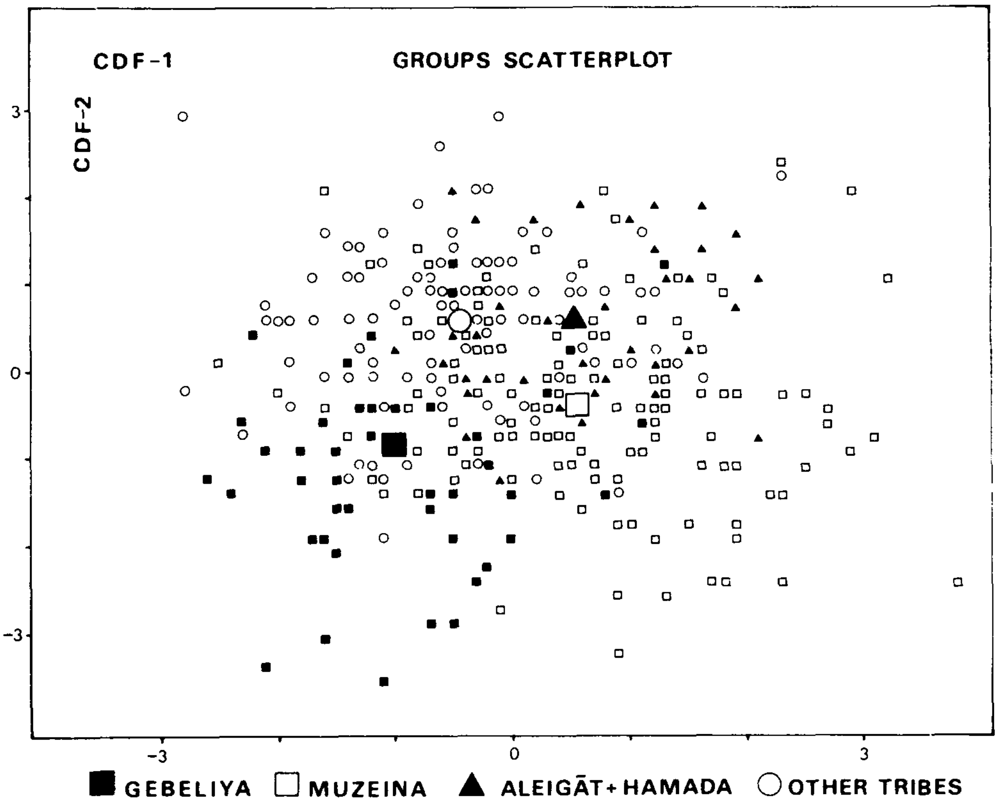
Step	Variable entered	F to enter
1	Chest circumference/Stature	12.44*
2	Subscapular skinfold	11.23*
3	Bizygomatic breadth	2.25
4	Sitting height/Stature	2.88
5	Biacromial breadth/Stature	5.92
6	Biiliac breadth	3.80
7	Leg length/Stature	1.18
8	Foot breadth/Foot length	3.53*
9	Bigonial breadth	7.16*
10	Trunk length	1.70
11	Foot breadth	1.55
12	Upper arm length	1.42
13	Body weight/Stature	2.62
14	Upper arm skinfold	1.02
15	Iliospinal height	1.37
16	Body surface area	1.06*
17	Acromial height	3.38
18	Biiliac breadth/Stature	1.04
19	Hand length	1.01
20	Total arm length	1.36
21	Kj	1.16*
22	Body weight/Stature^3	1.57

* Traits included in discriminate function for F=4.

Further information on the intergroup differences may be derived from the discriminant scores of the individuals after plotting them and the group centroids on a graph defined by the first two discriminant functions (Fig. 29). The centroids summarize also the group locations in the space defined by the discriminant functions, as seen in figure 29, where they are designated by large geometric forms. The spatial scatter of the scores provide insight into the separations achieved by the functions. Thus, on the horizontal axis (function No. 1) the discrimination is pronounced between Group 1 (Gebeliya) and Group 2

(Muzeina), whereas the separation on the vertical axis (function No. 2) is mainly between Group 1 (Gebeliya) and Groups 3 (Aleigat-Hamada) and 4 (all other tribes). We can now discern different meaning for the morphological differences between the groups, thus where the differences between Group 1 (Gebeliya) and Group 2 (Muzeina) refer mainly to shape while those between Group 1 and Group 3 (Aleigat-Hamada) are mainly ones of body size. It is also evident (Fig. 29) that there is no small measure of congruence between the groups, that is, one cannot discriminate clearly between the groups.

FIGURE 29: Plot of Discriminant Scores for Four Bedouin Tribes



The adverse influence of this congruence becomes clearer the more we observe the data given in Table 74. This table exemplifies the ability of the function to assort the individuals in the sample into one of the possible groups. In other words, the table indicates the probability that a certain individual will fit into the tribal category to which he belongs.

TABLE 74 : Percent of individuals correctly identified, by tribe, and F=1 and F=4, respectively.

			Predicted Group Membership							
Group	No. of cases		Gebeliya		Muzeina		Aleigat&Hamada		Other tribes	
	F=1	F=4	F=1	F=4	F=1	F=4	F=1	F=4	F=1	F=4
Gebeliya	56	62	(37) 66.1	(39) 62.9	(7) 12.5	(9) 14.5	(5) 8.9	(7) 11.3	(7) 12.5	(7) 11.3
Muzeina	141	159	(17) 12.1	(26) 16.4	(71) 50.4	(69) 43.4	(31) 22.0	(38) 23.9	(22) 15.6	(26) 16.4
Aleigat&Hamada	48	49	(6) 12.5	(5) 10.2	(5) 10.4	(11) 22.4	(30) 62.5	(23) 46.9	(7) 14.6	(10) 20.4
Other tribes	108	116	(17) 15.7	(22) 19.0	(14) 13.0	(10) 8.6	(15) 13.9	(19) 16.4	(62) 57.4	(65) 56.0

Note: Figures in parentheses are number of cases.

Mean percent of grouped cases correctly classified for F=1; 56.66 and for F=4; 50.76%.

Bedouin rock art

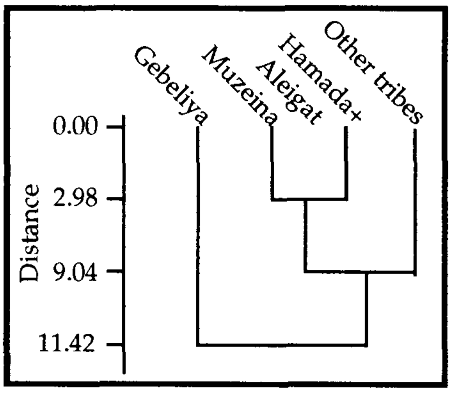
Evaluation of intertribal morphological distances by cluster analysis

We performed a cluster analysis to measure intertribal morphological distances, according to the BMDP-PIM program (1983, pp.621-622). This program creates clusters of variables based on the measurement of a connection or similarity between variables, such as the coefficient of correlation, or of the distance between variables such as the Mahalanobis distance, which we preferred. Morphological traits included to compute the Mahalanobis distances on the intertribal level are the same as those used in construction of discriminant functions (see Table 73). The Mahalanobis distance matrices were carried out by discriminant analysis of morphological traits on intratribal level under conditions of F=4. On the basis of these matrices, morphological similarities between the Gebeliya and Muzeina tribes, and between the four studied tribes, were estimated by cluster analysis. In the present study, we relied on the mean (Average linkage) amalgamations rule to construct the group cluster (BMDP, 1983).

Biological distances between Bedouin tribes (Fig. 30)

As expected, the Gebeliya tribe, whose true origin is shrouded in uncertainty, possesses a separate morphologic identity and it does not link with one of the other tribes (Fig. 30).

FIGURE 30: Morphologic Similarity Between Bedouin Tribes*: Cluster Analysis (F=4, Average linkage).



The Gebeliya presents a distance from the other tribes which is larger that between the Muzeina, Hamada and Aleigat tribes. The fact that the Muzeina and Hamada+Aleigat, join into a single cluster affirms the existence of a biologic link between these tribes and their common historic and ethnic backgrounds (see also chapter on history of tribes).

Primary Components in Bedouin Morphology

In the course of our survey and evaluation of growth processes and morphological features of children (boys) in Bedouin tribes, we have used different traits and measures in classifying body structure. Clearly many of them are inter-correlated and hence their numbers could be considerably decreased. We may lose some information in the process but in turn we probably would benefit by a marked simplification of procedures and greater ease of translating and interpreting the results of the measurements. We opted to simplify matters by the method of Principle Component Analysis, which is in fact a mathematical procedure for reducing complex correlation systems to a few measures only. The use of such a tool for studying growth patterns linked with age has been adopted by several investigators (e.g. Waliszko and Welon, 1975; Welon et al., 1976; Relethford et al., 1978). Our own study however differs from those cited in that it was made on standardized data, owing to the small samples available to us in each age group. The PCA method employed by us is basically a transformation of the original variables into a series of linear combinations, or components, which are derived in such a way as to be orthogonal to one another. A further important feature of the latter method is that the components are derived continuously so that at each step the residual variance is computed as much as possible (Harman, 1967). Most of the total variance will be explained by a small number of components with no connection between them (i.e. uncorrelated components), which hopefully are interpretable as different measures of the variance.

The PCA in this study was carried out by computer program BMDP (Dixon and Brown, 1979). The program was run twice, once for the Muzeina sample, to identify the principle components defining an intratribal structure, and once for the overall sample in order to define the principle components for the total South Sinai Bedouin group. The decision as to the number of components (the program was run for 10 components in each sample) was made subjectively, albeit one could use for this purpose statistical criteria.

Studies from various biological areas have shown that the first component includes positive loadings only (Jolicoeur and Mosimann, 1960; Reyment, 1969; Relethford et al., 1978). This finding has been mathematically justified (Rao, 1964). Many, if not most, investigators of the subject regard the first component as a size component and the subsequent ones as shape components (Castle, 1913, 1929; Wright, 1918, 1932; Jolicoeur and Mosimann, 1960; Altmann, 1966; Reyment, 1969; Blackith and Reyment, 1971; Devor et al., 1986). According to this viewpoint, size is regarded as an unidirectional increase, while shape is in fact a measure of the relationship between different body parts (Lestrel, 1974). Recently, Devor and coworkers (1986) showed that body length and body width measures as well as measures of the head and face represent different body "fields" which are possibly under differing degrees of genetic control and environmental influence.

Finding the components for total South Sinai Bedouin group

Table 75 presents the loadings (squared multiple correlations) of each trait in one of the 10 components.

Only loadings whose values are greater than 0.40 appear in tables, where they are arranged in descending order in each column. The loading is interpreted as a correlation between the variables and the factors. The Vp values are the sums of the squared loadings per column and represent the variance explained by the factor. The results indicate that 80.5% of the total variance of the 41 original variables are accounted for in 10 components. We shall now examine the proportion of variance accounted for solely by each factor, and the variables which are correlated with them.

First component. The first component accounts for over 34.9% of the overall variance and is linked, as evident from the tables, mainly to bodily length measurements. This finding is supported in other studies (Welon et al., 1976; Relethford et al., 1978; Devor et al., 1986). The fact that most of the variables in this component have a high loading testifies to a high correlation between them. Therefore, in intertribal and intratribal morphologic comparisons of Bedouin populations, there is actually no need to use many variables describing length of different parts of the body; we could rely only on few out of the 24 represented in the first component with hardly any loss of information. In addition, table 75 enable us to choose the most suitable variables for representing the particular component since these are the ones with the highest loading. The fact that some of the variables have significant, i.e., relatively high, loadings in two components (e.g. Chest Circumference) indicates that there are at least two factors that affect the morphologic expression of this variable, e.g. in the present instance, both the growth of bone tissue as well as growth of adipose and muscle tissue. According to Devor et al. (1986) the first factor is a body length factor.

TABLE 75 Results of principal component analysis. First ten loading factors; All South Sinai Bedouin tribes combined; boys 5-13 years^.

Variables	I	II	III	IV	V	VI	VII	VIII	IX	X
Stature	.95									
Body surface area	.93*									
Acromial height	.92									
Iliospinal height	.89									
Kj	.85*									
Body weight	.85*									
Tibial height	.84									
Sitting height (1)	.82*		.42							
Foot length	.77									
Total arm length	.75			.61						
Upper leg length	.74									
Body weight/ Stature	.69*	.60								
Hand strength (R)	.65									
Lower arm length	.61									
Biacromial breadth	.61*									
Hand strength (L)	.60									
Chest circumference	.60*	.57								
Upper arm length	.59									
Trunk length	.56*		.50							
Body weight/ Stature^3		.86*								
Body weight/ Stature^2		.83*								
Chest circumference / Stature		.81*								
Body weight/Body surface area	.61	.66*								
Leg length/Stature			-.78							
Sitting height 1/Stature			.72*							
Head breadth				.74*						
Bizygomatic breadth				.72						
Bigonial breadth				.68*						
Total arm length/ Stature					.92					
Hand length					.69					
Biiliac breadth/ Stature						.92*				
Biiliac breadth	47					.82*				

Cont. next page

Table 75: Cont.

Variables	I	II	III	IV	V	VI	VII	VIII	IX	X
Subscapular skinfold							.76*			
Upper arm skinfold							.68*			
Head length								.85*		
Head breadth/ Head length				.45				-.84		
Foot breadth/ Foot length									.91*	
Foot breadth	.55								.69*	
Biacromial breadth/ Stature		.44								.60*
Upper body segment	.43									47
Morphological facial height	.45									
Vp value	13.1	4.39	2.30	2.25	2.11	1.94	1.91	1.90	1.67	1.40
% total variance	34.9	13.2	6.51	5.41	4.53	4.02	3.49	3.14	2.78	2.69
Cumulative % total variance	34.9	48.1	54.6	60.1	64.3	68.3	71.8	75.0	77.7	80.4

^ Only loadings >0.4 are shown

* traits significantly different between South Sinai Bedouin tribes, based on ANOVA, see table 67

Sitting height (2) was excluded from PCA

Second component. As noted in table 75, the second component accounts for about 13.2% of the overall variance. The loaded variables of this component are mainly the ones associated with weight/stature ratios, that is, to body mass, and indicate the connection between osseous tissue to muscle and adipose tissue. It is not surprising, therefore, that a variable like chest circumference is also represented in this component. Yet, while this latter component represents shape as commonly regarded, it probably represents more specifically shape of the trunk, and hence could possibly be considered a measure of trunk robustness. According to Devor et al. (1986) the second factor is a body bulk factor heavily loaded with the soft tissue measures and weight.

Third component. The third component accounts for some 6.5% of the overall variance and represents mainly variables associated with the trunk and its relation to body height; as such, the third component may possibly be regarded a measure of the trunk.

Fourth component. The fourth component accounts for about 5.4% of the overall variance and contains variables that represent breadth measurements of the head and face. Relethford et al. (1978) propose this component as a measure of brain size because, in their opinion, the high loading of all the three breadth measures concerned are indicative of expansion in the parietal region of the skull, and are not merely a general measure of breadth as some have proposed (see also Howells, 1951). In the study of Devor et al. (1986) there is a cranial factor with high loadings on head circumference and breadth.

Fifth component. The fifth component accounts for some 4.5% of the overall variance and is represented by variables that describe the upper limbs and their link with stature and, consequently, we may view it as an upper limb index.

Sixth component. The sixth component accounts for 4.0% of the overall variance. It represents the waist (biiliac diameter) and its link with body height. Hence, it may be defined as a "loin index".

Seventh component. This component accounts for about 3.5% of the overall variance. It is a direct representative of bodily adipose tissue.

Eighth component. The 8th component accounts for about 3.1% of the overall variance and in fact represents only head measurements. This component is noted in previous studies (e.g. Howells, 1951; Lombardi, 1976), where it was regarded as a general component of skull length. Relethford et al. (1978) rejected this view on the grounds that the component is poorly correlated with the skull length and skull breadth variables, and considered the eighth component merely as a measure of the head diameter. Our own findings (PCA) support this latter conclusion.

Ninth component. This component accounts for about 2.8% of the overall variance. It represents foot size. Most morphometric studies do not include variables associated with foot dimensions because these are apparently not contributing much beyond what is obtainable from other measures of bodily length and breadth dimensions. However, in the case of the Bedouins and their environment, this component is considered important.

Tenth component. The tenth and last component accounts for about 2.7% of the overall variance. This component represents the upper part of the body and its relation to stature. We elected to regard the component as a measure of the shoulder index (biacromial breadth/stature).

We shall briefly try to clarify why the results of the PCA for all the tribes (Table 75) were not identical with those obtained for the Muzeina tribe alone (Table 76), i.e., 1st, 2nd, 4th and 9th factors are almost identical in their traits' composition; 7th and 8th change positions and the other factors are loaded with different traits. We believe that the main reason is the differences in genetic constitution of the different Bedouin tribes. We have already seen that the level of the inbreeding coefficient in the Muzeina tribe is F=0.09802. Such a high level can in various forms result in abrogation of the correlations between morphologic traits, and consequently tend to the creation of different components. We may therefore expect that in each of the South Sinai tribes the PCA results would be somewhat different. The PCA results for all the tribes combined thus reflect no more than an aggregate of the different PCA's which must be taken into account when working with components rather than with the variables themselves.

The PCA results (Tables 75 and 76) inform us that when we compare the morphologic makeup of children from different Bedouin tribes it is desirable to choose the most highly correlated variables for each factor: Stature; Body weight/ stature3; Sitting height/ stature; Head breadth; Total arm length/ stature; Biiliac breadth/ stature; Subscapular skinfold; Head length; Foot breadth/ foot length; Biacromial breadth/ stature.

A local Bedouin "Doctor" treating a patient: notice that a nail and a match box are used to perform cauterization

TABLE 76 Results of principal component analysis. First ten loading factors for 41 morphological traits; Muzeina tribe only; boys, 5-13 years^ .

Variables	I	II	II	IV	V	VI	VII	VIII	IX	X
Body surface area	.94[1]									
Stature	.94[1]									
Acromial height	.92[1]									
Iliospinal height	.91[1]									
Body weight	.89[1]									
Kj	.89[1]									
Tibial height	.85[1]									
Sitting height (1)	.79[3]									.52
Upper leg length	.76[2]									
Body weight/ Stature	.75	.54								
Total arm length	.73[1]		.53							
Foot length	.73[1]									
Hand strength (R)	.68[1]									
Body weight/ Body surface area	.67[1]	.61								
Biacromial breadth	.61[1]		.61							
Hand strength (L)	.61									
Foot breadth	.61[2,3]								.50	
Lower arm length	.58[1]									
Upper arm length	.58[1]		.49							
Biiliac breadth	.53[1,3]				.50					
Chest circumference/ Stature		.84[2,3]								
Body weight/ $Stature^2$		.78								
Body weight/ $Stature^3$		.78[3]								
Chest circumference	.61	.63[1,3]								
Total arm length/ Stature			.84							
Biacromial breadth/ Stature			.75[2]							
Head breadth				.79[1]						
Bizygomatic breadth				.71[3]						
Bigonial breadth				.51						

Cont. next page

Table 76: Cont.

Variables	I	II	II	IV	V	VI	VII	VIII	IX	X
Biiliac breadth/ Stature					.68[1,3]					
Upper body segment					-.674					
Leg length/ Stature	.487					.737[2]				
Trunk length	.503					-.67[2,3]				
Head length							.854[3]			
head breadth/ Head length				.448			-.833[3]			
Subscapular skinfold								.771[2]		
Upper arm skinfold								.678		
Foot breadth/ Foot length									.937[2]	
Sitting height/ Stature										806[2]
Vp value	13.35	3.96	2.72	2.44	2.03	2.01	1.94	1.85	1.64	1.50
% total variance	35.73	11.89	7.40	4.90	4.76	4.35	3.80	3.06	2.93	2.79
Cumulative % total variance	35.7	47.6	55.02	59.9	64.6	69.0	72.8	75.8	78.8	81.6

^ Only loadings >0.40 are shown

1 traits significantly different between Gebeliya sub-tribes, based on ANOVA,

2 traits significantly different between 6 Muzeina sub-tribes, based on ANOVA,

3 traits significantly different for all other comparisons of Muzeina sub-tribes, based on ANOVA.

Evaluation of inter- and intratribal morphological differences in light of PCA results

The PCA method enabled us to reveal varied aspects of Bedouin morphology and to examine these morphological components in regard to inter- and intratribal morphological comparisons estimated by ANOVA. Morphological differences between the Gebeliya and Muzeina children will be examined in light of both the ANOVA and PCA methods. The variables are examined according to different regions of the body.*

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* In ANOVA comparisons between Gebeliya and Muzeina Bedouins, (+) will denote statistical significance (p<0.05) and (-) non-significanc (p>0.05).

Head and face

Variables associated with the head and face are represented in three different components. Three of the variables [bizygomatic breadth(-), head breadth(+), and bigonial breadth(+)] belong to the fourth component, one variable [cephalic index(-)] belongs to the eighth component, and another one [morphological facial height(+)] to the first component. In this manner, new elements which were not previously recognized are now added to the intertribal morphologic differences. For instance, two out of the three variables occurring in the fourth component indicate significant intertribal differences.

The trunk

The variables appearing under this heading fall into four different components. Four variables [biacromial breadth(+), trunk length(+), chest circumference(+), and sitting height(+)] belong to the first component, one variable [chest circumference/stature(+)] to the second component, another variable [ratio of sitting height (1) to stature(+)] to the third component, two variables [biiliac breadth(+), biiliac breadth/stature(+)] are in the sixth component; and one [biacromial breadth/stature(+)] belongs to the tenth component. We found that all the variables selected to represent one region of the body actually belong to five different components of the morphologic variance.

Upper limb

The variables appearing under this heading belong to two different components. Three of them [lower arm length(-), upper arm length(-), and total arm length(-)] belong to the first component, and two others [total arm length/stature(-) and hand length(-)] belong to the fifth component. Of the first component, none of the variables shows a significant intertribal difference, despite the fact that part of the variables representing the first component in other areas of the body (trunk and head) do show significant intertribal differences. Therefore if one chooses a small number of variables for the first component, to which most of the variables belong, the results differ from those derived from a one-way analysis of variance of all the studied variables (ANOVA).

Lower limb

The variables here occur in two different components, with three of them [upper leg length(-), tibial height(-), and iliospinal height(-)] represented in the first component and another one [leg length/stature(-)] in the third component.

No differences among the Muzeina and Gebeliya tribes were noted in regard to the morphology of the leg.

Foot

The variables here are represented in two different components, one [foot length(-)] belonging to the first component, and two others [foot breadth/foot length(+) and foot breadth(+)] to the ninth component.

Subcutaneous adipose tissue

The variables here, namely, subscapular skinfold (+) and upper arm skinfold (+), belong to the seventh component. Skinfold measures are, in fact, the only morphologic trait in which there is full accord of the variables between it and its component.

Hand strength

The two variables included here [hand strength R(-) and hand strength L(-)] belong to the first component. Inasmuch as they also have a high loading, it seems their contribution to the intertribal morphologic differences is very negligible.

Heights and weight

All the variables in this category [stature(-), iliospinal height(-), acromial height(-) and body weight(+), body weight/stature(+)] have a high loading in the first component. Some of these variables, especially those associated with weight, show significant intertribal differences while the remainder (associated with longitudinal measurements) do not show significant differences.

Body size and shape

One of the variables here [body surface area(+)] is linked with high loading to the first component while the remaining four [body weight/ $stature^2$(+); body weight/$stature^3$(+); chest circumference/stature(+) and body weight/body surface area(+)] are the core of the second component.

Basal metabolism

Here, the single representative variable [KJ(+)] appears in high loading in the first component.

Intertribal differences, the link between the PCA and ANOVA.

The connection between the PCA and ANOVA results in regard to the morphological differences between the tribes in general and between the Muzeina sub-tribes in particular, is elucidated in Tables 75 and 76 respectively. The variables displaying significant differences in the ANOVA for inter- and intratribal comparisons are marked by asterisk within the tables of the PCA.

From Table 75 it is clear that the morphological differences between the Gebeliya and the Muzeina boys is not restricted to a specific component of the overall variance. In the first component one can separate between variables linked directly to osseous tissue growth, mainly in the limbs which possess a large genetic element (Osborne and DeGeorge, 1959), and variables linked to muscle or adipose tissue of the trunk, in which the genetic determinant is relatively smaller.

Now let us assume that, for the purpose of analyzing intertribal morphologic differences, we would have used ten representative variables (the first ones in each component), and that we would have applied them in the ANOVA system.

The question, however, is not in how many traits the tribes differ morphologically, but rather whether such differences can be revealed by using a small number of metric variables. In our opinion, analyzing the variables within the components with regard to the ANOVA results shows that conclusions drawn from a restricted number of variables may be misleading, that important information can be lost.

The link between the PCA and ANOVA, as far as the intratribal differences are concerned, is shown in Table 76.

To simplify matters we elected to use the results of the run of the ANOVA on the Gebeliya tribe, a run which examined the morphologic differences between boys of the Awlad Gindi sub-tribe and those of the other sub-tribes. It may be recalled that of the 41 examined traits, 16 (39%) were found to show significant difference among the subtribes. In the division of variables by ten components (Table 76), it was found that all the traits, except two, separating the Gebeliya sub-tribes were concentrated in the first component. Hence, it can be argued with considerable justification that the morphological differences between boys of the various sub-tribes of the Gebeliya tribe are concentrated in one major aspect of their morphology.

The fact that most of the variables manifesting significant intratribal differences are contained in one component and are of a relatively high degree of heritability (see Osborne and DeGeorge, 1959; Kobyliansky, 1984), supports the hypothesis that the intratribal difference between the children stems from different genetic background. And if we examine the morphologic differences between various sub-tribes of the Muzeina, for example between Group 2 (Mehaysina, Gsenat and Dararme) and Group 3 (Gawanme), we note that 16.7% of variables (7 of 42 traits) showing significant intratribal differences according to ANOVA are distributed over five components (I, II, IV, VI, and VII). If we employed ANOVA only with the first variables within each component (Table 76), we would have found that 21.4% of the variables showed significant morphological differences between the sub-tribes.

It should be remembered that in summarizing our ANOVA results we claimed that the morphologic differences between boys from the various sub-tribes of the Gebeliya (38% of the traits significantly different) were more prominently significant than those between the boys from the various sub-tribes of the Muzeina (9 of 42 traits, or 21.4%, of traits significant). This condition is reflected also in the results of the PCA, albeit in a different manner.

The morphologic differences between children from various sub-tribes of the Muzeina are scattered over most of the components. On the other hand, the morphologic differences between children from the various sub-tribes of the Gebeliya tribe are concentrated in the first component. This clearly indicates that the source of morphological variation largely differs between tribes.

Geographical Factors In Intertribal And Intratribal Morphologic Variability

South Sinai is essentially a mountainous region with mountain peaks of 2500 meters or more. In this chapter we shall attempt to ascertain whether morphological differences among Bedouin boys are affected by the high altitude of South Sinai. Much attention has been given in the literature to the affects of high altitude on growth and development (e.g. Eveleth and Tanner, 1976). Most of it, however, deals with groups in regions where the elevation exceeds that of South Sinai, heights usually in excess of 3000 meters. Probably any differences between the groups in South Sinai, living at different altitudes, will be more the result of the biome.

Investigators of populations in geographic regions of high altitudes, such as the Quechua in the Andes (Frisancho, 1966, 1969), the Aymaras in the Andes of Bolivia (Rothammer and Spielman, 1972) and the Sherpa in the Himalayas (Pawson, 1974; Basu et al., 1980; Majumder et al., 1986) provide data indicating a slower and longer duration of growth compared to coastal peoples, also lower average body weight and stature, a higher ratio of weight to stature, shorter legs compared to trunk length and a larger chest circumference. A recent study by Majumder et al. (1986) on two ethnic groups, the Sherpa and Lepcha from the eastern Himalayan region, showed clear differences in morphological traits between population groups living at low (1000-2000 m) and high (>3500 m) altitudes. Of the 16 variables examined, the most important discriminant was sitting height, and the least important was head breadth.

Yet other published data on high altitude groups indicate opposite findings. For example, the study on the Kuzul-Djar populations in high altitudes of the USSR (Miklashevskaya et al., 1973) shows average smaller dimensions in chest circumference, in chest depth and in chest breadth, than in groups living at low altitudes. Another example of conflicting results occurs in the highlands of Ethiopia (Simien Mountain), where populations are larger-bodied than those of the lowlands, also taller and heavier, but they did not possess a greater chest circumference than lowlanders (Harrison et al., 1969). Although anthropometric differences have been observed between high and low altitude populations (Baker and Little, 1976; Baker, 1978), these differences have been attributed to different factors: environmental stresses such as hypoxia, cold, etc. (Hurtado, 1974), or to sociocultural factors (Weitz, 1984). The findings of the most recent study (Majumder et al., 1986) on the effect on adult body dimensions of altitude, geographical distance, ethnicity-religion and occupation showed that 1)altitude has a significant effect; 2)ethnicity-religion and occupation have no discernible effect; 3)the effect of geographical distance is inconsistent.

We selected the Muzeina tribe as a model for evaluating the effect of high altitude because it is the only tribe in South Sinai whose members are distributed over a wide geographic area, ranging from coastal settlements like Dahab and Nuweiba to mountainous settlements like Tarfat Qiderein (see Fig. 1). The other Bedouin tribes in South Sinai inhabit restricted geographical regions and topographically uniform areas (see Fig. 2). For example, the Gebeliya tribe resides only in the center of the High Mountain area and its sub-tribes, as noted, originate from different "ethnic" groups from at least two different geographic regions, Egypt and southern Europe.

The Muzeina tribe was divided into a "Coastal Group" (Nuweiba, Dahab, Hereize and et-Tur), and a "Mountain Group" (Bir-Saal, Santa Katharina, Tarfat Qiderein and Feiran). The elevations of sites in the latter group ranged from 600-700 meters (Bir-Saal) to 1200-1400 meters in the region surrounding the high peaks of the South Sinai mountains (e.g. Gebel Katharina, 2642 m; Gebel Musa, 2285 m; Gebel Umm Shaumar, 2586 m).

We must take into account that owing to migration routes of some of the sub-tribes, and the cross-sectional nature of our investigation, it is possible that some individuals considered to be the "Coastal" group may have belonged to the "Mountain" group, their presence in a particular settlement during the study being fortuitous and temporary. It is worth noting that there exists at least partial correlation between the territorial assignation of individuals to coastal or mountainous settlements and their social affiliation (sub-tribe), which may have some effect on our results.

In order to control the effect of "blood relationship" while evaluating the effect of topography, we performed the following. First, we compared mountain and coastal boys of the Shadadine and Smehat sub-tribes with Alwan as their ancestor, with mountain and coastal boys of the Dararme, Gsenat and Mehaysina sub-tribes with Ali, the son of Farag, as their ancestor. Second, we compared mountain and coastal boys of the Gawanme, with Ghanem as their ancestor, with mountain and coastal boys of the Shadadine and Smehat sub-tribes, with Alwan as their ancestor. The third comparison referred to the six separate sub-tribes, namely, the Shadadine, Smehat, Dararme, Mehaysina, Gawanme, and Gsenat.

The rationale behind these various divisions was the structure of the genealogical tree of the tribe and its use to assess the extent of influence of the "blood relationship" factor on the morphological and developmental differences between the groups.

In order to evaluate in Bedouin children the effect of "altitude" on general morphology while controlling "blood relationship", we performed three separate runs of the two-way analysis of variance on the standard scores so that in each run the components of "blood relationship" were changed (see below).

<u>The sample</u>

The samples for each of the three runs are given in Table 77.

<u>TABLE 77</u>: Number of Muzeina boys aged 5-13 years, according to "blood relationship" (descendents) and place of residence (altitude).

	Descendant			Subtribes*						
Residence	Alwan	Farag Ali	Farag G'hanem	1	2	3	4	5	6	Total
Mountains	23	23	21	11	1	12	21	10	12	67
Coast	11	88	7	11	30	3	7	55	0	106
Total boys	34	111	28	22	31	15	28	65	12	173

* Numbers refer to sub-tribe as follows:

1 - Smehat+Shadadine 2 - Dararme 3 - Mehaysina-A (Saradike clan)

4 - Mehaysina-B (all other clans) 5 - Gawanme 6 - Gsenat

Results

The summarized results of the two-way analysis of variance are given in Table 78.

In each run 42 morphometric variables were examined. The number of physical traits manifesting significant differences between coastal and mountain children was small, the maximum being in the third run, 4 out of 42 traits, namely, tibial height, bizygomatic breadth, upper arm skinfold and leg length/stature. None of these four had any significant interaction with the second independent variable of "blood relationship". Hence, although it might be that differences in place of residence are responsible for the observed morphologic differences in these traits between Muzeina boys, it is more logical to assume that a chance factor is involved. Also in the third run, the "blood relationship" factor was found to be responsible for morphological differences between Muzeina boys in 9 out of 42 traits examined: iliospinal anterior height, bizygomatic breadth, subscapular skinfold, biiliac breadth, upper leg length, trunk length, sitting height/stature, leg length/stature, chest circumference/stature.

TABLE 78: Number of traits for which a significant/non-significant difference was found between ethno-territorial Muzeina Bedouin groups by means of MANOVA, based on 42 traits.

	Independent variables					
	Altitude		Blood Relationship		Interaction	
Runs according to ethnic origin	Sign.*	Non-Sign.	Sign.	Non-Sign.	Sign.	Non-Sign.
First run	3	39	2	40	1	41
Second run	0	42	4	38	2	40
Third run	4	38	9	33	1	41

*Significant when $P<0.05$

1 The first run: Distribution of the independent variables: altitude and genealogical origin (degree of blood relationship).

The first independent variable: mountain residents vs. coastal residents.

The second independent variable: Alwan descendents vs. Farag Ali descendents.

2 The second run: Distribution of the independent variables: altitude and genealogical origin.

The first independent variable: mountain residents vs. coastal residents.

The second independent variable: Farag G'hanem descendents vs. Alwan descendents.

3 The third run: Distribution of the independent variables: altitude and genealogical origin.
The first independent variable: mountain residents vs. coastal residents.
The second independent variable: Shadadine, Smehat (1); Dararme (2), Mehaysina-A (3), Mehaysina-B (4), Gawanme (5), Gsenat (6).

The combination of the two independent variables (the interaction effect) in the third run showed significance only in one variable, subscapular skinfold.

In sum the results indicate:

a) There was little morphologic difference between mountain and coastal groups in the Muzeina tribe. The few significantly different traits obtained are not correlated and are not ones we would expect to obtain under the altitude variable, those associated with the respiratory system, for example.
b) Morphologic differences between groups in the Muzeina tribe can be detected when its members are categorized according to their genealogical ties. These morphological differences are more pronounced than the differences obtained by site of residence only. The more precise the genealogical classification, i.e., the more restricted the social grouping, the more pronounced the trend towards morphologic variability among the groups.
c) Combination of the two independent variables (interaction) does not contribute more to an understanding of the morphologic differences between the sub-tribes than does each independent variable alone.

Nutrition In Bedouins: Inter- And Intratribal Morphological Differences

Apart from a few romantic references on the subject, the nutritional status in Bedouin society has never been studied in detail. Burckhardt (1822) noted that the Bedouins of South Sinai were the poorest among the Bedouin tribes. He wrote:

> *The Towara are some of the poorest of the Bedouin tribes, which is to be attributed principally to the scarcity of rain and the consequent want of pasturage. Their herds are scanty, and they have few camels... Their means of subsistence are derived from their pastures, the transport trade between Suez and Cairo, the sale at the latter place of the charcoal which they burn in their mountains, of the gum arabic which they collect & of their dates &*

other fruits. The outcome of this trade at Cairo culminates in purchasing clothing and provisions, particularly corn, for the supply of their families; and if anything remains in hand, they buy with it a few sheep and goats at Tor or at Sherm, to which latter place they are brought by the Bedouins of the opposite coast of Arabia (p.561).

Burckhardt also estimated their annual per capita income and mentioned that their food list is meager, thus:

They live, of course, according to their means; the small sum of fifteen or twenty dollars pays the yearly expenses of many, perhaps of most of their families, and the daily and almost unvarying food of the greater part of them is bread, with a little butter or milk for which salt alone is substituted when the dry season is set in, and their cattle no longer yield milk (p.562).

Twenty years after Burckhardt, Sinai was visited by another famous traveller and investigator, namely, Robinson (1841), and he, too, noted the low nutrition level of the Bedouins, particularly among children and the elderly. He wrote:

The young and middle-aged men looked well and hardy; but there were old men and sick persons and children, who came around the convent, the very pictures of famine and despair. These miserable objects, nearly naked, or only half-covered with tatters, were said to live very much upon grass and herbs; and even this food now failing from the drought, they were reduced to mere skeletons (p.201).

Robinson (1841) further claimed that the Towara tribes were among the poorest of the Middle Eastern Bedouin tribes (pp.203-204).

Almost identical accounts on the means of subsistence of Bedouins are provided by a later traveller, Palmer (1871). Palmer also noted the dire state of Bedouin children in the Sinai, most of whom lacked clothing, were undernourished and exposed to diverse diseases. Among the numerous folklore tales gathered by Levi (1980) in South Sinai are many that describe periods of famine and plague.

These tales reinforce the impression gained from reading the journals of travellers and investigators in the 19th century and lead to the conclusion that poverty was, then as now, rife among the Bedouins of South Sinai. Similar impressions occur in the report by Marx (1974, p.29) on the life of Bedouins in the Israeli Negev. He comments:

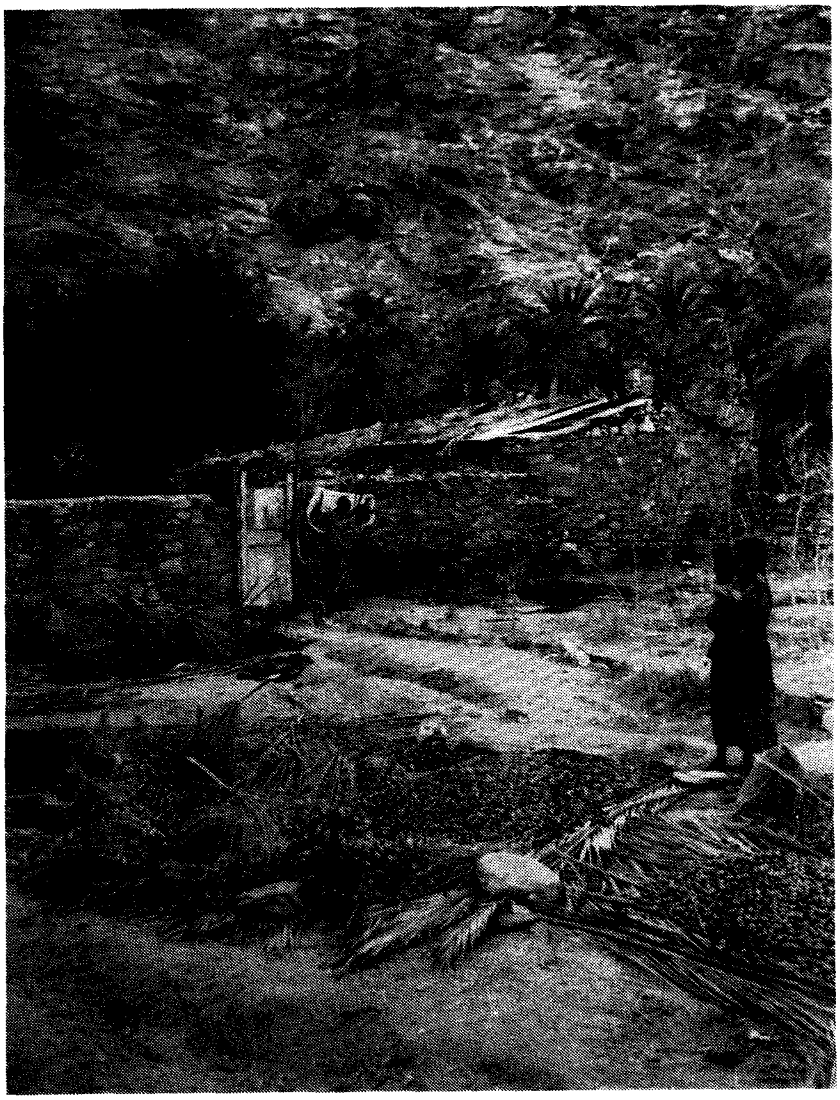
In the course of a regular working day the Bedouin is accustomed to eating a single meal only, mostly comprised of "Pat" (Pate') - a dish of flour boiled in water and oil which serves as a main course (Idda) and is served any time between 8 AM and 5 PM, as the master of the house so wishes on the *particular day. On getting up in the morning, the Bedouin is mostly accustomed to drink a cup of coffee or tea together with a slice of dried bread from the previous day. Meat is eaten only on festive occasions and the main staples are cereals which the Bedouin has learned to store for prolonged periods... In the spring, the diet is enriched with milk and wild vegetables such as Khubeisa [Malva plant] and Kima [truffle]. In other parts of the year the diet does not include vegetables or fruits... many Bedouins, even the wealthy among them, suffer from undernourishment, general malaise and even tuberculosis, to which the Bedouins are more susceptible than any other society (p.129).*

A first attempt to tackle nutritional status in terms of the energy contribution of traditional Bedouin economy was made by Perevolotzky and Perevolotzky (1979). They calculated the energy value of the product of an orchard in the Gebeliya tribe as tantamount to 2,237,760 calories which they believed comprised 55.8% of the yearly energy consumption of a Bedouin family. To this we should add the energy value obtained from the flock, namely, milk - 15.4%, and meat - 6.0%, which also represent the energy value referable to the family consumption per year. According to these calculations, the basic economics of the Gebeliya tribe provide about 77% of the energy expenditure of a Bedouin family. But these figures refer to conditions in about 1965, before relative modernization in the region. The socioeconomic changes that occurred in the wake of the takeover by Israel in 1967 led to a significant diminution in the relative energy value (per yearly family expenditure) provided by the aforementioned economies. Thus Perevolotzky and Perevolotzky wrote:

The Israeli rule has brought about numerous transformations in Bedouin life. The employment situation, for one, has changed, with practically unlimited and well-paying job opportunities opening up (owing to settlement of East Sinai, tourism, etc.). Thus, even though there was shut-down of the markets for the sale of the fruits of the orchard and herds, and despite the rise in the cost of living (mainly because of rampant inflation in recent years), the standard of living increased. Along with this, there was change also in the patterns of migration, the Bedouins coming to settle closer to vehicular routes and forming permanent settlements. These latter have had a drastic effect on the development of natural resources. The clear outcome was the abandonment of many orchards concomitant with the inauguration of job opportunities in Israel (1968-1970) and also the pronounced diminution of the flocks (p.53).

Israeli rule plainly brought about substantial changes in the Bedouin economy, generally for the better, including a rise in the nutritional level. Most of the children surveyed in the present study were born after 1967 and therefore grew up under nutritional conditions immeasurably better than those of their parents. In Table 79 are given data on the monthly expenditure of a Bedouin family in the 1960's compared with that in the 1970's, according to Perevolotzky and Perevolotzky (1979). Part of the observed rise in the level of consumption may be due to an increase in size of the family.

The amounts of food products the South Sinai Bedouins received gratis from various welfare agencies appear in Tables 80 and 81. All Bedouins were eligible to receive economical support, although the amount of support depended largely on the individual's specific welfare situation.



Harvesting the dates at the Feiran Oasis

TABLE 79: Average monthly consumption by Bedouin families in South Sinai in the 60's and 70's (data from Perevolotzky and Perevolotzky, 1979).

Product	1960	1975
Rice	14 kg.	15 kg.
Sugar	8 kg.	15 kg.
Oil	5 kg.	7 kg.
Flour	18 kg.	40 kg.
Lentils	4 kg.	7 kg.
Vegetables	-	50 kg.
Canned meat	-	5 cans
Canned sardines	-	30 cans
Canned vegetables	-	10 cans
Poultry	-	3 units

TABLE 80: Support per month per capita received by South Sinai Bedouin from different welfare agencies including the Israeli government (kg)[1].

Food product	Full Support	Partial Support	Temporary Support
Flour	6.50	6.50	3.25
Soy beans	2.00	2.00	1.00
Rice	2.50	2.50	1.25
Lentils	0.50	0.50	0.25
Milk powder*	0.50	0.25	none
Canned butter*	0.50	0.50	none
Oil	0.50	0.50	0.25
Sugar	5.00	none	none
Tea	0.60	none	none
Additional money	equivalent to value of products	up to 50% of value of products	none

[1] Official information received from the Israeli Ministry of work and Welfare for 1978.

* received from the Red Cross occasionally

Full welfare support - to those with no other income

Partial welfare support - to those with partial income

Temporary suport-to those with permanent income, every three months

TABLE 81: Number of South Sinai Bedouins receiving food support (full or partial) in 1979, according to data supplied by the Israeli Ministry of Work and Welfare.

	Full support	Partial support	Temporary support	TOTAL
Place*	No. of indiv.	No. of indiv.	No. of indiv.	No. of indiv.
Santa Katharina	80	21	1344	1445
El-sahab Tarfat Qiderein	92	43	913	1048
Feiran A Wadi Sulaf	49	18	302	369
Feiran B Wadi Tar	64	10	531	605
Um-Gsur Ilianes, Nasrin	99	29	664	792
Wadi Raraged Wadi Sidri	144	34	639	817
Abu Ga'ada Tar	79	16	856	951
Wadi Baba	25	5	203	233
El-ramla	86	9	545	640
Bir Nasib	78	14	451	543
Et-Tur	125	19	890	1034
Hereize	35	7	598	640
Dahab	127	51	769	947
Nuweiba	96	11	680	787
Waset	39	18	327	384
Khasham Altarif	52	11	339	402
TOTAL	1270	316	10051	11537

*see Fig. 1

Note:Different sources present different numbers for the South Sinai populations between 1970-1980. In the present case there is some infiltration of elements which are not formally included in the Towara framework (e.g. Tarabin).

Full welfare was given to those with no source of income, and included food products, and a sum of money equal to the value of the food products given. Partial support was given to those who had some source of income, and consisted of the same amounts of most of food products as given for full support, but half the amount of money. Temporary support was given to all other Bedouins, and included about half the amounts of food products as above, with no financial support. The level of financial support was determined according to the average salary per month of the Bedouins in the region. Food was usually received from three main sources: the CARE Organization (USA), the International Red Cross, and the Military Governor of South Sinai.

In addition to our anthropometric study on the Bedouins, we gathered information on the kinds of food consumed by Bedouin children in the Sinai. We prepared a special form written in Arabic listing 79 different kinds of food (including wild herbs that Bedouins are accustomed to eating). These forms were distributed in ten different schools in South Sinai, and the teacher cooperating would every morning write down for each pupil the items consumed the previous night (without stating amounts). This procedure continued for one week, in some cases 2 weeks, and was repeated every 6 months over a period of 3 years. Thus we could evaluate the changes in types of food habits over both brief and extended periods, as well as the influence of seasonal changes on food consumption. Other fluctuations in the kind of food consumption as a consequence of economic instability to which a Bedouin family is exposed were also recorded as well as the effects of cultural and social happenings, such as holidays, religious ceremonies, marriage, circumcision, etc.

a. The geographical factor

We chose four geographic regions in South Sinai, each with its own typical Bedouin economy. First was the coastal region (Dahab, Nuweiba) in order to assess the piscatory component in the Bedouin `food basket'; second, the large, water-rich oasis (Feiran), to check the agricultural component; third, the dune regions, serving as grazing land (G'hamlat-Hemaier, Bir Beida), to assess the contribution of sheep to the diet; and fourth, the mountain region (Nasrin) as a neutral region with no apparent economic or nutritional "advantages" of any kind.

The results are indicated in Table 82 and may be summarized as follows. With the exception of the coastal region, where an average 30% of the children eat fish daily, there are no significant differences between the regions in the array of food items made available to the children. Territorial location of a tribe apparently is no major factor in the available food items afforded its children with the possible exception of the coastal Bedouins.

b. <u>The seasonal factor</u>

On seasonal differences in the food staple one can learn from a comparison of the data for Dahab area which were collected in the end of the winter and beginning of spring, with those which were collected at the end of the summer and beginning of winter (Table 82). It should be pointed out that for the majority of food products, there was no difference in the consumption rate, the primary differences being in the consumption of milk and milk products, and mutton. In the winter, when pasture is abundant, the sheep produce more milk and some of the numerous lambs are sacrificed (mainly the male animals). Concurrently, there is a drop in the consumption of fish, primarily because of the strong winds blowing in the bay which cause high waves and prevent fishing near the coral reefs. In the summer, the situation reverses, mutton becoming rare, and fish consumption increases considerably; vegetables and fruits also become more prevalent.

A Bedouin child might taste meat only at a special festive occasion. Indeed, a month could pass between one meat "meal" and the next.

The main staples in the children's diet are various flour products, primarily "phatir"; the latter is a bread variety favored by Bedouins, comprised of flour and water only. Other common food items are rice and lentils.

<u>Energy sources and calorie consumption in South Sinai Bedouins compared with various populations</u>

All estimates were based on data obtained from welfare agencies as well as on our questionnaire data and our personal knowledge of Bedouin economy. We estimated the caloric intake of a Bedouin child (aged 8-9 years) between 1500-1800 calories per day. Since our calculation takes into account only the main energy sources (flour, rice, oil and lentils) the mean caloric intake (1667 kC) might actually be somewhat higher. This number is very similar to that obtained by Pervolotzky and Pervolotzky for the Gebeliya tribe (1979).

TABLE 82: Food consumption by Bedouin children in South Sinai: Percentage of children who obtain one of the enumerated food items per day .

Region	Coastal Plain					Mountains		Dunes		Oasis*
Tribe	Muzeina					Gararsha		Aleigat		All tribes
Place	Dahab				Nuweibba	Nasrin		Bir Beida		Feiran
Product/Dates	Feb.	Mar.	Apr.	May	Feb.	May	June	May	June	Apr.
Staples										
Sugar	84.9	-	85.1	79.0	-	-	-	-	-	85.7
Milk	95.2	64.0	43.4	49.5	96.0	68.2	79.8	73.2	76.9	37.9
Eggs	15.7	6.8	10.0	10.3	2.2	1.5	0.8	7.1	4.3	36.6
Rice	54.5	48.8	57.1	48.0	58.2	58.7	48.7	46.4	48.3	57.1
Meat (1)	9.8	7.1	6.3	4.5	8.2	1.5	6.7	3.5	7.6	5.0
Fish (2)	38.4	32.0	32.2	27.3	36.0	5.0	0.0	6.2	2.1	4.8
Bread (3)	82.7	80.5	79.0	71.4	84.5	77.7	78.9	66.9	70.3	73.4
Sweets (4)	10.9	3.4	24.9	19.4	29.7	26.1	22.6	17.8	-	29.7
Vegetables A (5)	16.2	17.1	10.0	8.8	22.2	19.0	21.0	23.2	16.4	11.9
Leguminous plants (green) (6)	1.0	0.0	5.1	2.7	2.8	1.5	0.8	1.3	0.0	2.0
Leguminous plants (dried)(7)	37.3	26.8	29.7	26.4	26.2	29.3	-	24.1	28.5	20.6
Vegetables B (8)	11.3	1.7	11.5	14.8	15.4	11.1	-	16.0	9.8	18.3
Local cooking plants (9)	4.3	0.0	3.0	4.2	2.8	0.0	-	5.3	12.0	1.6
Condimemts (10)	4.0	2.4	2.4	0.0	2.3	0.0	0.0	0.0	0.0	1.0
Citrus fruits(11)	13.5	0.0	10.3	7.9	14.2	10.3	-	5.3	0.0	6.5
Deciduous fruits (12)	0.0	-	4.5	3.3	2.8	1.5	-	1.7	0.0	2.5
Local fruits (13)	8.4	-	3.6	1.2	0.5	0.0	-	0.0	0.0	0.0
Other fruits (14)	0.0	-	3.3	8.5	0.0	0.0	-	0.0	0.0	0.0
Preserve	2.9	-	0.9	1.8	1.7	0.7	-	0.0	0.0	0.0

*The Feiran oasis is inhabited by people from all Bedouin tribes of Sinai

-No information

Note: Many fruits (e.g. figs. pears) and vegetables (e.g. beets, lettuce) were excluded from the table since they are rarely included in the Bedouin food basket.

1 Including chicken, mutton and canned meat; 2 Including dried, fresh and canned fish (tuna, sardines, etc.); 3 Israeli bread, local bread (patir, pita), biscuits, bagels, macaroni, etc.; 4 Chocolate , candy, waffles, chewing gum, etc.; 5 Potatoes, carrots, radishes.; 6 Horsebeans, beans, peas, other pulses.; 7 Lentils, beans, peas, pulses, etc.; 8 Corn green peppers, cucumbers, onions, tomatoes, cabbage, etc.; 9 Meluchia, gergir, rijla, etc.; 10 Pickles, canned tomatoes, olives, etc. ; 11 Oranges, mandarins, etc.; 12 Apples, apricots, peaches, etc.; 13 Dates, rapes, almonds.; 14 Watermelon, etc.

In Table 83 we show the average caloric consumption in several populations of contrasting economies. As noted, the caloric consumption of the Bedouin child population of South Sinai is low, and their dietary combinations differ widely, compared with other groups. Not only do the proportions of their energy-yielding foods differ greatly, but also the sources by which they are obtained. The intake of energy from protein is low among South Bedouins, comprising only up to 7% of the total caloric intake, compared to 13-14% for other comparable groups. Worth noting is that protein needs (grams per day), according to European standards of 30-50 gr at age 5, 50-80 gr at age 12, 50-90 gr for adult males, and 40-70 gr for adult females (Weiner, 1977), are far beyond the amount available to South Sinai Bedouins. This protein inadequacy is one of the great dietary hazzards of these Bedouins. Fat comprises 23% of the total caloric intake, which is similar to that in Israeli and British groups, much lower than that of Eskimos, and higher than that of the Kikuyu (Kenya). The main staple in Bedouin society is carbohydrates, about 70% of the total caloric intake, which appears to be true also for many African populations, whereas in Israeli and British child populations, this dietary component provides only 50-58% of the total caloric intake.

TABLE 83: Average daily caloric consumption and daily intake per person of protein, fat, and carbohydrates in five contrasting economies[1].

Calorie sources							
Region	Calories	Protein		Fat		Carbohydrates	
		g/day	%	g/day	%	g/day	%
South Sinai (Bedouin)	1667	28	6.7	43	23.3	290	70.0
Israel*	2920	130	21.8	71	26.9	305	51.3
Britain**	3000	100	13.4	110	33.1	400	53.5
Kenya (Kikuyu)**	2153	100	18.5	22	9.2	390	72.3
Alaska (Eskimos)**	3100	377	47.1	162	45.5	59	7.4

[1] % = percent of total caloric consumption

* from Baily (1972)** from Weiner (1977)

In sum, the Bedouins can be categorized in nutritional terms as a "low protein,high-carbohydrate" dietary group (Weiner, 1977, p.410), in spite of being a pastoral society with large herds of sheep and camels, and having to import carbohydrate sources (mainly cereal grains) due to poor cultivation conditions. Consequently, the Bedouin children suffer a chronic lack of protein.

Correlation between body structure, climate and caloric consumption

The customary formula for estimating the body weight factor in energy consumption, according to Gugenheim (1964) is: $E = 152 \times W^{0.73}$, or $E = 815 + (36.6 \times W)$, E representing the needed energy in calories, W designating body weight in kg. Thus, a male weighing 45 kg should consume 2450 calories per day and a man weighing 80 kg requires 3730 calories. The Bedouins have a comparatively slight body structure. An average Bedouin adult male weighs 57 kg and is 169 cm tall, and accordingly his energy consumption would be, according to the formula, 2908 calories. In contrast, the average Israeli adult male weighs 71 kg and is 174.5 cm tall (Kobyliansky et al., 1979-1980), requiring an energy expenditure of 3413 calories. The average Bedouin adult woman, weighing 49 kg and 156 cm tall, would require about 2000 calories per day, compared to an Israeli adult woman who weighs an average of 56 kg, and is 160 cm in height, requiring some 2375 calories. The sex factor is also important in that a woman consumes fewer calories than would a man of the same height and weight.

Another factor affecting energy consumption is the climate. According to various computations, an increase of 5 degrees C in the mean annual temperature results in a reduction of 2.5% in the caloric intake, while a 5 degree C drop in the annual temperature leads to a 1.5% increase in the caloric intake (Gugenheim, 1964). Consequently, in South Sinai, which is a relatively warm region compared to most areas on the European continent, the caloric intake per day of the Bedouin is lower by approximately 7.5-10% than that of the European of comparable age.

In sum, owing to differences in body size and climatic conditions, adult Bedouins generally require on the average almost 900 calories less than do Israelis and Europeans. The above calculations are not totally applicable for children since the developmental process demands additional caloric expenditure.

Influence of age and physical activity on the caloric intake

The caloric expenditure is dependent also on age and physical activity. Between the ages of 20 and 30 years, a man is at the height of his physical activity and thereafter his physical activity and basal metabolism are on the decline (Gugenheim, 1964). It has been noted that after 30 years of age for each decade up to age 50, the caloric intake diminishes by 3%, each decade from 50 to 70, by 2.5% and each decade from 70 on, by 10% (Gugenheim, 1964). A growing boy requires a relatively large amount of energy and the faster the rate of growth the greater the caloric requirement. Taking into account the mentioned conditions (e.g. body build, climate), the question arises as to the needed caloric intake for proper development of a Bedouin boy. According to American standards, children aged 4-6, whose mean weight is 18 kg and mean height is 109 cm, require 1700 calories per day; those aged 7-9 with a mean weight of 27 kg and height 129 cm, require 2100 calories; those 10-12 years of age with a mean weight of 36 kg and a height of 144 cm require 2500 calories; and finally, children aged 13-15 with a mean weight of 49 kg and a mean height of 162 cm need 3100 calories for proper development. If we take into account that Bedouin children live in warmer regions, show different patterns of growth, and probably are less physically active than American children, we may estimate that Bedouin children of comparable ages would need 300-500 fewer calories for proper development, e.g., for age 6, 1500 calories; for age 8, 1800 calories; and for age 12, 2100 calories. Yet, and despite corrections made for temperature, body build and physical activity, the number of calories available to the Bedouin children is less than the above "norm".

The influence of nutrition on growth

It is well established that an insufficient supply of food hampers the growth of children (Tanner, 1962). Most of the studies supporting this assumption belong to one of two categories. The first comprises studies made on human societies that had undergone a nutritional crisis and then reverted to their normal level, as in the case of wartime populations (e.g. Ellis, 1945; Howe and Schiller, 1952; Kimura et al., 1959). The main conclusion drawn from such studies was that following the nutritional crises which hamper development, at a later "normal" stage the children regain their full biological development. Studies of the second type are more controlled and are performed mainly on animals. Such studies show that only the most deficient nutrition can harm the growth process to an irreparable extent. In most instances, improved nutrition will "restore" the animals to their normal level (Schultze, 1955; Widdowson and McCance, 1960).

From the 1960's on, the majority of investigations on growth and development have been focusing on the correlation between social status (with its nutritional implications) and development of children (e.g. Douglas and Simpson, 1964; Barry and Robert, 1978; Rona et al., 1978; Schutte, 1980; Little et al., 1986). The main conclusions from these studies are: a)children of low social status present comparatively lower values of weight and height; b)the morphologic differences between children of different social strata are already evident at very early ages, usually pre-school; c)the smaller dimensions of children of lower social status stem from retarded development and late sexual maturation; d)children of low status may `catch up' with children of higher status at a later age, provided their diet is improved.

The question of adequate nutrition for proper development among Bedouin children has two unique aspects: First, there is almost no socioeconomical stratum among South Sinai Bedouin families, and therefore all Bedouin children can be studied as a single group; and second, the Bedouin children of today are the products of a long-time adaptation to nomadic life in the desert, and of a special diet. Selection was in favor of those who could properly develop under the harsh desert conditions, i.e., those who manifested physiological and morphological characteristics, such as small body size, low rate of basal metabolism, etc., which were advantageous under conditions of inadequate nutrition. Their "advantage" lies in their reduced demand for energy.

There is also some evidence suggesting that reduced body size may be an adaptive response to poor nutrition (Frisancho et al., 1973; Stini, 1975), although the latter has been found to be associated with higher morbidity and mortality (Martorell et al., 1981), reduced physical working capacity (Shephard, 1985), and reduced muscular strength and motor performance (Malina and Buschang, 1985). To be sure, the Bedouins have "weeded out" behavioral habits in which energy costs were too high. Thus, the low rate of physical activity is not the result of laziness, as ascribed in so many travellers' reports (e.g. Burckhardt, 1822; Robinson, 1841). Rather, by a combination of physical traits and daily activity, present-day Bedouin children succeed in growing and developing fairly adequately despite the small quantity, poor quality and lack of variety of their food.

A respectable study carried out on the diet in an African tribe is relevant in this connection. Thus Fox (1953) showed how the balance between calories expended and calories available is reached in an African tribe during one year, and how the group was content with a low level of activity, working no harder than necessary, and their body weight kept low. Yet, when intake of energy increased, the opposite was observed.

Studies undertaken recently, contrary to many published works, indicate that poor nutrition does not necessarily hamper the intellectual capacity, nor even physical activities, but only causes change in the behavioral pattern (Robin et al., 1983).

VII. INBREEDING LEVEL AND MORPHOLOGICAL DIFFERENCES BETWEEN AND WITHIN SOUTH SINAI BEDOUIN TRIBES

In the last part of this chapter we shall attempt to ascertain whether the distribution of the morphometric traits in the tribes and sub-tribes of Bedouins in South Sinai deviate from the norms observed in large populations with random matings. If, indeed, deviation should be observed, we could attribute a not inconsiderable portion of the observed genetic variability to inbreeding (albeit selection and genetic drift could also come into play).

Theoretical Background

In previous chapters we have discussed the possible drop in heterozygosity in the Bedouin tribes, and the possible influences of inbreeding (mainly first-cousin marriages) on the phenotype of the group. We now consider the link between inbreeding and morphometric traits in the Bedouin. Crow and Kimura (1970, p.83) in their discussion of inbreeding noted possible changes in the mean and variance of a trait (e.g. stature, weight, etc.) within populations with different levels of inbreeding under various models of dominance and epistasis

The concept that inbreeding leads to an increase in the proportion of homozygotes in the population, was developed via the inbreeding coefficient by Wright (1921). Wright was thus the first to offer a tool for estimating the extent of inbreeding in a population. This tool has been refined and adapted for various population conditions, both by Wright himself and by some of his associates (e.g. Kimura, 1955; Crow and Kimura, 1970; etc.). Crow and Kimura (1970) showed that the frequency of heterozygotes in the population drops at the rate of $1/2Ne$ (N= the effective population size) per generation (independetly of the number of alleles involved).

Let us here attempt to translate theory into practical terms. In an panmictic population the distribution of the genotypes for a given trait will appear approximately as follows: at the center of the distribution curve and around it there will be a concentration of individuals heterozygous for a particular trait, while the homozygotes will appear at the margins.

The Statistical Processing

Our age-tribal samples of Bedouin boys were small, primarily due to the small size of the total South Sinai Bedouin population. Hence we were forced to "increase" the samples by converting measures into standard scores for each age-tribal group separately, and by combining standard scores of all children of a particular tribe, regardless of age group. Taking these new distributions, we performed the necessary statistical manipulations, that is, the measures of skewness and kurtosis ("peakedness") for evaluating the new distributions and their deviations from the norm.

The computation of these two statistical measures (kurtosis and skewness) was done according to SPSS, Condescriptive Statistics (Novusis, 1990).

In a distribution which has a totally symmetric bell-shaped curve, skewness and kurtosis measures acquire the value of zero. It may be recalled that when the scores tend to trail off to the right, or positive end of the scale, it is considered positively skewed; conversely, when scores tend to trail off to the left, the negative end of the scale, it is negatively skewed. If the kurtosis value is positive, the distribution is more peaked (narrow and high, designated as leptokurtic), whereas a negative value implies a flattened curve (platykurtic).

In view of the small size of the samples on which our computations were based, we necessarily relied mainly on calculations specific for small samples (Johnson, 1949; D'Agostino and Pearson, 1973; Dunaveskeya et al., 1973) to determine the deviations from normal distribution as expressed in the measures of skewness and kurtosis.

Distribution of quantitative traits in the various tribes of South Sinai

The measures of skewness and kurtosis for the distributions of each of the studied morphometric traits among boys in four tribes are given in Table 84. As noted in the table, the several Bedouin tribes manifest only a few (2-3) traits that appear statistically significant, with no special tendency towards skewness or kurtosis.

On the basis of these results, we conclude that most of the physical traits in all of the Bedouin groups display a close approximation to a normal distribution, i.e. follow a fairly symmetrical bell-shaped curve. The few traits deviating from the normal curve may be products of genetic processes acting within small isolated groups, or indeed the result of inadequate sampling.

Although not statistically significant, it seems noteworthy that of the 41 traits considered, the distribution of 38 showed negative kurtosis in the Gebeliya tribe, 22 such in the Muzeina tribe, all 39 in the Hamada-Aleigat group, and 32 in the "other" or remaining tribes. There is indeed a tendency in large panmictic populations for some of the morphometric trait distributions to present negative kurtosis (Wolanski and Takai, 1976), but not at the rates and frequencies observed in the Bedouin tribes of South Sinai. As noted in Table 84, a negative skewness occurred less frequently than a positive skewness. Skewness and kurtosis differed both in regard to traits, and frequency of each among the tribes. For example, in the Gebeliya tribe the trait "Hand length" had a high negative kurtosis and a positive skewness tending towards zero, whereas in the Muzeina tribe this trait manifested positive kurtosis and a positive skewness (Table 84).

TABLE 84 Kurtosis (K) and skewness (S) for some metric trait distributions in different Bedouin groups.

TRIBES								
	Gebeliya (N=66)		Muzeina (N=253)		Hamada&Aleigat (N=64)		Others (N=134)	
Variable	K	S	K	S	K	S	K	S
Stature	-0.238	0.359	-0.336	0.187	-0.319	0.200	-0.249	0.059
Iliospinal height	-0.385	-0.019	-0.180	0.080	-0.612	0.349	-0.111	-0.037
Tibial height	-0.280	-0.132	-0.353	0.219	-0.832	0.346	-0.136	-0.005
Acromial height	-0.310	0.236	0.632*	0.419*	-0.439	0.274	-0.380	-0.037
Sitting height (1)	-0.109	0.493	-0.081	0.171	-0.679	0.219	-0.643	0.187
Foot breadth	-0.623	0.359	-0.338	0.110	-0.734	-0.291	-0.367	0.051
Foot length	-0.891	0.016	-0.234	-0.078	-0.320	-0.216	-0.541	0.071
Head length	-0.906	-0.236	0.095	-0.291	-0.396	0.070	-0.404	0.142
Head breadth	-0.699	-0.575	-0.512	0.048	-0.772	0.213	-0.758	0.351
Bizygomatic breadth	-0.994	-0.224	-0.436	0.204	-0.670	0.252	-0.758	0.208
Bigonial breadth	-0.231	-0.655*	2.543*	1.077*	-0.426	-0.260	-0.283	-0.480*
Morphological facial ht.	-0.845	0.075	-0.395	-0.079	-0.535	0.140	-0.015	-0.220
Biacromial breadth	0.309	-0.756*	-0.108	-0.030	-0.293	-0.253	0.203	-0.320
Biiliac breadth	-0.761	0.004	-0.140	0.163	-0.975	0.130	0.237	0.598*
Chest circumference	-0.195	0.527	-0.68*	0.072	-0.780	0.058	0.012	0.349
Body weight	-0.535	0.541	-0.140	0.324	-0.926	0.268	-0.316	0.085
Hand strength (L)	-1.128*	-0.029	-0.470	0.167	-0.293	0.059	-0.449	-0.013
Hand strength (R)	-0.218	-0.141	0.130	0.093	-0.326	0.075	-0.190	-0.029
Total arm length	-0.527	0.195	0.337	0.387*	-0.471	0.326	-0.424	-0.024
Upper body segment	-0.068	-0.231	0.777*	-0.412*	-0.318	0.251	0.098	0.263
Upper leg length	-1.147*	0.098	0.419	0.192	-0.728	0.198	0.248	0.286
Upper arm length	-0.307	0.374	0.481	-0.092	-0.045	0.703*	-0.139	0.258
Lower arm length	-0.213	0.143	1.393*	-0.021	-0.314	-0.004	-0.060	-0.184
Hand length	-0.629	0.003	0.172	0.212	-0.404	0.167	0.257	0.094
Trunk length	-0.130	0.177	-0.077	-0.001	-0.156	0.096	-0.608	-0.055

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Table 84: cont.

Body weight/Stature^3	-0.627	0.173	0.025	0.298	-0.585	-0.111	-0.053	0.286
Body weight/ Stature^2	-0.756	0.103	0.176	0.312	-0.641	-0.021	-0.321	0.114
Total arm length/Stature	-0.821	-0.279	0.063	0.066	-0.373	0.046	-0.228	-0.122
Sitting ht.(1)/Stature	-0.647	0.366	1.689*	0.015	-0.723	-0.175	-0.053	0.008
Leg length/Stature	-0.652	0.260	-0.275	-0.014	-0.911	0.027	-0.382	-0.427
Foot br./Foot length	-0.672	0.291	-0.097	-0.141	-0.219	0.462	-0.225	0.067
Head br./Head length	-0.653	0.555	0.525	0.495*	-0.836	0.121	-0.531	0.226
Biacromial br./Stature	0.111	-0.604*	-0.457	0.079	-0.722	-0.429	-0.332	-0.107
Biiliac br./Stature	-0.903	-0.088	-0.512	0.040	-0.824	-0.253	-0.722	0.217
Chest circumf./ Stature	-0.687	-0.083	0.257	-0.252	-0.560	0.162	-0.644	0.100
Body weight/Stature	-0.739	0.453	-0.032	0.247	-0.867	0.187	-0.295	-0.019
Body surface area	-0.530	0.459	-0.337	0.261	-0.957	0.141	-0.424	0.069
Body surface area/ Body wt.	-0.922	-0.219	0.075	0.024	-0.360	-0.195	0.003	0.069
Kj	-0.538	0.541	-0.136	0.324	-0.934	0.294	-0.306	0.081

Note: Sitting height (1) differs from Sitting height (2) - see Tests and/or explanations chapter. Upper arm and subscapular skinfolds were excluded from the analysis because they have highly positive skewed distributions also in panmictic conditions.

* $p \leq 0.05$

Adult Bedouin during argometric test (standing R. Nefesh)

Distribution of quantitative traits in the Muzeina tribe and its sub-tribes

In the Muzeina sub-tribes (Table 85), the distribution measures of the traits differ from those in the tribe proper (see Table 84). For example, in the Shadadine, 13 traits show significant kurtosis. Significant skewness obtained for 9 distributions (eight positive and one negative), the same in which significant kurtosis was displayed with the exceptions of body weight and sitting height.

When we combine the four sub-tribes Shadadine, Dararme, Gawanme and Gsenat into a single group, and weight the sample size for each sub-tribe to compute a group result, we obtain results which are almost identical to those obtained for the entire tribe which included all six sub-tribes without weighting their relative size in the general tribal population.Only in one trait, namely, hand length, is significant skewness observed in the distributions for the four sub-tribes, which was not observed for the tribe as a whole (Table 85).

In sum, the data on skewness and kurtosis provide no strong evidence of inbreeding on the expression of the various morphometric traits in the tribes or the sub-tribes. Yet, despite the lack of statistical significance for skewness and kurtosis in most of the distributions, we cannot ignore the relatively high values of these measures. We believe that such high values for most of the traits studied, at least suggest a tendency for deviation from the "normal" distribution.

As is known, skewness and kurtosis are sensitive measures of `normality' of distribution, and in samples smaller than 100 even the slightest deviations from the norm drastically affect their values. Thus, for instance, narrow and tall curves which are based on small samples are liable to show negative skewness because at one tail of the curve there is a fortuitous high frequency of cases. The fact that we obtain negative skewness for such a curve, however, can be misleading, and may not reflect the `true' distribution of the trait.

We therefore decided to employ two additional measures as a check on our skewness and kurtosis results. First, we constructed for each trait separately the distribution of its frequencies according to the `Frequencies-SPSS' procedure (SPSS, 1975). Because we replaced the raw scores of the individuals with standard scores, the x-axis carries units of standard normal deviates (at intervals of 0.5 units, ranging from +5.0 to -5.0), while the y-axis presents the frequencies in percentages; and second, we constructed distributions of traits representing different components of explained variance selected by Principle Component Analysis, and determined their deviations from the normal distribution.

In addition to the statistical tests, a detailed examination of the actual distribution pattern of the various morphological traits within the South Sinai Bedouins was also carried out.

TABLE 85 Kurtosis (K) and skewness (S) for some metric trait distributions in different Muzeina sub-tribes.

SUB-TRIBES								
	Shadadine (N=22)		Dararme (N=27)		Gawanme (N=30)		Gsenat (N=79)	
Variable	K	S	K	S	K	S	K	S
Stature	3.642*	1.548*	-0.211	0.215	-0.441	0.706	-0.487	0.117
Iliospinal height	3.422*	1.706*	-0.844	-0.020	-0.154	0.266	-0.149	-0.001
Tibial height	3.785*	1.438*	-1.024	0.329	0.143	0.312	-0.538	-0.164
Acromial height	0.929	0.743	-0.256	0.207	-0.550	0.549	-0.041	0.105
Sitting height (1)	0.932	-0.093	0.300	0.710	-0.040	0.208	-0.167	-0.169
Foot breadth	-0.354	-0.285	-0.538	0.711	-0.642	0.233	-0.269	0.001
Foot length	-0.765	0.050	-1.101	0.184	0.074*	0.290	-0.247	-0.201
Head length	0.297	-0.262	-0.554	-0.025	-0.117	-0.397	0.778	-0.666*
Head breadth	-0.951	-0.147	-0.356	0.237	-0.591	0.006	-0.600	0.247
Bizygomatic breadth	-0.062	0.558	0.554	0.177	-0.359	-0.020	-0.738	0.023
Bigonial breadth	1.890*	0.943*	0.823	-0.917*	7.029*	2.073*	-0.753	0.098
Morphological facial ht.	0.072	-0.344	-0.508	0.011	-0.264	0.187	-0.651	-0.219
Biacromial breadth	0.051	-0.435	0.690	-0.771	-0.018	0.005	-0.406	-0.002
Biiliac breadth	-0.613	0.262	0.009	0.134	0.910	-0.043	-0.185	0.109
Chest circumference	-0.111	0.330	-0.317	-0.077	0.627	0.732	-0.865	0.029
Body weight	1.616*	0.493	1.234	0.416	0.586	0.773	-0.418	0.305
Hand strength (L)	0.743	0.781	-1.187	-0.041	0.447	-0.012	-0.526	-0.123
Hand strength (R)	-0.863	0.108	1.337*	-0.155	-0.101	0.038	0.034	0.263
Total arm length	4.608*	1.306*	-0.858	-0.070	0.483	0.572	0.275	0.298
Upper body segment	0.142	0.904	0.171	-0.740	-0.723	-0.109	0.846	-0.193
Upper leg length	2.649*	1.421*	-0.766	0.006	-0.652	-0.255	1.654*	0.471
Upper arm length	-1.130	0.107	-0.279	-0.612	1.016	-0.447	-0.211	0.106
Lower arm length	3.257*	1.391*	-0.763	-0.177	-0.297	0.213	0.650	0.246
Hand length	0.760	0.570	0.108	-0.201	0.366	0.847	-0.494	-0.046
Trunk length	-0.034	-0.599	-0.450	-0.327	0.672	0.628	-0.197	-0.123
Body weight/Stature^3	1.019	0.132	-0.079	0.231	-0.246	-0.105	0.384	0.359
Body weight/ Stature^2	0.282	0.337	0.432	0.627	0.133	0.225	0.461	0.203
Total arm length/Stature	-0.608	-0.414	0.475	0.371	-0.536	0.008	-0.402	0.427
Sitting ht.(1)/Stature	4.292*	-1.403*	-0.551	-0.632	2.872*	1.154*	1,355*	0.043
Leg length/Stature	-1.217	-0.302	0.799	0.664	0.426	-0.498	-0.638	0.009

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Table 85: Cont.

SUB-TRIBES								
	Shadadine (N=22)		Dararme (N=27)		Gawanme (N=30)		Gsenat (N=79)	
Foot br./Foot length	-0.148	0.210	-0.075	-0.139	-0.552	0.061	-0.104	-0.148
Head br./Head length	-0.304	0.876	-0.458	0.080	2.974*	1.134*	0.320	0.477
Biacromial br./Stature	-0.864	0.328	-0.401	-0.558	-0.770	0.132	-0.221	0.103
Biiliac br./Stature	0.385	-0.175	-0.023	0.702	-0.668	-0.176	-0.364	-0.104
Chest circumf./Stature	0.319	0.801	-0.078	-0.198	0.191	-0.090	0.439	1.029*
Body weight/Stature	0.745	0.298	1.155	0.500	0.501	0.600	-0.294	0.092
Body surface area	2.195*	-0.928	0.491	0.322	0.042	0.590	-0.595	0.257
Body surface area/Body wt	0.557	0.406	0.643	0.323	-0.325	-0.164	0.390	0.042
Kj	1.658*	0.507	1.241	0.422	0.588	0.774	-0.404	0.299

* significant $p \leq 0.05$

For notes, see Table 84

Distribution of traits representing different components of morphology, as detected through PCA. Muzeina tribe.

The distributions of 8 variables (converted to standard scores) representing, according to PCA, different aspects of child morphology correlated weakly with one another, as noted in Table 86. These variables are examined relative to theoretical normal distribution in Figures 31-38.

Prof. Ben-David (Kobyliansky) taking head circumference measure from an adult Bedouin.

TABLE 86: A correlation matrix between eight morphological traits in Muzeina boys, aged 5-13 years.

PC[1]	LV[2]	Trait	St	LAL	CC	HB	UBS	HL	HAL
I	.958	Stature (St)	-						
I	.618	Lower arm length (LAL)**	.523	-					
I,II	.576	chest circumference (CC)*	.554	.346	-				
IV	.746	Head breadth (HB)	.205	.085	.206	-			
X	.476	Upper body segment (UBS)**	.517	.204	.259	.047	-		
VIII	.854	Head length (HL)	.301	.219	.157	.026	.231	-	
V	.694	Hand length (HAL)	.337	.167	.164	-.073	.233	.167	-
I	.439	Morphological facial ht.	.392	.258	.237	.082	.298	.123	.131

[1]PC= Principal Component

[2]LV= Loading Value

* Statistically significant negative kurtosis

** Statistically significant positive kurtosis

FIGURE 31:Standard Score Distribution of Body Height in Muzeina Boys, Compared to Normal Theoretical Distribution.

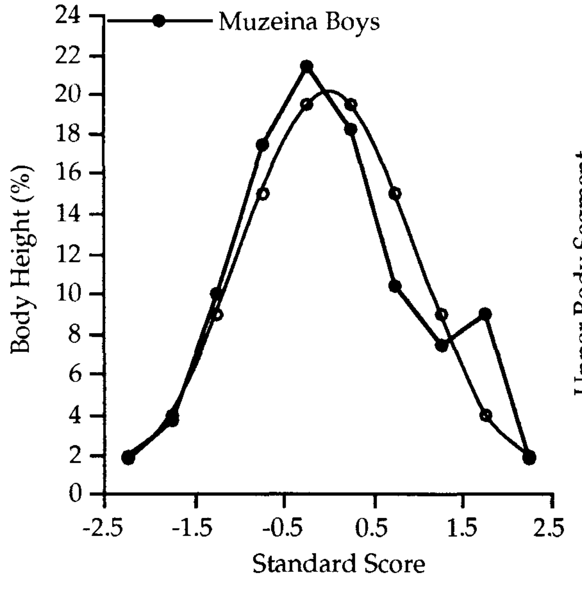


FIGURE 32: Standard Score distribution of Upper Body Length in Muzeina Boys, Compared to Normal Theoretical Distribution.

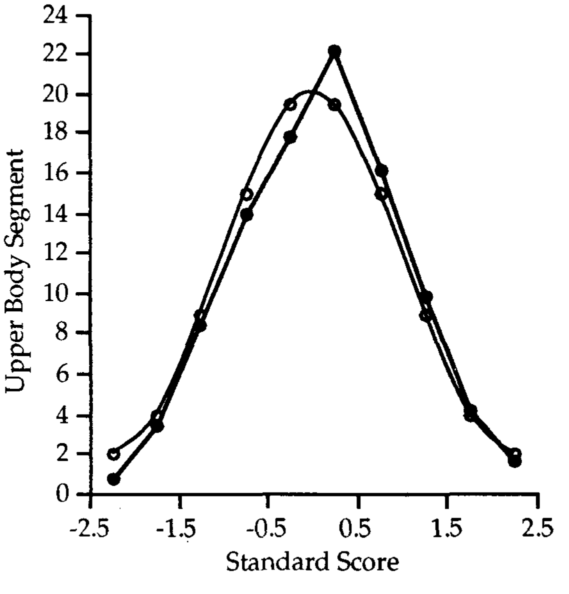


FIGURE 33:Standard Score Distribution of Facial Height in Muzeina Compared to Normal Theoretical Distribution.

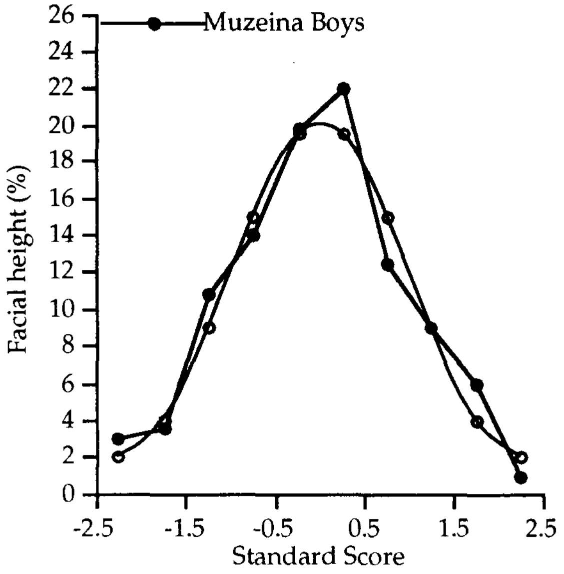


FIGURE 34: Standard Score Distribution of Head Length in Muzeina Boys Boys, Boys, Compared to Normal Theoretical Distribution.

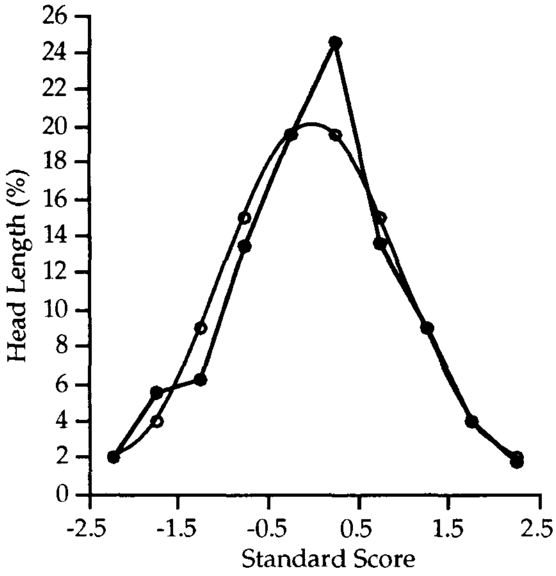


FIGURE 35:Standard Score Distribution of Hand Length in Muzeina Boys Compared to Normal Theoretical Distribution.

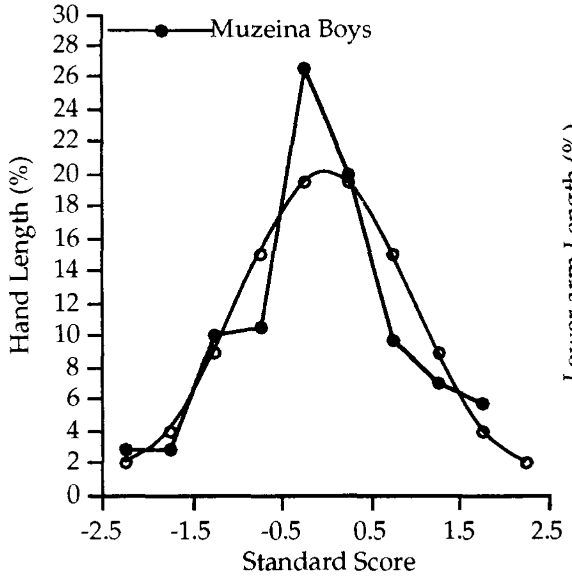


FIGURE 36: Standard Score Distribution of Lower Arm Length in Muzeina Boys, Compared to Normal Theoretical Distribution.

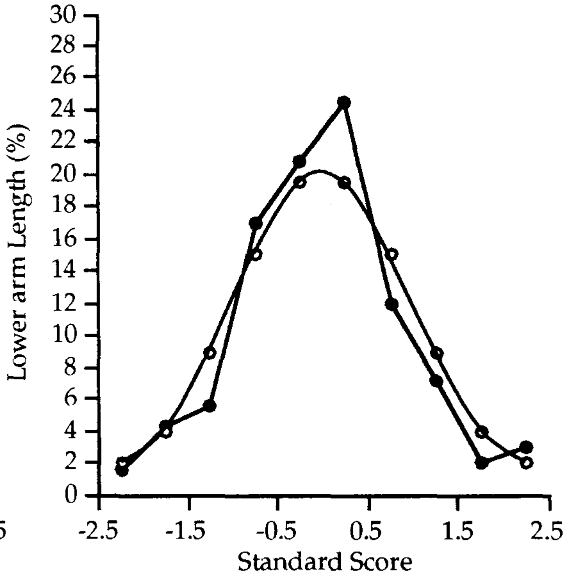


FIGURE 37:Standard Score Distribution of Chest Circumference in Muzeina Boys, Compared to Normal Theoretical Distribution,

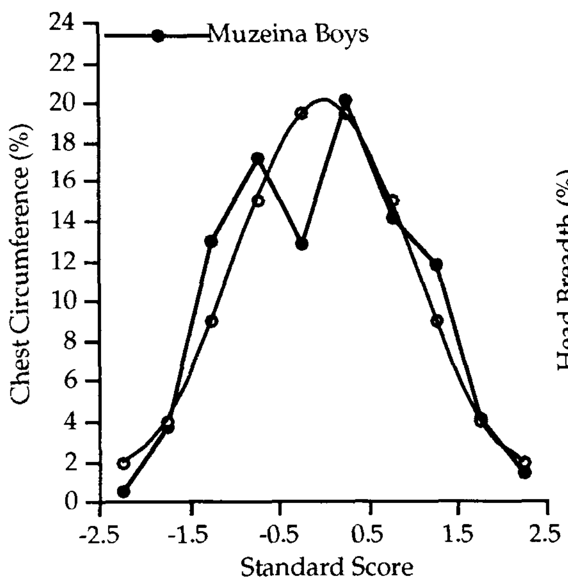
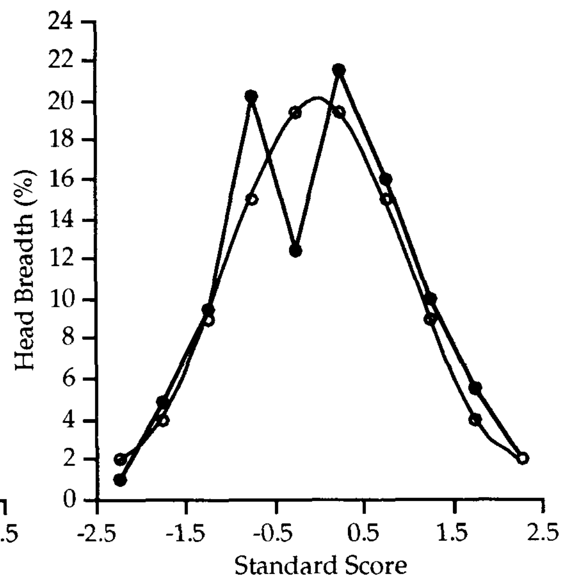


FIGURE 38: Standard Score Distribution of Head Breadth in Muzeina Boys, Compared to Normal Theoretical Distribution.



Three different types of distribution are recognized. First, more or less "bell-shaped" distribution curves are noted for stature, upper body segment length, and facial height (Figs. 31-33) second, there is a more narrow and peaked distribution for head length, hand length and lower arm length (Figs. 34-36); and third, one notes a bimodal distribution for chest circumference and head breadth (Figs. 37-38).

It would seem that two main forces may be acting on these traits, namely inbreeding and stabilizing selection. Inbreeding leads to a diminution in the number of heterozygotes and a reciprocal increase in the number of homozygotes.

On the further assumption of parallelism between the distributions of biochemical traits (whose gene frequencies are known) and that of quantitative traits (see Kobyliansky and Livshits, 1983), it becomes possible to use morphometric trait distributions to measure a decrease in heterozygosity of a population or group, provided that the observed phenomena are not the outcome of `disruptive selection' which there is no good reason to assume in the present instance. When a trait distributes normally, 50% of the cases will fall within the range of ±0.67 standard deviations from the mean, which we consider as indicative of heterozygosity in individuals. In a population in which effective inbreeding occurs, there will be a diminution in the proportion of cases falling into this range (±0.67 S.D. from the mean), a state which represents a decreased number of heterozygotes and a corresponding increase in homozygotic individuals.

This link between a drop in heterozygote frequency and inbreeding, expressed in terms of F, can thus be estimated from the following equation: $M_2 = M_1x(1\text{-}F)$, where M_1 is the theoretical percentage of heterozygotes in the normal distribution (panmictic condition) and M_2 the corresponding percentage in the new distribution (inbred condition). The difficulty, as already noted, is how to construct phenotypic units that can fit the various genotypes. On the assumption that the external expression of the trait is determined by a number of loci and that the non-additive component among these is low, we can then postulate the existence of a `super locus', that is, a single "imaginary" locus which is responsible for the phenotypic expression of the trait. Thus we could assume that the heterozygote cases indeed concentrate about the mean for the trait while the tails would contain the homozygote cases, as would be expected in a system of mono-loci. The diminution in the heterozygosity of such a `super locus' would be gradual, proceeding from the center to the tails.

We now return to the previously proposed computation system $M_2 = M_1x(1\text{-}F)$. If in a normal distribution of a trait 50% of the cases are at a distance of ±0.67 standard deviation from the mean, then in a population in which the inbreeding coefficient is F=0.09802 the 50 percent level will decrease to 45.1%, a drop of 4.9% in the number of heterozygous individuals for the given trait in the population. If we limit the range of heterozygosity in the distribution to only ±0.5 standard deviation from the mean, then for the Bedouin inbred population with F=0.09802 the expected number of heterozygous individuals will be about 34.5%. Now we may calculate the relative decrease in heterozygous individuals directly from the plotted metrical trait curves. In the two traits in which there is a bimodal distribution, the heterozygosity (within the range of ±0.5 S.D.) diminishes to 32.8% for chest circumference and 34.2% for head breadth. These observed values are very close to the expected 34.5% under an inbreeding pressure of F=0.09802.

The drop in the frequency of heterozygotes described above is understandable because of its linkage with inbreeding and explains the bimodal curves that were obtained for some of the traits.

We shall now attempt to ascertain the action of the second factor, stabilizing selection, on the shape of the curves observed. Stabilizing selection, or selection which acts against the tails and in favor of the middle of a distribution curve, is generally related to the increase in number of heterozygous cases. The effect of this mechanism is to reduce the variance in the population (Roughgarden, 1979, p.140). Evidence for stabilizing selection has been obtained in both human and animal studies. For example, it was found that among neonates with extreme values of weight and height, the mortality was higher than among neonates which were closer in these two respects to the population mean (Cavalli-Sforza and Bodmer, 1971; Ulizzi et al., 1981). The process whereby the individuals homozygous for morphologic traits are less resistant than the heterozygous individuals, coupled with the fact that heterozygous parents tend to be more fecund than homozygous parents (Goldstein and Kobyliansky, 1984; Kobyliansky and Livshits, 1983), lead to a constant increase in the number of individuals who are heterozygous for a given trait.

The influence of `stabilizing selection' (Se) on the frequency in the population of individuals heterozygous for a considered trait can be computed from the following equation: $Se = (M_{obs.} - M_{exp.})/M_{exp.}$, where $M_{exp.}$ = mean ±0.5 standard deviation. This equation indicates the relationship between the observed frequency of heterozygotes and that expected within the limits of a defined standard deviation. For example, in the trait of lower arm length, there is an increase of 19.1% in the frequency of the heterozygotes as derived from the following computation: Se =(45.6%-38.3%)/38.3% where 45.6% = the observed heterozygote frequency in the range of ± 0.5 S.D. from the mean of the lower arm length trait in the Muzeina tribe (Table 87), and 38.3% = the expected heterozygote frequency in the range of ±0.5 S.D. from the theoretical mean of the trait in a large population with random breeding.

TABLE 87 Changes in the frequency of "heterozygous"-modal individuals for some morphological traits, as affected by stabilizing selection and inbreeding.

Traits	Obs.-Exp./.Exp.
Stature	4.2
Lower arm length	19.1
Chest circumference	-14.4
Head breadth	-10.7
Upper body segment	9.4
Head length	15.1
Hand length	26.9
Morphological facial height	-4.7

Of the eight morphological traits examined (Figs. 31-38) six (stature, lower arm length, upper body segment, head length, hand length) show an increase in the frequency of heterozygotes, ranging from 4.2-26.9%, and three (chest circumference, head breadth, facial height) show a decrease (4.7-14.4%).

The question which naturally arises at this point is which of the traits are affected by selection and which by inbreeding? Or we could pose the further question that if each of the traits is affected by both these forces, which of the two ultimately determines the expression of the trait?

The answers to such and similar questions are not unequivocal. Insofar as we have selected traits which are not interdependent (see the correlation matrix, Table 86), let us also assume axiomatically that they are based on different genes (even though they are multifactorial). Inbreeding characterizes a given population. There is clear evidence of its existence in the Bedouin population (high F value) and, therefore, it comprises a factor in determining the expression of a trait, probably in a bimodal distribution. The evidence in the literature for the occurrence of selection against homozygous individuals is overwhelming, and consequently it also cannot be ignored. Hence, we conclude that in the Bedouin population, stabilizing selection `counteracts' the effects of inbreeding. It follows, therefore, that the true effect of stabilizing selection, as computed by percentage of individuals heterozygous for a particular trait, is actually higher but is somewhat offset by the influence of inbreeding.

Thus far we have assumed that the tribe (i.e., the Muzeina, Gebeliya and the like) is the biological unit in which the forces of selection and inbreeding act. This assumption is predicated primarily on the relatively high percentage of intermarriages among the sub-tribes (ca. 75%) and on the low rates of intermarriage between the tribes (3%). Yet, because female migration between sub-tribes is somewhat selective, and because the rate of first-cousin marriages is very high, it seems reasonable to assume that some of the morphological traits will distribute differently among the sub-tribes. To examine this assumption we chose eight morphometric traits which are poorly correlated (Table 86), in order to ensure independence of the variables. For four sub-tribes of the Muzeina for which the representative sample sizes were fairly adequate (Shadadine, Dararme, Gawanme and Gsenat), we computed the frequency distribution. Since all individual scores were standardized, all age groups for each sub-tribe could be combined. We postulated that if these four sub-tribes differ somewhat in their genetic composition, we should obtain as a result (at least for chest circumference and head breadth which are platykurtically distributed in the total Muzeina sample) a leptokurtic distribution for each trait in each sub-tribe. The genetic translation of this result would be a) a decrease in the percentage of heterozygous individuals compared to a panmictic "normal" population and a rise in the percentage of homozygous individuals; and b) distributions which are highly positively or negatively skewed. Whether a sub-tribe will manifest a positive or negative skewness for a specific metric trait is random. Genetically, this means that concentration of the homozygous individuals in each sub-tribe in one of the tails of the curve is random.

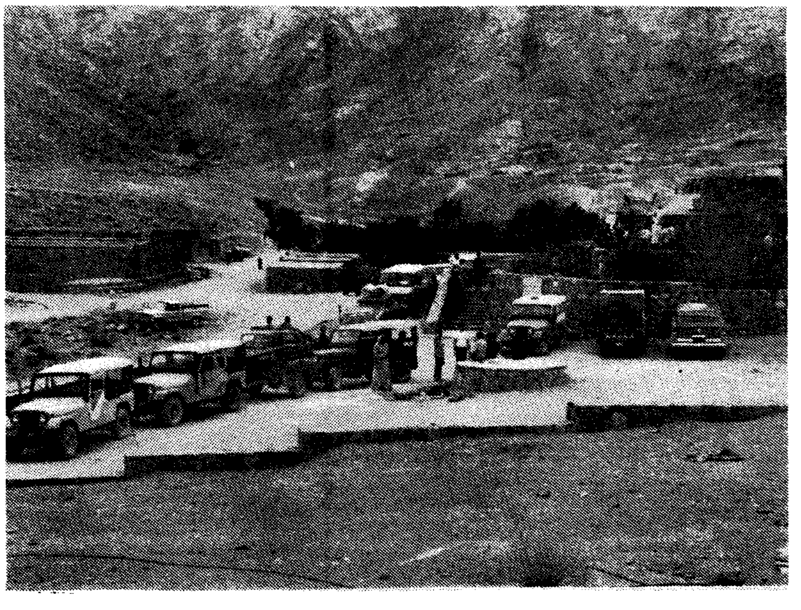
Our results show that, as expected, in two of the eight examined traits, namely, chest circumference and head breadth, there is a significant drop in most of the sub-tribes, in the percentage of individuals who are heterozygous for the trait. The mean frequency of "heterozygous" individuals for the trait of chest circumference is 32.8%, whereas the expected drop as a result of inbreeding (F=0.09802) is to 34.5% [from the computation of 38.3% X (1-F)]. Three sub-tribes show a clear decrease in the number of "heterozygous" individuals (Shadadine=33.4%; Gawanme=25.9%; and Gsenat=24.6%) and one shows an increase (Dararme=46.6%). Regarding the trait of head breadth, the observed mean of heterozygous individuals was 34.2%, also very close to the expected value. Among the sub-tribes, the frequency ranged from 31.0-36.7%. In all the remaining traits, there was no decline in heterozygotes; of the two traits which did show a decline in heterozygote frequency, only chest circumference displayed fortuitous intersubtribal fluctuations of "homozygous" individuals on both sides of the curve. For example, in the Shadadine most of the individuals "homozygous" for chest circumference (47.7%) concentrated at the left side of the curve and only 19.1% at the right side, while in the Dararme sub-tribe 36.7% of "homozygotes" concentrated on the right side of the curve (in contrast to the Shadadine) and only 16.7% on the left. However, for head breadth, the majority of "homozygous" individuals in all four sub-tribes concentrated on the left side of the curve. These results at first glance appear to be unlike the expected, i.e., random bunching of "homozygous" individuals on one side of the curve owing to randomness of the allele fixation, but since we are dealing with only four groups, the probability that most of the "homozygous" individuals will occur randomly on the same side of a curve for a particular trait in all four sub-tribes is fairly high. For the sake of completeness of the statistical analysis, we further tested whether the drop in number of heterozygotes expected as a result of inbreeding pressure, is also statistically significant for the two selected traits of chest circumference and head breadth.

We found that the kurtosis was indeed negative but its significance was only borderline. The various reasons that could account for the lack of significance of this parameter in most of the distributions have already been discussed.

We attempted another way of assessing the significance of the kurtosis values for chest circumference and head breadth. This time we used a test that takes into account only part of the overall distribution (±0.5 S.D. from the mean) and not all of it (as in the previously used test). Thus we hoped to reduce to a minimum the influence of extreme cases on the general nature of the distribution, for this is highly significant for such distributions as are based on small samples (Rokitzky, 1974). The underlying assumption of this test is that the difference between observed and expected frequencies will not be greater than the standard error of the observed values. Thus: S.E. of Obs. = $\pm\sqrt{p|n-p|}/n$ (Rokitzky, 1974, p.40), where n = the observed frequency and p = the expected frequency.

For chest circumference the data were: Exp. (P)=0.383x180=68.94, Obs. (N)=0.328x180=59.04, the Difference=9.9. According to the above formula, S.E. of Obs. (N) = 6.29, and because (Exp.-Obs)>S.E. of Obs. (9.90>6.29), the drop of kurtosis in the distribution of this trait is significant.

The same computation was made for head breadth, where the raw data were: Exp. (P)=0.383x187=71.62, Obs. (N)=0.342x187=63.95 and the Difference=7.67, resulting in S.E. (N)=6.48, and because 7.62>6.48 the drop in kurtosis for the distribution of this trait is also significant.



Leaving the Sinai

VIII. SUMMARY AND CONCLUSIONS

Most populations in the world today reside in more or less man-made environments. Relatively few have remained in the natural ambiance in which they had developed for hundreds or even thousands of years, continuing to maintain direct ties with it. One of the latter, as we have shown, is the South Sinai Bedouin group which adopted the arid areas of the Middle East as its permanent residence, adapting to this extreme environment biologically, socially and behaviorally.

The first chapter introduced the study, especially the influence of the marriage patterns on the growth and development of the child in human isolates. The relevant published literature on the subject is also reviewed. The aims of the study are stated, namely, to elucidate the connections between historical, demographic and social variables on the one hand, and the biological structure of the human population on the other. Following was a study of growth and development, perforce by the cross-sectional method. Next, the characterizing features of the studied population are considered, namely, isolation, inbreeding, uniformity of the environment, uniformity of the population, small-size of population, transitory aspects and tribal organization. Penultimately, the sample is described, comprising 563 boys between the ages of 5-13 years and deriving from nine different tribes in South Sinai. Finally, the `tools' of the study are enumerated, including techniques of anthropometric measurements.

The second chapter reviews possible links between cultural variables (historic, ethnographic and demographic) and biological variables (organization of the genotypes into the various social frameworks).

In the historical area, we have provided the testimonies of numerous investigators and travellers, commencing in the 19th century (Burckhardt, 1822), as regards the origin of, and the ethnic ties between, the various tribes, thereby reconstructing possible biological relationships among the tribes. Our study revealed that the Bedouin tribes of South Sinai initially immigrated from various other regions, albeit having a historic depth of 800 to 1000 years in their present region. The origin of most of the tribes was found to be the Arabian peninsula. They comprise four major groups, represented by the Gebeliya (mixed origin: North Africa, Middle East, Europe); the Muzeina; the Aleigat-Hamada tribes; and the group comprising the Awlad Said, Gararsha and Sawalcha tribes. Conclusions were evaluated in light of genetic evidence gleaned from various studies aimed at establishing similarity or disparity between the tribes in gene frequencies of various biochemical systems.

In the ethnographic portion of the second chapter we defined the organizational levels of the social institutions, namely, tribal suprastructure, tribal affiliation, tribe, sub-tribe, clan (khamula), extended family, and biological or nuclear family. The organizational-social structure of each of two tribes (Muzeina and Gebeliya) was discussed at length. These two tribes were frequently compared. In the biological context, we discussed all the "affiliated families" adopted by the various tribes and, with time, incorporated by them. We have shown that such families, albeit becoming part of the organizational framework of the tribe, were not always integrated into its biological framework, i.e. females from these families were not taken as brides by members of the tribe. Special emphasis was placed on the means of studying the Hams, the "blood feud" group. We have shown that the Hams, despite constituting only a judicial framework, serves as the best source for studying intratribal social dynamics and reconstructing marital patterns going back five generations. The information gathered from the study of some 55 "blood feud groups" (genealogical lines, comprising about 3000 individuals) revealed that the Sinai Bedouins comprise an endogamous society at the tribal level, 97% of marriages in the Muzeina tribe taking place within the tribe, with a certain preference for consanguineous marriages, 14.6% of the marriages being between first cousins.

In the demography portion of the second chapter we presented the main demographic characteristics of the South Sinai tribes. The average number of sub-tribes per tribe was found to be 4.2; the mean number of members per tribe was 1150 (range 183-3000); the number of nuclear families ranged from 56 in the smallest tribe to 880 in the largest. Cited are the revolutionary demographic changes that took place among the South Sinai Bedouins as a result of Israeli Defence Forces presence in the area from 1967 to 1982. The three main changes were first, the cessation of Bedouin movements westward to Egypt; second, a rise in rates of fecundity and a decrease in mortality and a consequent rise in average life expectancy, and thirdly, the foundation of families at a relatively early age (marrying age of males dropping from 26 to 20). Such "changes" inevitably led to a rapid numerical increase of the population (from 0.62% per year prior to 1967, to 2.2% at the time of the study). We have presented detailed demographic data on the composition and size of the social frameworks, discussing also the connection between size of the social framework and its genetic composition. We presented and analyzed the demographic characteristics of the entire Bedouin population in the Sinai, for example, age and sex distribution, fertility and mortality patterns, social regulation of fertility, etc. It was noted that curbing excessive growth of the Bedouin population would be dependent largely on external factors (e.g. birth control), since the socio-economic infrastructure after

1967 encouraged birth. We discussed the problem of a high male to female sex ratio among the Bedouins, showing that the most convincing explanation for the phenomenon is the so-called X-heterosis.

The main findings in the final, demographic part of the second chapter were:

1) the population tended to be young, as many as 44% being in the 0-14 years age group (G_{15}+G_{16}); 2) a high male to female sex ratio of 106.9 (G_{16}); 3) as much as 6.9 percent of families, beyond the reproductive period and without children (G_{15}); 4) a high proportion of remarried women (17%); 5) prevalence of second marriages; 6) a low marrying age both for females (17.5 years) and males (23.0 years) (G_{15}+G_{16}); 7) a high mean number of living children per family (5.0 by the time of menopause); 8) overall familial fecundity of 6.98 children; 9) on average, wives of polygamous males bear fewer children (4.03) than do those of monogamous males (5.0); 10) male mortality higher than female mortality by 6% in the child population; 11)a clear link between consanguinity of parents (first cousin marriages) and mean number of children per family; 12)a low number of polygamous families (12.1%).

In the third chapter we discussed the complex of factors which influence the genetic makeup of the Bedouin population. We relied here on the existing historical, ethnographic and demographic information compiled in the previous chapter. We considered the subject of `effective population size' and the factors which affect it directly, such as differential fertility, sex ratio, polygamy, temporary changes in population size and consanguineous marriages. In addition, we discussed the various ways of computing `effective size' (Ne). We found that in a population like the Muzeina tribe, with approximately 3000 members, "effective size" would be only 846 individuals, and not an expected 1000. We reasoned that such an Ne size (800-1000), although diminishing the genetic variability in the tribe (Fixation index = 0.000591), cannot be the pivotal mechanism which accelerates this process.

A considerable portion of the third chapter was devoted to elucidation of the inter- and intratribal migratory processes in the Muzeina. It was shown that almost all of the population mobility (up to 97%), measured by comparing husband and wife origins in 300 families, took place up to the tribal level. Of all marriages within the tribes, in the Ghesenat subtribe, as an example, about 77% were marriages where both husband and wife were of the same sub-tribe, and of the remaining couples, more than 20.5% of the wives were from sub-tribes which genealogically were close to the sub-tribe of the husband (i.e., sub-tribes which share a common ancestor). Consequently, we concluded that the tribe or sub-tribe should be regarded not only as a social-organizational framework, but also as an `independent biological group'.

Extensive study of the various mating types helped to illuminate certain aspects of `internal migration' within the tribes. We defined six mating types and computed their frequency in the various subtribes of the Muzeina. These were: Hams or cousin matings (3.8-14.6%), extended family matings (18-22.4%), clan matings (33.7-45.7%), sub-tribal matings (8.5-12.9%), tribal matings (11-15.0%), and tribal affiliation mating (2-4%). For each of these we computed, with the aid of the Hams records and the genealogical structure of the tribe, the genealogical depth common to both mates, namely, two generations for Hams matings; 6 for extended family matings; 8 for clan matings; 10 for sub-tribal matings; and 12 or more generations for tribal matings. All this information pertaining to frequency of the various marital patterns on the one hand, and the common genealogical depth of the mates in each marital pattern on the other hand, enabled us to compute the relative contribution of the endogamous component (Fxe=0.0038615) to the coefficient of inbreeding - F. Thus we possessed most of the components for computing the general inbreeding coefficient F for the most recent generation of the Bedouin population, using the series of equations developed by Wright (1931).

The components at hand were: effective population size (Ne) = 846; migration into the tribe (M) = ca. 3%;; marital patterns (Fxe) = 0.0038615. We found that the F value for the last generation (the 16th since the Muzeina tribe was involved) equals Fxi_{16}=0.0044502. This value did not seem to us to adequately represent the true biological status of the tribe, mainly because it did not take into account the contribution of preceding generations (FA) to the F. Ignoring a continuing process of inbreeding, taking place over hundreds of years within a small group, could crucially affect the value of F. Therefore, by a careful reconstruction of the demographic history of the Muzeina tribe, based on two different models of the dynamics of intertribal social processes, we evaluated the contribution of preceding generations (FA) to the F. The FA component, we discovered, produced a critical change in the magnitude of the inbreeding coefficient value (F) and thus completely altered our thinking on the genetic structure of the Bedouin society. The new F value obtained for the Muzeina tribe was 0.09802, a very high value that has rarely been recorded for any other human population.

Since we had data on the gene frequencies in the different tribes for various biochemical systems (blood group P, haptoglobin, sensitivity to phenylthiocarbamide, ABO blood groups), we could determine whether it was justified to assume a high inbreeding coefficient for the population. The obtained results were almost identical with the calculations based on socio-demographic data (F=0.09802). In addition we tried to elucidate which of the two factors, genetic drift or selection, lead to the observed intertribal differences in gene frequencies. We examined the relationship between the observed and expected variance of the inbreeding coefficients (F_{ST}) and found that the observed variance ($S^2_{obs.}$) was significantly lower than the expected variance ($S^2_{exp.}$). Hence the difference in gene frequencies was attributed to random processes, such as genetic drift, rather than to selection.

In the third chapter we also considered the connection between a high inbreeding coefficient and biological variables. A review of the literature revealed that even if there was no complete consensus regarding the extent of influence of inbreeding on morphometric traits, the existence of such an influence is hardly debatable. The chapter concluded with a detailed review of the factors which were likely linked to the biological structure of the Bedouin society (with respect to history, ethnography and demography).

The fourth chapter considered growth and development processes in the Bedouin children examined, boys aged 5-13 years.

We opted to determine chronological age by three different criteria, namely, chronological age as reported (information provided by the child himself in conjunction with important events that took place in the South Sinai region, and/or by the school teacher or the local sheikh); dental age; and skeletal age. We showed that the reported chronologic age tended to be somewhat higher than the "biological" age, i.e., age based on stage of bone development or tooth eruption. Yet, considering the fact that the correlation coefficients between the biological and chronological ages were high ($0.89>r>0.81$), we decided to compare growth and development in Bedouin children with those in non-Bedouin children by their chronological age.

The main conclusions arrived at from comparing development in Bedouin and European boys were the following: The Bedouin children developed faster in weight and height at the early ages than did the European children. Since no data were available for Bedouin boys under 5 years, this conclusion derived mainly from comparison of theoretical regression lines of the two groups. Starting from age 7, however, the gap between the two groups closed, and subsequently the European children were found to develop faster than the Bedouin. In bodily breadth traits, within each age group, none of the Bedouin boys attained the mean values of the European boys. At age 13 the Bedouin boys resembled children of other Middle East groups but were shorter than their European counterparts. In body weight the Bedouin boys manifested the lowest mean values of all the compared groups, excepting low-caste Indian children. The Bedouin boys had a relatively narrower head and short face compared with like diameters in European children. As for the body extremities, up to about age 9 the Bedouin boys had on the average longer limbs than European boys but at subsequent ages the situation reversed. Amount of subcutaneous adipose tissue was comparatively low in Bedouin boys, and so also was their energy expenditure needed to perform a defined task.

By use of measures linking body to shape, we were able to summarize the morphologic differences between Bedouin boys and those from European countries as follows: Bedouin boys had a narrower body build relative to their stature; longer limbs relative to stature; a lower weight per unit of surface area; and a negligible amount of subcutaneous fat.

After examining the morphological differences between Bedouin boys and children of some other ethnic groups in the fifth chapter, we compared the body size and shape of Bedouin children from the different tribes in South Sinai. We concentrated mainly on the morphological differences between children of the Muzeina and Gebeliya tribes. The statistical processing of the data was by the two-way analysis of variance, with geographical origin, age and interaction. Our results showed that the Gebeliya children had, on average, a narrower head and longer face than Muzeina children. The latter possessed a broader body structure, e.g. broader shoulders, broader hips and greater chest circumference, both in absolute terms as well as relative to stature. Both Muzeina and Gebeliya boys had the same mean stature, but the former weighed more on average and had more subcutaneous adipose tissue and a lower ratio of body surface area to body weight.

The significant morphologic differences between the Muzeina and Gebeliya boys found expression in body surface area, the ratio of body surface area to body weight and the ratio of body surface area to stature, all invariably having lower values in the Muzeina group.

Concerned that the observed differences between the tribes might be due to the small samples in each age group, we combined all the age groups into a single sample for each tribe by converting the measurements into standard scores and constructing new distributions (a legitimate procedure considering that the MANOVA result did not show significant Age x Tribe interactionn effect). We then performed a one-way analysis of variance (ANOVA) since one factor, age, was now canceled out. To this analysis we added another, the statistical Scheffe method which enabled assessment of how the morphologic distances between individuals from the two tribes, Muzeina and Gebeliya, were affected by inclusion in the sample of individuals from other tribes. The obtained results were almost identical with those obtained by MANOVA on the small "age-tribal" samples. Yet, before ascertaining conclusively the reality of morphologic differences between the Bedouin children at the tribal level, we felt the need to rule out the possibility that the observed morphology in each tribe was actually a combined one, i.e., where each sub-tribe contributed to the overall morphology of the tribe although each had its unique morphological identity and differed largely from the other sub-tribes. Such a possibility seems likely if we take into consideration the fact that 77% of marriages are between members of the same sub-tribe. The genetic implications of such a possibility are discussed at some length.

We examined the morphological differences between boys of the sub-tribes in the Muzeina and the Gebeliya tribes. In the Muzeina tribe, all the sub-tribes have a common ancestor. Hence, what can lead to group differentiation here would be the fact that most of the brides (75%) originated from this framework; hence there was endogamy at the sub-tribal level. In the Gebeliya tribe, ancillary to the high percentage of marriages at the sub-tribal level, was the fact that one of the sub-tribes, the Awlad Gindi, was probably Egyptian in origin. The morphology of boys in the Gebeliya sub-tribes (Awlad Gindi vs. the Wehebat, Hamaida and Awlad Salim) was compared by a one-way analysis of variance based on standardized scores. The results showed that one-third of the traits studied manifested significant differences between the boys of the Awlad Gindi sub-tribe and the boys of the three other sub-tribes. We found the Awlad Gindi children taller in all body height measures; with a broader head and longer face; a broader girth; weighing more; and having longer limbs than the children of the other three sub-tribes, as well as manifesting greater body surface area and caloric expenditure per defined task.

In the Muzeina tribe three different groups were recognized, namely, Group 1 (Shadadine and Smehat subtribes, with Alwan as ancestor); Group 2 (Gsenat and Dararme subtribes, with Farag-Ali as ancestor); and Group 3 (Gawanme subtribe, with Faraj-G'hanen as ancestor). The obtained results indicated less marked morphologic differences than those between children of the sub-tribes of the Gebeliya. The discriminant traits which significantly differentiated between children of the Muzeina sub-tribes numbered only five or six, such as between Groups 1 and 2 in foot breadth and length, upper leg length; between Groups 2 and 3 in foot breadth, head length, chest circumference, trunk length, cephalic index, and chest circumference/ stature; between Groups 1 and 3 in sitting height, upper leg length, hand length, and chest circumference/stature. We concluded that the evidence showed little morphologic difference among the Muzeina sub-tribes. However, we did note a certain consistency in the direction of the differences, and therefore reasoned that the few significant results found in the Muzeina sub-tribes might be a forerunner, as it were, of future greater morphologic differentiation. And indeed when the morphology of children from each sub-tribe was examined separately, and not in groups of sub-tribes, the differences between the children became more pronounced and even correlated, surprisingly, with what we knew about the genealogical ties between the sub-tribes (see Chapter II), to wit: the morphological differences between children from subtribes, classified as genealogically remote from one another, are greater then between children from close subtribes.

It would seem, therefore, that morphologic differentiation between the children followed, to a considerable extent, socio-biological differentiations. Hence an important lesson was learned, that even in tribes regarded as a homogeneous group, i.e, having a common ancestor, there may arise, as a consequence of social processes, e.g. selective marriages, social frameworks such as sub-tribes which differ biologically from one another.

Once the morphologic differences between the tribes were established, we sought the reasons for such, as presented in the sixth chapter. We proceeded in four "directions" (altitude, nutrition, tribal origin, and marital patterns) as possible explanations.

1) Altitude. There is a marked disparity in altitude between the peripheral regions and the central region in the topography of South Sinai. At least two regions can be defined whose microclimates and vegetation differ considerably. One of these regions is that of the mountains, reaching an altitude of 1200-1400 meters, while the other is the coastal region or sea level. We chose the Muzeina tribe as our study model because it is the only tribe that has members scattered both in the mountain region as well as along the coast. To evaluate the effect of the topographic "altitude" variable (the first independent variable) on the "morphologic structure" variable (the dependent variable), while controlling the "origin-subtribe" variable (the second independent variable), we processed several runs of two-way analysis of variance. In each run we changed the components of the "origin" variable by running different sub-tribes. There was no significant influence of the altitude variable on the differential morphology in the Muzeina tribe.

2) Nutrition. Owing to the variegated nature of the South Sinai region, the economics in the different regions might have constituted a factor in the observed morphologic differences. Our extensive nutrition survey concentrated on four geographic regions, each of which presented a different economic picture. Thus the coastal region people subsisted largely on seafood as their major component in the diet; people in the the large water-rich oasis relied on

agriculture and orchards; the dune region depended on herding; and finally, the inhabited areas of the bare mountain region which offered no particular economic advantage. Our results showed that, barring the coastal region where, on the average, 30% of the children subsist once a day on seafood (summer only), the composition and content of the diet is rather uniform for the children of the various tribes in the different geographic regions in South Sinai. Therefore territorial localization of a tribe does not appear to afford any special economic advantage in terms of nutrition to its children.

The ancillary findings of our nutrition survey were also summarized in this chapter as follows: the available food is poor in variety; there were sharp fluctuations in the variety and quantity of the food from season to season; and the daily caloric supply was extremely low (computed as 1667 calories per day, with 70% derived from carbohydrates).

3) Tribal origin. A review of the history of the South Sinai tribes indicated that the origin of most of the tribes could be traced to the Arabian peninsula. However, oral historical accounts connect the Gebeliya tribe with geographic regions other than the peninsula (Egypt, Europe?). We assumed that if tribal origin played a role in defining intertribal morphologic differences, the differences between children of the Muzeina tribe and those of the Gebeliya tribe should be revealed by their relationship with other nearby Mediterranean groups. Hence, by means of cluster analyses, we estimated the morphological associations among boys of 7 groups, namely, the Muzeina and Gebeliya South Sinai Bedouin tribes; Kenous, Arab Nubian and Feddji from Egypt; and two Jewish Israeli groups, one with parents born in the Middle East, and the other with parents born in North Africa. We found that Gebeliya and Muzeina boys resembled each other morphologically more than they resembled any of the other boys. However, without exception, the morphological association of the Gebeliya boys with the Egyptian groups was greater than that manifested by the Muzeina boys, whereas the morphological resemblance of the Muzeina children to either of the Israeli groups was greater than that manifested by the Gebeliya children. These results partially confirm the accounts regarding an Egyptian element in the Gebeliya tribe, and repudiate the possibility of a European origin.

4) Marital patterns. Possibly marital patterns, that is, mode and extent of inbreeding among the tribes, could account for their morphological differences. In the introductory section we pointed out that the disagreement among investigators as to the influence of inbreeding on morphological and other variables is not on the actual existence of such an influence but rather on its

extent. We therefore assumed, knowing the social structure of the tribes, described in Chapter 2, that we could find evidence of inbreeding as a depressant influence in the growth and development of Bedouin children. As a first step, we discussed the possible decline in heterozygosity among the Bedouins with inbreeding, and the possible effects with time on the phenotype of the group due to intermarriage. In addition, our theoretical knowledge was broadened with respect to the association between the distribution of genotypes and quantitative (usually metric) traits. Our basic premise was that in a trait which distributes normally, the heterozygous individuals would concentrate around the average value, whereas the homozygous individuals would tend to occur at the extremes. We assumed that if in large populations with random matings most of the morphometric traits distribute normally or close thereto, then among the Bedouins (wherein the Ne, or effective size, is small and matings are not random), we should obtain for the studied morphometric traits deviations from the norm owing to changes in frequencies of the genotypes.

Since the measures were converted to standard scores, we could not employ the customary statistics for evaluating distributions, but had to rely on other measures, such as deviation from symmetry or skewness, and relative flatness of the curve or kurtosis. The criteria for obtaining significance for these two statistics were derived from tables especially constructed for small samples. The obtained results showed a relatively low frequency of traits that distribute with significant skewness and kurtosis. Thus, the Gebeliya showed two traits (upper leg length; hand strength left) with significant negative kurtosis and three with statistically significant negative skewness (bigonial breadth, biacromial breadth, biacromial breadth/stature) , whereas the Muzeina showed five traits with significant positive kurtosis (bigonial breadth, lower arm length, sitting height/stature, acromial height, upper body segment), one with negative kurtosis (chest circumference) and four with significant skewness (three positive; acromial height, bigonial breadth, cephalic index and one negative; upper body segment). In addition, we selected eight traits by Principal Component Analysis and reconstructed the observed frequency distributions at intervals of ±0.5 S.D. from the mean. We then compared them with the expected frequencies in normal distributions. Three major types of distributions were obtained, namely, 1)close to the normal distribution; 2)narrower and more high-peaked than the norm; and 3)bimodal. We concluded that the shape of the curve reflects primarily the action of two antagonistic forces: first, inbreeding, which leads to reduction in the number of heterozygotes in an endogamous population; and second, stabilizing selection, which acts against individuals at the edges of the distribution and leads to a rise in the number of heterozygotes. Through the inbreeding coefficient F (see Chapter 3), we calculated the expected drop in the heterozygote frequency as a result of inbreeding and compared it with that observed in the normal distribution where 38.3% of cases fall within ±0.5 standard deviations from the mean.

We assumed that in traits affected by inbreeding, there would be a decrease in the percentage of individuals concentrating around the mean, which would be proportional to the F. We showed that the inbreeding coefficient for the South Sinai Bedouins (F=0.09802) was expected to diminish on the 38.3% level (X±0.5 S.D.) by about 4% the frequency of heterozygotes in the population. Such a result was in line with the drop in the number of heterozygotes on the bimodal distributions, which reflected the influence of inbreeding. On statistical analysis we found that the drop in percentage of heterozygotes, as evident from the bimodal curves, was significant. The rise in the frequency of the heterozygotes, calculated from the narrow and tall curves to be 5% on the average, and attributed by us to the mechanism known as "stabilizing selection", was also found to be significant. It was concluded that in such traits where the forces of inbreeding and stabilizing selection met, they would cancel out each other's effects.

Finally, in the seventh chapter we attempted to ascertain tribal morphologic identity and the traits whereby this might be defined by means of discriminant analysis, by which we compared individual morphology with the mean morphology of the tribes. We computed the probability of successfully classifying children into their tribal group. In the first stage of our computation, we used a limited sample which included only the children of the Muzeina and Gebeliya tribes.

Our results showed that more than 78% of the children could be successfully related to their tribal group based on their morphology. When we enlarged the sample to encompass children from four Bedouin tribes, the success of classification diminished to 50.8%.

In summing up (eighth chapter) the subject of intertribal and intratribal morphologic differences, we defined main components, those single variables whereby one could define in the best way the Bedouin tribal morphology. Use of principle component analysis (PCA) revealed that by employing ten factors, we could explain 80% or more of the overall morphologic variance. Principal Component Analysis was based on standard scores of 41 morphological traits.

We also attempted to detect intertribal differences by the components of the morphologic variance (size and shape), defining a general characteristic common to each group of variables which represented a component of the variance as obtained from the PCA results. Our results showed that the morphological traits in which the tribes differed significantly are not necessarily concentrated in specific components.

Lastly, we assessed possible correlation between the historic-social evidence for the origin of and interrelations between the South Sinai Bedouin tribes, and the existing evidence on morphologic similarities and dissimilarities among them. It may be recalled that in earlier chapters we demonstrated fairly good correlations between the tribes with respect to various biochemical systems.

We attempted to "close the circle" between the first and last chapters by attempting to ascertain how the Bedouin tribes related from the standpoint of origin. For this purpose we resorted to cluster analysis, so as to join or dissociate the groups by the measurement of similarity or variance between the mean values for the traits. We found, both for the sub-tribes within the tribal framework, as well as for the tribes within the Towara, a greater morphologic similarity between tribes of similar origin.

As indicated, some of our conclusions are firmly founded; others, however, require further consideration and research.

Anthropological research is of critical importance for understanding past and present biological processes. And indeed we should remember that a human population displays close interrelations between its cultural history and its biological evolution. In the first chapter we stressed the fact that human populations still suitable for an anthropologic study such as ours were becoming scarce. The present study, which has dealt with the interactions between culture and biology within the Bedouin population has merely opened a small window on a limited subject, but constitutes, we hope, a gateway to a larger complex of universal biological problems which lend significance to the development of man as a sapient animal.

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APPENDIX 1:

Computation Methods of Population Effective Size

Two alternative methods of computing the overall effective size for the last generation (Ne_{16}) in the Muzeina tribe are here presented. Three different parameters were taken into consideration: Ne_s = the effect of sex ratio on Ne size; Ne_p = the effect of polygamy; and Ne_m = the effect of migration.

Method A

$Ne_{16} = Ne_1 + Ne_2$

When Ne_1 takes into account the effect of polygamy on Ne:

$[1/8\ Ne_p = (3/32\ N_f + 1/32\ N_m)]$

in proportion to its frequency (f_p) in the tribe:

$(Ne_1 = Ne_p \times f_p)$,

and where Ne_2 takes into account the sex ratio in the population:

$([1/Ne_s = 1/4\ N_f + 1/4\ N_m)]$

in proportion to the percentage of monogamy ($100-f_p$) in the tribe:

$Ne_2 = Ne_s \times (100-f_p)$.

Next we subtract the influence of immigration on the Ne:

$Ne_m = Ne_{16} \times (1-m)^2$.

The value of Ne_m is the effective size of the population with which we shall deal hereafter.

For the Muzeina tribe, we have the following data:

The sex ratio: N_m/N_f=106.9; the population size: N_{16}=3000; polygamy rate: p=12.1%; migration rate: m= 3%.

Normally, in a population of 3000 individuals, 1000 will be in their reproductive period. Considering the sex ratio (106.9), this group is composed of 515 males and 485 females.

Interpolation of these data into the formula yields for polygamy:

$1/8\ Ne_p = 3/16{,}480 + 1/15{,}520 = 507.23$

$Ne_1 = 507.23 \times 0.12 = 60.86;$

for the sex ratio:

$1/Ne_s = 1/4\ (1/515 + 1/485) = 999.11$

$Ne_2 = 999.11 \times 0.88 = 879.21;$

$Ne' = 60.86 + 879.21 = 940.07;$

and for migration rate:

$Ne_m = 940.07 \times (1\text{-}0.03)^2 = 884.51$

Method B

Let us use the formula for differential fertility in such a manner that the polygamy problem will be indirectly bypassed. We shall compute the Ne from the two components Nem and Nef (see chapter on "Factors which affect the genetic composition of the Bedouin tribes".) Clearly in a polygamous society, where there are probably more mothers than fathers, the values of vtw (variance in number of children per mother) and vtt (variance in number of children per father) will not be identical. After we obtain the values of Nem and Nef we shall compute the Ne from the sex ratio formula. We should mention that the sex ratio must be used whenever Ne is computed since changes in the sex ratio diminish the heterogeneity of the population proportional to it.

For the Muzeina tribe we have the data:
sex ratio = 106.9; the effective population size Ne = 1000.
kw = 3.06 vtw = 4.19
kt = 3.83 vtt = 7.42

$$Nem = \frac{Nmkt-2}{kt-1+vtt/kt}$$

$$Nef = \frac{Nfkw-2}{kw-1+vtw/kw}$$

Nem = 423.17

Nef = 422.43

Where kw and kt are the mean number of children per mother and father, respectively, Ne_m and Ne_f are the estimated number of males and females, respectively, in relation to the effective size (Ne) of the tribe in the 16th generation. The values obtained for Ne_m and Ne_f enable computation of the Ne in the following way:
1/Ne = 1/4 (1/423 + 1/422);

Ne = 846.15.

The difference between the value of the Ne obtained by the first method and that obtained by the second is relatively minor, having only marginal effect on the fixation index (influence of genetic drift).

APPENDIX 2:

Stages of Coefficient of Inbreeding (F) Computation in the Bedouin Population based on Muzeina data:

Computing Fxi_{16}

A. We compute Fxe_i for the tribe in the last generation as related to breeding patterns only:

1. $Fxe_i = \sum_{i=16}^{16} [\frac{1}{2}^{n'+n+1}]$

The mean result obtained is 0.003978.

B. We compute the effect of genetic drift during the last generation. In determining Ne we elected to use the result obtained by the second method (see Appendix 1), which is based mainly on the differential fertility and sex ratio formulas.

C. We compute Fxi for the 16th generation:

2. $Fxi_{16} = 1/2Ne + [(2Ne-1)/2Ne \times Fxe_i] = 0.004566$

Computing FA

The computation of FA, the contribution of the previous generations to the the F level, is problematic owing to the uncertainty which exists regarding the biological processes occurring in early generations. Hence, most investigators prefer to ignore this factor. However, in the present case it is mandatory to consider the FA because of the considerable effect it may exert on the final value of F. Ideally, the computation is done by the following formula:

3. $FA_{15}=1-(1-\Delta F)^{15}$

4. $\Delta F=(1-M)^2 \times [1/2\overline{Ne} + [(2\overline{Ne}-1)/2\overline{Ne}] \times F\overline{x}e]$

5. $1/\overline{Ne}=1/(t-1) \times [1/2Ne_1+ 1/2Ne_{2+...}+1/2Ne_{t-1}]$

6. $F\overline{x}e= \sum_{i-1}^{16} [\frac{1}{2}^{n'+n+1}] 15$

In as much as various factors (e.g. M = immigration rate, Ne = effective size, Fxe = breeding patterns, t = number of previous generations to common ancestor) exert a differential effect on F, we discuss each separately and show the necessary steps in their computation.

Computation of the different variables (M, Ne, $\overline{F}$xe)

Immigration rate (M): In the last three generations the immigration rate in the Muzeina tribe ranged between 2-4%. We have no information on immigration rates in earlier generations and therefore perforce must use the mean value of the immigration rates in the last three generations (3%) as a constant for all the tribal generations except the first five. Since the mean size of the Hams (blood feud group) starting from the 6th generation will thus remain constant (see below), the number of possible consanguineous marriages per generation will also remain constant.

Effective size (Ne): Computing the average weight or effect which genetic drift exerts on the F value in the Muzeina tribe was done in several stages: a) we calculate the rate of natural increase (P), the rate of population growth (r) and the doubling time (Dt) for previous generations; b) we calculated the population size per generation to a depth of 16 generations; c) we took a third of the population size and computed the breeding size of the population per generation; d) we computed the effect of differential fertility and sex ratio on the breeding size of each generation and on the effective size.

Coefficient of inbreeding ($\overline{F}$xe): The simple and easy way to achieve a partial solution of the problem would seemingly be to compute the coefficient of correlation between the group size and the frequency of the various breeding patterns, with emphasis on first-cousin marriages, and then construct a regression equation and use it to predict the Fxe values for the various generations. This system, however, has two main drawbacks. First, there is no linear correlation between the two variables and second, even more important, the structure of Bedouin society is such that the number of individuals in the Hams (blood feud group) after the first five generations (from the tribe's foundation) remains more or less constant regardless of the number of generations. Having assumed that neither the mean number of children per family nor the sex ratio changed in the last generations, we may justifiably argue that the number of first cousins in each generation remains fairly constant as well. What does vary is the number of second, third and fourth cousins who, however, as previously shown, exert little influence on the $\overline{Fxe}$. The number of blood feud groups in each generation will increase and so also will the tribe, but the mean number of individuals per blood fued group, regardless of generation, will remain more or less constant.

Method of computation. On the basis of the preceding, it is clear that the computation of Fxe is to be made for two periods of genealogical time: the first extending from the founder's generation to the 5th generation, and the second, from the 6th generation to the penultimate one, that is the generation of children examined by us (G5 in Hams records). Hence the computation of Fxi for the last 10 generations is:

$$\overline{Fxi}_{6\text{-}15}=1/2\overline{Ne}_{6\text{-}15}+[(2\overline{Ne}_{6\text{-}15}-1)/2\overline{Ne}_{6\text{-}15}] \times \overline{Fxe}$$

and computation of $\overline{Ne}$ for the last 10 generations yields: $\overline{Ne}_{6\text{-}15} = 113.63$.

Therefore the mean effect per generation of the genetic drift on the $\overline{Fxi}_{6\text{-}15}$ will be:

$$\overline{Fin}_{6\text{-}15}=1/2\overline{Ne}_{6\text{-}15}$$

$$\overline{Fin}_{6\text{-}15}=0.0044$$

The effect of the breeding patterns on $\overline{Fxi}_{6\text{-}15}$ is estimated only on the basis of first cousins, since: 1)each individual in each of the 10 generations has, on average, an identical number of first cousins; 2)the relative contribution of this breeding pattern (from the overall contribution which marital patterns have) in determining the value of Fxe exceeds 95% and therefore it is unnecessary to compute all the components of the breeding patterns, in this case Fxe = Fxe_1; and 3)since the number of first cousins per individual is identical in all generations, we can employ the rate of first-cousin marriages which was determined for the blood feud groups, with the 16th generation taken as a constant for the other 10 generations (6-15). Thus:

$$\overline{Fxi}_{6\text{-}15}=[(2\overline{Ne}_{6\text{-}15}-1)/2\overline{Ne}_{6\text{-}15}] \times Fxe$$

$$\overline{Fxi}_{6\text{-}15}= 0.9556 \times 0.003834= 0.003817$$

Now we can compute the mean value of F for the last 10 generations thus:

$F_{6-15} = (0.0044+0.003817 \times (1-0.03)^2 = 0.007731$

And from this, to compute the FA_{6-15}:

$FA_{6-15} = 1-(1- F)^{10} = 0.07468$

Determining the contribution of the first five generations to the overall coefficient of inbreeding (F) of the tribe is problematic mainly because the social frameworks in the tribe during this period are not yet consolidated. And in the absence of any guiding principle to follow its social development, we must inspect each generation and learn its possible behavior, with respect to marital patterns, migration, etc., and then try to evaluate the overall contribution of these generations to the overall coefficient of inbreeding (F).

As a rule one can continue to compute the Ne for the first five generations in the same way it was done for the later generations. However, we must exclude the first generation since it is responsible for introducing the primary genetic background into the group. Our computation of the average effective size for the first five generations therefore becomes:

$\overline{Ne}_{1-5} = 22.49$

and the mean effect per generation of the genetic drift on the Fxi_{1-5} will be:
$Fin = 1/2Ne_{1-5} = 0.0222$.

<u>Computing immigration rate (M) for the first five generations.</u>

The potential for consanguineous marriages is largely reduced in the first generations mainly because of the small tribal size, ranging from 46 individuals in the first generation to 187 in the sixth. Therefore, it is clear that many individuals in the first generations will take brides who are outside their Hams (blood feud group). Since the Hams is patrilinear in nature, all the males will always be of the same tribe, while the females can be either from inside or from outside the group. The role of immigration is therefore expected to increase, and can be estimated from the size of the tribe in those generation in which that value is similar to the size of the extended family or clan in the present generation. Since 68.7% of marriages are within the clan, the average rate of immigration for generations 4 and 5 is 32%, whereas for generations 1, 2 and 3 (extended family) it is 65%. Thus, the average migration rate for generations 1-5 is approximately 48%. The effective size of the group in the first generations is small, and hence, the influence of genetic drift may mask the impact of inbreeding. And since the fixation of genes cannot act twice, that is, once under the effect of genetic drift and again under the effect of breeding patterns, one cannot use breeding patterns in the first to fifth generations as a component in the final value of $FA_{1\text{-}5}$. Therefore, the influence of breeding patterns for the first five generations must be computed thus:

$$F_{1\text{-}5} = (1/2\overline{Ne}_{1\text{-}5}) \times (1\text{-}M)^2 = 0.022 \times 0.27 = 0.00594$$

and the $FA_{1\text{-}5}$ computation is:

$$FA_{1\text{-}5} = 1-(1-0.00594)^4 = 0.0236$$

After calculating the inbreeding coefficient of the tribe for two genealogical time periods, we computed the combined contribution to the value of F.

In the first stage, the mean $F\bar{x}i$ for 16 generations is computed by:

$$F\bar{x}i_{1\text{-}16} = (FA_{1\text{-}5} + FA_{6\text{-}15} + Fxi_{16})/16$$

$$F\bar{x}i_{1\text{-}16} = (0.0236+0.07468+0.004566)/16 = 0.006427$$

The final F value follows:

$$F = 1-(1-F\bar{x}i_{1\text{-}16})^{16} = 0.09802$$

It is note worthy that the obtained value of F is relatively high compared to that recorded in other societies. The F value in the 16th generation, ignoring the contribution of previous generations, will be:

If: $Ne = 846$; $Fx_{15} = 0.00398$; $M = 3\%$;

$$F = [\,1/2Ne + (2Ne-1)/2Ne \times Fxe] \times (1\text{-}M)^2$$

$$F = (0.000591+0.999 \times 0.00398) \times 0.041$$

$$F = 0.004297$$

APPENDIX 3:

Child populations compared with our South Sinai Bedouin boys, by place, group, and author(s).

Country of origin	Designation in graph	Origin of population samples studied	Authors
Egypt	**Muzeina**	**South Sinai**	**Present study**
U.S.S.R.	U.S.S.R.	Moscow	Vlastovskii, 1976
France*	France	Paris	Sempe et al., 1971
United Kingdom*	England	London	Tanner et al., 1966
Poland*	Poland-R	Rural	Wolanski, unpubl.
Poland	Poland-C	Cracow	Pawel, 1964
U.S.A.*	U.S.A.	Cincinnati	Rauh et al., 1967
U.S.A.	U.S.-W	White	Vital and Health Statistics, 1974
U.S.A.	U.S.-N	Negro	Vital and Health Statistics, 1974
Lebanon*	Lebanon	Various	ICNND, 1962
India*	India A	Well-off	Raghavan et al., 1971
India*	India B	National	Indian Council of Medical Research, 1972
India*	India C	Maharastrians	Sharma, 1970
Israel*	Israel-A	Arabs	Shiloh et al., 1959
Israel	Israel-E.E.	East Europe^ (Jews)	Kobyliansky et al., 1985
Israel	Israel-M.E.	Middle East^ (Jews)	Kobyliansky et al., 1985
Israel	Israel-N.A.	North Africa^ (Jews)	Kobyliansky et al., 1985
Israel	Israel-G	Total (Jews)	Kobyliansky et al., 1985
Senegal*	Senegal	Dakar	Masse, 1969
Mozambique*	Mozambique	Lourenco	Martins, 1968
Tunisia*	Tunisia	Tunis (poor)	H. Boutourline-Young, unpubl.
Ethiopia*	Ethiopia	Addis Ababa	Eksmyr, 1971
Egypt*	Egypt-G	National	McDowell et al., 1970
Egypt*	E-1	Villages	Jasicki, 1965
Egypt	E-2	Kenouz	El-Nofely, 1978
Egypt	E-3	Arab	El-Nofely, 1978
Egypt	E-4	Fededji	El-Nofely, 1978
Egypt	Egypt-Si	Siwah	Pawel, 1964
Egypt	Egypt-Se	Seaside	Pawel, 1964
New Guinea	New Guinea	Kaiapit	Malcolm, 1970

* Material taken from Eveleth and Tanner (1976) and consequently these authors are mentioned as a reference point for the source of the material but are not included in the bibliographic list.

^ Origin of parents.

APPENDIX 4:

Legend to tables and figures:

List of Tables:

Legend to figures:

Biology of Desert Populations-South Sinai Bedouins: Growth and Development of Children in Human Isolates

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