THE INDIVIDUAL NORMAL—THE PROBLEM OF ORTHODONTIA*

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THE growth of a science is due to an accumulation of facts. No opinions, beliefs, or convictions, even though advanced by men otherwise highly deserving, can take the place of real and sufficient evidence. At times, science progresses by flashes of intuition, yet more often, its progress is due to the patient and careful unveiling of facts by systematic research. Clinical experience, based upon rather indefinite doctrine, has carried us far enough to put beyond doubt the value and need of orthodontic treatment to many individuals; nevertheless, if orthodontia is to grow and become of practical service to humanity, it will be the result of scientific investigations of actual conditions, research which follows the truth wherever it may lead.

We have been attempting to build a science upon an ideal. An ideal scheme of the occlusal relations of the teeth we have called "normal occlusion." Such a conception as this has been the basis of our diagnosis and treatment; in fact, at the present time, it is finding expression in the endeavor to solve the problem of the correction of malocclusion of the teeth by means of a mathematical formula. However, though the developments of the future establish the value of mathematical analysis as a step in diagnosis, a conception of the problem of orthodontia as purely a mechanistic one is without scientific justification. It is for the purpose of defining the normal and indicating the way to approach the question of malocclusion of the teeth of the human individual that the considerations of this essay are presented. The subject matter treats of a problem of so fundamental a character that it seems advisable to present briefly the conception of the nature and purpose of orthodontia which has resulted in the seemingly unorthodox point of view.

The concept of the normal dental arch is the foundation of modern dentistry. Although the dental arch is often referred to as being composed of the teeth and their supporting structures, a dogmatic definition of it does not convey a true idea of the nature of the conditions which surround all dental operations. The concept of the dental arch is not limited to a study of the morphologic characteristics of the teeth together with their supporting and surrounding structures; it is more comprehensive. It is a concept derived from a study of the action, reaction, and interaction of different elements of the dental arch in the continual adjustment of life; it is a concept of the nature of living tissues as they stand in physiologic correlation. The structural elements of the teeth; the osseous, nervous, vascular and muscle tissues of the face and jaws intermingle and blend into one another and are controlled in their mutual relations by the more dominant influence of factors involving the entire organism. The line of demarcation between the dental arch and the other tissues of the living organism is not definite. Living tissues blend through an intermingling of structural elements,

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while the central nervous system and the circulatory system, the avenue of the internal secretions, maintain the fundamental unity of the organism as a whole. The purpose of dentistry is to assist in establishing and maintaining the normal functional activity of the living dental arch. Hence the ultimate success of dental operations is not determined by their relation to tooth structure alone. All work upon or within the teeth involves living tissues which stand in physiologic correlation with other tissues of the living organism.

Orthodontia is ordinarily defined as "that science which has for its object the correction of malocclusion of the teeth."¹ Such a definition is of little value because it does not convey an idea of the nature of the problem involved in the correction of malocclusion. We believe it to be nearer the truth to define orthodontia as that branch of dentistry which treats of the forces controlling the form of the dental arch. This indicates in a general way, at least, the extent of the phenomena to be considered in diagnosis and treatment. The form of an organ or part is the result of an interaction of forces; it is the result of the interaction of function and structure. Structural form can not be accounted for by environmental factors alone, neither can heredity explain away all variation. It is the interaction of one with the other, the combined influence of the extrinsic with the intrinsic which determine the form of structures. Therefore the subject matter of the science of orthodontia is derived from the two phases of biology, heredity and environment, and is, in the main, a study of the fundamental truths and laws of science as they are expressed in the growth and development of the dental arch of the living human being; and the relation of these truths and laws to specific abnormal structural conditions. Orthodontia is essentially a science of form development.

From such a standpoint as this, the field of orthodontia broadens beyond a study of occlusion. Inasmuch as the teeth are the primary factors in the evolution of the dental arch, and the principle function for which they exist lies in the physical relations of their crowns, the study of occlusion constitutes a large part of the science. It is, in a degree, an index of the developmental condition of the adjacent structures of the teeth and a register of the forces acting upon them.

Orthodontia is concerned with a collection of structures of different origin, varying in developmental nature, reacting to different influences, yet organized for a common purpose. The occlusal relations of the teeth constitute but one element of a complex of structures interdependent in life, and subordinate in evolution to the organism as a whole. Nowhere in the living organism is there an instance wherein parts of such diverse character are more closely associated or more dependent upon each other than in the dental arch, and it is the purpose of orthodontia to so treat these diverse elements, directly or indirectly, that they will express, individually and collectively, the normal development of the individual organism.

The difference in the developmental nature of the teeth and adjacent structures is a characteristic of the dental arch most significant in the study of malocclusion. Enamel is derived from the ectoderm, while muscle and connective tissue structures are derived from the mesoderm. The dental bulbs appear as shallow inverted cups and beneath their centers is found the condensed connec-

tive tissue which gives rise to the body of the tooth, the dentine. The primitive dental bulb is projected directly into the embryonic connective tissue, which underlies and covers the tooth band on all its free surfaces.² Ectodermal epithelium pushes into the embryonic connective tissue and the enamel organs thus formed are of such a different nature and are susceptible to such an entirely different set of influences that they mark the slightest variation in the development of the connective tissue structures. The crowns of the teeth are completely developed in adult form long before they function in mastication and in use they wear away, while bone, muscle, vascular and nervous tissues depend for their complete development upon the stimuli of function. This wide difference in the developmental characteristics of the tissues which compose it, make variations in the form of the dental arch more obvious than in other parts of the organism where the tissues are more nearly of like nature. For this reason a scientific interpretation of the normal is more essential in orthodontia than in other fields of orthopedia where the structures are, in a greater degree, molded and harmonized by function in the ordinary activities of life. In fact, the fundamental problem in orthodontia is to determine the normal dental arch of the individual organism. It is a problem of the individual as distinguished from class, group, or species and as such is inseparably linked with the phenomena of variation.

The most obvious thing about the individual organism is its variability.³ Variation in form and function is universal among living beings. Although two individuals will resemble each other, possessing certain characters in common, yet invariably upon close examination these characters will be found to differ from each other in degree or in proportion. Differences extend to minute particulars and include all characters, function as well as structure, internal organs and parts as well as external proportions. No part of the living being escapes the influence of the law of variation. Hence an interpretation of the normal as it refers to the dental arch of the individual organism must find a basis in this law and must be determined by the methods employed in the analysis of the material relative to it.

The question of the normal has been handled as though it were only a problem of species. The attempt has been made to establish an imaginary line, called the "line of occlusion," as a criterion by which to determine the existence or nonexistence of malocclusion and deformities of the dental arch.⁴ Twenty years or more have passed since Dr. Edward H. Angle first defined the line of occlusion, yet for many the question of the normal is still unanswered. In owning that it is so, we do not honor Angle's work the less, for whatever value the future may assign to the line of occlusion in diagnosis, it will always be remembered that it was through the work of Dr. Angle that the problem of malocclusion was first studied as a problem of science. If he did not solve the question of the normal in his early writings, he gave the hope of its solution, undoubtedly, a greater thing.

The endeavor to utilize the line of occlusion as a standard by which to determine the normal involves a contradiction. As has already been emphasized, orthodontia is concerned with the dental arch of the individual organism while the line of occlusion is based upon a consideration of type. The contradiction lies in the assumption of an individual type.

Type is a word that has been used very loosely, but literally interpreted, it refers to a general form or plan of structure common to a number of individuals. It is the ideal representation of, or the most perfect exemplification of, a natural group. It is a composite of individual forms. An individual is not referred to as a class, neither is an individual a type, in either case the individual is but a unit in the composition of a class or type. I quote from Davenport⁵ a concrete case which will best illustrate the principle involved. "A random sample of Leaming corn, consisting of 327 ears gave the distribution as to length as illustrated in Fig. 1. It will be noted at once that there are more ears of 9 inches than of any other length, and that the distribution decreases in both directions, but unequally, from this highest frequency. This highest frequency, or most common length, shows clearly what is the prevailing type as to length in the crop, and it is held by statisticians to be the best obtainable expression for type. When it is ascertained, therefore, we know at once what is the natural type of the race or variety so far as the character in question is concerned, and when this is determined for a number of important characters we shall have

Fig. 1.

a good knowledge of the racial type as a whole. But in obtaining the mode of another character as circumference or weight, the ears tabulated as typical will not necessarily be the same as those which constitute the group of highest frequency in a study of length." Consequently, "while we might obtain the mode of the circumference, number of rows, weight of ear, or any other desired character, and having done so are able to describe definitely a typical ear," it should be clear that the typical is not a concrete thing, existing in natural form, but is of the nature of an abstraction, a model or pattern from which the individual presents some degree of variation. The word type used with individual refers to certain marked racial characteristics which the individual possesses. It directs attention to certain traits or features which are common to different individuals. It can not in any sense apply to the individual as a specific standard of normality, for there is a great range of individual variation without departure from type.⁶

Furthermore, the concept of the line of occlusion embodies the idea of the teleologists who believed that normal organs and parts express the most per-

Fig. 2.

Fig. 3.

fect means of performing the function for which they exist. This theory has long since been abandoned. Huxley says that teleology, as commonly understood, received its death-blow at Darwin's hands.⁷ Darwin simply affirmed that organs and parts work well enough to enable an animal to survive, but admitted the possibility of improvement in their form and function, and his opinion holds true today.

Therefore in the face of constant variation and incompleteness, it is evident that the normal as it applies to the individual organism can not be deter-

Fig. 4.

Fig. 5.

Fig. 6.

mined by a study of type taken of itself alone or of structural perfection. If the typical is utilized as a definite standard of normality of the individual and all variations from it classified as abnormal then the normal individual does not exist. It is not reasonable to base our diagnosis upon a concept which can never be realized in natural forms.

The scheme of occlusion expressed in the ideal relations of the inclined planes of the cusps of the teeth is a working hypothesis; it is a theory to be adopted as a guide in an investigation of the real nature of occlusion. A hy-

pothesis is not proved; it is assumed to account for a fact or an occurrence. If you were to determine the ingredients of a chemical compound, a general knowledge of its kind or character would decide the methods to be employed, and each succeeding process would be the result of an assumption or theory that such pro-

Fig. 7.

Fig. 8.

Fig. 9.

cedure would reveal one or more of the constituent elements of the compound. In other words, in chemical analysis a theory which has a basis in fact, is the assumption, the belief, the hypothesis which leads to the investigation that reveals the real nature of the phenomena in question. A hypothesis leads to facts; it does not express actual conditions already established. The ideal scheme of occlusal

relations commonly called "normal occlusion" is a concept derived from a study of the law of occlusion, and is the mental picture, the working hypothesis, essential in an investigation of the nature of occlusion, as it is in the mouths of men today. Such a concept furnishes the groundwork for a study of the facts, the real evidence which constitutes so vital a part of the subject matter of orthodontia.

Fig. 11.

Fig. 10.

Fig. 12.

Fig. 13.

The word "normal" means a resultant of correlated factors. As it is used in orthodontia, it refers to either one of two classes of phenomena; either to the general form of a character as seen in a group of individuals or to a complex of the individual organism. The former signifies a correlation expressing the typical form of an organ or part as seen in many individuals; the latter

signifies a correlation which is best suited to the life activities of the individual organism as a whole. Hence, in the study of occlusion then we are concerned with two groups of phenomena, the *species normal* and the *individual normal*.

The species normal is a concept derived from the observation and comparison of the occlusal relations of the teeth of many organisms. It is the result of combining, of bringing together in one concept a variety of structural con-

Fig. 15.

Fig. 14.

Fig. 16.

Fig. 17.

ditions, each different from the other, no two alike, as illustrated in the study of the typical ear of corn. The species normal might be considered as a composite of the occlusal relations of the teeth of many organisms. If it were possible to make a composite photograph of the occlusal relations of the teeth of a group of individuals from all angles, the result would portray the typical occlusion, the species normal.

The word "normal" in the phrase "species normal" refers to the resultant of a correlation of structural conditions. In much the same sense, R. E. Lloyd⁸ uses the word "normal" as the majority. The word "species" is chosen for its literal sense. Although it is often used to designate an aggregate of individuals, varying around a normal type, such is not the strict interpretation of the word. Many species that were once thought to be distinct from one another have later

Fig. 19.

Fig. 18.

Fig. 20.

Fig. 21.

been united by the discovery of intermediate forms. Perhaps the most notable instance illustrating the arbitrary character of the grouping of the species, is where two animals which were at one time classed as belonging to different species were later proved to be male and female of the same. Of course, it is true that at a given time, the forms of living things may be arranged in specific groups, and between the immense majority of these there are at the present

time no transitional forms. However, we know from the law of variation that even the characters which determine the grouping together of certain individuals are not identical but vary in some degree, in some way from each other. It is with these variations that we are concerned in orthodontia. In its most literal translation, species means an abstract form, an abstract condition of occlusion, if you will, around which a group of variations oscillate.⁸ It is in this sense

Fig. 23.

Fig. 22.

Fig. 24.

Fig. 25.

that it is used in the phrase "species normal." It seems better to convey the idea of the typical in this way than to employ the "collective normal" of the psychologist. Species although used synonymously with typical seems preferable as it contrasts more clearly with individual.

The "individual normal" is the result of the correlated activity of many parts of the individual organism.¹⁰ It is the result of a complex of physiologic

processes. The Individual Normal refers to the form of occlusion best adapted to the needs of the organism as a whole. It refers to the condition of occlusal relations which is the most effective in maintaining in its most stable form the equilibrium expressed in the life phenomena of the individual organism. It may or may not approximate the species normal. It is not an artificial creation built upon an ideal plan. It is the most perfect condition of occlusion that the

Fig. 27.

Fig. 26.

Fig. 28.

Fig. 29.

nature of the tissues and the functional activities of the organism as a whole will permit.

The dental arch is a mobile equilibrium reflecting the inheritance and life activities of the individual organism as a whole. To know when the form of a dental arch is normal for a particular individual is a difficult problem, and its solution, which is so vital to orthodontia, involves a consideration of the funda-

mental principles and laws of science. There is no short cut to a solution of the problem of deformities of the dental arch.

A science in its growth passes successively through the speculative, the qualitative, the quantitative, to the predictive stages of development.¹¹ As a result of speculation, qualitative work is done, and from the general principles thus established, quantitative methods can be evolved which, in a varying degree, will make prediction possible. Much qualitative work is necessary in orthodontia before it can lay claim to quantitative methods of procedure. A statistical study to ascertain the typical occlusion, the species normal, of man is yet to be done. Although a most perfect occlusal relation may have been born into the race, we do not know enough of the true nature of occlusion as it is today. Of course such an investigation would be a difficult and tedious task. In fact

Fig. 30.

Fig. 31.

it is futile to suppose a very fine degree of accuracy in recording observations of this nature. Yet research of this kind is one of the first essentials in establishing orthodontia in science. General principles derived from studies of groups and species are indispensable in a study of the individual organism. They are indices to individual characters.

Much of the evidence in the following illustrations is still obscure. The studies of it have not been carried far enough to establish its full value. Yet certain tendencies are sufficiently clear to justify a preliminary report. No further claim is made than that the evidence in its present form points to a correlation of a physiologic nature and indicates one of many ways to approach the question of the individual normal. The study is of involuntary tongue movements.

The apparatus used is patterned after that of E. W. Scripture in his work on Stuttering and Lipping.¹² It consists of a kymograph and tambour which is connected by rubber tubing with a very delicate rubber bulb (Fig. 2). The bulb is inflated by forcing air through the auxiliary tube. When this is done, the recording needle is raised as shown on the drum. With the patient holding the tube in the hand a base line is recorded upon the smoked paper. Then the end of the tube is held firmly between the incisor teeth, placing the bulb between the tongue and the hard palate. The patient is told to allow the tongue to rest against the bulb, and the following tests are made, each one being preceded by marking the base line and all are of one minute duration: First, subject sitting still looking out of window; second, reading to himself; third, cutting figure out of paper as seen in Fig. 3; fourth, writing verse of song with pencil upon back of paper; fifth, repetition of first. Approximately two hundred charts have been made. Figs. 4, 5, and 6 will give an idea of the variations met with. From the anatomic structure of the tongue and its involuntary character, an irregular line might well be anticipated. But the difference in the character of the lines and the relation of this difference to the structure of the dental arch is at least significant. The charts were classified according to their general character, without consideration of sex and very little regard to age. Of course the class distinctions were not absolute, there being transitional records in all instances. However, certain things were evident. The majority of the charts of patients with the overbite form of malocclusion were in the same class. They were characterized by an irregular tongue line which dropped to and often below the base line. While this was not seen in all of the cases that, from a study of occlusion alone, would be classed as overbite cases, it has not as yet occurred where other forms of malocclusion were present.

Fig. 7 is malocclusion associated with Fig. 5; Fig. 8, malocclusion associated with Fig. 9; Fig. 10, malocclusion associated with Fig. 11; Fig. 12, malocclusion associated with Fig. 13; Fig. 14, malocclusion associated with Fig. 15. The last case is particularly interesting in its similarity to the others from the fact that the patient is from six to eight years older.

The open bite cases and those with the relatively short overbite show the tongue line well above the base line.

Fig. 16 is malocclusion associated with Fig. 17; Fig. 18, malocclusion associated with Fig. 19; Fig. 20, malocclusion with Fig. 21; Fig. 22, malocclusion associated with Fig. 23.

The cases illustrated in Figs. 20 and 22 have responded to treatment without difficulty, while Figs. 8 and 10 are quite different. The teeth move easily but there is a constant tendency to relapse.

Fig. 24 is malocclusion associated with Fig. 25; Fig. 26, malocclusion associated with Fig. 27; Fig. 28, malocclusion associated with Fig. 29; Fig. 30, malocclusion associated with Fig. 31.

Note rhythm in the tongue line of Figs. 24, 26, 28 and 30. In each of the first three cases the incisors would push forward unless appliances were worn intermittently. It will be obvious to many that the absence of a gauge to register the pressure of air in the rubber bulb admits an element of error in the records. This is, of course, also true of the condition of the rubber on the tambour and

bulb. But recognizing all this, the fact is that the rhythm evident in these three charts was not seen in any of the others. What further study will reveal I can not say.

Fig. 30 is associated with Fig. 31 which is a chart of a boy with chorea manifest in the superficial muscles around the orbits.

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DISCUSSION

Dr. John V. Mershon, Philadelphia, Pa.—After reading Dr. Johnson's paper many times, I feel that it is a mistake to discuss it. I consider it so near a perfect presentation of facts that to add to it would be impossible, so my remarks should not be considered a discussion. I am only going to call your attention to some facts and emphasize what seem to me to be very important.

The whole trend of Dr. Johnson's paper is to show that we have been undertaking to work an ideal which does not exist, that is our past conception of the ideal normal occlusion, and he has given us the correct standard to which we can work, and a basis on which to start to study. The study of the individual normal must be measured by the functional activities of the forces of development. Dr. Johnson has very properly called our attention to the fact that the orthodontist can no longer depend on the morphologic characteristics of the teeth, and their supporting and surrounding tissues, but that we are dealing with a portion of the human being, and that the mouth and all the organs which compose the oral cavity are just as much a part and parcel of the human being as the lungs, the liver or any of the other organs, and are affected by the internal conditions both in its growth and development, and we must treat the individual as a whole.

Dr. Johnson's definition of orthodontia is a great improvement over anything we have had previously, he defines it as that department of dentistry which treats of the forces controlling the form of the dental arch. Later on in the paper Dr. Johnson, in referring to normal variations, states that these variations are not confined to the osseous tissues in which the teeth are located. We have the same variation in the form and size of the teeth, as nearly all tissue form depends on function. The teeth are formed before they begin to perform the function for which they were originally designed. These facts would seem to prove conclusively the fallacy of undertaking to predetermine the size and shape of the dental arch purely by measuring the tooth material, and entirely disregarding the forces which operate through function to produce form.

Dr. Johnson has also shown us that arch form is of the individual normal. It would be interesting in studying these slides which Dr. Johnson has been showing, if we could have an analysis of the individuals from which these records were made, as to what deformities may exist in the other parts of the body. The story told by these slides seems to be very closely related to the work done by Dr. Johnson and Dr. Hatfield on muscle development. In their investigations they showed the relationship between the lowered muscle tone and bad osseous development. These records which Dr. Johnson has been showing are another connecting link between a certain type of osseous deformity represented by a certain type of malocclusion which expresses itself indirectly through the nerv-

ous system by the way of the involuntary muscle fibers in the tongue which are responsible for the variations shown on the records. In both of these investigations it simply goes to prove that malocclusion is only a local expression of a general constitutional condition. The result of these investigations should further impress us with the facts that orthodontic appliances are not the only prescription necessary in the treatment of malocclusion. A great deal more importance should be attached to the value of these investigations than Dr. Johnson seems willing to admit. I think this society should be congratulated that we have men who are willing to spend the time and energy necessary to make these investigations and give them to us absolutely free, such as Dr. Johnson has been doing this year and last year.

Dr. William C. Fisher, New York City.—I find there is very little left for me to say after the paper of Dr. Johnson and the discussion of Dr. Mershon.

Dr. Kemple said that Dr. Johnson wanted me to discuss his paper. He spoke to me at a meeting of the Academy of Medicine in New York about it, and I thought he was poking fun at me, and I so told him, and I still believe so. After I had read the paper, I did not believe Dr. Johnson wanted me to discuss it. Dr. Johnson and I had dinner together and during that dinner he outlined the salient features of his paper to me and showed me some of these slides.

His paper is a little different from the one he gave me. "If the typical is utilized as a definite standard of normality of the individual, and all variations from it are classified as abnormal, then the normal individual does not exist." That is the meat of that particular part of his paper. Typical and normal do not *mean* the same thing; they can not *mean* the same thing and they can not *be* the same thing, but unfortunately many have frequently confused them into *meaning the same thing*.

Dr. Johnson spoke of the influence of heredity. How many of us, when our little patients come in, make concrete models and immediately base our diagnosis on them, outline the appliance to be used, have it made, and put it back on the patient? And that is as far as we have gone in our diagnosis. How many of us look into the antecedents of the child, and how many of us think what the normal for that child should be? Nine times out of ten even the most conscientious of us have unconsciously in our mind's eye the so-called normal arch type, and we do not consider the child. This leads to the point I would like to bring out which I get from his paper, namely: How will this affect our work? That is what we want to get out of all papers presented here. What difference will it make in our treatment of cases? To me it has a very important bearing on the treatment of malocclusions of the deciduous teeth.

I was asked the question in this meeting recently, "What would be your treatment of a child between five and six years of age where there is pronounced malocclusion?" My answer was that in the majority of cases I would condemn the orthodontist. I do not believe that we are warranted in interfering with many of the deciduous malformations for the reasons brought out in Dr. Johnson's paper,—study the individual normal. We can not possibly tell exactly and know in what direction a child will develop, what the normal of that child can be, later when seen at the age of four or five years. The parents and the relatives of a baby at the first and second year will tell you and admit to you that the child is a living image of the mother. By the time that child reaches five or six years of age it is so absolutely changed in its appearance that it may resemble the father and have no resemblance whatever to the mother. As time goes on and the child develops it may lose its resemblance to either one of the parents and may take on the resemblance of one of the grandparents. Changes occur in the families where you study the physiognomy of the children. With that point in mind, how can we determine the treatment of these deciduous cases? In my own practice I have for a long time confined orthodontic interference in malocclusion of the deciduous teeth to the expansion of the inferior cuspid region, and that only rarely.

To know the individual normal is to know your science. In other words, it can not be laid down by rule and compass, but can be realized only by years of experience.

Dr. B. E. Lischer, St. Louis, Missouri.—I hesitate to discuss this very interesting paper extemporaneously because it is a philosophical dissertation on fundamental problems.

Dr. Johnson made the statement in the first paragraph of his paper that if orthodontia is to be of practical service to humanity, we will have to study this subject. I would like to insert the word *more*. The fact that we are here today is proof that we have been of some value to humanity. That, however, is a minor criticism.

He has called our attention to the factor of *variation*. The study of variation, as I understand it, has led to the concept that *variations* are of *germinal origin*; they are congenital. But there is another subject in connection with this matter that requires out attention; namely, *modifications*. These are wrought in an individual's lifetime, are *soma-togenic*, or *acquired*. Many modifications can be found in the facial features; I refer particularly to those due to the anomalies of dentition. And while I would not detract one iota from the imperious hypothesis of occlusion, I want to call your attention to the fact that we will shortly have to study in greater detail the facial modifications of our patients.

For several years I have taken life size photographs of the face of every patient that comes to my office, and I find these are of great value to me. I have reference particularly to the facial features that are involved in the orthodontic treatment, and I have been amazed at the many variations and modifications that we are confronted with. I am convinced that many of our preconceived theories will have to be exploded.

But as I have previously said, I am not prepared to discuss this paper as I should like to, and I want to thank Dr. Johnson for its very able presentation. It seems to me that it opens up tremendous possibilities.

Dr. Milo Hellman, New York City.—I shall discuss Dr. Johnson's paper, for it merits

Fig. A.—Illustrating diagrammatically the various forms of the dental arches of the Anthropoid apes.

discussion. In doing so, however, I shall touch upon one point in order to bring out in a concrete form a suggestion Dr. Johnson has passed by so lightly. And that is the remarks made relative to the mathematical calculations employed as predetermining factors for the various dental arch forms.

If you will permit me to show one or two diagrams which I have used in connection with a paper read before the Alumni Society of the Dewey School of Orthodontia, I shall bring forward some comparative evidence bearing upon this topic.

If the contention is correct that the dimensions of the teeth will predetermine the form of the dental arch in man, the evidence obtained from comparative studies would verify it. With this end in view, I examined a number of anthropoid apes, comprising all the genera included in the family. These are the gibbon, the orang, the gorilla, and the chimpanzee. The skulls of the apes examined belong to the collections of the United States National Museum of Washington, D. C., and the American Museum of National History of New York. While the teeth of the anthropoids themselves bear a close resemblance in form to those of man, with the exception of the canines and lower first premolars, the arch forms differ considerably. However, the form of the dental arches may be classified under six main types. These are the pear-shaped, the inverted U-shape, the divergent-shape, the oval-shape, the saddle-shape and the lyre-shape. (See Fig. A.) Each dental arch in the anthropoid series must fall under one of these forms. But there are generic differences in the prevalence of arch form and the frequency of their appearance in each group. Thus, the gibbon presents the arch forms under 2, 3, 4, 5, 6; the orang, under 1, 2, 3, 4, 5; the gorilla, under 1, 2, 3, 5; the chimpanzee under 1, 2, 3, 5, 6. Moreover, each genus exhibits a preference for a certain type of arch form. In the gibbon, the upper arch form most frequently noted is the lyriform; appearing in 73 per cent of

cases. In the orang, the ypriform appears in 38.5 per cent; in the gorilla, the U-shaped form appears in 46.1 per cent and in the chimpanzee the lyriform appears in 40 per cent of cases.

If there is any relationship between the size of the teeth and the form of the arch we should find similar sized teeth in a particularly shaped arch. That is to say, if we take the 73 per cent of cases in the gibbon that fall into the lyriform arch, the central incisor of each of these cases should be of uniform size, or taking the combined dimension of all they should at least have a higher average than the central incisors of the cases belonging to all the combined other forms. This should be evident if there is any definite correlation. But actually it was not so. On measuring all central incisors belonging to the lyriform arch they were found to vary; and averaging their dimensions, it was also

Fig. B.

Fig. C.

Fig. B.—Illustrating the relationship of the mesiodistal diameter of the upper central incisor and upper first molar of each individual orang possessing the same arch form. *I* indicates the incisor curve, and *M*, the molar curve; showing no correlation whatever between these dimensions. Numbers indicate dimensions of the teeth in millimeters.

Fig. C.—Illustrating the labio-lingual relationship of the upper central incisor and first molar, worked out in the same manner as in Fig. B.

found that there was no difference in the average for the central incisors belonging to one particular arch form, for the combined forms of all the arches showed a similar average. The same test was made upon all the anthropoids and the conclusion reached is that the average dimension of the incisors belonging to one arch form is no higher than the average of the central incisors belonging to the different arch forms. It was then of interest to find out whether there is a correlation between the two dimensions of one tooth in a

particular arch form; that is, is there a correlation between the mesio-distal diameter and the labio-lingual diameter of the same tooth in the same arch form? There was found to be none. Is there a correlation between the mesio-distal diameter of two teeth in the same form of arch? That is, is the mesio-distal diameter of the central incisor and the mesio-distal diameter of the first molar of the same dental arch in correlation?

Fig. B illustrates a diagram which will convey the answer.

Taking for instance, the pear-shaped arch of the orang, the mesio-distal diameter of the central incisor varies in that one arch form in different individuals between 9 and 16 millimeters. That is all right. It has a right to vary. But if there be a correlation between the dimensions of this tooth and those of any other tooth the dimensions of the other tooth should vary accordingly. So on arranging the dimensions of the incisors varying between 9 and 16 millimeters according to size, the ascending curve in Fig. B, *I* was obtained. But on charting the molars belonging to each individual whose incisors are thus marked, as indicated by the vertical lines, the irregular curve as may be seen in Fig. B, *M* was obtained. While there is a gradual rise in the mesio-distal dimension of the incisor, the sizes of the molars fluctuate up and down showing that there is absolutely no relation between the two. A similar arrangement of the labio-lingual dimensions of the same teeth, as may be seen in Fig. C, produced no different results. This test was made on every arch form of the various genera the result not changing at all. These records undoubtedly show the sort of correlation existing between dimensions of the teeth and of the form of the arch, thus having a concrete bearing upon a few of the points referred to by the essayist.

With relation to the charts of Dr. Johnson, he suggested that we should not pay any attention to them. To my mind they are very indicative, and I do not hesitate to say so.

I have been intensely interested in the study of the etiology of malocclusions for the last five or six years, and have made many studies and charted a good many cases to find something of value. I have published several papers on the subject, and the last contribution I made was based on the general disturbances of the individual in their relation to malocclusion. In the various studies I have found that there is a considerable correlation between malocclusion of the teeth and malnutrition of the individual in early infancy. Also subsequent disease processes, due not only to artificial feeding, but also to various conditions associated with disturbances that bring about artificial feeding are found to be correlated with occlusal anomalies. I would therefore be very much interested to know whether Dr. Johnson has made any examinations into the past history of the cases of malocclusion from which he has obtained these charts, because I feel that in some cases, like children who have suffered from exudative diathesis, there are certain defects which they probably never overcome. These defects would give expression in some sort of curve which may be indicative of some particular disturbance or disturbances in infancy.

Dr. V. E. Barnes, Cleveland, Ohio.—We should regard these arch forms as an expression of deformity rather than of normality. We may differ as to normal development. The development which we find in children of five or six years of age is in the majority of cases an expression of abnormal or deficient development, for the reason that in the Caucasian races we have a history of malnutrition, of insufficient nourishment due to artificial feeding. As I pointed out in a paper presented in 1912, we must not take those cases which come to us as normals. If a patient succumbs before maturity we may express that case generally as an abnormality. We must look at the case at first, not as normal, but as abnormal. Until it is a part of the normal we accept with considerable question the normal and abnormal. The types should be taken as expressions of deviations from the ideal. I do not know that we can calculate a perfectly normal arch. I do think, however, we can mathematically calculate an arch from the size of the tooth given us, and that is our limit, the zero measuring point from which we may later calculate deviations if they are constantly determined.

I have not had enough time to digest Dr. Johnson's paper, but I think he has tried to prove that the individual normal may be expressed in the malpositions of the teeth as we find them in that individual.

Dr. W. H. Gilpatric, Boston, Mass.—I did not intend to bring up the subject that I am about to refer to, but inasmuch as Dr. Hellman and Dr. Johnson led up to the predetermination of the dental arch to a certain extent, I shall refer to it.

Dr. Hellman spoke of apes. We as orthodontists are not today dealing with apes. He also spoke in regard to measuring one central incisor and predetermining the arch from it. I do not believe that can be done.

In the past two years and a half I have been working on the predetermination of the dental arch, and, as I understand and construe Dr. Johnson's paper, the individual normal arch. Nature has given us a certain tooth substance; we have not selected it for that individual case, and if patients come to us with these abnormalities, what are we going to do?

If you have 85 millimeters of tooth substance in the case of Johnny Jones, and 85 in the case of Billy Smith, does it not stand to reason that you are dealing absolutely with the same tooth substance in each arch? That you are going to have but slight variation from the contact point, and which you need to get in order to have the same shaped arch.

If you have 90 millimeters of arch tooth substance to deal with from the buccal groove of the first molar to its opposite, you can vary that arch but very little and still have normality. It is impossible. If you have 85 millimeters you naturally would have a different shaped arch from one where you had 90 millimeters.

What are the men doing with the cases that come to them? What basis have you for the predetermination of the arch? Nothing but the eye at the present time. Dr.

Fig. D.—Orthodontographic Normal Arch containing $84\frac{1}{2}$ mm. of tooth substance, and arch width 55 mm. from buccal groove of first molar to its opposite.

Johnson is working on the right track, but there are a dozen different strings leading to the same point, and I am glad Dr. Johnson and several other men are making investigations along this line.

Supposing across the buccal groove from one side of the arch on the upper to the other you have 55 millimeters for a given tooth substance, if you have an ideal arch width to work to on a given tooth substance, and start in and prove that, it will help you. In my work I started out and worked very nearly a year, then I started to prove whether the work was correct. I began looking for the normal in the human mouth, and I have at the present time about fifty cases, and I can predetermine those arches for a given tooth substance. The greatest variation I have is one millimeter, and that is caused by the loss of the lower six year molar on one side.

I would like to make an appeal to the members here to get at these normal cases to check up my work and look for the normal for a given tooth substance to see what nature has done. My cases that I have treated and have established good relation between the tooth substance and the width of the molars, have been the easiest and most successful in retention. Here you see (indicating) the buccal groove measure, and I wish all the men, those who have been in practice for a long time, would go over their cases and tabulate those that have been most successful in retention, and see whether they shape or correspond with the work I have done up to the present time.

As I said before, I did not intend to speak on this subject, but I have been working along this line for a considerable time. It is an evolution of the work of Dr. Hawley,

Dr. Williams, and Dr. Stanton, and I have what I call the orthodontographic normal arch for a given tooth substance.

I have also developed a simple machine for surveying the malformed arch, and I wish to take this opportunity to present arches and the machine to you. I will give you the drawings, you can have them made, and if you wish to have that part of the arches copyrighted, so that you can have control of them, they are yours.

If my work is any help to you men, you are welcome to it.* You can take it, pick it to pieces, or combine it with other ideas of other men. If there is anything in it that is good, save it and do not throw it away.

Dr. Frederick C. Kemple, New York City.—A few years ago in company with Dr. Clarence J. Grieves at the Baugh Institute of Anatomy in Philadelphia, I had the privilege of examining a rather large number of wet sections of the heads of children of ages varying from infancy to adult life. These specimens were made by Dr. Warren E. Davis for the purpose of studying the development of the accessory sinuses.

I was interested in finding out if there was any correlation between the development of the dental arch and the development of the nasal spaces and accessory sinuses. I was also interested in learning what change in the anatomic structure of the base of the skull might be induced by widening the upper dental arch that could possibly result in relieving pressure upon the pituitary body. The specimens examined, and there were quite a large number, apparently showed no definite relationship whatever between the development of the upper dental arch, the nasal spaces, and the accessory sinuses. Neither could either of us see how the widening of the upper dental arch could bring about a lowering of the body of the sphenoid bone, or in any other way relieve pressure upon the pituitary body. The anatomist in charge of the Institute ridiculed the idea of such a thing being possible.

Before examining these specimens and others in Dr. M. H. Cryer's collection, I had a preconceived notion that there was a definite relationship existing between these parts; that they developed more or less symmetrically; that well developed sinuses and nasal spaces accompanied well developed dental arches, and vice versa. But in my limited investigation I have found no evidence to support this theory. In fact just the opposite condition is found to exist so frequently that I am led to believe there may be no interdependence in the development of these parts. I am afraid that many of the idealistic theories in orthodontia will vanish into thin air under the searchlight of thorough scientific investigation, such as is being carried on by Dr. Johnson and Dr. Hellman.

It is a well-known fact in physiology that "hard structures must give way to the soft." In other words, slight pressure of any of the soft tissues upon any of the osseous tissues causes a giving way of the osseous tissue, either by resorption of the bone itself or by a change of its form. The records that Dr. Johnson is making of the nervous muscular action of the tongue are along this same line.

I am glad to have heard Dr. Johnson's paper, and to have seen the charts shown by Dr. Hellman. It is all very illuminating, and promises a brighter future for orthodontia. If a few more men will join in an effort to get at the truth, to uncover *facts* in orthodontia, it will not be many years until our specialty will rest on a scientific foundation, instead of being built upon the sand of a host of beautiful theories.

Dr. Hellman.—Dr. Johnson, you have shown one case in which the upper incisors were persistently drifting forward after retention. Did you observe whether that child or person was lisping?

Dr. Johnson.—No sir. We could not find any difficulty anywhere, and I would not have been led to this extreme if I had.

Dr. B. W. Weinberger, New York City.—I hesitate to discuss Dr. Johnson's paper because it would be unfair, for one can not do it justice without first thoroughly reading it. It proves one thing, however, that the general tendency of orthodontia in the last few years has changed and is progressing more towards the physiologic than the mechanical side. We must pay attention to the correlated facts between the various organs outside of the mouth and that brings us back to the point of the nervous system. This brings up

the question of calcium metabolism which has a direct bearing on tooth development and jaw growth. I do not know whether Dr. Johnson is familiar with the work of the neurologists. These men are paying a great deal of attention to the endocrine organs and their relation to the teeth and tooth substance, and to the construction and form of the teeth, and what direct bearing they have on the various nervous disturbances with which they have to deal. How much stress and how they are paying attention to the teeth and their form in trying to solve the various questions of thyroidism, pituitarism, and so on through the various cycles may be seen from recent literature. I think, as orthodontists, we have been very lax and in the future will have to pay more attention and open our eyes to the work that these men are doing. As orthodontists, we will have to recognize the knowledge that these men possess and the attention they have paid to the teeth and the bearing they have on calcium metabolism and on nervous disturbances with which they have to constantly deal. One of the main factors to be considered, and one of the first things they observed, is the blood pressure.

I want to ask Dr. Johnson whether he has taken into consideration blood pressure in charting these cases, because it is more than a nervous tendency for the tongue to raise the tip; and also indirectly to the endocrine organs which have a prenatal origin.

Dr. Johnson (closing).—I am very grateful to the men who have discussed my paper. It is very satisfying that Dr. Hellman should present the evidence he did at this time as he was wholly in ignorance as to what my paper was to be. We have evidently arrived at the same conclusions though following different lines of study.

Dr. Lischer misunderstood the reading of my paper. Variation I did not consider as exclusively of germinal origin. It may be of germinal origin or it may be of environmental origin. The form of an organ or part is the result of an interaction of forces. Two stones of different character exposed to the same environmental forces will take on different forms; and two stones of the same character exposed to different extraneous forces will show different conditions. The determining factor of form may be either heredity or environment. When we refer to the formative influence of function the word function is used in its broadest sense and not as referring to the specific activity of an organ or part. Function expresses all of the dynamic processes of the living organism; the complex of chemical reactions; the action, reaction and interaction of organs and parts in the adjustment of life.

Dr. Lischer.—Do you recognize modification?

Dr. Johnson.—Yes.

Dr. Lischer.—As distinct from variation?

Dr. Johnson.—The word variation covers the modification of form.

A Member.—What do you mean by modification?

Dr. Lischer.—Something that happens in the individual's lifetime.

Dr. Johnson.—The enlargement of a muscle as a result of exercise is modification, it is also variation. Variation may be qualitative as in mutations, illustrated in the work of Morgan on the *Drosophila*; or it may be quantitative as in the development of a muscle. I fail to see in what way my concept of the problem of orthodontia and the remarks of Dr. Gilpatric coincide. I have merely endeavored to formulate a concept which will serve as a scientific basis for the study of the individual organism. The slides have indicated one way to study the forces determining the form of the dental arch.

Dr. Weinberger asked about blood pressure and the internal secretions. I have not gone into these things far enough to answer the question intelligently. There are, of course, a great many correlations we can make.