

# HEREDITY AS A FACTOR IN CRANIAL AND FACIAL DEVELOPMENT

BYRON O. HUGHES, PH.D., ANN ARBOR, MICH.

SINCE the keynote of this symposium is *Physical Anthropology in Relation to Other Biologic Sciences*, it will be appropriate to outline briefly the way in which physical anthropology, orthodontics, child development, and genetics have cooperated to formulate problems, to secure data, and to analyze results on the general question of the role of heredity in development. A review of the literature revealed a lack of adequate data to be the major obstacle to an understanding of human heredity. Many of the articles dealing with human heredity have been based on empirical and logical argument and have been inadequately documented in their presentation of supporting evidence. Evidence from experimental genetics warrants the belief that the principles of genetics, as we know them today, apply to humans. I seriously doubt, however, if it is safe to assume that knowledge of heredity in other animals gives knowledge of inheritance in humans. We may apply the principles of genetics to human data with considerable confidence; we should hesitate to argue further.

The experience of the geneticist has been especially important to us both in ascertaining what types of data to obtain and in outlining techniques for analysis. The physical anthropologist contributes refined, and, on the whole, accurate measurement and observation techniques. The evaluation of the detailed attributes of the dentofacial complex and the clinical significance of these features has been a very valuable contribution of orthodontics to data collection and to analysis. The staff in child development has provided an elaborate collection of data which permit examination of developmental continuities.

The report which follows is thus the result of cooperative endeavor, and I wish to emphasize the real values which attain when one directs the resources of several fields to the solution of problems.

## DATA

The present report is a general summary of the findings based on the following information: Anthropometric measurements and observations on 213 families of Armenian-speaking peoples and on 487 families residing in various parts of the United States, mainly in Michigan. Developmental records on children and supporting measures and observations on parents in 137 families who have children in the University of Michigan Elementary and High Schools. Detailed dental records supported by anthropologic, photographic, and radiographic data on 113 families who submitted themselves to examination in the orthodontic clinic in the Dental College of the University of Michigan.

## ANALYSIS

These data have been analyzed in terms of the various interfamilial relationships and by comparing these figures with those when the total series was treated

Research Associate in Orthodontics, University of Michigan, School of Dentistry.  
Read before the Anthropological and Psychological Section (H) of the A.A.A.S., Philadelphia, December, 1940.

as a random sample of the population. Differences between the two sets of figures indicated the operation of familial factors. In general it was assumed that the presence of familial factors indicated the presence of hereditary ones even though it was not possible to attain satisfactory control over environmental forces which, presumably, would be concentrated in family groups. Familial features were further analyzed in terms of the various principles established by experimental genetics.

#### RESULTS

The results obtained so far are preliminary and exploratory. They enable us to refine our techniques of observation and data collection and aid materially in a more precise formulation of problems that may be attacked systematically.

#### GENETICS AND GROWTH

From the point of view of development heredity becomes a part of a process that extends at least from conception to maturity. Most, if not all, hereditary features undergo vast changes between inception and adulthood and frequently it is very difficult to describe the end product in terms of its appearance during the process of development. This brings us to an important point. Is growth inherited? And, if so, is it inherited as a general factor which influences the attributes of the body as a whole or is growth different and distinct for each feature? The evidence from the University Elementary School strongly supports the latter viewpoint. Here we find a number of patterns of growth. In some individuals the growth of a single attribute is very much like that of any other attribute so that we may write a growth equation and have it generally descriptive of the total organism. In other individuals the pattern of growth of one attribute is considerably different from the growth pattern of another so that several growth equations would have to be written to describe the development of the total organism. These diverse patterns of growth have a random distribution in the population as a whole and are definitely concentrated within the familial lines. Growth is certainly a familial as well as an individual phenomenon, and although the environmental circumstances within a family are generally concordant toward the production of similarity, experimental attempts to modify some of the growth patterns have met with little success. The evidence, on the whole, indicates growth to be strongly dependent upon hereditary factors. The facial region is composed of many parts which exhibit a rather marked degree of growth independence. Many of the apparent discrepancies in the dentofacial complex due to growth and the resultant malocclusions represent real genetic differences. Growth independence is observable in the cranial region but is not particularly striking. From the standpoint of observation during development hereditary features can be divided into two groups: those which display familial patterns throughout the growth process, and those which fail to give any hereditary evidence until pubertal cycle is established. The majority of anthropometric measures belong in the first group. Many attributes, particularly those showing strong sex difference, appear in the second period. Other features, as pattern baldness, are not amenable to observation until after adulthood has been attained. Recognition of these time or growth sequences is fundamental in data collection and in analysis.

The contribution each parent makes to his child's features needs further study. At present there is little evidence to support the belief that children resemble one parent more than they do the other in craniofacial features. So far as our data go, we have no evidence of *sex-linked* or *sex-influenced* inheritance in the craniofacial complex. The contribution of each parent is of equal importance and the inheritance is autosomal. It is not possible to estimate the number of genes or chromosomes involved. We suspect the number to be large rather than small and would not be surprised to find each of the chromosomes represented in the craniofacial region. This would give twenty-four linkage groups and permit considerable independence of parts.

Most of the craniofacial features, attribute as well as measurement, appear to be multiple factor traits. Single genes segregating normally seem to be the exception rather than the rule. Likewise, completely dominant genes and their recessive alleles are poorly represented. The amount of true intermediacy for the multiple factor traits in the facial region is surprisingly low. The cranial region is more productive of intermediacy.

The following statements serve as illustrations of the above points. When the father and mother are alike in an attribute, the child likeness to parent is 85 per cent and to sib is 88 per cent; the trait is emphasized by the child in 7 per cent of the cases and is clearly different in 8 per cent. When the father and mother are unlike for a trait, the child is truly intermediate between the parents in 17 per cent of cases; the resemblance is toward the father in 37 per cent and is toward the mother in 35 per cent of instances. The amount of divergence from the midparent, or true intermediacy, is not dependent upon the sex of the parent, rather it depends upon the nature of the trait itself. For example, if the male parent presents a broad ovoid maxillary arch and the female parent a narrow V-shaped or tapering arch, the children, on the whole, would show trapezoidal to tapering arches. That is, the resemblance would be *toward* the mother. If it were the male parent who carried the V-shaped arch the resemblance would be *toward* the father. I believe it is the behavior of a number of features like the one illustrated above that has given rise to the proposition that sex of the parent is responsible for the appearance of traits which are autosomal in inheritance. The amount of clear-cut child difference from both parents amounts to 11 per cent.

The incidence of asymmetry is lower in the cranial region than in the facial region, and the number of asymmetries is four times as great among children with asymmetric parents as it is among children whose parents show absence of asymmetry. Facial asymmetries are almost independent of cranial asymmetries.

In the cranial region length, breadth, and height are dependent upon hereditary factors, probably some for each bone of the vault. The three diameters are rather independent of each other in family lines with breadth factors exhibiting a mild degree of partial dominance.

The dentofacial complex is particularly interesting in the marked degree of part independence which it shows. The mandible and maxilla are certainly independent of each other and our evidence goes further to indicate that in the mandible the ramus, body, angle, alveolus, and teeth are not too dependent on each other, while in the maxillary region teeth, alveolus, and maxilla are in-

dependent. Multiple factors are involved in the production of all of these features, and there is a partial dominance shown in what might be called the deficiency group of traits.

The size and shape of the malar bones depend upon genetic factors. Although multiple factors are involved, the number of these appears to be limited and children are generally intermediate between the two parents. Palate height seems to depend upon a single gene segregating normally. Palate width is more complicated; the anterior part appears able to expand or contract quite independently of the posterior part and anterior constriction has a familial distribution which indicates it to depend upon a single dominant gene. Many other features could be listed and described in approximately the same way. These serve to illustrate the extensive operation of heredity in the cranial and in the facial regions.

The use of the word independent in the discussion should, perhaps, be qualified. The total living organism is a more or less well-integrated whole and the amount of absolute independence of parts tends to be limited rather than extensive. Some traits, as individual teeth, ear lobes, bones of hand or foot, may be entirely omitted from the organism without materially affecting its welfare. Other features are permitted but little independence of action without seriously interfering with or even terminating the existence of the organism. The single gene responsible for amaurotic family idiocy or the sex-linked gene responsible for hemophilia serves to illustrate. Teratology abounds with examples of genetic independence too extensive to maintain life. These limitations are recognized in the use of independence in the discussion.

I have already indicated growth and heredity to be parts of the same phenomenon. Any feature we observe has undergone both differentiation and growth. The entire process is lawful and, on the whole, orderly. Geneticists have suggested growth to be due to the action of genes on cytoplasm and differentiation to be due to the separation of different cytoplasmic products of the genes into different cells. However this may be, our evidence supports a belief that the growth of a trait is integral with the heredity of the feature.