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METABOLIC DISTURBANCES IN RELATION TO THE TEETH*†

CHARLES F. BÖDECKER, D.D.S.

INTRODUCTION

The principal purpose of this paper is to call the attention of the medical profession to its responsibility in preventing dental disorders. Recent investigations indicate that dental health may sometimes be linked with general health, and that dental ailments may be symptoms of systemic derangements. Hence it is necessary that physicians in general and pediatricians in particular should evince more interest in dental problems.

General practitioners of medicine and dentistry who attempt to cover their vast fields are interested mainly in generalities; it is therefore the aim of the author to confine himself to these, and to leave the details for the study of those particularly interested in this subject (pediatricians and dentists). For these a fairly extensive bibliography is appended.

The teeth have been regarded until very recently as organs outside of the field of nutrition. As a result of such an erroneous conception, the field of dentistry has long been relegated to a group of specially trained men who combat the diseases of the teeth merely by reparative means. The only preventive treatment instituted to protect the dental mechanism against destruction has been an attempt to promote oral cleanliness. If such cleanliness is defined as a sterility of the oral cavity, then it can be regarded as futile.

The present form of dental service, inadequate as it is in really *preventing* dental destruction, is available to only a small part of the public. The proportion of the popula-

* From the laboratory of Histo-pathology, Columbia University School of Dental and Oral Surgery, New York.

† Delivered November 3, 1933.

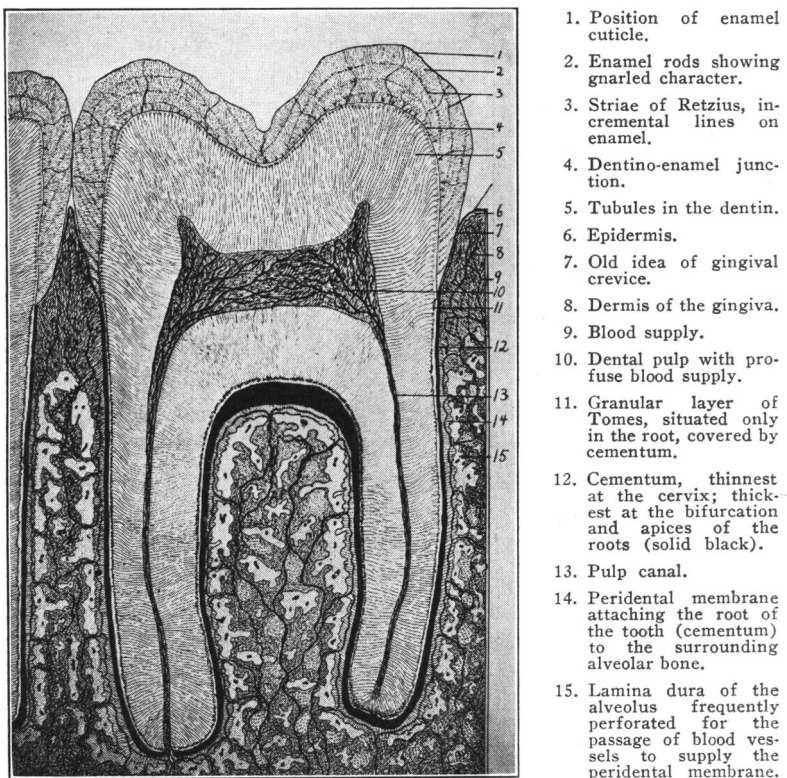
tion who receive dental care has been variously estimated to be no higher than twenty to thirty per cent. The reason why only symptomatic treatment has been resorted to by the dental profession as a whole is that systemic disturbances were thought to have no ill effect on fully formed teeth. It was believed and is still considered by many to be true that the calcified dental tissues receive no "nutrition" (added mineral salts), hence a disturbance of the nutritional balance of the body could have no ill effect on the teeth. Such erroneous views are very slowly giving way to a more sane, a more biological conception of the dental organs. Some health workers in general and the promoters of food products in particular, have filled the columns of periodicals and journals with commands to "feed your teeth." However praiseworthy this may be, a great deal of investigation must be undertaken before such an act can be understood scientifically, and furthermore, much work must be done to define the specific beneficial elements necessary to dental health. We know as yet too little of the histo-pathology of the dental tissues and almost nothing of their physiological activity. Dental physiology, as applied to the metabolism of the dental tissues, is in fact an almost non-existent science. With this in mind it is comprehensible that, as yet, little definite information can be given as to the relation of specific systemic disturbances to dental diseases.

TISSUES OF THE TEETH

Some knowledge of the dental tissues is necessary for the comprehension of the manner in which metabolic disturbances may affect the teeth. A diagram, Figure 1, shows a longitudinal mesio-distal section of a lower molar and surrounding tissues. It is noted that the dentin forms the bulk of both the crown and the root of the tooth. Its formative and probably its nutritional organ, the dental pulp, or "nerve", occupies the interior of the crown and root; it is profusely supplied with blood vessels and nerves. The root dentin is covered with cementum which serves for the attachment of the root to the surrounding bone,

while the crown dentin is protected by enamel of varying thickness to withstand the force of mastication. It will be seen that each tooth can be regarded as a functioning unit, having its biological connection with the body through the vessels and nerves of the dental pulp. Incomprehensible as it may seem from a biological point of view, the dental pulp is believed by most investigators to have no function (except to form secondary dentin) after the completion of the tooth. In spite of the presence of a

Fig. 1. A Mesio-Distal Section of a Lower Molar, Alveolus and Gingival Papillae.*



* From Charles F. Bödecker, "Elementary Histology for Dental Hygienists." New York, 1933. John Felsberg, Inc.

profuse blood and nerve supply in the dental pulp, it is believed that the calcified dental tissues, particularly the enamel, have no connection with the body. This erroneous view seems to be held by all except Beust¹, Fish¹⁰, and the author^{2,3}. The newer researches, however, are forcing more and more investigators to accept a saner biological conception.

An examination of Figure 1 shows that the enamel, covering the entire exposed portion of the tooth, is a protective tissue to prevent destruction from the outside. The resistance of the tooth, particularly of a young person, is therefore primarily dependent upon the ability of the enamel to withstand attack of the acid which is supposed to be active in dental caries. Evidence is accumulating to show that the resistance of the enamel (and also that of the dentin) against external attack is dependent upon systemic conditions. When this is finally proven, the varying activity of dental caries will become more clear. The entire subject is now under active investigation by the Columbia University Dental Caries Research Group, financially assisted since 1930 by the Commonwealth Fund of New York.*

* The Commonwealth Fund Grant for the Study of the Cause of Dental Caries:

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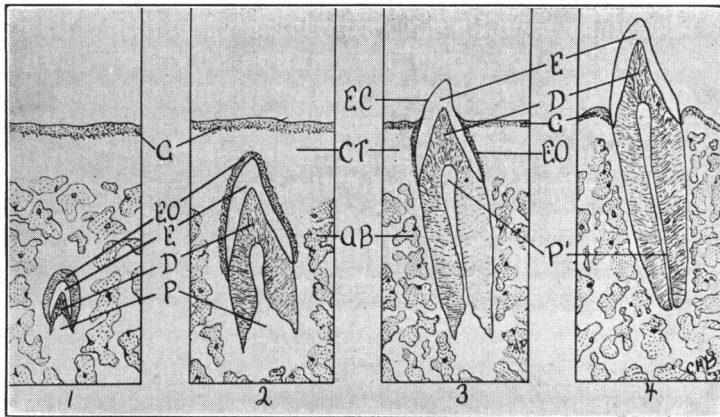
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Mention must be made of the manner in which the teeth are developed, for the proper understanding of the metabolism of the dental tissues. A comprehension of the development of the enamel is particularly essential in this respect. This structure is formed by the enamel organ of ectodermal origin. Enamel growth of the teeth begins at the dentino-enamel junction and progresses outwardly, so that the last formed enamel is on the surface of the tooth (Figure 2, diagrams 1 and 2E.) The tooth then

Fig. 2. Stages in the Eruption of a Tooth.



The enamel organ is destroyed when the tooth pierces the gingiva, hence it is believed that the enamel requires no further mineral salts.

G—Gingiva.

D—Dentin.

EC—Enamel Cuticle.

EO—Enamel Organ.

P—Pulp.

CT—Connective Tissue.

E—Enamel.

P₁—Dental Papilla.

AB—Alveolar Bone.

pierces the gum tissue in order to become a functioning unit of the oral cavity and thus the enamel organ is destroyed. (Figure 2, diagrams 3 and 4.) Its remnant forms the enamel cuticle (EC) which, being cut off from all blood supply, can no longer function; thus no new enamel can be developed after the eruption of the tooth. *It is for this reason that the mistaken conviction has so*

long existed that systemic disturbances cannot affect the enamel by means of the circulatory system and that therefore fully formed teeth can be acted upon only from the exterior; *i.e.*, by the saliva, bacteria, and by food retention in the oral cavity. This belief has long been a barrier to the investigation of the possible systemic causes of dental caries.

A further strengthening of this erroneous belief was the conviction that this tissue is a purely mineral structure, containing no protein matrix. If this were true, then it would be impossible for lymph, originating from the dental pulp, to penetrate the enamel. As has been stated previously, the young functioning tooth was considered to be completely matured and no mineral salts ("nutrition") were needed after this time. The comprehension of the attitude of most investigators of teeth is necessary for a thorough understanding of the problem of dental caries. Hence it is essential to recapitulate the incorrect conception of the enamel held by many investigators even today; this is that the enamel of fully formed teeth can not be affected from within by general metabolic disturbances because:

- a. Its formative organ is destroyed on the eruption of the tooth.
- b. It is an inorganic structure, containing no protein matter which might serve as channels for the distribution of mineral salts.
- c. It is therefore impermeable to a possible calcifying or decalcifying lymph which might originate from the blood stream by way of the dental pulp and the dentin.

For these reasons, the enamel was considered to be completely matured when the tooth pierced the gum, and therefore systemic disturbances, whatever their nature, could not affect the "nutrition" of the enamel. In line with this reasoning, it was thought that a deleterious influence could affect the enamel only from the exterior.

This view is slowly losing ground as:

- a. The enamel has been shown to contain a protein matrix, which may include channels for the transportation of lymph; this matrix is more abundant in youth than in later adult life. [Bödecker³, Gies⁴, Malleson⁵, Bibby⁶.]
- b. The enamel, under certain conditions, has been shown to be permeable to dyes, etc., in vitro and in vivo. [Bunting and Rickert⁷, Beust⁸, Klein and Amberson⁹, Fish¹⁰, Bödecker^{11,12}, Applebaum^{13,14}.]
- c. The enamel has been shown to undergo a progressive hardening after the eruption of the teeth. [Karlström¹⁵.]
- d. The enamel shows structural variations in calcification as defined by the Grenz-ray (soft x-ray). [Hollander, Applebaum and Bödecker¹⁶.]

All these observations support the view that the enamel is permeated, at least in children and young adults, by a lymph which may increase its hardness, and protect it against the external destructive products of bacteria and decomposing food debris. It is possible therefore that dental caries, which is most prevalent in children and young adults, may be due to a failure on the part of the body to mature the teeth thoroughly after their eruption and to build up sufficiently their resistance to external attack.

The irritating cause of dental caries is probably an acid, formed by the decomposition of food debris around the teeth; this we term the *environmental* (exciting) cause of caries. This factor, however, does not complete the picture of the disease; a predisposing factor seems also to be present.

Balanced against the environmental causes of dental caries, there appears to be a *protective* mechanism in each tooth (the dental pulp), which increases the resistance of the dental tissues to attack. Figure 3 a, b, c, expresses the

Fig. 3. Diagrams to illustrate the two opposing factors active in dental caries. The exciting cause of the disease is the fermentation of food debris and other factors affecting the teeth from the *exterior*. This is shown in the diagrams as the attacking factor (A). Opposed to this is the protective factor (P), a defense mechanism active from the *interior* of the tooth; its activity is dependent on systemic conditions.

Fig. 3a.

HIGH IMMUNITY TO DENTAL CARIES

(Primitive Races)

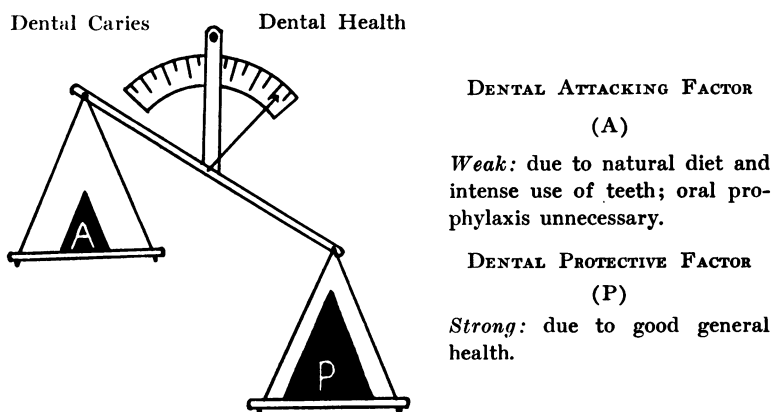


Fig. 3b.

SLIGHT SUSCEPTIBILITY TO DENTAL CARIES

(Average Civilized Persons)

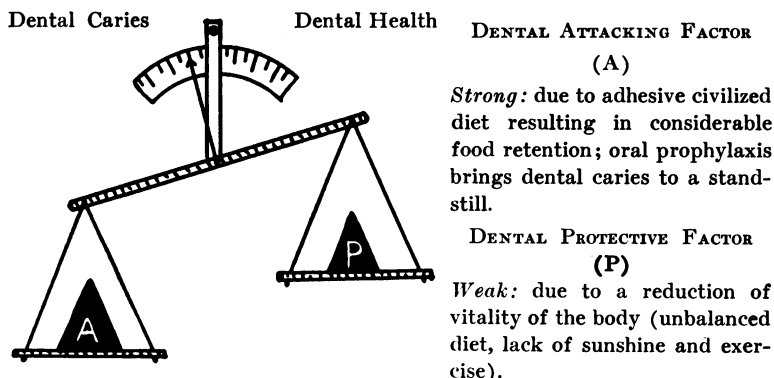
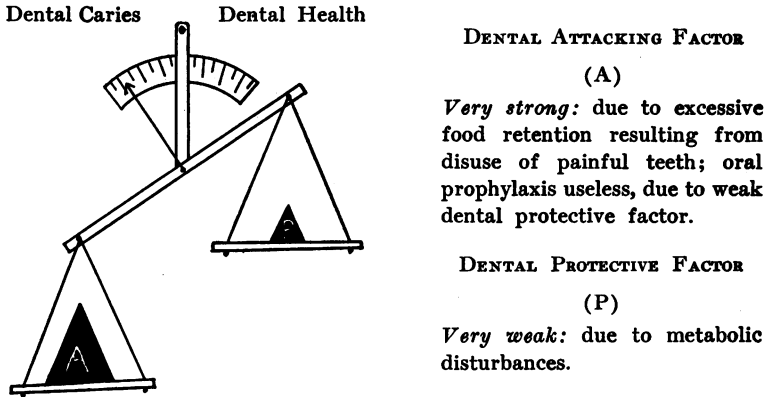


Fig. 3c.

GREAT SUSCEPTIBILITY TO DENTAL CARIES

(Persons suffering from systemic disturbances)



view of the author concerning the mutual relationship of these two major factors active in dental caries. The proper functioning of the protective mechanism is dependent largely on optimal systemic conditions. It is therefore clear that the attacking factor (food debris, bacteria, etc.) is counterbalanced by the protective factor. Thus a reduction of the natural protection of the teeth, through systemic disturbances, results in an increased activity of dental caries, unless it is counterbalanced by a more strict oral hygiene; frequent use of the tooth brush removes the food debris around the teeth and thus reduces the formation of oral acid (Figure 3b).

Civilization has changed our diet as well as our habits, so that our physical resistance has been lowered, in comparison to that of primitive people. Thus the teeth have lost their natural protection and we must resort to artificial means of cleansing to reduce the environmental causes of caries (food debris, bacteria, etc.), in order to combat dental destruction. This brief description of the two opposing factors of dental caries explains the necessity for scrupulous oral hygiene in *civilized* people, for most of us have a lowered resistance to dental caries.

Persons with rampant caries (Figure 3c) have such an exceedingly low resistance (P) that no amount of brushing of the teeth can prevent their decay.

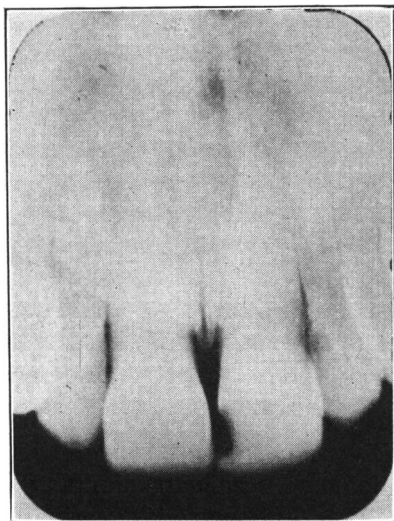


Fig. 4. X-ray of two central incisor teeth which shows that saliva, food retention, and bacteria cannot be the only factors in the cause of dental caries, as only one of the two closely adjoining tooth surfaces has become carious.

The findings of the Agnews¹⁷, Boyd and Drain¹⁸, Eddy¹⁹, Percy Howe^{20, 21}, Hanke²², Martha Jones²³, Marshall^{24, 25}, McBeath²⁶, Klein and McCollum^{27, 28}, May Mellanby^{29, 30, 31}, Price^{32, 33, 34}, and others show that dental disorders may be greatly reduced by a proper adjustment of the diet. Some of these investigators maintain that a lack of vitamin C is principally responsible for the activity of dental caries (Howe, Hanke). Weston Price regards vitamin B and mineral salts as the important elements in a caries free diet. Some believe that the lack of vitamin D is the offending factor (Mellanby). Finally, a disturbance in the calcium-phosphorus balance (which includes vitamin D) is the factor to which most recent investigators point as being

responsible for the high activity of dental caries. This conception is held by the Agnews, Jones, Marshall, Klein and McCollum, as well as by the Columbia University Dental Caries Research Group. The report of this group to the Commonwealth Fund, March, 1933, contains among much other material this statement:

"It is clear from these experiments that systemic factors associated in some way with the calcium-phosphorus metabolism are definitely related to the resistance of the teeth to decay. Whether other systemic factors exert an influence remains for future investigations to determine."

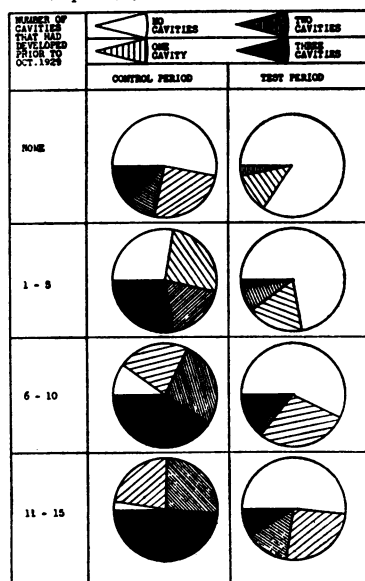
The sources of vitamin D appear to be an important factor in the prevention of dental caries, as shown by the observations of McBeath, of our group. This investigator was able to reduce dental caries to one-ninth its activity by irradiating children, ranging in age from 8 to 14 years, with ultra-violet light; that is, *dental caries was nine times more active in the control group than in the experimental group*. Mellanby and Jones believe that a diet, composed largely of cereals, is harmful, inasmuch as they have observed a marked increase of dental caries under these conditions. Hanke (Chicago Dental Research Club) has recently published an extensive report concerning "Nutritional Studies on Children²²." Their results are typical of the work of other investigators in reducing dental caries by dietary means. Observations were made on 323 children over a period of two years; the results are shown in a copy of one of their graphs (Figure 5).

DISCUSSION

The foregoing brief report of experiments to control dental caries by dietary means shows that it is possible, in the majority of children, to reduce and even in certain cases to prevent, this very common destructive dental disease. The divergence of opinion, concerning the specific beneficial factors, active in maintaining dental health indicate that our problem is not yet solved. Furthermore, the harmful elements of the diet which seem to exist, have

Fig. 5.

Correlation of the number of cavities that had developed to October, 1929 (total previous decay) with the incidence of dental caries during the control and test periods.



Each circle is divided into segments which show the percentage of children in which no, one, two and three (or more) cavities developed during the period designated above. The number of cavities that had developed prior to October, 1929, appears at the left. Read circles from left to right to determine changes occasioned by a change in diet. Read circles from top to bottom to determine variations in the incidence of dental caries associated with an increasing tendency toward this disease.

From "Nutritional Studies on Children," M. T. Hanke, et al, The Chicago Dental Research Club, *Dental Cosmos* **75**, 742, August, 1933.

not yet been definitely specified. An excess of carbohydrates is still held by some investigators to be partly responsible for an increased activity of dental caries. The work of Mellanby and Jones indicts cereals as the principal cause of the great activity of dental caries. Cereals have been fed commonly to generations of children, and it is possible that this type of diet, which forms an acid ash in the body, is harmful to the teeth and explains at least in part the intense activity of dental caries in the young [Mellanby³⁰, Jones²³ and Kugelmass, King and Bödecker³⁵]. Kugelmass expresses a definite opinion on this subject: "children maintained on ketogenic diets, *base-forming* in

their mineral content, showed low life caries indices, while those maintained on ketogenic diets, *acid-forming* in their mineral content showed marked dental caries." Further that: "children free from dental caries showed consistently a dietary intake excessive in alkali-forming minerals, with a preponderance of raw fruits and vegetables."

The following quotation of Hanke²² is interesting inasmuch as it indirectly throws light on the relation of the teeth to the body. Hanke says: "It is becoming increasingly evident that dental caries can be influenced in some cases by modifying the diet. The change in diet must, then, either lead to a change in the oral condition or lead to a change in the tooth itself. It is impossible at present to determine just why dental caries should be arrested by a change in diet. An incontrovertible proof as to whether the change occurs in the oral cavity or in the tooth itself is not contained in our studies nor in those of other investigators to which we have had access."

The results of McBeath²⁶ are particularly instructive in this respect, inasmuch as the beneficial effect of ultra-violet light rays does not reach the teeth by way of the mouth, but must affect primarily the systemic condition, which in turn improves the resistance of the dental tissues to caries. All forms of dietary additions such as orange juice, cod liver oil, vegetables, fruits, etc. come into direct contact with the teeth and therefore might be thought to increase their resistance to dental caries by means of this contact. But this condition does not apply to the observations of McBeath concerning the effect of ultra-violet light. It is thought by many investigators that the saliva is the beneficial or harmful agent affecting the teeth during varying systemic conditions, but Figure 4 shows that this can not always be true. In this x-ray we note that caries has attacked only one of two closely adjoining teeth. Saliva can not be made responsible for attacking one tooth and protecting the other.

The fact therefore that teeth may be benefitted by ultra-violet irradiation is an indication of their biological con-

nection with and dependence upon the body. The frequent reiteration of this statement may seem needless to an audience composed principally of biologically-minded medical practitioners, nevertheless it is necessary, in order to break down the prejudice under which most investigations of dental caries have been carried on.

A study of the recent literature on the subject of dental caries shows marked contradictions. Some investigators point to the advantages of a diet composed chiefly of fruits and vegetables and stress the benefits of ultra-violet light. They strengthen their argument with examples of the excellent teeth noted in some primitive races living in the tropics. Contradictory evidence in this respect is presented by the Eskimos, who live six months in darkness and subsist on an entirely different diet, a high protein diet. Their teeth are in an excellent condition so long as the race is not exposed to our civilized diet [Waugh³⁶]. These two contradictory observations are so confusing that some people have disregarded diet as a major factor in the cause of dental caries. However, Martha Jones suggests a rather ingenious explanation of this paradox. She believes that an abundance of ultra-violet light, such as people of the tropics enjoy, results in a slight acidosis, hence such people require a highly alkaline diet, namely fruits and vegetables to maintain the normal balance. The Eskimos, on the other hand, living in a region where there is a scarcity of ultra-violet light, tend as a result to an alkalosis; hence they require a higher acid ash diet in order to counteract this alkalosis. This view appears plausible, for it is a common practice of dietitians to advise the reduction of meat consumption during the summer months in the temperate zones, and the increase of the protein content of our diet during the winter months. Dr. Jones is continuing her researches in this direction and if her views are correct, it will clear our conception of the type of food necessary to maintain dental health under different climatic conditions; and thus the apparent paradox of dentally perfect races living on radically different diets will be removed.

Dental caries is undoubtedly due to a number of causes. The author suggests that the relation of the teeth to systemic disturbances may be expressed tentatively in the diagram shown in Figure 6. This chart is presented merely to crystallize our thoughts on the problem. If this theory, showing the complexity of the causes of dental caries is approximately correct, we begin to understand why the views of different investigators are so widely divergent, and to comprehend that each may be correct in his individual observations made in localized districts. For instance, the activity of dental caries in one locality may be due to a lack of sufficient mineral salts resulting from an impoverished soil, as is claimed to be the case in South Africa. [Lennox³⁷] In a second locality, dental caries may be caused by a lack of sufficient sunshine; in a third, to an absence of one of the vitamins. Naturally each observer believes that the deficiency he observes is the sole cause of dental caries; and he may be correct so far as his locality is concerned. The chart (Figure 6) shows a number of deficiencies, each of which may be regarded as a contributing factor in dental caries, since such a deficiency can disturb the metabolism of the body. This in turn reacts on the dental pulp, the nutritional organ of the tooth. A disturbance of the function of this organ results in a derangement of the protective mechanism of the tooth; this constitutes the predisposing cause of dental caries. It is only when the natural protection of the teeth is lowered through an improper functioning of the dental pulp that the exciting causes of dental caries can become active (food debris, bacteria).

All investigators who have observed nutritional experiments have noted that the activity of dental caries is reduced under improved nutrition. But the fact that this disease can not be prevented in all cases, again shows that our understanding of the problem is by no means complete. We do not yet comprehend the mechanism of destruction of the dental tissues during the feeding of an unbalanced

diet; neither can the manner be agreed upon in which the teeth are protected during the period of proper nutrition. This protective dental mechanism whose disfunction allows the teeth to be ravaged by dental caries, must first be defined by the histologist and physiologist in order to make further progress in the solution of the problem of dental caries. When that is achieved, attempts will be made by the chemists to analyze the dental lymph and to find differences in the constitution of this fluid in caries-immune and in caries-susceptible persons. Then, knowing the elements necessary to maintain a high resistance of the teeth to decay, we may possibly administer these elements to the body, at the same time stimulating the organs responsible for their assimilation. It will be important also to define those food elements affecting body fluids which result in systemic disturbances permitting the decalcification of the teeth; when these are recognized, the medical profession can warn the public of the dangers of an improper diet, and can stimulate public interest in individual responsibility in maintaining general health for the possession of sound teeth.

CONCLUSION

Recent findings indicate that a disturbance of the calcium-phosphorus balance exerts a deleterious influence on the teeth, making them more prone to dental caries. In the light of this knowledge, it seems necessary that dental caries should no longer be treated solely by reparative means but that true prevention, by systemic treatment, should be instituted.

The teeth are often so seriously affected by caries during childhood that a number must be removed; thus such persons go through life with an impaired dentition, or, if pulp removal is resorted to, one or more possible sources of dental foci of infection are present. The dangers of focal infection may have been exaggerated by some, nevertheless there is still a real danger and this danger should be faced squarely.

The only certain way that dental foci of infection can be eliminated in the future and at the same time insure all persons a full complement of teeth, is to *prevent* the inception of dental caries.

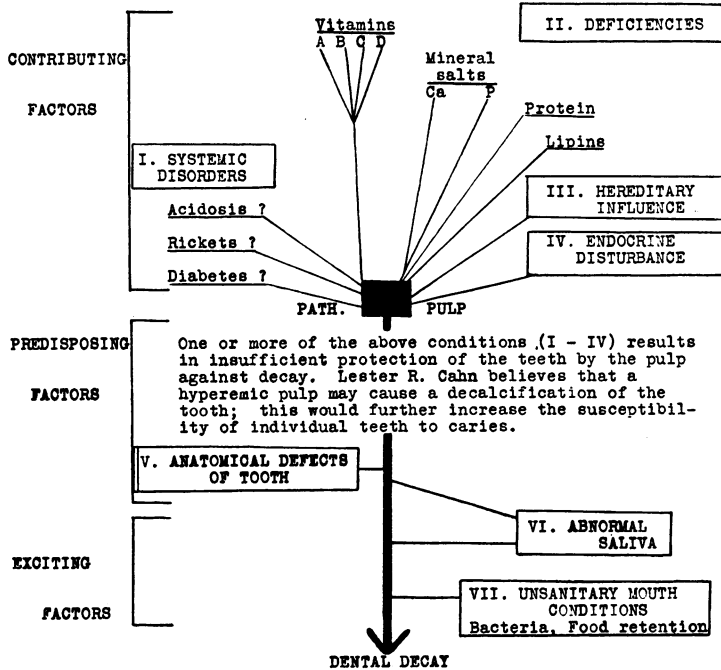
In the future, the principal duty of the dentist will be, as it has been in the past, the repair of the ravages of dental caries and pyorrhea alveolaris. On the other hand, the responsibility for the *prevention* of dental disorders will rest on the shoulders of the medical profession. In this connection the dentist will be able to perform another valuable service, namely that of noting oral disturbances which may be reflected from incipient systemic disorders. Thus, the dentist who sees his patients in a state of comparative good health, can warn them of impending trouble and suggest a consultation with the physician. Observant dentists have frequently noted that their reparative dental work does not keep pace with the rate of dental destruction, and in despair they sometimes suggest to the patient a consultation with the family physician. This action is definitely the duty of the dentist. However, an attempt to prescribe should not be made by the dentist. This should be done only by the physician after a thorough physical examination in order to define the deficiency existing in the case of each patient.

For a better understanding of dental disorders having a systemic origin, it may be advisable in future to create a new specialty covering particularly the borderline of dentistry and medicine. Even though it is uneconomic to train all dentists as medical graduates, it is advisable, nevertheless, to instruct a selected group of men in both fields of medicine and dentistry. Such men will be able to act as consultants and to suggest systemic treatment of general disturbances which are suspected of causing oral diseases.

There is evidence that rampant dental caries is a symptom of some systemic disturbance and it is suspected that pyorrhea alveolaris can be regarded in the same light. I have frequently referred a person to a physician for a

Fig. 6.

SOME POSSIBLE FACTORS INVOLVED IN THE CAUSE OF DENTAL DECAY
MOST ACTIVE DURING YOUTH



physical examination, and in many cases the condition of the patient was pronounced normal. However, in some instances, systemic disturbances were diagnosed some time after the first consultation. This leads me to believe that our laboratory tests, particularly in relation to the blood and the endocrines, are not sufficiently delicate to define some as yet unknown variation from the normal, which may exist in incipient systemic disturbances. The teeth, being farthest removed from the source of general nutrition, probably suffer first as a result of certain metabolic disturbances. Hence it is my belief that the teeth may at some time in the future be regarded as a delicate indicator of some phases of bodily health, even before a physical examination discloses any systemic derangement. This

view is by no means new, it was generally maintained during the last decades of the nineteenth century, but has been since disregarded as a result of the belief that the welfare of the teeth was not dependent upon bodily conditions.

Consequently, if we wish to prevent dental caries in children and young adults, and pyorrhea alveolaris in the middle aged and the old, systemic treatment must be instituted. For the purpose of defining such a mode of treatment, a more intimate association of physicians and dentists is necessary.

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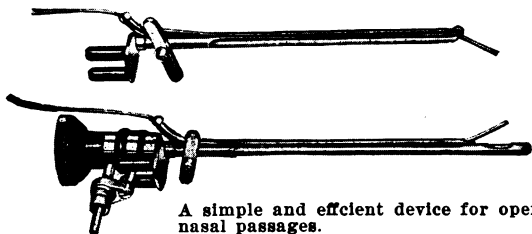
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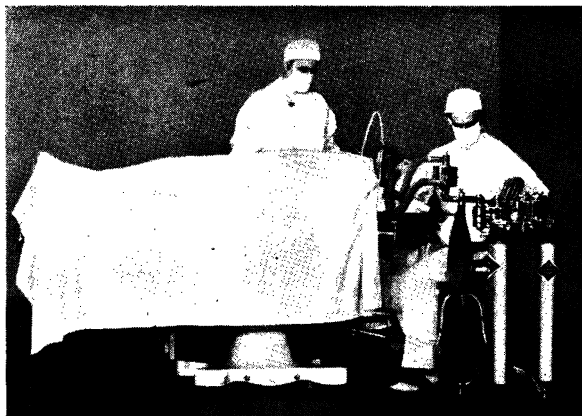
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