Section of Odontology.

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The Endocrine Factor in the Production of Immunity and Susceptibility of the Teeth to Caries.

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The modern trend of thought amongst members of our profession is one of dissatisfaction with the theories of the ætiology of dental caries on which we were brought up, and the dental literature of to-day reflects this dissatisfaction. I desire, therefore, to-night to draw your attention to the possibility of the endocrine apparatus playing a part in the causation or the prevention of this disease.

Although Miller's theory will explain the onset of caries, and Sim Wallace's conclusions help us to see the reason for its prevalence, and although these theories may be true, many of us feel that they are by no means the whole truth of the matter. They leave too many questions unanswered, too many undoubted clinical facts unexplained; and, above all, if they in any way approach the whole truth, the results, bad as they undoubtedly are, should be infinitely worse. If the destruction of enamel, due to chemical action, is a simple matter of the solution of lime salts by organic acids—if there is no other factor in the equation—then the extraordinary thing is not that dental caries should be rampant, but rather that it should be possible for teeth to exist at all under modern circumstances. Then, the fact that we see good, sound, hard teeth in adult life, seems to be the problem needing elucidation, before that of the rapid destruction of the teeth of children and young people. For, knowing the affinity of lime salts for acids, and the certainty that acids can be and will be formed in close proximity to the teeth, whatever precautions we may take, we must necessarily postulate an immunity in the mouths of some, to account for the condition that we know to exist, and assume the necessary corollary, that the absence of this immunity engenders a susceptibility to dental caries. In other words, we presume a predisposing cause, without which tooth destruction cannot take place.

On this matter, Dr. Kirk has said:—

"Every practitioner knows that susceptibility to dental caries is . . . . . a thing that comes and goes. So clearly and so broadly is this fact recognized, that it is generally conceded amongst dentists that youth is the period of greatest susceptibility, and that, assuming normal conditions of health, the tendency is markedly diminished, if, indeed, a period of immunity does not normally supervene, when adult age is reached. It is also a well-established fact that pregnancy tends to inaugurate a period of susceptibility, the old axiom 'for every child a tooth' has its equivalent expression in practically every civilized tongue. It is also known from wide clinical observation that dental caries is not of necessity a filth disease. Some teeth kept as clean as patient and dental operator can keep them, decay, and decay recurrently; other teeth, in mouths into which a toothbrush has never entered, and which are offensively filthy, do not decay. Our theories must be sufficiently comprehensive to fairly explain these peculiarities, otherwise we have not arrived at the whole truth of the matter."

This being so, from a preventive point of view at any rate, we must turn our attention to the predisposing cause, for if teeth are, or can be made, immune, exciting causes do not matter; on the other hand, if they remain susceptible, our daily labour is for the most part in vain, for we know that there is little hope of saving them beyond to-morrow.

In an earlier paper, I put forward the theory that the predisposing cause of dental caries was a diminution of the calcium-utilizing power of the body, brought about by a loss in balance in the secretions of the endocrine glands, resulting in a greater or less degree of calcium starvation of the tissues of the body. I now wish to amplify this theory, and to show how this calcium hunger is brought about, and how it reacts upon the teeth.

The first point I would emphasize is the all-important necessity of a complete covering of the erupted portion of the tooth with enamel. However thin this may be in parts, so long as it is complete, no tooth destruction can take place; conversely, once the enamel has been removed throughout its whole thickness, over however small an area, the tooth is doomed, unless artificial measures are taken for its preservation, except in that extraordinary condition known as arrested caries, to which I shall refer presently. Consequently, in considering the ætiology of dental caries, it is to the enamel alone that we need direct our attention.

Clinically we all recognize differences in the enamel of various teeth in colour, in opacity, and in hardness, the extremes being perhaps the teeth of the gouty man and of the consumptive child: even in healthy patients there is a noticeable difference in the extremes of life. Further in certain cases, we can predict with much certainty, that some teeth will in later life fall victims to pyorrhœa, and that any fear of caries is groundless. Pickerill proved experimentally that some teeth were hard, and some soft, using the terms "sclerotic" and "malacotic" to deferentiate the two types; and although analysis seems to show that the quantity of lime salts is not much greater in the immune than in the susceptible tooth, we know that there is a clinical difference, and that, other things being equal, a tooth that has erupted ten years is harder than one that has erupted two years; consequently, it appears probable that a vital change from a soft to hard condition is slowly taking place in these teeth, and it is this vital change which produces the immunity to caries.

In considering this subject the body chemistry of the salts of lime must be briefly discussed. Lime is found in the body in two forms:—

(1) Fixed in the tissues as inorganic salts which help to build up the framework of the body.

(2) A quantity serving as part of the alkali reserve of the body, as an ionic salt, and having many uses. The fixed lime has passed through this embryonic stage; some of this ionic lime will later be used for the purpose of body building or repairing, but in the meantime it has other necessary functions to perform, not only as an alkaline salt (its necessity as such will be considered later when discussing the question of acidosis), but also on account of its calcium ions, which are necessary for giving tone to muscle, for the proper functioning of the heart, and also for keeping nervous tissue in a proper excitable state, for without these calcium ions there can be no proper transmission of nervous excitability from nerve to nerve cell or from nerve cell to muscle.

Now lime salt must enter the body by way of the food supply, but the question of ingestion and of a balanced diet is in itself insufficient. It is necessary to remember that "within the intestine" does not, by any means,

imply " within the body," nor is absorption by itself always sufficient, as, without utilization and fixation the salts may still be lost. Lime salts may be, and often are, excreted unchanged in the fæces, or they may in part be absorbed into the blood stream, utilized or not as the case may be, as ionic lime and excreted in the urine. In this case also they are useless for tooth-building (I here mean not simply original calcification of tooth tissue, but the constant hardening process that I believe to be continuously going on); for this purpose they must be definitely fixed in the tooth substance. Thus we see that both absorption and fixation are necessary. Increasing the quantity in the diet, and care in selecting an easily absorbed quality are in many cases, by themselves, quite useless for dental prophylactic purposes, a fact well recognized by the medical profession in treating conditions such as rickets and osteomalacia, both of which are regarded as being due to lime shortage. In fact it would seem that the amount of calcium required to keep the body in health is extremely small; it has been estimated as about 0·75 grm. daily for an adult, and it would be a simple matter to determine how much milk alone would supply this amount, if all the lime contained therein could be absorbed, utilized, and fixed. Of course if this irreducible minimum is not given in the food it is quite probable that dental troubles might ensue, but it is difficult to imagine a diet that will not contain this, short of actual semi-starvation.

Gies found that a diet ordinarily considered to be deficient in lime salts produced no effect on the teeth of puppies in one hundred and twenty-seven days, and that it was necessary to reduce the calcium content of the diet of rats to 3 mg. a day for seventy days before signs of demineralization were found in the teeth. This appears to show conclusively that as regards lime salts any diets that we have to consider provide an ample sufficiency, and it is for the body itself to take, utilize and fix, what is provided: if this is not done it is the fault of the body itself rather than of the diet. (I am purposely leaving out of consideration now for the moment the question of vitamins to which I shall refer later, and am considering only the question of lime salts as a part of the diet.)

The next point for consideration is the need of lime salts during different periods of life; for this purpose a normal lifetime may be divided into three stages—viz., growth, reproduction and decay. During the first period the body is hungry for lime salts; bone and tooth building are active and the whole body is living at a great rate. In a healthy child nature has seen to it that this supply is forthcoming, but the margin is small and any little upset in absorption and utilization is quickly felt. Calcium hunger may change to calcium starvation, with its deleterious effects, both from the point of view of a shortage in the laying down of inorganic lime and its fixation in the bones and teeth, and from that of the need of ionic calcium, as shown by the tetanic convulsions so commonly seen during this period.

During the second period, that of reproduction, the balance between intake and output of calcium is more stable, and in men at any rate, lime is only needed to make good wear and tear and to replace waste; in women, however, there is a difference which Blair Bell summarizes as follows :—

" In men the reproductive calls on the metabolism are not great, their metabolism during the reproductive period, after growth has been established, is mainly concerned with individual needs; compared with women, the nerves must be steady, the mind stable, and the physical strength great, and all the endocrine glands are adjusted with this end in view—the preservation of a steady uniform metabolism in which no sudden alterations occur. There is, therefore, little reason for pathological lesion of hyperplasia

or hypoplasia to supervene in his organs of internal secretion, and this is what we find, provided that the changes at puberty do not overstep the mark. On the other hand in women, during this period there are bound to be sudden and rapid alterations, due to the demands of pregnancy and lactation, and with menstruation there is a large excretion of calcium and other substances previously required for growth of skeletal and other structures, but which are now no longer required until pregnancy occurs, when a fresh body is to be built up and nourished by the maternal metabolism. Thus, to a certain extent, a woman by her catamenia is kept in practice and protected from too sudden and great demands on her metabolic activity, and the periodic fluctuations in her economy are provided for by the capabilities of her endocrine apparatus."

Thus we see that during the reproductive period of life in both sexes, pregnancy excepted, there is less calcium hunger, less danger of calcium starvation, than during the period of growth, but that there is always a greater tendency to that state in women than in men, and if pregnancy supervenes, even the greater conservation that this condition entails may be insufficient to counteract this tendency; especially in women who were near the border line before.

That the calcium drain in pregnancy is considerable, is well shown by the experiments of partial parathyroidectomy in cats; these showed no signs of tetany unless they became pregnant, when the convulsions occurred, showing that the condition was latent and that conception only was necessary to upset a balance held with difficulty; indeed so well is this fact recognized that the fœtus has been well termed a calcium parasite.

Lastly, the period of decay. Now the balance of calcium equilibrium is in the opposite direction—the tendency is for the body to receive and utilize more than is necessary; lime is not required for growth, less repair and replacement is wanted, and the excess is liable to be stored in awkward places, arteries degenerate and joint troubles commence, the tendency to calcium hunger is replaced by a tendency to calcium saturation.

If with these facts in mind we consider the periods of life subject to susceptibility or immunity to dental caries as put forward by Kirk, we see that the greater tendency to calcium hunger gives rise to a greater susceptibility, and vice versa; growth and pregnancy are the periods of susceptibility, later life and old age of immunity.

The metabolism of lime salts is believed to be controlled by the endocrine apparatus, a term I use advisedly, for modern knowledge of the various glands of which this apparatus is built up shows conclusively that they are all part and parcel of one complicated machine working together for one end, which may be summed up in the word "life" in its broadest sense. With special reference to the calcium salts, these glands may be divided into two groups—one regulating absorption, utilization and fixation; and the other excretion.

In full health there is a perfect balance of calcium metabolism—just such amounts as are required at the time are utilized and the remainder excreted; any upset in this balance, whether by increased excretion, diminished utilization or otherwise, will lead to signs and symptoms of disease. In the first group of glands, the utilizers, we place the parathyroids, the pars anterior of the pituitary, and the medulla of the suprarenal, possibly also the thymus; in the second group the gonads (ovary and testis) and possibly the thyroid.

With regard to those glands in the first group, possibly they are not interchangeable, each may have its appointed part to play; the relation between parathyroid insufficiency and tetany seems to point to the fact that this gland presides over and in some way regulates the conversion of food lime into ionic calcium, for Howland and Marriott found that whereas healthy blood

contained 10 to 11 mg. of lime per 100 c.c., in rickets this was reduced to an average of 9·4 and in tetany to 5-5·6 mg. per 100 c.c. In acromegaly, amongst other symptoms there is an increase in the deposit of fixed inorganic lime, and as this disease is probably due to hyperplasia of the pars anterior of the pituitary, this may be the gland that converts the ionic calcium produced by the parathyroid into fixed inorganic material in bones and teeth. This point I do not unduly emphasize, as I have no authority to quote, but I would point out that these glands acting together are necessary for the utilization of these salts and the building of them up into the tooth structure.

We have considered the age incidence of susceptibility of the teeth to caries, and have found that it coincides with the period of threatened calcium starvation; we will discuss the normal activity of the various endocrine glands and the gland groups, with these various periods of calcium hunger.

In childhood, the most noticeable feature is that the gonads are inactive, have not reached the stage of functional activity and that the thymus is present in an active state. The child is thus placed in an exceptionally fortunate position for receiving and utilizing a large amount of lime. As the thymus deteriorates the gonads become active; thus there is an imperceptible passage into the second stage—that of a more stable balance between assimilation and excretion.

The question of menstrual flow in woman, if normal, is to her advantage as we have shown, but if excessive or if her tendency is towards undue calcium hunger, this may upset the balance, and may well account for the undoubted fact that as a sex the teeth of women are worse than those of young adult men of the same age group. But in ill health there is an interesting interaction between the ovary and the menstrual cycle which may to some extent regulate the loss.

In pregnancy the ovarian activity is in abeyance and as a rule remains so during lactation; this places the mother in a favoured position for conservation of her lime salts for the benefit of the child and incidentally of herself.

In old age again the gonads lose their potency and calcium excretion is diminished. We see therefore that in health the whole endocrine apparatus regulates the metabolism of lime salts, to the benefit of the individual, at all periods of life; but that an upset in the balance between utilization and excretion will have a greater effect, or produce that effect with a milder upset, at certain periods than at others, and that these periods are similar to those in which we find an increased susceptibility to dental caries.

The following points illustrate the question of the metabolism of lime salts in pathological conditions:—

I have shown that a normal balance between the assimilating and excreting glands is necessary for health. What will upset this balance, and in which direction will it be upset? For an upset balance in favour of the excretory group will result in calcium starvation and one in favour of the assimilators will produce calcium saturation.

I started my researches in pre-war days with the infectious fevers, for it is a recognized fact that the endocrine apparatus is concerned with bodily immunity, and should the patient succumb to an acute infection the glands will be stimulated to increased activity, to produce excessive secretion which acts as auto-antitoxin (Sajous). It is reasonable therefore to suppose that if the patient recover, the period of overwork may be followed by a reactive period of underaction. The late Rupert Farrant in his study of the thyroid post mortem found this to be true, so true indeed that he considered it was

possible from post-mortem examination of the thyroid alone, to say from what disease or group of diseases the patient had died.

With children, this reaction of the endocrine apparatus from over-stimulation is almost certain to be in one direction, for in their case the assimilators work practically unopposed, consequently the reaction should show itself—if it shows itself at all—in the direction of calcium starvation, which will affect all bodily tissues more or less. I found that the saliva of children convalescent from measles and scarlet fever was deficient in alkalinity, and that this deficiency was due to, or at any rate concomitant with, a lessening of the lime salts in the saliva. (As time is limited I omit discussion of figures; they can be found elsewhere.) I also found that a suitable plurigland preparation, administered to these children by the mouth, had a rapid and considerable effect both on the alkalinity of the saliva and on its calcium content. I myself contracted scarlet fever during this time, and confirmed these findings on myself, beguiling the tedium of convalescence with the burette and the microscope. This then was a point gained, and would seem to indicate a reason for increased susceptibility to caries in acute illness, a condition that we know to exist. For increased alkalinity of the saliva would doubtless act by neutralizing organic acid at the moment of formation, whereas a diminished alkalinity, below a certain point, would be less able to do so; and although these acids would readier combine with the alkali of the saliva, if that is not present they must perforce neutralize themselves with the lime salts of the enamel.

I next attempted to discover what could reasonably be considered a satisfactory alkaline index for the saliva, by taking saliva from all patients with whom I came in contact. As expected, I found considerable variation, but these variations fell into definite groups and all seemed to be explainable. For this purpose I estimated the hydrogen ion concentration of the saliva using the colorimetric method of standard tubes, which gives better and more accurate results than, and is simpler than, titration.

I found that in good health and in people without progressive caries (that is active destruction of enamel) the alkaline index was higher in children than in adults. It was highest of all in old people, especially in those suffering from pyorrhœa with subgingival tartar formation, but in children and adults with progressive caries and in adults suffering from ill health, especially active tuberculosis, the alkaline index was low; in some of the latter cases I found an hydrogen ion concentration to be as low as Ph 5·8, indicating a definite acid saliva.

I was unable to combine these estimations with that of the hydrogen ion concentration of the blood, or to make any estimations of the calcium content of this tissue owing to the lack of opportunity and apparatus; the results would have been interesting. These results are what would be expected; healthy children with active assimilatory glands are able to keep free from calcium hunger, in fact they have lime salts in reserve, ready to be used for body building, an excess not required and therefore not present in healthy adults; on the other hand as age increases this excess again appears, not because it is required, but because of defective elimination; where, however, the children or adults are in bad health and caries is active, we find signs of deficient assimilation.

This brings me to the first stage of my hypothesis that an upset of endocrine balance predisposes to dental caries by causing a diminution of the alkalinity of the saliva.

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But there is a second and I believe more important manner in which the lack of usable lime salts may effect the dental tissues. There are two well recognized diseases exhibiting in some directions opposite symptoms, namely, acromegaly and osteomalacia; in acromegaly, one of the most pronounced symptoms is an increase in the deposition of lime salts in certain bones; the lower jaw is perceptibly enlarged and thickened, the skull enlarges and if the disease arises before the junction of the epiphyses of the long bones, these are considerably increased in length, producing the phenomena of gigantism. In osteomalacia, on the other hand, there is a definite demineralization of the skeletal tissues; unfortunately in reading up this matter from a dental standpoint, I could find but little as to the state of the teeth, our medical confrères in the past have not considered these organs sufficiently, and it is rare to find any statement of their condition; if they are mentioned at all, it is some vague remark to the effect that the teeth decay rapidly and that pyorrhœa is present. This we know to be a contradiction of terms, for both conditions are rarely found at the same time; as we dentists recognize that these two states are antagonistic, and that the teeth that succumb to pyorrhœa are, generally speaking, the hard sound teeth that have withstood caries. I have never seen a case of osteomalacia, so I cannot speak as to the condition of the teeth; I have, however, during the last twelve months, had under my care two pronounced cases of acromegaly, both in women, the diagnosis of one of which I was able to confirm by a radiograph of the skull, which showed an enlarged sella turcica and great increase in the thickness of the bones of the vault of the skull, and both of these women had had their teeth removed for pyorrhœa.

Now the symptoms of acromegaly are caused by an increase in the secretion of the pars anterior of the pituitary body, and although I have no personal experience of the teeth of patients suffering from osteomalacia, a condition the reverse of acromegaly so far as the deposition of lime salts is concerned, I have lately had a patient whose condition seems to point to a disease known as dystrophia adiposo-genitalis, due to hypo-function of the pars anterior of the pituitary. She had lost all her teeth from caries; her first child was an anencephalic monster but she also had bonny fat twins of 6 years old, whose temporary teeth were a mass of small amalgam fillings. These results of observation in endocrine disease are interesting and not without point as will be seen later in the argument.

Various ductless glands have been made answerable for the onset of osteomalacia, the suprarenal by diminished secretion (Bossi), the ovary by hypersecretion (Bell), and the pituitary by hyposecretion (Knowles); and Erdheim found a hyperplasia of the parathyroids in this disease, which however he believed to be due to an antagonistic response to ovarian hyperplasia—at any rate it will be seen that it is an upset balance of metabolism in the direction of lime starvation. Thus we see, in the comparison of these two diseases, that under certain conditions the body has the power of fixing lime in excess (in the bones at any rate) or of yielding it up, that is of either hypercalcification or of decalcification as the case may be; and as the hypercalcification or decalcification is very excessive the results are most noticeable.

Bearing these facts in mind consider for a moment the hard "gouty" tooth and the soft tooth of acute tuberculosis, the enamel of one so hard that a steel drill will penetrate it with difficulty, that of the other so soft that it can be scraped with an excavator, the edges of the cavities so cheesy that one does not know where to stop in preparing them, and the resultant filling so unsatisfactory as to make the conscientious dentist despair. Consider again the teeth

of some children, where the greatest and most intelligent care of parent and dentist is insufficient to preserve the temporary dentition in good working condition until it is replaced by the permanant dentition. Were it not for the fact that we know that in many instances a time will come when conditions will improve, we should be inclined to refuse to spend time and labour on what seems a hopeless task.

Consequently we know definitely that not only bones, but teeth also, harden or soften in pathological stages. As to how this hardening or softening process takes place I shall not discuss, except to say that there are two possible ways. Each of these ways in turn has been declared to be impossible by presumably competent observers; one route is by way of the pulp, the other by way of the saliva; the pros and cons of the matter I must leave in more capable hands, but that the hardening or softening does take place must be obvious to all; it has been suggested that the normal hardening may be analogous to crystallization but this does not account for abnormal softening. I may however mention here the experiments of Dr. Head, quoted by Gies. Dr. Head placed extracted teeth in a solution of organic acid (fruit juice) and found that the surfaces turned chalky white, and that the enamel softened. This was proved by placing the teeth in a suitable machine containing a needle with a weight superimposed and by altering the weight and measuring the depth to which the needle was driven into the tooth. After this the teeth were immersed in saliva and the chalky white appearance of the surface disappeared and the normal enamel surface again presented, with an increase in hardness.

Head postulated that fermentation in the mouth caused an abstraction of calcium from the tooth, so that one out of every three atoms of lime was removed, and that if lime was returned to the surface of the tooth, in sufficient quantity, the abstracted portion was replaced, particularly so if the saliva were alkaline. This point is interesting and may possibly account for a condition of things which actually takes place.

We now see that pathologically, at any rate, bones harden or soften to extreme degrees and that this change is due to endocrine derangement; we know also that teeth both harden and soften in pathological stages. May not the same causal agents underlie the alteration in the consistency of the teeth as well as of the bones, that is, that the teeth are affected in this way by an alteration in the endocrine secretion? A fact to be mentioned before I pass to the next point is that the hardening process, to some extent, is physological and the softening pathological; I will return to this later in the argument.

Have we any knowledge as to why this change in the fixation or the withdrawal of lime salts is brought about? I believe we shall find the *modus operandi* in the study of that pathological symptom-complex, somewhat badly termed "acidosis" which accompanies certain diseases; to make my reasoning clear the pathology of this condition must be briefly discussed.

Acidosis does not necessarily mean an increased storage of acids or acid salts in the blood and body tissues, nor need it mean an increase in the production of acid in bodily metabolism. Sellards' definition of acidosis is that "it is a diminution, from any cause, in the reserve supply of the alkaline bases in the blood and other tissues of the body, the physico-chemical reaction of the blood remaining unchanged, except in extreme conditions." Except in extreme cases, which we are not now considering other than to use them as illustrations, where their very severity renders results clearer, this must be so, for a very slight alteration in the reaction of blood towards acidity as measured by the hydrogen-ion concentration is incompatable with life.

In the normal metabolism of food-stuffs there is a constant tendency towards the production of acid radicals, arising from the combustion of carbon phosphorus and sulphur, which exceed the basic radicals present: consequently, to preserve the alkaline reaction of body fluids this excess acid must be got rid of. This is accomplished normally by several different methods—e.g., acids from the blood can be removed from the body by the lungs, by respiration in the form of carbon dioxide, by the kidneys in the form of acid salts, by neutralization with ammonia formed in the metabolism of nitrogen, and lastly by using up the body supply of alkaline salts extracted from the foods. Each and all these methods are utilized in health, when a constant fight is being maintained to keep down an ever-threatening acidosis, and for the victory, which is essential to life, the carbonates and phosphates of the blood must be in sufficient quantity to enable them to undertake their appointed task.

The first line of defence lies with the carbonates. Acid in the form of CO_2 is being constantly formed in the tissues; respiration lowers the concentration of CO_2 in the lungs and allows the higher concentration in the tissues to escape by way of the blood to the lungs and thus to be eliminated. Any excess of CO_2 in the blood at once stimulates the respiratory centre to increased activity, and soon brings about an equilibrium. This is seen constantly in the threatened acidosis of hard physical exercise; the CO_2 is carried by the carbonate of the blood from tissues to lungs, and there released and eliminated. Other acids can be and are excreted the same way: they simply displace the CO_2 from the carbonate, setting this free to be eliminated by the lungs, and leaving a neutral salt to be excreted by the lungs, e.g.—

$$NaHCO_3 + HCl = NaCl + H_2O + CO_2$$

Here, however, the process robs the body of alkali, for every molecule of acid would use up a molecule of carbonate, and if this loss is not compensated the animal would rapidly succumb to the effect of an acidosis produced by reason of the insufficiency of carbonate present in the blood to carry the carbon dioxide formed in the tissues to the lungs. This difficulty is partly overcome by the power of the kidneys to excrete an acid urine from neutral or slightly alkaline blood, through the chemical properties of the phosphates; for whereas the phosphates in the blood are in the form of the di-sodium monohydrogen phosphate, which is alkaline, that in the urine is the monosodium di-hydrogen phosphate, which is acid. If you work out the equation you will see that the reaction saves sodium carbonate, and thus renews this alkaline salt periodically to the blood, e.g.—

$$Na_2HPO_4 + H_2O + CO_2 = NaH_2PO_4 + Na\,HCO_3$$

On the other hand, acids may be renewed by the kidneys, taking with them, however, body alkali in the process, e.g.—

$$Na_2HPO_4 + HCl = NaCl + NaH_2PO_4$$

Porter points out the importance in bodily metabolism of this di-sodium salt of phosphoric acid, which he believes to be the true physiological alkalinizer of the blood, and definitely states that without these salts nature is unable to hold the other mineral substances in fixed relation to the tissues (bones, teeth, &c.); especially is this true of lime salts. Porter goes on to say that this salt is not met with as such in the food, but is formed continuously in the body, in health, through the interaction of HCl and trisodic phosphate,

and slowly and continuously enters the blood stream. This suggestion is upheld by the work of Sherman, who found that the substitution of a 0·4 per cent. secondary sodium phosphate (Na_2HPO_4) for a small part of the calcium lactate present in the diet prevented the appearance of rickets in young rats fed on a diet deficient in fat soluble A.

Thus we see that even in health acids either formed endogenously within the body, or taken in food, do slowly and gradually act as a drain on the alkali reserve of the blood and tissues, and if health is to be maintained this reserve must be continuously replenished, and this is done by the utilization of the salts of sodium, potassium, magnesium and calcium, the absorption and utilization of which is under the control of the endocrine apparatus. In health this reserve, though never large, is sufficient, but in disease several factors may cause shortage—e.g., there may be an increased production of normal acids, or even abnormal acids may be formed; some diseases of the kidneys may upset the delicate mechanism by which its power of discrimination and alkali saving may be lost; alkali itself may be lost in other ways than in neutralizing acid, such as by excretion in acute diarrhœa, or even the absorption and utilization of alkali may be interfered with. At any rate this reserve supply of alkali becomes diminished in quantity and insufficient for its purpose.

Extreme conditions of acidosis are met with clinically in such diseases as diabetes, and in the last stages of some cases of nephritis; it is also seen in certain food-intoxications in children in pregnancy, and certain other conditions, and is easily recognized by its physical signs. There are, however, many conditions in which an acidosis has been found by chemical laboratory methods to exist where there have been no acute symptoms, that is, where it has been proved that the alkali reserve of the body is reduced to a greater or lesser extent; these cases have been termed by Sellards "compensated acidosis." Now it must be remembered that this compensation has been brought about at the expense of the patient in other ways, e.g., the alkali reserve, though sufficient to preserve life, may be at a dangerously low ebb and unable fully to carry out the purpose which it was originally intended to perform. By using the bicarbonate toleration test (which is performed by giving large doses of sodium bicarbonate until the urine turns alkaline) Sellards has shown that a diminution of the normal alkali reserve equivalent to 40 to 50 grm. of sodium bicarbonate was unaccompanied by any noticeable clinical symptom, that a deficit of from 75 to 100 grm. produced definite dyspnœa, whilst a deficit of 150 to 200 grm. was required to produce definite air hunger and coma.

From this we see that there must be many cases in which an acidosis is present which by its very compensation gives a lower alkali reserve, with all that this may mean to the patient, without any definite signs or symptoms of disease. As Langdon Brown has put it "a living organism is like a spinning top, only in equilibrium whilst it keeps going, but unlike a top it is provided with a delicate mechanism by which it may readjust its balance if this is disturbed. Disease is the resultant of the action of some external force and the reaction of the body; this reaction may be sufficient to restore the equilibrium—i.e., a return to health, or the external force may overcome the balance altogether—i.e., death supervenes. Between these two extremes a new though inferior position of equilibrium may be attained—i.e., the disease is more or less compensated; in this position the machinery works, but with more friction and the reserves are diminished."

I am not suggesting that calcium is the most important element in the

alkali reserve, it is not; but in proof that these salts form an important part, I have authorities to quote. Marriott and Howland, working on the acidosis in the terminal stages of nephritis, found a marked diminution of the calcium in the blood serum, as low in one case as 1·5 mgr. per 100 c.c. of blood, as compared with 10 to 11 mgr. in normal cases; this low calcium content they believe to be due to an excess of acid phosphate which the damaged kidney could not excrete, at any rate administration of phosphate caused a further diminution of calcium of the blood serum, whereas administration of calcium reduced the acid phosphate, presumably by neutralization.

Again, Osborne, Mendl and Ferry have produced coma by feeding rabbits for a long period on a diet poor in salts, which was overcome by adding calcium and potassium phosphates and the citrates of sodium, magnesium and calcium to the food, and Peabody believes that the muscular twitchings of uræmia are due to lack of lime salts.

I think, therefore, that we are justified in believing that calcium salts form part of the alkali reserve of the body, and so long as they are a part they perform important functions, one of which is the gradual and continuous hardening of the teeth, both enamel and dentine. If, however, they are commandeered for a more vital purpose, namely, keeping the patient alive by overcoming or compensating an acidosis, they are not available for their primary purpose, and the teeth must, for the time being, remain unhardened—i.e., susceptible. Further, it would seem probable, and I find several authorities for my suggestion, that should the acidosis be more severe a definite demineralization may take place associated with the separation of lime salts from bones and teeth—i.e., the teeth themselves may have to surrender some of their lime salts that have been built up into definite tooth structure. The result is not merely a stoppage in tooth building but a very definite breaking down.

What clinical evidence have we for this suggestion? The condition in osteomalacia has already been referred to; here the bones may become so soft that they can be cut with a knife, or squeezed like a sponge; lime salts are certainly extracted from them. From a dental point of view, the condition of arrested caries may start in much the same way, and as I have previously pointed out we have here something quite different to caries as we ordinarily see it. The tooth that we finally see as an example of arrested caries commenced its downward way, not as a minute destruction of enamel followed by a hollowing out of the dentine and then a cracking away of unsupported enamel, which is the usual way in which a tooth cavity is formed—rather is there here a wholesale destruction of enamel and practically none of dentine, which, contrary to all expectations, instead of being rapidly disintegrated, becomes hypercalcified. The enamel has evidently been destroyed *en bloc* and I suggest that the cause of this is twofold, first, loss in the alkalinity of the saliva caused by a diminution of its lime content, and secondly through a definite withdrawal of lime for an important and vital function; later on the dentine has become hypercalcified by a definite improvement in health and a consequent flooding of the blood with salts of calcium.

The history of these patients suggests that this may be so. In measles for example, the necessity for neutralization or elimination of toxins causes an increased activity of the endocrine apparatus; this will be followed by a reaction, resulting in a lessened assimilation of lime salts, which, combined with an acidosis associated with all acute fevers and caused by increased katabolism, gives a lowered alkali reserve. The demand of the body for alkali leads to rapid

tooth destruction; then, during and after convalescence, the gland balance reasserts itself with perhaps a compensating swing of the pendulum in the opposite direction, and we get a hypercalcification of the dentine. If however this beneficial reaction is too late to save the pulp we get the dead six years old molar level with the gum in a child of from 8 to 10 years old.

I have not been able to find much literature on the connexion between endocrine derangement and acidosis, but references are continually cropping up, and it would not seem unreasonable to connect the two; for the satisfactory working of the endocrine apparatus is an important factor in metabolism of the alkaline salts, on which depends the alkali reserve, which is the final source of safety in a threatened acidosis. This idea is also supported by the fact that the periods of calcium hunger, which as I have shown are also those of the greatest risk of endocrine derangement, are the periods of life during which there is most chance of an acidosis without definite disease, viz., childhood and pregnancy.

Respecting the former period Howland says that "the low level of carbon dioxide tension and the low hydrogen-ion concentration in the young explain their susceptibility to acidosis, which," he contends, "is not an uncommon condition in infancy and childhood." Sellards says: "Some chronic acidosis during the period of growth might conceivably bear a relation to some of the effects of malnutrition seen in children"; and pregnancy is, as we know, a state in which the risks of an acidosis are considerable. Again Crile has shown that a state of acidosis was present combined with signs of exhaustion of the adrenals, the thyroid, and the pituitary in a number of diseases, in infection, in physical exhaustion and various psychical states. And lastly findings are reported after experimental parathyroidectomy similar to those of Howland and Marriott quoted above, namely, a decreased elimination of phosphate in the urine combined with a diminished amount of calcium in the blood serum and tissues.

Sajous also believes that the alkalinity of the blood is intimately connected with secretion of the adrenal glands. "Adrenoxidase," by which term he designates adrenal secretion circulating in the blood, laden with oxygen, he believes to be the main alkalinizer of the tissues, and the blood platelets as drops of adrenoxidase he finds strongly alkaline.

There is one point in the consideration of acidosis that should be noted by those members of our profession who are obsessed with the idea that the amount of carbohydrates in modern diet is the important factor in the production of caries, and would cut this down to a minimum, and this is that carbohydrate starvation is a very direct cause of acidosis. This frequently appears in diabetes when carbohydrate metabolism is interfered with, and for this reason, that unless the carbohydrate in the diet be sufficient, complete combustion of fat is prevented. Fat is split up into glycerine and fatty acid and unless sufficient carbohydrate is present the breakdown goes no further and the acid appears in the blood. It is contended that for the complete oxidation of three molecules of fat, at least one molecule of carbohydrate is essential. Wyatt has said that "unless the mixture of metabolites oxidizing in the body contains more than thrice fatty acids to one of glucose the body smokes with acidosis like an automobile run with too much oil."

In starvation the body lives on its own fats and carbohydrates and as the latter may give out first, the fat may be incompletely broken down and the alkali reserve is called upon to neutralize the fatty acids formed.

As a result of an investigation of an epidemic of acidosis in out-patient

tonsillectomy cases Ross found that 22 per cent. of cases showed acetone and 15 per cent. diacetic acid in the urine before operation, and that after operation this was increased to 50 per cent. acetone and 35 per cent. diacetic acid (these abnormal products show a condition of acidosis) but with glucose feeding and no purgative before operation these figures were very considerably reduced. This would seem to show that not only does the condition necessitating this operation predispose to acidosis, but that the operation or the anæsthetic increases that predisposition. An investigation was then instituted into the condition of all patients coming to operation in the Winnipeg General Hospital with the following results: all patients who showed either clinical symptoms or laboratory signs of acidosis were those who had been ill for some time with infections, toxæmias of pregnancy, conditions causing degrees of starvation, or were ill-nourished children. All emergency operation cases showed symptoms of acidosis, which was increased with the length and severity of the disease. Women were more liable to be affected than men, and children than adults, and the acidosis was increased by fear. Doubtless this, then, is the rationale of the pre-operation treatment of children with large doses of glucose to prevent post-anæsthetic vomiting, and it should be borne in mind when laying the blame for caries on the large carbohydrate intake in children, and perhaps the fact that children like sweets and dislike fat may be explained physiologically.

How then may this endocrine derangement be brought about? The classification adopted is mainly McCarrison's:—

(1) In direct disease of any one gland or group of glands — e.g., (*a*) myxœdema, (*b*) acromegaly, or (*c*) diabetes.

(2) Functionally as a result of over-stimulation due to acute exanthematous fevers, acute or chronic infections, bacterial toxins.

(3) Defective or improper feeding—e.g., semi-starvation or lack of vitamins.

(4) (*a*) Residence in unsanitary surroundings: (*b*) intestinal toxæmias, stasis and constipation; (*c*) consanguinity and heredity; (*d*) psychic causes, fear, rage, pain, worry, insomnia.

This classification is of course incomplete, but it gives an idea of the variety of causes which may bring about the condition. Limitation of time prevents discussion of these causes, except for calling attention to the question of vitamins, which from our point of view, is to-day very much in evidence. Mrs. Mellanby has shown that feeding with foods otherwise sufficient but from which vitamin A has been abstracted leads directly to deterioration of the dental tissues, and just lately Howe has even produced what would appear to be definite carious cavities in the teeth by a vitamin-free diet, but so far as I know, neither have shown the morbid process by which these effects are produced. McCarrison, however, provides the connecting link, for he proves conclusively that food deficiencies have a definite action on the endocrine apparatus, and it is through the various glands which form this apparatus that these changes are brought about in the teeth. His book on "The Study of Deficiency Diseases" gives further particulars.

Summarizing briefly, my points are these:—

(1) So long as the enamel remains intact there can be no caries.

(2) Enamel in health progressively hardens as life proceeds.

(3) This hardening is due to a progressive laying down of lime salts, taken from the body store of ionic calcium.

(4) This body store is, in health, equivalent to the need of the individual at the time, and is preserved by the endocrine apparatus, which is also the fixer of lime salts in the teeth.

(5) If the endocrine apparatus is thrown out of balance in the direction of calcium starvation, this reserve store is diminished, and fixation of lime salts in the teeth is interfered with.

(6) An upset in endocrine balance in childhood, youth and pregnancy will be in the direction of calcium starvation.

(7) Calcium starvation will lead to a diminished calcium index in the saliva, with a lessened alkalinity of that secretion, thus directly promoting caries.

(8) Endocrine derangement, leading to a loss in balance towards calcium starvation, will tend to produce a condition of acidosis by lessening the alkali reserve of the body; in the compensation of this condition the calcium salts, together with other alkaline salts, will be utilized for acid neutralization, and therefore not be available for the hypercalcifying the teeth.

(9) If the acidosis be more severe, built-up and fixed inorganic lime will be torn away from bones and teeth to help build up this alkali reserve, and thus preserves life, lowering the resistance of the teeth to caries.

(10) That without this susceptibility to caries, exciting causes such as food fermentation do not matter; but if immunity be removed hardly any reasonable care and attention are sufficient to preserve the teeth entire.

(11) That endocrine derangement, as described in this paper, will account for all the conditions leading to dental caries, whether they be diet, lack of vitamins, or altered salivary secretion.

In conclusion, other facts that I should have liked to have brought forward I must keep for another occasion. I hope, however, that I have said enough, and said it well enough, to interest you in this matter. I can hardly hope in the course of a single evening to have done more. I quite realize that much of this theory is built on hypothesis, and that many points are at present "not proven," yet much of the ground on which it rests, though uncertain, is not without probability, and is accepted as more than probable by competent observers and workers, both clinicians and pathologists. I contend also that this theory answers most, if not all, questions and difficulties that daily arise in our practice in a way that no other theory does. If, then, I have convinced even a minority of my audience of the possibilities of these suggestions so that they will not dismiss the matter, as report says it has been dismissed by one at least of the leaders of our profession, as "this rot about the ductless glands," I am satisfied.

Perhaps when the Dental Board gets to work and has funds at its disposal to organize a definite research into these matters, the factor of the endocrine glands in relation to the production of immunity and susceptibility of the teeth to caries will not be forgotten.

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DISCUSSION.

Professor HALLIBURTON said that as he had not the special technical knowledge to discuss purely dental questions, he would address himself to the general problems raised in Mr. Broderick's suggestive paper. In all of these more information was needed, and this must be based on experimental research. The principal problems were concerned with (1) calcium metabolism, (2) endocrine organs, (3) vitamins and (4) acidosis. The first in this list was the bed-rock, and until this important subject was unravelled, it was premature to attempt to explain how it was influenced by Nos. (2) and (3), important factors as both undoubtedly might be. Knowledge of both was so fragmentary and imperfect that it was unwise to formulate theories as to how they acted. There was always a tendency among enthusiasts to magnify at the start any new conceptions, and this was taking place to-day in reference both to vitamins and hormones. The whole question of acidosis was equally immature, and Mr. Broderick had only quoted those authorities whose views fitted in with his theories. While not wishing to disparage Mr. Broderick's work or to discourage a young investigator from doing more, his advice was to get your facts first and theorize later. The converse procedure was generally disastrous.

Dr. LEONARD WILLIAMS said that he had been asked to contribute something from the point of view of the endocrinologist to this important discussion, introduced with so much interest, instruction and suggestiveness by Mr. Broderick. The passage which had struck him most forcibly was the one which told of a leader of the profession referring to endocrinology as "this rot about the ductless glands." Quite a distinguished physician, too, who had written a book on dietetics, had spoken contemptuously of the "stunt of the vitamins." This was a species of irritation that progressive seekers after truth had always to encounter. If they were to take a broad view of the subject which Mr. Broderick had dealt with in such admirable detail, the question would be "What were they to do to be saved from this deadly heritage of caries." Dr. Harry Campbell, who had been discussing this question for years, contended that if they were to cease feeding their children on carbohydrate pap and to feed them as they fed puppies, on material which compelled vigorous mastication, they would ensure a normal development of the jaws and thus abolish malposition and malnutrition of the teeth with the consequent caries, pain and pyorrhœa. He (Dr. Leonard Williams) agreed with all this, but with certain reservations. The first was contained in the aphorism that they could not make bricks without straw, that was, that teeth could not be sound unless during the period of their development the calcium metabolism was good and vigorous, and there could not be good and vigorous calcium metabolism without normally acting endocrine glands. The calcium co-efficient was claimed by the protagonists of the various glands to be a function each of his own particular gland. One said it was the thyroid; another affirmed it to be the pituitary; yet another was convinced it was the adrenal, and so on; the truth really being that it was not any one of them individually, but all of them collectively. If, then, a good supply of calcium had to be ensured for the teeth, a good team of endocrine glands must also be ensured, and all this must be begun while the child was still *in utero*. In gout, as was known, they began with the grandfather; in defective teeth they need go no further back than the mother. Now, what were they to do with this mother? The answer was quite simple. They must feed her on vitamins. Vitamins were to the endocrine glands what the endocrine glands were to the economy, namely, an urgent and paramount and ever present necessity. He was therefore in agreement with Dr. Harry Campbell but he went further back. A great deal could be done with the child by means of correct feeding, but the foundations must be well and truly laid, and this could only be effected by seeing that the mortar had plenty of lime in it from the time of conception onwards. Lime was necessary to the teeth and jaws; endocrines were necessary to the lime, and vitamins were necessary to the endocrines. As soon as the child had erupted its teeth, it must be taught to masticate, and here was his second reservation to the acceptance of Dr. Harry Campbell's teaching. The child must masticate, he must work for his

living, on that they were agreed. But he would further insist that a child must not only chew, but it must chew vitaminous foods. If it chewed devitalized foods it might develop its masseter muscles and to some extent its mandible, but unless its endocrines were working normally it would not do full justice to its facial development, and its endocrines would never work normally without vitamins. The endocrine gland of most interest to odontologists was undoubtedly the pituitary. He said this, even while emphasizing the fact that the endocrine glands were like a team, no one member of which ever played for its own hand, but always for the side, the work of each member of the team reacting mutually; the cohesive element in the team, the *esprit de corps*, was represented by the vitamin. To the pituitary, therefore, he would direct very special attention. The high arched palate and the undeveloped mandible, which were so often associated with adenoids, were usually what mathematicians called a "function" of pituitary insufficiency. He did not deny the implication of the thyroid factor, but it was usually only an accessory; the real culprit was generally the pituitary. The lack of development about the bones of the face which was the sure precursor of dental troubles, if due predominantly to the thyroid, was accompanied by mental dullness, nocturnal enuresis and stunted growth—the typical cretinoid child. Where the pituitary was at fault the picture was very different. In spite of the adenoids, if any were present, they had before them a seemingly well grown child of bright intelligence. But if the mouth were examined badly-developed outside upper incisors would often be found, and inspection of the hands would reveal nails with no half-moons at their roots. In addition, there was often in these cases some vagary of pigmentation which was usually manifested by little black moles dotted indiscriminately about the otherwise fair skin. Dentists treated these undeveloped jaws by very ingenious mechanical contrivances. There was nothing against these except the inconvenience which they often occasioned to nervous patients, but if such children were treated, as they so easily might be, for their endocrine defect, the success of the instrumental treatment would be greater and the period of inconvenience much less. If dentists were going to prescribe pituitary, two points of importance needed emphasis. The first referred to preparation and administration. They must choose a reliable preparation of the whole gland, neither pars anterior nor infundibulum separately, but the whole gland, and they must give the whole gland in adequate doses. The advertised doses were far too small. To obtain any satisfactory results they must start with 5 to 6 gr. three times daily, and they need not be afraid of increased blood-pressure. Blood-pressure in children did not matter, and what was more important was the too little appreciated fact that pituitary taken by the mouth did not raise the blood-pressure. The pressor substance was destroyed in the stomach. The second point needing emphasis was that they would be disappointed with pituitary therapy unless at the same time they put their young patients on an intensive vitamin dietary. To give endocrine substances without intensive vitamins was like giving iron without aloes. A success was possible, but not certain. An intensive vitamin dietary consisted exclusively of uncooked foods, "unfired foods" the Americans called them, dairy produce and uncooked fruits and vegetables. Primitive man at one period knew nothing of the cooking stove, and yet it was precisely at that period, when living on herbs and roots and fruits, and probably on raw meats, all of which required vigorous mastication, that he had raised himself from the level of the brute to the position which he now occupied. The diet of children consisted too much of boiled milk and devitalized pap. No wonder they grew up with rickety backbones and limeless teeth. The profession had become too puffed up with pseudo-scientific pride, and in their futile endeavour to conquer truth with a test-tube they had only succeeded in boiling their common sense in a sterilizer. Man was not built up on artificial foods but on milk, and milk was what it was because it contained in itself the physiological trinity—calcium, endocrines and vitamins. And the greatest of these three was vitamins.

Mr. JOSEPH A. WOODS desired to encourage the reader of the paper to continue with his researches, because although he felt that the investigations so far were not entirely convincing, yet the results were very stimulating to thought and were well worthy of further elucidation. He agreed with Mr. Broderick that the present theories

of causation of dental caries did not explain all the conditions sometimes met with in clinical experience. Mr. Woods found it difficult to accept the proposition that enamel was capable of undergoing the changes suggested; at the same time the theory that enamel once formed was incapable of any further vital change seemed out of keeping with other tissues of the body. He was not sure that he had ever observed the dental conditions during pregnancy which were referred to in some text-books, and which the author seemed to have come across. He had seen one case which he believed to have been osteomalacia. The patient was a man of middle age, and during the progress of the disease the teeth did not seem to be affected in any way. No loss of lime salts was to be observed, and softening was not to be detected when the teeth were cut by instruments.

Mr. J. G. TURNER said that Mr. Broderick appeared to try to establish two main points in the dental aspect of his thesis: (1) That diminished alkalinity of the saliva led directly to dental caries; (2) that enamel, after eruption of the tooth, underwent both increase and, under certain circumstances, a normal or at least purposeful decrease of its lime salts. Both these points were susceptible of examination from a clinical and matter-of-fact standpoint. Dealing with the first point, was it certain that saliva of whatever alkalinity ever reached the sites of dental caries? Dental caries depended immediately on the lodgment of sticky, starchy, and sugary food, together with acid-producing germs. After a meal these deposits were always to be found on the parts of the teeth unreached by any of the friction of mastication, and they were at once covered by a layer of mucus. In point of fact decay always began in these stagnation areas, never on the well-rubbed areas, a fact which at once showed that susceptibility to decay was particular to particular portions of each tooth, not general to the whole tooth or to a whole set of teeth. This meant that saliva had practically no influence over dental caries in the presence of sticky food, it never reached the occluded acid which was being formed in contact with the enamel under a covering of sticky food and mucus. It was literally like "water off a duck's back." Mr. Broderick talked of an increased susceptibility to caries in acute illness, during which the lime-content of the saliva was lowered. Apart from the fact that, supposing such an increase to exist, it was entirely conformable to the germ-carbohydrate stagnation theory of caries, such a connexion had never been proved. Observers had failed to note that the decay which became apparent during the six weeks or three months of an illness began months or years before, and, irrespective of health, was due to show itself at this time. Caries of enamel was a slow process. He (Mr. Turner) did not know of any published observations tending to show its rate of progress, but by grinding sections of children's teeth, chiefly six-year molars and bicuspids, the age of eruption of which was approximately known, estimating the length of time the tooth had been in the mouth from the age of the child and the age of eruption, and noting the depth to which enamel destruction had progressed, he had been able to determine that the least time required to perforate the enamel at the buccal gum edge (this was not the extreme edge of the enamel) was nine months, and at the abutment area two years. Such figures entirely put out of court all observations hitherto made on decay of illness or pregnancy. Turning to the second point, that the enamel underwent changes of composition, Mr. Broderick asked them to believe that enamel hardened continuously during life, unless some untoward influence such as disease or pregnancy interfered, when it might suffer a diminution of lime salts and apparently reharden later. Mr. Broderick seemed to believe these changes were brought about by lime salts in the saliva. Certainly this was a hard point to prove! If the contention already advanced, that mucus was impervious to saliva, were correct, salivary action fell to the ground at once. Clinically he did not know of the hardening. He (Mr. Turner) knew of the difference between hypoplasic and well-formed enamel, and in defiance of Mr. Broderick's opinion, the hypoplasic enamel remained soft throughout life. Dentine certainly hardened with age, so long as the tooth-pulp persisted, and it was to this increased density of dentine that the deeper colour of older teeth was due, not to alteration of enamel. Purposeful withdrawal of lime-salts from enamel seemed too fantastic for argument, but he might point out that by the time, during the illness, the decay was observed, the lime-salts had mostly

disappeared. Mr. Broderick suggested this purposeful destruction of enamel as an explanation of the absence of enamel in so-called arrested caries. This was a very unfortunate suggestion. In the human subject arrested caries was found under two conditions—in the temporary molars where the enamel was normally not very hard and readily broke away when undermined by decay; and far more frequently in hypoplasic permanent first molars, where the missing enamel had practically never been found. Moreover many of the subjects of "arrested caries" had never been ill again since the original malnutrition of childhood which caused their hypoplasia. As to the dentine, he was extremely doubtful whether either hardening or absolute arrest ever occurred. He had never indeed seen truly arrested caries: destruction of dentine always continued, modified by the smooth, clean surface produced by attrition. Mr. Broderick quoted Head's experiment, but here it was at least possible that the saliva had completed the unfinished work of the acid, and what had been left was only a deeper layer of the enamel. The hard gouty teeth and the soft tubercular teeth Mr. Broderick talked of were quite unknown to him (Mr. Turner); and he would controvert another point Mr. Broderick put forward as if it were current dental knowledge. He did not find that pyorrhœa and dental caries were mutually exclusive: on the contrary he found them commonly associated, and there was one form of dental caries so directly associated with pyorrhœa that he had called it "decay of pyorrhœa," namely, that found at the necks of the teeth and on the roots of the teeth, as the destructive processes of pyorrhœa lay more and more of the tooth open to the attack of caries. Mr. Broderick quoted Dr. Kirk, that youth was the period of greatest susceptibility, the tendency thereafter being towards immunity in adult life. That dental caries was pre-eminently a disease of youth was certain, but in his experience the predisposition to decay remained unaltered throughout life. The observed lessening in the incidence of decay was to some extent the result of fewer sweets and some effort at cleanliness, but was due more to extraction of decayed teeth which allowed of "drainage" of the remainder. In spite, however, of this lessened incidence, the expectation was that in the absence of efficient cleaning every tooth would eventually become carious. Finally, he must challenge Mr. Broderick to substantiate almost his opening sentence. Mr. Broderick asserted that "these theories (i.e., the germ-carbohydrate stagnation theory) . . . left too many questions unanswered, too many undoubted clinical facts unexplained." What were they? He regretted having to present nothing but destructive criticism, but he was sure Mr. Broderick would none the less continue his search for truth.

Mr. HOWARD MUMMERY observed that he had not expected to be called upon to take part in the present discussion, but would confine his remarks entirely to the histological question, as this was of great importance in determining if there were channels in the enamel through which such interchanges as were suggested by Mr. Broderick could take place. He had never found it possible to believe that they could have in the living human body an absolutely inert, impenetrable, dead substance incapable of change or nutrition. The descriptions of enamel in the text-books had usually been confined to enamel of perfect structure which did not appear to show any channels or spaces in the calcified tissue; at all events refraction did not allow of their detection. Enamel, however, despite emphatic statements to the contrary, was not usually of perfect structure, and showed many areas which were distinctly penetrable by stains. Professor Walkhoff, although denying the presence of organic matter in the enamel, said there were scarcely any teeth of civilized man which did not show some defects of structure in the development of the elements of the enamel either in their size and arrangement or with regard to their calcification. Both Walkhoff and Leon Williams had found similar defects in the enamel of the anthropoid apes. If there were spaces in the enamel communicating with living tissue in the dentinal canals, and staining methods certainly showed that such communication did take place, they must be penetrated by lymph, and even if not occupied by solid organic material, would probably serve as channels for the interchanges of the body fluids. Mr. Mummery had recently repeated the staining experiments first described by Mr. Douglas Caush in 1904, by several different methods, and he had not found a single specimen that did not show staining areas in more or less abundance. With regard to penetrability from without,

the progressive hardening of the teeth with the growth of the body had, he thought, been established by the experiments of von Ebner, von Beust, Pickerill, Gottlieb and others, as the stain had been shown to penetrate less and less deeply into the enamel as age advanced.

Mr. BRODERICK, in reply to Mr. Woods, suggested that Mr. Mummery's work showed the possibility of the changes in the enamel which he had mentioned. With reference to the increased susceptibility to caries during pregnancy, it was pointed out that there was, in this condition, a physiological change in the endocrine balance, the results of which would be a greater conservation of lime salts; consequently it would only be in those women with a tendency to calcium hunger that tooth destruction would be noticeable. Mr. Broderick also suggested that possibly Mr. Woods might be mistaken in his diagnosis of osteomalacia; the sex and age of the patient pointed rather to Paget's disease or osteitis deformans, a condition in which, although in the early stages the bones were apt to become bent, there was actually an increase in thickness. Many of Mr. Turner's conclusions were so contrary to those of his own that he must leave it for the dental profession to judge between them, but he would point out that, whereas Mr. Turner fixed his mind on exciting causes, he (Mr. Broderick) was considering predisposing causes only, which might account for the disparity. At any rate he had found that food lodged quite as much between the lower front teeth, especially in older people with some recession of gum, as elsewhere, yet these teeth were almost immune to caries. Mr. Turner mentioned the "decay of pyorrhœa," by which term he designated cavities at the neck and roots of teeth laid bare by absorption of alveolus; but, as already pointed out, by caries, in this paper he (Mr. Broderick) meant progressive destruction of enamel, which was not present in these situations, and the destruction of cementum did not in any way upset the premises that caries and pyorrhœa were antagonistic. With regard to the questions unanswered and the clinical facts unexplained by the carbohydrate stagnation theory, he would refer Mr. Turner to previously published communications he (Mr. Broderick) had made on the subject.