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## ORIGINAL COMMUNICATIONS

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### Mottled Teeth:

An Endemic Developmental Imperfection of the Enamel of the Teeth  
Heretofore Unknown in the Literature of Dentistry.\*

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IN COLLABORATION WITH

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IN the years 1906 and 1907 several dentists resident in the Rocky Mountain region told me of a peculiar condition of the teeth in certain areas in their neighborhood, which they said was not found elsewhere, and which had not been described in the literature. This condition they called *mottled enamel*, or *mottled teeth*. These men claimed that a very large proportion of those born and reared in these areas had teeth of this character. I requested that some of the teeth be sent to me for examination, and after a time (1908) I received the crowns of a number of incisors with the astonishing report that the teeth of a very

large proportion of the children in the areas mentioned were of the same character.

#### GENERAL DESCRIPTION.

All of the crowns I received were of incisors that had been cut away for the purpose of putting on artificial crowns to improve the appearance of the persons. Each of these was of normal tooth form. The lingual surfaces of these teeth were generally an opaque paper-white, but mottled with normal spots and clouded areas. The labial surfaces were in part of an abnormal white color resembling white unglazed paper, but a considerable

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\* In this writing Dr. Black confines himself to a discussion of the histo-pathological condition, giving only such references to clinical features as seemed necessary for an understanding of the subject. All clinical features, efforts to find causation—indeed every other feature—will be presented by Dr. McKay in a paper soon to be published.

portion of the surface was mottled with dark brown. Some had black bands running across the labial surfaces; some had dark brown bands bordered with yellow which faded away into a paper-white, with normal enamel toward the gingival portion; some of them had enamel of normal color over the immediate incisal edge, but this did not extend to the labial surface. All of the paper-white and discolored portions were opaque, having none of the translucency of normal enamel.

In all of these teeth the usual glaze of the surface of the enamel was complete. That is, Nasmyth's membrane, which covers the outer ends of the enamel rods, was normal. An exploring tine, the point of which was very hard and sharp, would glide over the surface without catching, the same as it would do over normal enamel.

The greater number of the teeth sent for examination had split through the center of the crowns lengthwise, and it was easily seen with a hand lens that the abnormal portion of the enamel was generally confined to the outer third, more or less, of its thickness, in all of the central part of the labial plate. The inner half of the enamel—that next to the dento-enamel junction—seemed more generally to be normal, or nearly so, in all of the teeth. The imperfect enamel thinned away toward the gingival line in some, and in others retained its thickness until it included the whole thickness of the enamel where this thinned away toward the gingival line. The dentin was normal in all of the teeth. It was evident that this condition of the enamel did not carry with it any deformity of the dentin, and the general form of the teeth was normal.

It became clear to me during this superficial examination that this was a type of dystrophy of the enamel of which nothing had appeared in dental literature. Not only this, but if the statements were correct, it was endemic in type. Heretofore no endemic conditions of the teeth have been known. Further, if the reports that 87½ per cent. of the children reared in these areas were af-

flicted with this endemic condition, the cases were numbered by thousands, and the individual deformities were of a very grave character.

I went into the examination very thoroughly aroused to its importance, and in 1909 visited a number of susceptible areas and studied the conditions on the ground. On account of the intrinsic importance of the general subject, I will give a brief summary of the dystrophies of the enamel known at this time, at the close of this article.

#### ESSENTIALS.

The essential malformation in this condition is the failure of the cementing substance between the enamel rods in the outer one-fourth to one-third, more or less, of the surface of the enamel. When this exists alone the enamel is a dead paper-white. In many of the cases a coloring matter is found in place of the cementing substance between the enamel rods, and on this hinges the great variety of appearances. Some of the teeth are a paper-white that glares and impresses itself as something abnormal whenever the person opens his lips, some are brown, some nearly black, some quite black. Every degree conceivable of the co-mingling of color—natural white, paper-white, dark and yellow, is found. This condition is found in from 70 to 100 per cent. of the persons born and reared in certain afflicted areas.

As everything we do in the study of this condition of the teeth will have to do with this coloring, I had better state here as concisely as possible what I have found this coloring matter to be, before proceeding further.

#### "BROWNIN."

Since I commenced the study of mottled teeth seven years ago I have, as occasion has offered, been studying the coloring matter, which is one of the very ugly features of this condition. In this study I have found this same coloring matter, so far as I am able to determine, in most kinds of malformation of the

enamel. Especially is it abundant in the contemporaneous accretional deformities, commonly known as atrophy or hypoplasia of the teeth, and in what we call enamel whorls, and various other dystrophies of the enamel of lesser note. It is a dark brown coloring matter that is deposited in much more than half the cases in which the enamel rods are not cemented together with the normal cementing substance.

When I wrote the articles on the "Physical Characters of the Teeth," I noted certain facts regarding the color as it related to the strength (DENTAL COSMOS 1895, pp. 410 and 411), and from the fact that these tests all gave results that were opposite to and contradicted the general notions of dentists, they made a deep impression upon my mind. The supposition before was that a person with very light teeth would be more susceptible to caries, while a person with dark teeth would be more nearly immune, the idea being that light teeth were soft and that dark teeth were hard. My instrument tests showed exactly the opposite. The dark teeth were less strong than those which were lighter in shade. A tooth from which a slab was cut and which when held up toward the light showed a translucent and a changing light as it was turned about, could always be depended upon to bear a high crushing stress before it would break.

Recently I have found a brown coloring matter continually in the dark teeth, not only in the dentin, but more prominently in the enamel, which may be removed by solution and the teeth rendered white without appreciable injury to them. The enamel is weaker for the reason that this brown coloring matter takes the space of the normal cementing substance between the enamel rods wherever it occurs, and this coloring matter seems to have no strength. The more of this material there is in the enamel of what we call the normal tooth, the darker will be the color and the weaker the tooth. Where there is so little brown coloring matter in the enamel that it would not be spoken of

as abnormal, the teeth are a shade or several shades darker than the whitest teeth. It lends a harmony between the teeth and the general coloring of the features of the brunette type that makes a soft graceful expression of the countenance. This brown coloring matter is normal to the teeth if the amount is not so large as to cause disfiguration.

This material appears regularly in very noticeable amount in about one-half the cases of the various dystrophies of the teeth. The coloration in all of these cases is from the deposit of a brown coloring matter, not only in the normal teeth, but in the abnormal teeth as well. In the enamel whorl, which will be illustrated under the head of dystrophies, we find this coloring deep in the enamel, sometimes actually lying against the dento-enamel junction, making a very dark spot in a section, while the surface of the tooth is fair. The coloring matter is the same material, and its reaction to dissolving agents is the same in all of these various conditions. I have dissolved it out and made such teeth very white.

What the relation of this brown stain may be to melanotic growth in the soft tissues, I have not yet made an effort to determine. I have a distinct opinion—not founded on proper investigation, however—that the substance is the same, no matter where found, and is always the result, not the cause—as so often stated—of a failure of proper development of the tissue in which it is located. It is therefore a material thoroughly deserving of some name. In an effort to find a suitable name for use in dentistry I have used the word *brownin*, which seems to me in good form as a nomenclature word.

In the following pages further studies will appear in explanation of this.

#### PREPARATION OF THE MATERIAL.

The teeth, as previously stated, were split labio-lingually through their centers longitudinally when they came to me. Many of the crowns were incomplete in that they had been cut from the

roots some little distance from the gingival line. I ground the broken surfaces flat, polished them, and photographed them mounted in the pairs from each tooth. These were photographed

I then selected what seemed to be the least desirable specimen for a first trial in grinding thin sections.\* This was one-half of a tooth that had been split labio-lingually which had no mate. Much

FIG. 1.

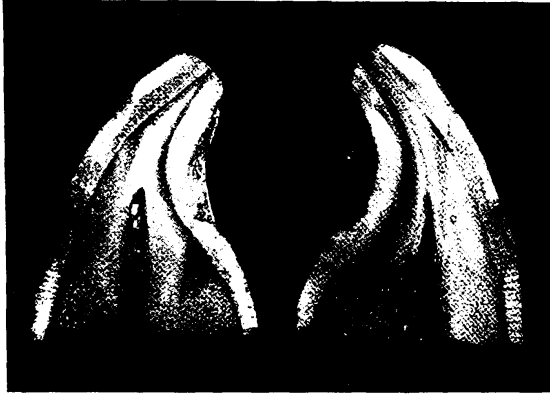


FIG. 2.

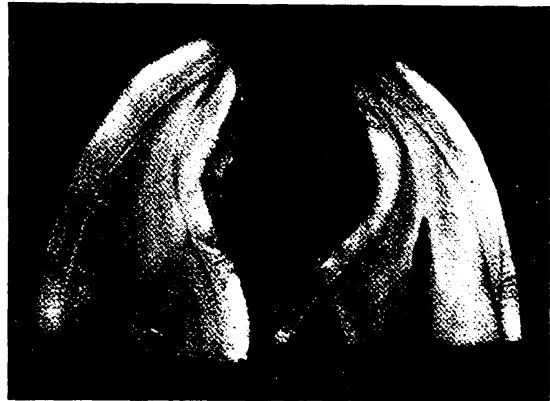
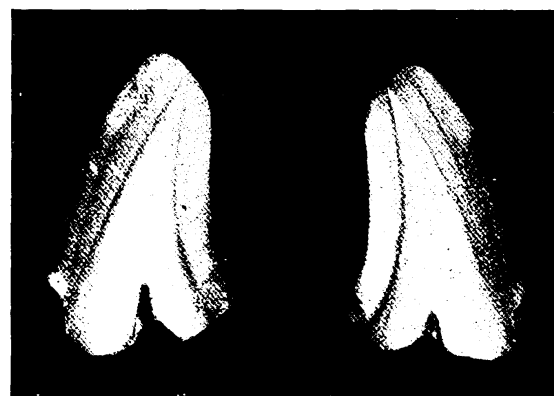


FIG. 3.



FIG. 4.



FIGS. 1, 2, 3, 4. These figures represent teeth that came to me split longitudinally and very perfectly in line. They had been cut off for the purpose of placing artificial crowns, and did not show the full length of the crowns. Figs. 1, 2, and 3 are central incisors, and Fig. 4 is a lateral incisor.

I ground the surfaces flat, polished them, and then set them up with these cut surfaces toward the camera, having opened the tooth like a book, laying one-half on one side and one-half on the other. In this position I photographed them with about six diameters enlargement. The material did not make brilliant pictures, but it will be seen by scanning the labial margins closely that the surface of the enamel is a different color from the inner portion. This may be seen also on the lingual surface, but it is not so prominent. This is the injured part of the tooth in mottled enamel. The thickness of the injury can be made out by careful examination of the figures.

by reflected light with enlargements of from six to eight diameters. (See Figs. 1, 2, 3, 4.) The material did not give very brilliant pictures, but they showed the outlines of the imperfectly developed enamel.

of the surface of this tooth was a dead paper-white. The cut and polished

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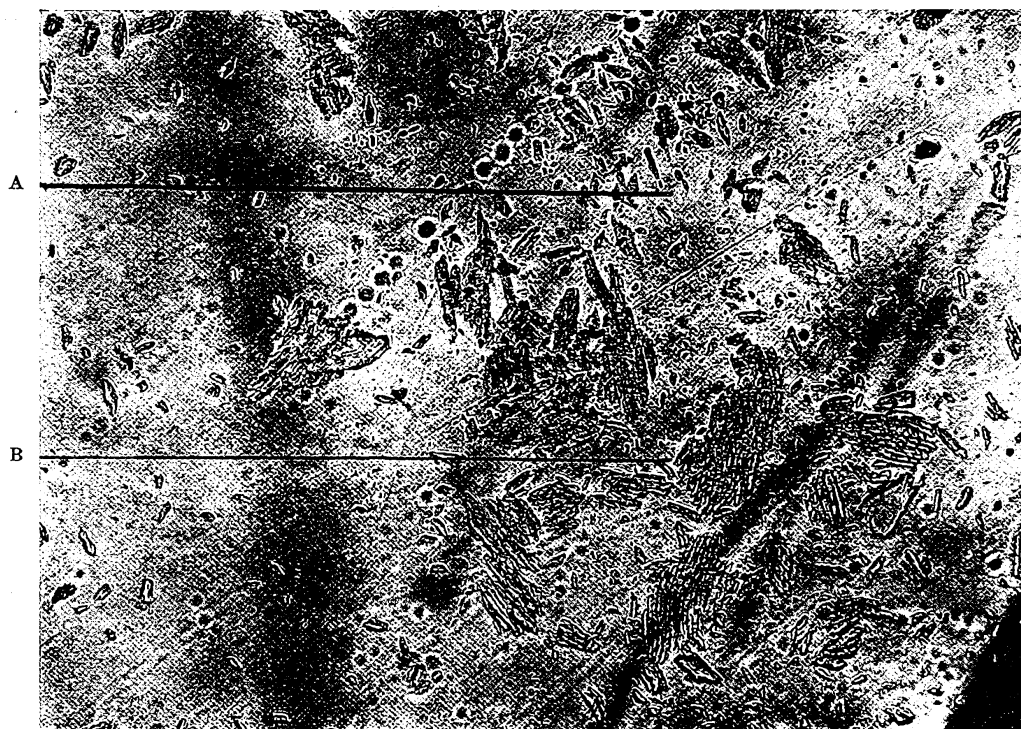
\* These grindings are made on a machine devised several years ago for grinding microscopic sections of hard substances. I have



surface of this was attached to a cover-glass with balsam. This was laid upon a disk of polished steel, and the bit of tooth bound down by a spring giving a pressure of about twenty-five pounds. While in this position it was dried at a

grinding. The cover-glass was also attached to a grinding disk with balsam, and dried sufficiently under pressure. With this I placed several scraps of broken teeth of no value on the disk to steady the pressure of the stone on this

FIG. 5.



A margin from a photomicrograph of the floating enamel rods mentioned in the text. It will be seen from this how the enamel rods break up when they have the opportunity, and often we may find single rods separated from the others, when using the microscope over the specimen.

A little debris which apparently is made up largely of individual enamel rods, or of just a few together, may be seen at A. A more considerable tuft of enamel rods, which seem to be hanging together with loose rods over them, is seen at B.

temperature of 120° F., so that the balsam was sufficiently hard to hold it in

recently added an electric cut-off, which stops the machine at a point determined upon before beginning. In practice this has been found to work satisfactorily to 1/2 of 1/1000 of an inch, or even to 1/4 of 1/1000 of an inch by especial care. By this method specimens of much material heretofore impossible of preparation for microscopic examination may be undertaken with certainty of success. For instance, I have good sections produced in this way of fossil dentin and enamel, in which the dentin had become so soft as to

little piece. An excellent section was obtained. By carefully warming the grinding disk, and at the same time making

crumble in the fingers. Yet from these I have obtained specimens as perfect as from fresh teeth, showing all of the histological characters. It is with this that I have been able to grind fine sections of ordinary salivary calculus, and even from the little scraps of serual calculus that have been removed from the teeth beneath the gingivæ. A description of this machine, with illustrations, is given in the appendix of my recent book on "Special Dental Pathology."

pressure against the edge of the cover-glass with a bit of pine wood cut for the purpose, the cover-glass was pushed off the disk before the section was loosened. This was cleaned and mounted on a glass slide by adding a very small amount of soft balsam. A hasty microscopic examination was then made. The whole section was in excellent form and the enamel rods well shown. *This demonstrated at once that there was a failure of the deposit of the cementing substance between the enamel rods.* The specimen was laid away flat for the soft balsam to harden. After about a half-hour, remembering a previous experience and having some misgivings as to the result, I carefully took another look at the specimen. I found all of the loose ends of the enamel rods afloat in the balsam. The soft balsam added had softened the hard balsam in which the specimen had been ground. For the purposes intended, the section was ruined. It served, however, to show most beautifully the fact that the enamel rods are not cemented together in any such way as in normal enamel. In this sense the specimen proved very valuable. (See Fig. 5.)

This first grinding had proved my measurements by the machine's micrometer to be correct for the grinding disk and thickness of cover-glass used, and I could now proceed with certainty as to results. A light-colored shellac was substituted for balsam for attaching the specimens to the cover-glass to prevent the scattering of the loose enamel rods after mounting. Sections as thin as these must remain attached to the cover-glass; otherwise they cannot be handled without going to pieces. Shellac is not dissolved in xylol balsam. Therefore a specimen attached to the cover-glass with a solution of shellac in absolute alcohol may, after it is ground, be mounted in balsam, covering-in the shellac without danger of the movement of the loose enamel rods. The grinding disk may be placed in xylol to dissolve the balsam with which the cover-glass is attached to the disk for grinding, without the danger of breaking the cover-glass which sometimes occurs in trying to push it off. It

is more difficult to keep shellac in condition for use, and the drying requires much more time. Shellac dissolved in alcohol will absorb a little water if the bottle is left open, and then will throw down crystals that will interfere with the finer microscopic observations, so that great care is necessary in the handling of it. This may be avoided by carefully excluding air from the bottle. When a new and very transparent solution of shellac is handled in this way it doesn't change the color of the specimen in any degree, and may be used in the finest technical observations. The other grindings were done by this method, using a very light colored shellac. Several of the pieces were retained for other treatment if the study of the sections then in hand should require.

#### THE HISTOLOGICAL CHARACTERS.

The sections were thin enough to afford an excellent view of the tissue. They presented a very considerable variety of injuries. The teeth were all from young persons, and were practically unworn except a few on the incisal edge. The enamel was normal in its outline form and normal in thickness in all of the specimens, but not normal in color. The group presented, as I found later by personal examination of many children, a series of bad cases of mottling. Some portions of the enamel were perfectly normal, both in color and histological development, in the majority of the specimens. A number of them were of a very dark brown color over a considerable portion of the labial surfaces, shading from the brown areas through varying shades of yellow, to opaque paper-white, and from this into the normal enamel color. All of the abnormal areas showed the same lack of development of the cementing substance which usually binds the enamel rods together. The degree of this injury varied in the different teeth and in the different parts of the crowns of individual teeth. Later, in examining the children, I saw many teeth that were much darker in color than those I had for cutting. This, how-

ever, was only a matter of degree of injury without difference in kind.

In all of the specimens the enamel rods were well formed throughout the enamel; in the imperfect areas the enamel rods seemed as regular and perfect in form as in the areas in which the cementing substance between them was normal. In areas in which the difficulty was simply a lack of the cementing substance which should be between

of the enamel, thus showing a remarkable difference from the contemporaneous accretional deformities of the enamel, in which the lines of accretion in the growth of the tooth are very closely followed.

While persons who have become skilful in the interpretation of things seen with the microscope may see the lack of cementing substance between the enamel rods, it is often very difficult to so make

FIG. 6.



Photomicrograph of a section of moderately dark enamel from a mottled tooth. There is no cementing substance between the enamel rods, the space being filled with brownin.

the enamel rods, the spaces were empty, or filled with air. Such areas were opaque paper-white because of the presence of air between the enamel rods.

In the dark-colored areas the brownin was found to be in the spaces between the enamel rods. The enamel rods themselves were as perfect and presented the same cross markings as in normal teeth, but they often made very dark photomicrographs. (See Fig. 6.) The lines of accretion in the growth of the enamel were about as usual in normal enamel. It was particularly notable that the lines and depths of the abnormal condition had no reference whatever to the lines of accretion or growth in the formation

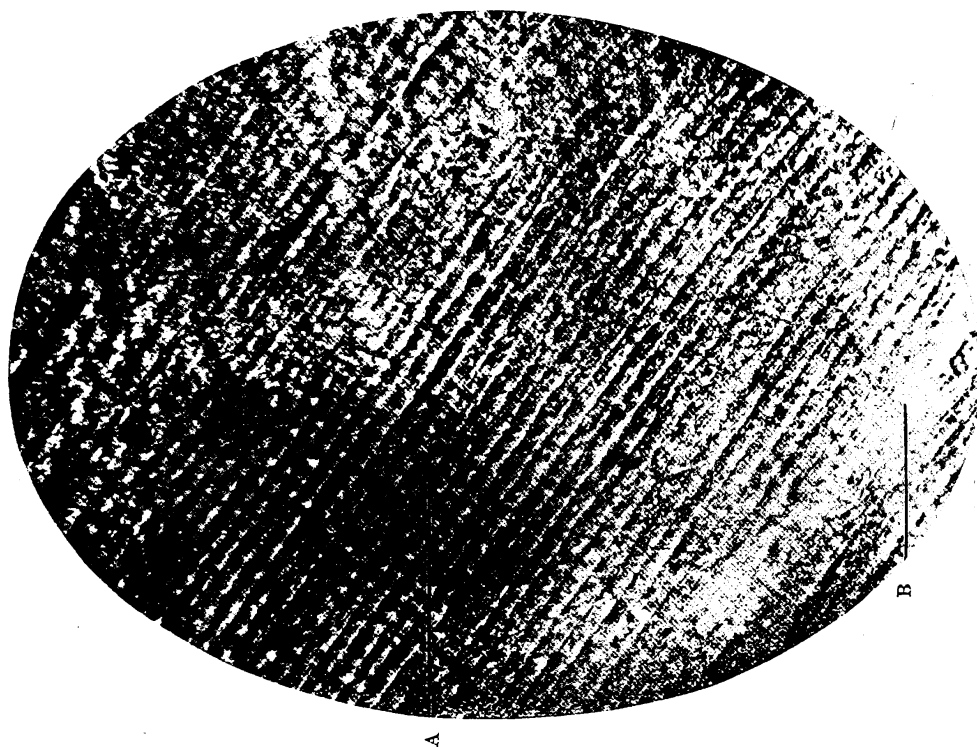
photomicrographs that this will be readily observed. I have, therefore, made an effort to place this in clearer light by photomicrographs of some very thin sections (see Figs. 7 and 8); also by an illustration with very sharp definition, from a dark area. (See Fig. 6.)

#### DEPOSITS OF BROWIN IN THE DEEPER PARTS OF THE ENAMEL.

In the four pictures, Figs. 9, 10, 11, and 12, it will be noticed that there are areas or lines of brownin distributed deeply in the enamel. These are taken from three different teeth.

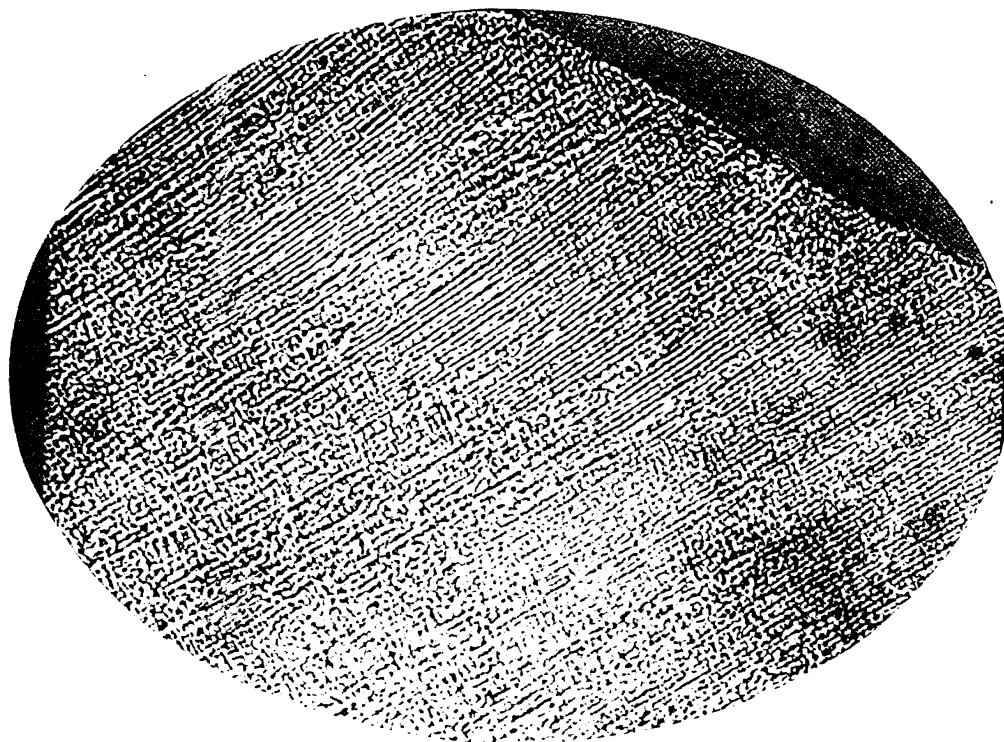
The yellow shades of stain seem to be

FIG. 7.



A photomicrograph of enamel that was considerably colored by the deposit of brownin. It will be seen that parts of the field show more color than other parts, as at A, and that some parts are very nearly white, as at B.

FIG. 8.

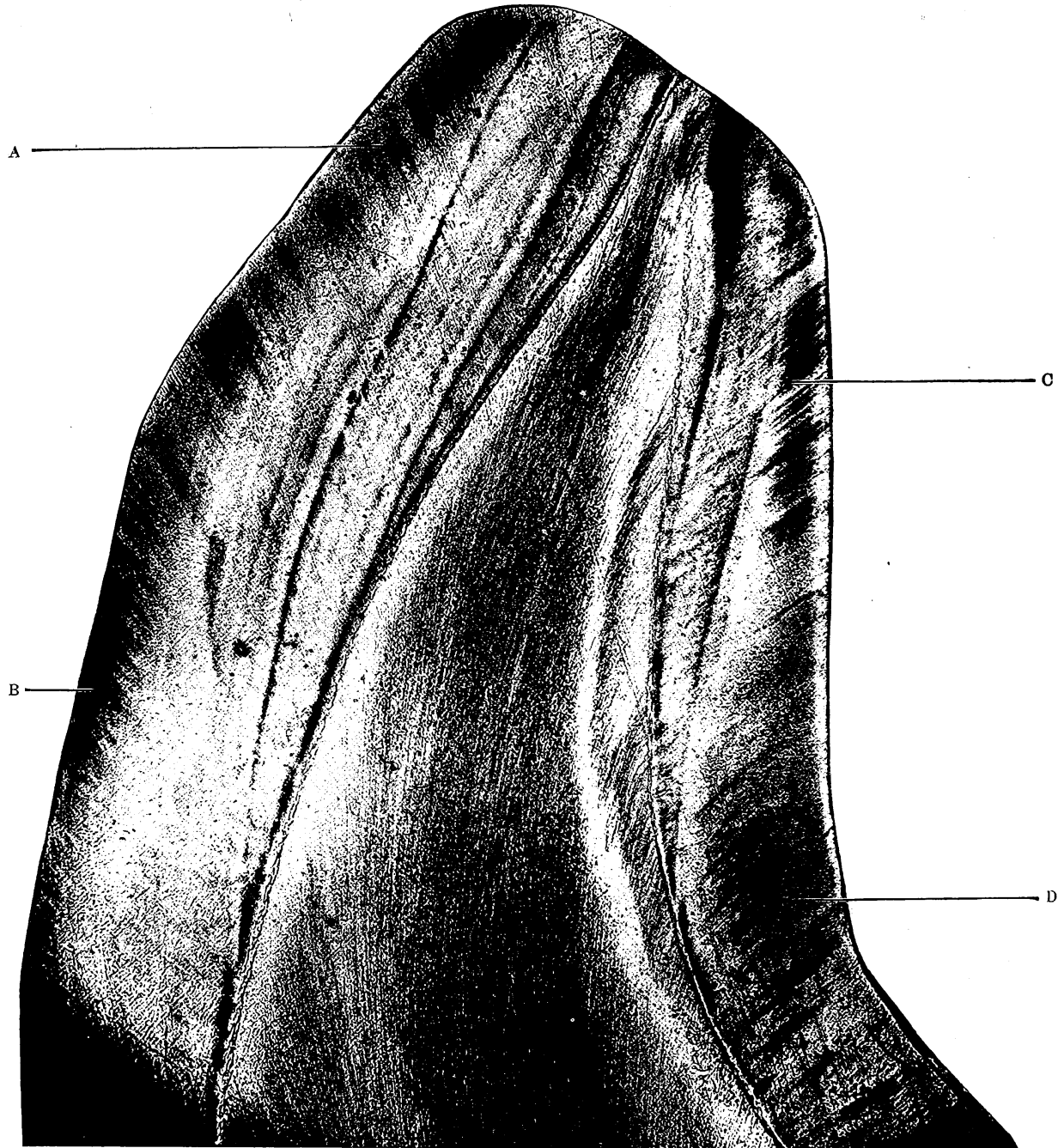


A photomicrograph made by a lower power, showing the enamel rods very distinctly. Most of the picture is from white enamel, but on one side we find that there is some marking of brownin between the enamel rods.

caused by brownin within the substance of the enamel which is covered by normal enamel. In this case the modifica-

low color appears to be caused by minute areas of brownin too small for the naked eye to distinguish as separate, and the

FIG. 9.



Showing the distribution of the brownin between the enamel rods, as at A, B, C, D. In Figs. 10, 11, 12, and 13 the color in the section is just as it was in the tooth before it was cut, not having been changed in the least. There will be an advantage in studying the four pictures together. Although they are similar, there is quite a little variation.

tion of color is caused by the partial showing of the brown through the translucent covering. In other cases the yel-

mingling of this with the translucent white gives the yellow shades. In my sections I find no yellow colors what-



ever. To the naked eye the tooth from which sections were made for Fig. 10 Distribution of brownin in the enamel as a whole is extremely irregular. In

FIG. 10.



The labial surface of an incisor (same tooth as Fig. 9) showing the irregularity of the filling of the spaces between the enamel rods with brownin. A, A rather thick deposit of brownin; B, very little brownin; c, a deposit of brownin along a line of accretion.

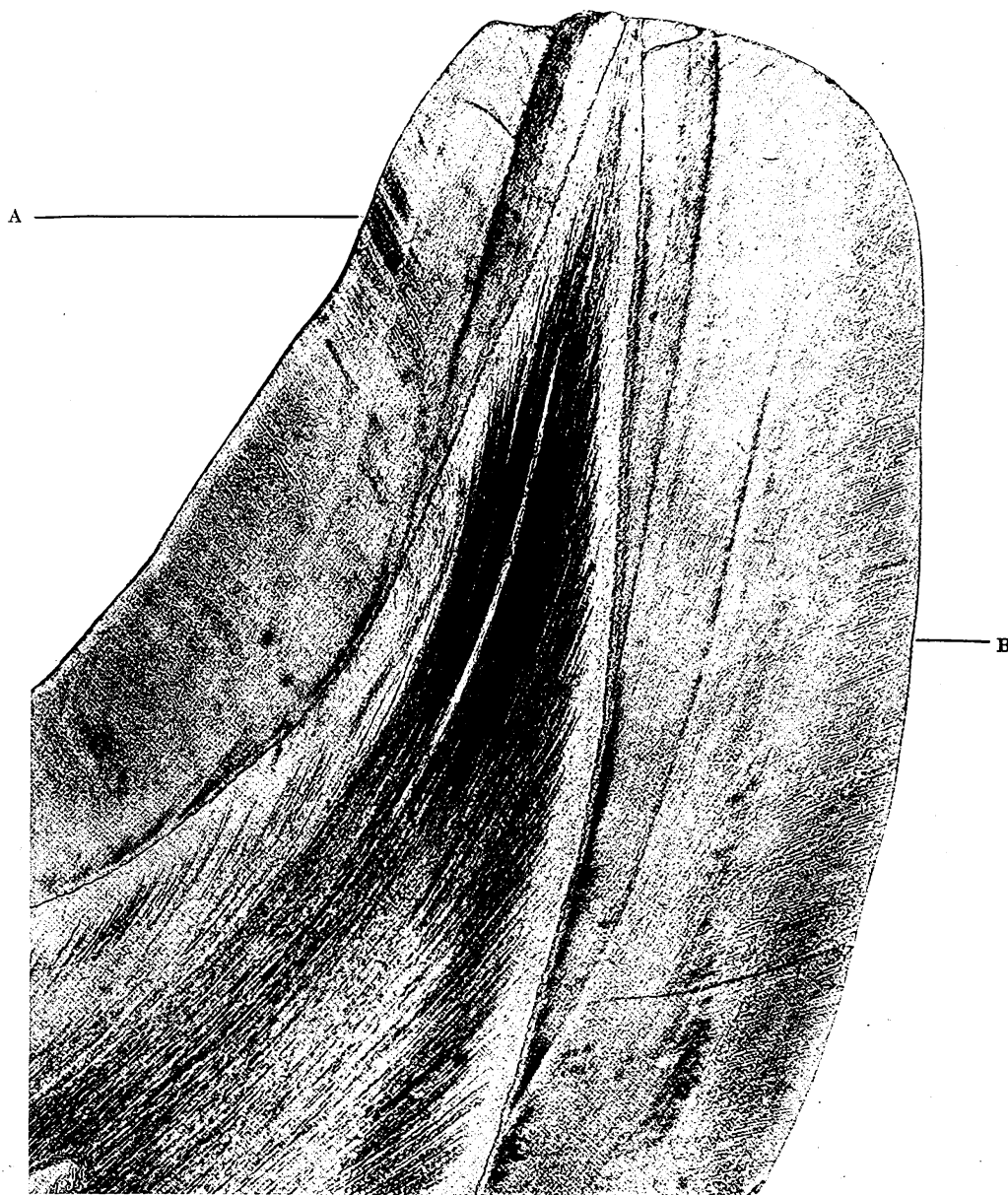
was a dark yellow rather than a full brown.

the darkest areas I found in the teeth furnished me, it was difficult to make a

photomicrograph that would show all of the spaces between the rods filled. Many of them are empty. This character of the deposit is quite well shown in Fig. 9,

been mounted for grinding in very light colored shellac show plainly that the limit of the imperfect enamel is not a sharp line, but that some of the spaces

FIG. 11.



A very light picture of the incisal portion of a central incisor showing a light deposit of brownin, making a yellow tooth. A, A few lines of brownin on the lingual surface of the tooth, most of the enamel being fair. B, White enamel on the labial surface.

which is made with low enough power to show the whole of the incisal portion of an incisor. This tooth was dark, but the dark brown stain was intense only in small spots.

The sections cut from teeth that have

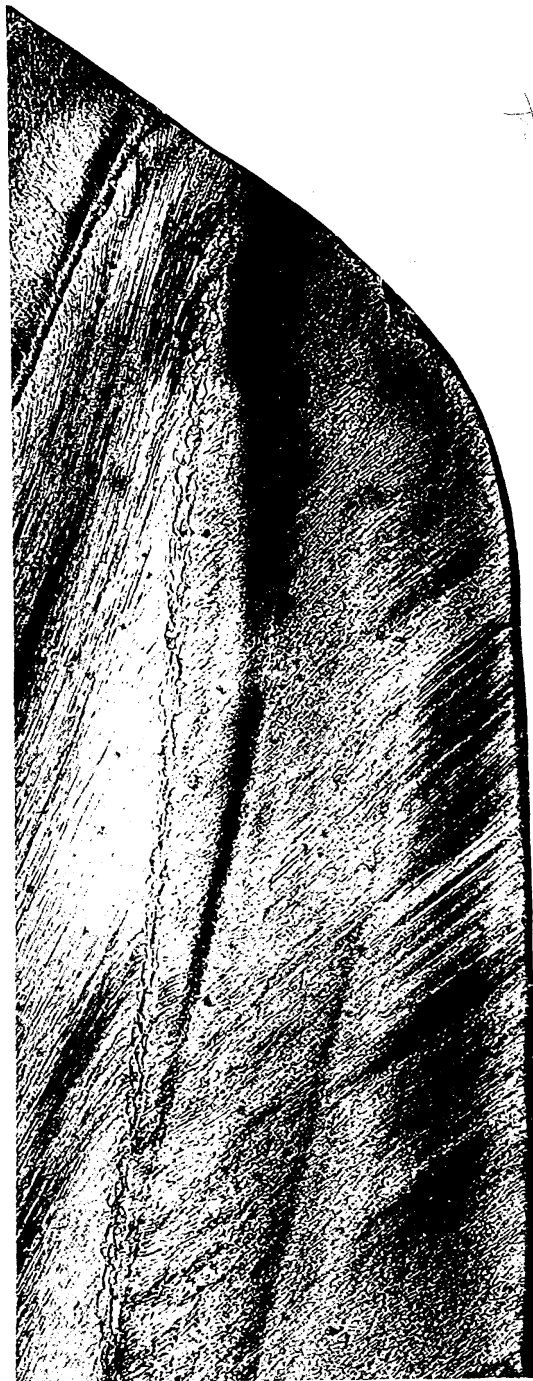
are open between the enamel rods much deeper than others. This causes the color produced by brownin to thin out into the perfect enamel.

There are also in this enamel many places where the color seems to be about

normal, in which small groups of spaces between the enamel rods are filled with the brownin. This is very sharply

the naked eye, but come out prominently with the medium powers of the microscope.

FIG. 12.



The lingual portion of a central incisor (same tooth as Fig. 9) showing a considerable deposit of brownin, and yet with many of the spaces unfilled.

brought out in some of the photomicrographs. Many of these islands of color are so small as to escape observation with

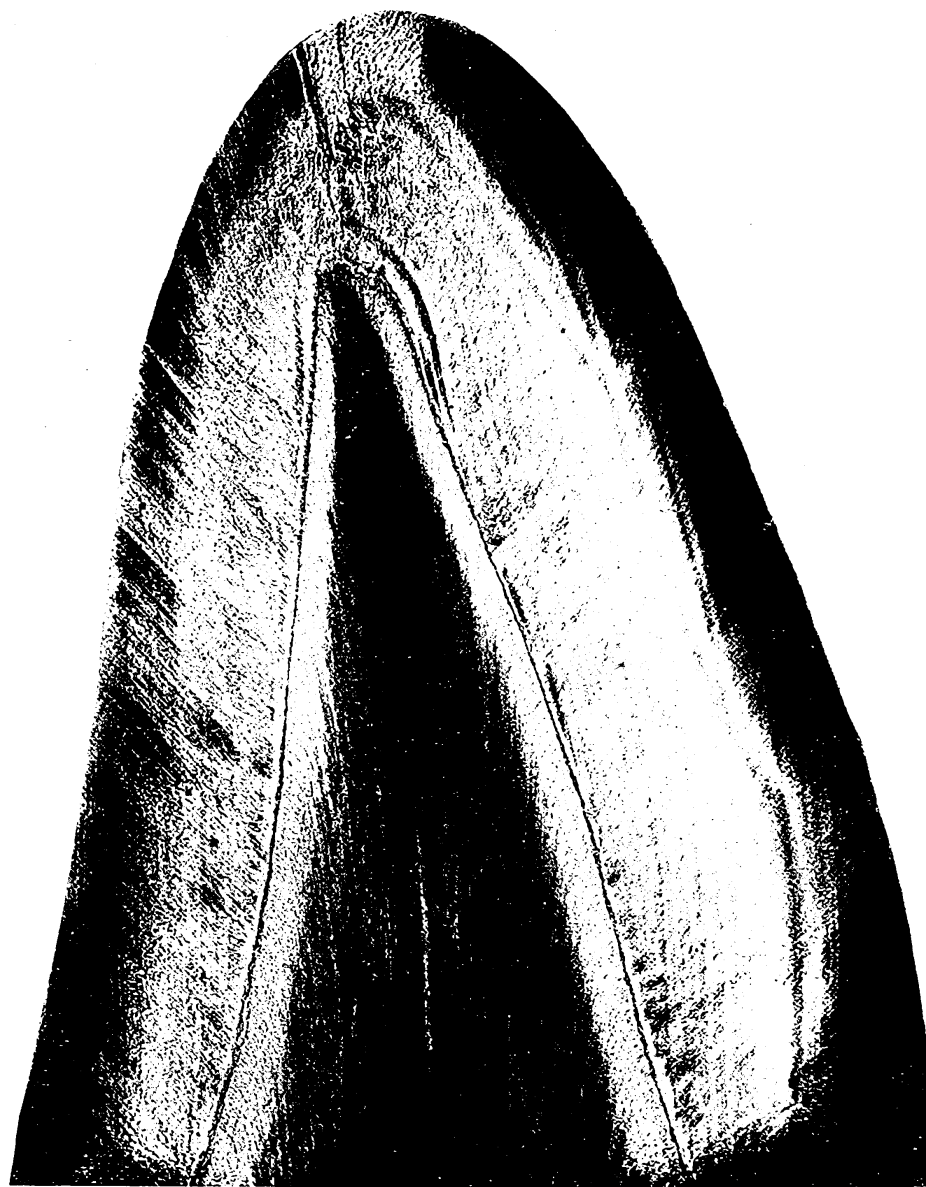
#### PERMEABILITY OF THE WHITE AREAS OF THE ENAMEL.

In studying this the reader should have certain facts clearly before his mind. We cannot stain the body of normal enamel with any staining agent we know. Even the anilin dyes dissolved in alcohol fail to penetrate it. It is a solid and is impervious to ordinary stains. Its surface may be stained until black or very dark yellow and various other colors, but when sections are cut the colors are found to be on the surface, and not within the tissue.

I selected a piece of tooth with very dark enamel and placed it in absolute alcohol for four days. Then I transferred it to gasoline, where it remained a month. When examined after that time it was white. All of the brownin had disappeared as completely as though it had never been there. The whiteness was paper-white, not the translucent whiteness of the teeth. It was now transferred to absolute alcohol for a few days to remove the gasoline. It was then transferred to some shellac dissolved in absolute alcohol, to which a few drops of gentian violet had been added. It remained in this for about a week at a temperature of  $120^{\circ}$ , occasionally varied by increasing the temperature to  $140^{\circ}$  for a time. In the meantime it was covered very closely to prevent evaporation. At the end of a week it was removed from this bath and laid upon a cover-glass and pressed down with a spring that gave about twenty-five pounds weight. While in this position it was cleaned of the shellac as perfectly as possible, and also the cover-glass about it was made clean. This was then placed at a temperature of  $120^{\circ}$  for a couple of days. When released from pressure the cover-glass was sealed to a grinding disk and placed in the machine and a section ground. This section is represented by the photomicrograph Fig. 13. In this the labial por-



FIG. 13.



In examining this figure the reader should have fixed in his mind the following: The substance of the perfectly developed enamel of the tooth has not been successfully stained; being a solid, it will absorb nothing into itself, therefore any staining in the substance of the enamel is the result of imperfect development which creates openings which will receive a stain.

The photomicrograph is of a portion of the crown of an incisor tooth from which all traces of color had been dissolved out, making the tooth very white. The piece was placed in alcohol for several days and then transferred to a solution of shellac which had been tinted with gentian violet. After remaining in that for two weeks it was mounted upon a cover-glass and dried for grinding, and a section was cut.

In studying this it will be seen that the labial surface of the tooth—the portion most injured by failure of the cementing substance between the enamel rods—has come out black. On the lingual surface a very different phenomenon occurs. Here the injury has been much milder than on the labial surface, and it will be seen that areas of white run through the dark areas, and that the brown shows in long lines instead of making a full brown. This shows that only a portion of the cementing substance between the enamel rods has failed.

tion of the enamel, which was very white, has come out a solid black, while the solid parts of the enamel remain clear. It is therefore the imperfect portions of the enamel which have taken up the color. This is a demonstration of the porosity of this part of the enamel, caused by the lack of the cementing substance between the enamel rods. The lingual portion is a beautiful showing of the manner in which the mottling occurs. Note the little patches of enamel rods without cement substance, with the spaces very solidly filled with color, with the clear strips between, in which the presence of the cement between the rods prevented the infiltration. This would make a gray enamel. Just as the white becomes greatest, the enamel becomes opaque white. Just as the solid tissue prevails, the enamel becomes normal in color.

In Fig. 9 there is a very small spot of brown standing by itself in the lingual portion of the enamel that shows something of the vagaries of the distribution of the brownin. This spot would hardly be discoverable by the naked eye. It is this skipping of the deposit of the cement substance that gives the different shades of gray between pure paper-white enamel and the fully normal color.

The possible removal of the brownin has been a feature of the studies I have made. These teeth are stained in their formation in the same manner as they are stained in enamel whorls. I have been particularly struck with the proportion of stains to the number of cases, in the two conditions. In each, the brown stains occur in about half the cases of injury. These stains are not superficial; it is the body of the enamel that contains the coloring matter. In contemporaneous accretional deformities and in enamel whorls, this coloring matter is often deep in the enamel, even against the dento-enamel junction, with perfectly normal enamel over it. In endemic mottled enamel the actual tissue of the tooth is stained during its growth. It is therefore not in any degree like what we know as green stains, the deposit of dark material upon the teeth

from fermentations, or any such accumulations. In bad cases the depth of the injury may include one-third of the thickness of the enamel; in mild cases the depth may be much less.

#### MOTTLED ENAMEL A NEW PROPOSITION IN DENTAL PATHOLOGY.

Endemic white enamel, or mottled enamel, is an entirely new proposition in dental pathology. Nothing of the kind seems to have been discovered heretofore in any part of the world. This endemic feature gives this description unusual novelty. When I visited a number of susceptible areas during the summer of 1909 I examined the children, and many of adult age, myself. Great numbers of children seemed to be easily gathered. It was quickly seen that the reports had not been exaggerated. The settlement of these regions is comparatively recent, and about half of the children were born and passed the earlier part of their lives elsewhere. When these were excluded, it has been found by the examination of the children in the public schools, that a little more than 87½ per cent. of those born and reared in these areas have teeth of the character described. The examination and compilation then made included about thirty-six hundred children. Very many more examinations have been made, and those are still in progress. This will be fully elaborated by Dr. McKay.

#### THE ESSENTIAL INJURY.

The most essential injury occurring in this mottled enamel is in the appearance of the teeth and the general evil effect on the countenance of the individual. The teeth are of normal form but not of normal color. When not stained with brown or yellow, they are a ghastly opaque white that comes prominently into notice whenever the lips are opened, which materially injures the expression of the countenance of the individual. When this opaque white color is mingled with spots of brown, or a very large proportion of brown, the injury is

still greater. In very many cases the teeth appear absolutely black as one sees them in ordinary social intercourse. I spent considerable time walking on the streets, noticing the children in their play, attracting their attention and talking with them about their games, etc., for the purpose of studying the general effect of the deformity. I found it prominent in every group of children. One does not have to search for it, for it is continually forcing itself on the attention of the stranger by its persistent prominence. This is much more than a deformity of childhood. If it were only that, it would be of less consequence, but it is a deformity for life. The only escape from the deformity is by the placing of crowns, and possibly of bridges or artificial dentures later in life.

The proportion of the cases so bad as this is really very large. They are not all of the worst type by any means, but the struggle for a better appearance of the teeth, or the stoical endurance of a terrible affliction, is certainly upon from 30 to 100 per cent. of the persons being reared in the various areas where this deformity is endemic. Many of those counted as having mottled teeth are injured in such slight degree as almost to pass unnoticed. Every degree of injury, from solidly brown front teeth to the white flecking here and there, is represented.

#### SPORADIC CASES.

A few sporadic cases have been seen from different sections of the country which, in considerable part, simulate the endemic cases. I have a photograph showing the upper incisors of a person born and reared in Chicago which are much like the endemic condition. There are also some white flecks on several of the other teeth, but these are slight. Another case is that of a boy who grew up on a farm in Indiana. The incisors were badly marked with a dark band across their labial surfaces. All of the other teeth were normal. I have seen two other sporadic cases of this char-

acter, but failed to obtain photographic records of them.

I have found that one must be especially careful in tracing histories of the cases. For instance, a lady brought her boy of about thirteen years to see me because of the very distressing appearance of his teeth. This presented a complete picture of the endemic mottled enamel. The incisors were badly flecked with very dark browns and yellows, mixed more or less with paper-white. The mother stated very positively that the child was born in Chicago and had always lived in Chicago, and I was unable to get any other statement from her. A few days later an older sister came to ask my advice about her own teeth. In talking with her the statement came out that the family had spent much time in an area in which I happened to know the condition was endemic, locating the time as "when Johnny was a baby." They had visited the region, remaining there a part of each year for a number of years. This girl had mottled enamel on her bicuspid and second and third molars, but her incisors and cuspids were normal. It was true that Chicago had been the home of the family, and when asked about their wanderings the mother had not recalled the visits to this region.

#### DIAGNOSIS.

This brings up the question of diagnosis of mottled teeth. Before I saw a case, dentists had endeavored to describe the condition to me. The effort was a failure. I got no mental picture that was at all like what I saw when I visited the areas. If I could not recognize the picture drawn by the dentists who had long observed the condition, how could I expect others to do so? How could I expect others to differentiate this condition of enamel from various dystrophies. The whole matter became clear very readily when I saw some of the teeth, and cut them and made sections and brought them under the microscope, but not before. The histological study of such teeth is so recent that few men have had any knowledge of it.

## TIME OF LIFE AT WHICH THE INJURY OCCURS.

One thing I wish to impress particularly upon the mind of the reader just here. Faults in the form or color of the teeth may occur from errors in growth, or may occur from causes acting upon them after the teeth have been fully formed. Any departure from the normal in the enamel of the teeth, the dentin, or the form of the teeth, from errors in development, must occur while the teeth are growing. This must be differentiated sharply from deformities that are acquired after the teeth have grown, about which more will be said later. The tissues of the teeth are not changed in any wise by physiological processes after they are once formed. This explains the fact that some teeth of an individual are found to be marked and others not, and why the incisors are more persistently marked than other teeth.

This has relation to the time in the life of the child in which the enamel in different groups of teeth is growing, having reference now only to the permanent teeth. The deciduous teeth are always normal in this respect. The permanent teeth are naturally divisible into three groups. The first group includes the first molars, the incisors, and the cuspids. The enamel of this group is growing during the first five years of the child's life, excepting that the cuspids frequently continue to the seventh year. The second group includes the bicuspid and second molars. The enamel of this group begins growing at from five to six years, and is completed at from nine to eleven. The third group includes the third molars only. The enamel of these is growing ordinarily from the tenth to the fourteenth or fifteenth year, but presenting considerable variation of the time of completion of the growth. This is an approximate statement.

It occurs, therefore, that if the child is not in the locality of endemic mottled enamel during the time of the growth of the enamel of any one of these groups of teeth, that group will not be marked.

Or if a child is in the locality only during the time of the growth of one, and elsewhere the rest of the time, only that one group of teeth will be marked. It therefore follows that if a child born in the locality is removed and lives elsewhere for the first five years, the first molars, incisors, and cuspids will be normal. If the child returns to the locality at the end of the five years and continues to live there, the other two groups of teeth will be mottled. Having lived a part of the time in this area does not seem to carry with it a continuance of the injury after removal. Neither does living elsewhere during the growth of the enamel of the incisors, and then coming into the endemic area, prevent the injury to the teeth which have yet to grow their enamel.

Among the children examined there was every opportunity for the study of this feature of the difficulty, for among them there were many who had come into the territory at any and all periods of the growth of the enamel. By examining the teeth one could tell pretty closely the age at which they had come into the locality. This, then, expresses the general idea of the susceptibility of the different groups of teeth. Lines cannot be drawn too sharply, however, for we must remember that among those born in that region, about one in every ten persons is immune—that is, has normal teeth. This presents some very curious features. Some one child in a family may have normal teeth, while the teeth of the brothers and sisters are mottled. I saw a pair of twins, a girl and a boy. The girl's teeth were horribly brown, while the boy's teeth were normal. These two children were seen together so persistently as to occasion general remark. They ate at the same table, slept in the same house, played together, and their habits and environment had been the same since birth.

The rule is, other things being equal, that the younger the child at the time of the occurrence of any injury to the development of the enamel, the more grave the injury. According to this rule the incisor teeth are more persistently

and more severely mottled than any other group of teeth. Curiously enough, however, the first molars, which have generally just begun formation of the enamel at birth, are notably less severely mottled than the incisors, which begin the development of their enamel a little later. In the contemporaneous accretional deformities, the first molars are more severely injured than the incisors, as the rule. For all the other teeth the general rule stated seems to hold true. Dr. McKay's paper will deal especially with this feature, from information derived directly from the examination of many thousands of school children.

#### DENTAL CARIES.

As to caries, the teeth of these children compare favorably with those of other communities where endemic mottled enamel is unknown. They have a mild climate and almost continuous sunshine during the day. The children are out practically every day the year round, and this in itself certainly has its effect in limiting the amount of dental caries. But when the teeth do decay, the frail condition of the enamel makes it extremely difficult to make good and effective fillings. For this reason many individuals will lose their teeth because of caries, though the number of carious cavities is fewer than elsewhere. Yet I was of the opinion, at the end of several weeks' examination and study of the conditions; that if the appearance of the teeth could be endured, the injury in their development would, on the whole, not reduce the general usefulness of the teeth.

#### THE DYSTROPHIES OF THE ENAMEL— NOMENCLATURE.\*

The condition resulting from imperfect, defective, or bad formation of

growth constitutes a dystrophy; *dys*—imperfect, defective, bad; *trophy*—growth, development. Therefore, any dystrophy noted must have occurred during the growth of the tissue. A tooth that is misshapen, off color, or otherwise deformed during growth, is in the condition of dystrophy. Acquired deformities, such as erosion, abrasion of the teeth in chewing food, etc., after the teeth have formed, are excluded from dystrophies.

The dystrophies of the enamel consist of imperfections in development due to some disturbance of nutrition during the time of its formation or growth. In each class of cases some part of the tissue is either imperfectly developed, or some particular part has failed to develop, or has developed in an erratic manner. Among these dystrophies there are certain things common to several, such as imperfection of the cementing substance between the enamel rods. In others, as in distortions of the dento-enamel junction, there may be no absence of the cementing substance between the enamel rods. It is only recently that these conditions have received such histological study as to make out the scheme of each, and separate them into special classes of deformity. The gross appearance of some of the more frequent of these deformities of the teeth has of course been well known for many years.

When I wrote on atrophy or hypoplasia of the enamel, in my "Operative Dentistry,"\* there had been no studies published in the English language, and but one short paper by Dr. Zsigmondy of Vienna, in the German language, read before the World's Dental Congress in 1893, which has never been translated into English, describing the histopathological condition of abnormal teeth as determined by microscopic study of prepared sections of the tissue. I received the first specimens of mottled enamel

find a simple term to apply to the condition here referred to as contemporaneous accretional deformity, described in his work on "Operative Dentistry" as atrophy or hypoplasia.

\* "Operative Dentistry," 1908, Black.

\* This part of this article was written by Dr. Black only a few weeks before his death. He was not then satisfied with the terms applied to the various dystrophies, and expressed his intention to revise them before publication. He was especially anxious to

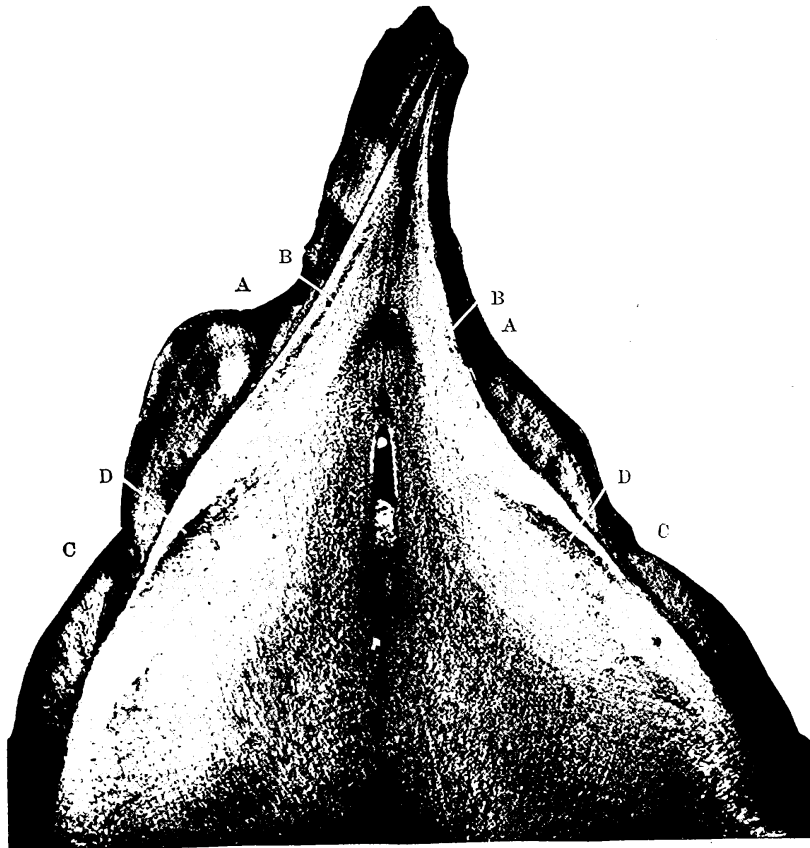
about the time of the publication of my work on "Operative Dentistry."

In these distortions all manner of things come under the eye and much of the tissue appears chaotic in form. The usual color of the teeth, which we speak of as white, is really a transparent or

that we would scarcely recognize them as human teeth. The color was so far from that of the normal as to attract the attention of the observer as something wrong and abnormal.

After the "Operative Dentistry" was published, many abnormal teeth were

FIG. 14.



Labio-lingual section of an incisor showing two zones of contemporaneous accretional or lineal deformity which occurred at different times in the growth of the tooth. As explained in the text, the term contemporaneous indicates that a similar deformity occurred to other teeth which were in process of development at the same time. The lines of the earliest deformity in the enamel are shown at A, A, and the corresponding deformity in the dentin at B, B. The lines of the second deformity in the enamel are shown at C, C, and the corresponding deformity in the dentin at D, D. The line of interglobular spaces in the dentin is more clearly shown in Fig. 15, which is a higher magnification, from the same section, of the second zone of deformity on the labial side.

translucent color, which gives a peculiar impression to the eye and softens the whole expression of the face. Some of these teeth were a paper-white instead of the usual color of the human teeth, and others again were tinged with variations of shade, and were even brown or black—giving them an appearance so vague

sent to me by dentists widely scattered throughout our country. In examining these teeth, I was struck with the regular appearance of certain marks that would form a basis of classification. These were distinguishing features of the various cases, which I had not observed or mentioned in my writing in such a

way as to indicate an essential difference between one deformity and another. I recognized in the mottled teeth an es-

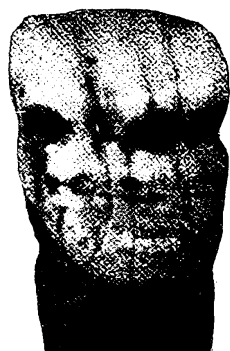
may be grouped in such a way that each one will be distinguished as a special deformity, and those that are essentially

FIG. 15.



Higher magnification of the second zone of deformity on the labial side of the section shown in Fig. 14. The lines of accretion are exceptionally clear in that portion of the enamel which was formed previous to the period of malnutrition. The enamel formed subsequently overlaps this, thus partially filling the gap caused by the failure of formation of the intermediate portion. It will be noticed that the line of the deformity follows the lines of accretion. The line of interglobular spaces in the dentin, which occurred at the same time as the deformity in the enamel, is well shown. The deposit of brownin is sufficient to partially obscure the line of deformity in the enamel.

FIG. 16.



Labial surface of a central incisor, photographed to show the appearance of the groove. The brownin deposited along this groove makes it appear darker than it really is. A part of a section cut from this tooth is shown in Fig. 18.

FIG. 17.



Lingual surface of the same tooth as shown in Fig. 16.

essential point in the deformity which I had not seen in other conditions.

All of these deformities thus far seen

alike may be grouped together. Sections prepared for microscopic observation form the basis of this classification.

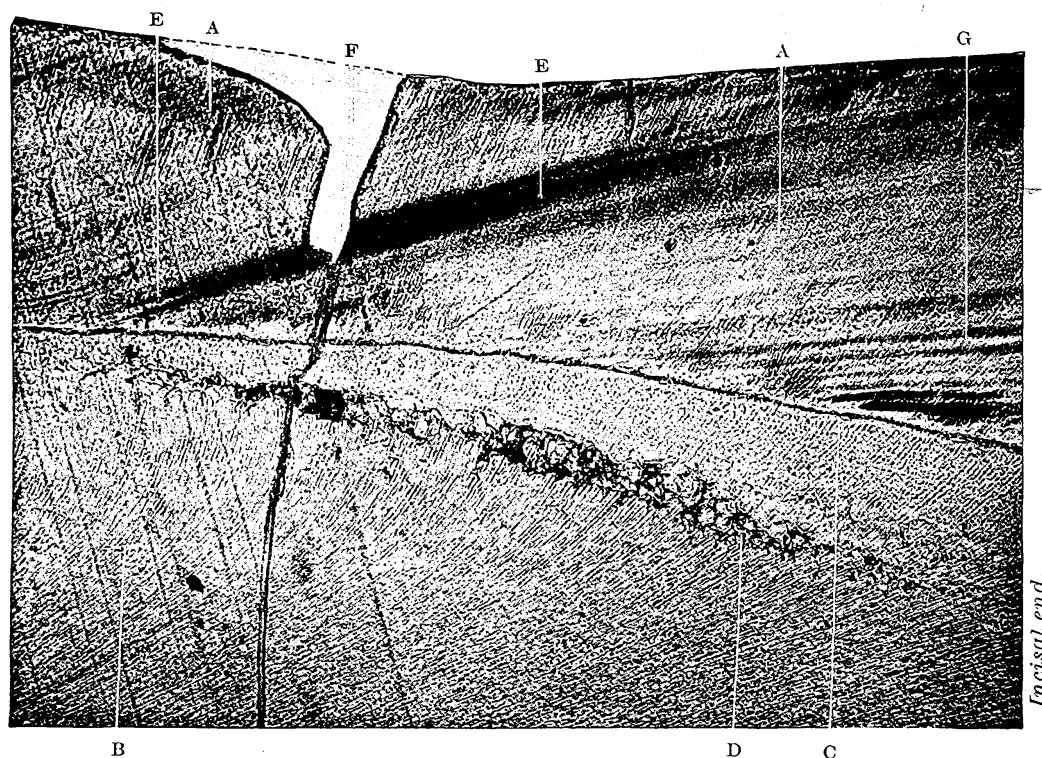
These examinations have convinced me that the words *atrophy* and *hypo-*



*plasia* are no longer desirable. These words have been used almost continuously in the past in describing abnormal teeth of any and all classes, and have

continued use of this word has become a bar to progress, and it will be noticed that I have in this writing substituted the word *dystrophy*.

FIG. 18.



A photomicrograph of part of the labial portion of a section of the central incisor shown in Figs. 16 and 17. This is a slight deformity, in which the growth of the enamel was interrupted for but a short time. The section was broken and the parts replaced in position. A scrap of enamel was lost, as represented by the dotted line.

A, A, Enamel; B, dentin; C, dento-enamel junction; D, injury in dentin showing line of interglobular spaces; E, E, injury in enamel; F, an accidental break in the specimen, which has been put together, but a scrap was lost, represented by the dotted line; G, incremental lines, showing the layers in the growth of the enamel. Note particularly that the injury follows these layers exactly both in the enamel and the dentin. Note that the injury begins toward the incisal edge of the enamel as shown by the groove in Figs. 16 and 17, and that as it proceeds it enters deeper and deeper in the enamel, passing rootwise diagonally to the width, in a slightly curved direction, until it comes in contact with the dento-enamel junction; there the mark is reflected toward the incisal edge in the dentin, and proceeds deeper and deeper in the dentin until it runs out of the section.

On the other side of the full section of the tooth a similar mark occurs, both in the dentin and enamel, not shown in this picture.

come to represent anything supposed to be abnormal in growth. This they cannot properly do, and it seems actually necessary that another word be substituted. We cannot tolerate the grouping of numbers of conditions under one word without special divisions having been formed, and this is exactly what has been done with the word *atrophy*. The con-

#### NOMENCLATURE.

*Contemporaneous accretional deformity, or lineal deformity.* (Figs. 14 to 21.) A deformity occurring along the lines of accretion, contemporaneously in all teeth in process of development during a period of malnutrition. This is the condition described in my work on



"Operative Dentistry," as *atrophy* or *hypoplasia*. In this the enamel rods, the cementing substance between the rods, and the dentin are all involved. In a section through the crown of such a tooth, the deformity appears as a line passing from the surface of the enamel, obliquely rootwise along the line of accretion, until it reaches the dento-enamel junction; it is reflected through the den-

will appear in every section. These marks pass through the entire tooth crown without any omission and may be seen in the least and the greatest deformities presented. Owing to the deposits of brownin which occur, one may in some cases fail to observe the distinguishing features. In the dentin there is only a line of interglobular spaces. The abnormal coloration may be any

FIG. 19.

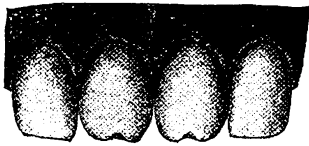


FIG. 20.

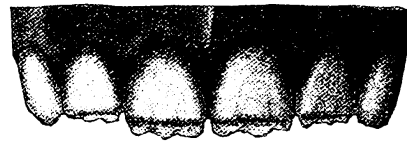


FIG. 21.

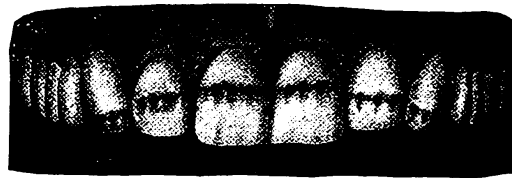


FIG. 19. Contemporaneous accretional deformity of the upper central incisors, showing as a notch in the incisal edge. This has been called the "Hutchinson tooth," and has been incorrectly referred to as being a positive sign of hereditary syphilis. In all cases in which the incisors show such a deformity, the occlusal surfaces of the first molars are also involved. Note how the angles of the central incisors are rounded toward the injuries, showing a disposition of the tissues to draw in and fill up the injury caused by the failure of formation of the central lobe of the tooth.

FIG. 20. A similar deformity involving the incisal portions of the central and lateral incisors. The first molars would also be deformed.

FIG. 21. A similar deformity occurring as a result of malnutrition a little later in life, and involving the central and lateral incisors and the cuspids. The first molars would also be deformed.

It should be understood that the deformity in these six front teeth and the first molars occurred at the same time. The central incisors were more fully developed than the laterals, and the laterals more than the cuspids, as shown by the position of the line of injury on the various teeth.

tin, still following the accretion lines in the growth of the dentin until it arrives at the dento-enamel junction on the opposite side, when it is again sharply reflected, passing through the enamel as before.

In any of these the distinguishing marks may be seen in a section cut labio-lingually through the crown. If the section is cut mesio-distally they appear also, and if we quarter this again, they

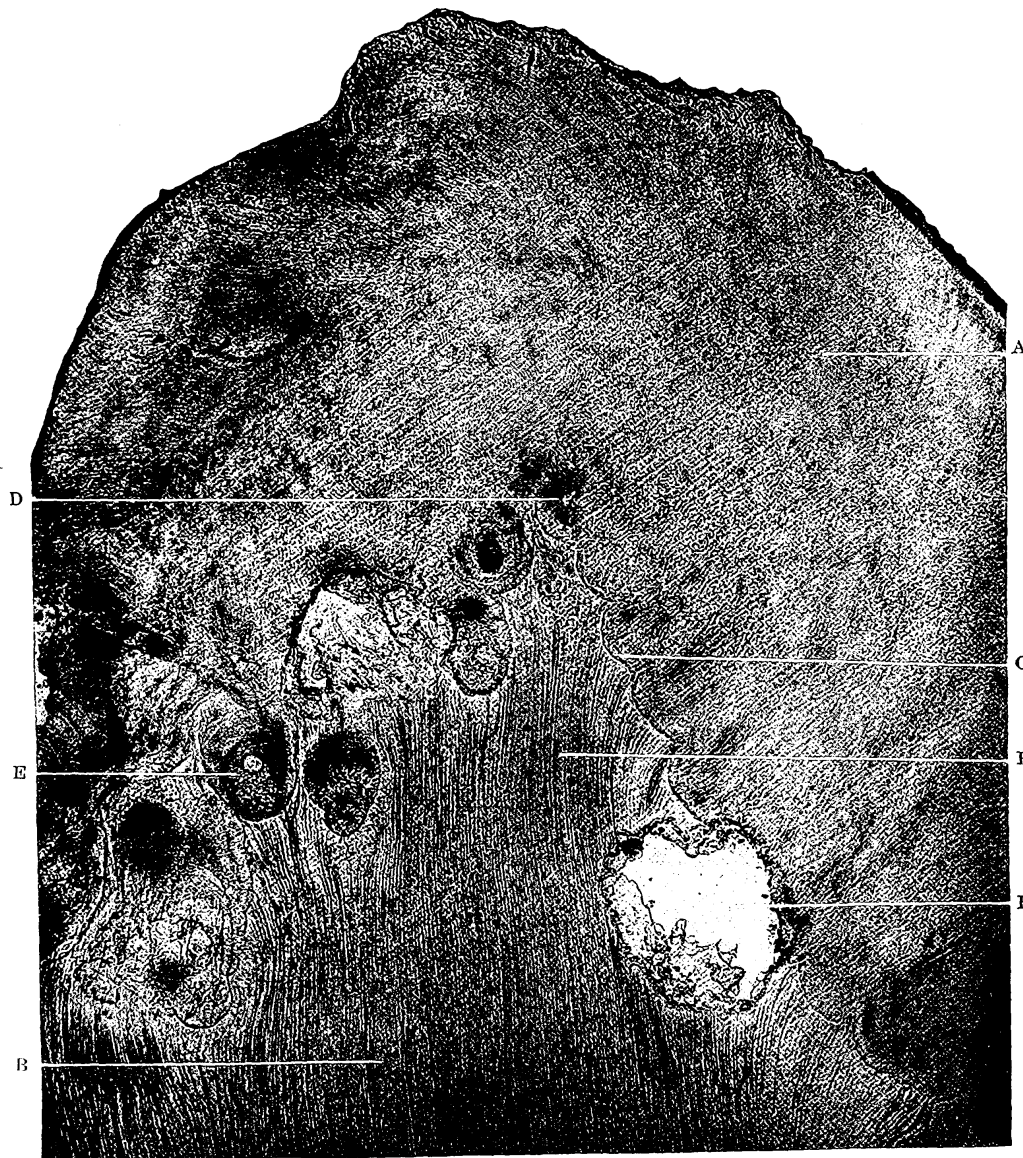
change from the normal to a deep brown along the marking that extends around the tooth crown, but usually the enamel of the tooth in other portions is normal.

In these cases there is pretty generally a mark across the labial surface of the incisors. There may be only a little depression running across, so slight as not to be easily observed, or a very grave abnormality of the tooth. Accompanying this there may be a notable shortening

of the tooth crown, and that portion between the defect and the incisal edge of the tooth may have a very bad appear-

from the labial view. The groove which runs around the tooth may show some white flecks along its margin, or the

FIG. 22.



A section cut from a case of scalloping of the dento-enamel junction, otherwise called *wrinkled teeth*. The enamel is marked A, the dentin B. The scalloping of the dento-enamel junction is shown very nicely at C. An open space in the enamel appears at D. Another very irregular formation of enamel is marked E. There is a large open space in the dentin at F, which contains scattering fragments of enamel. This section is from one of sixteen teeth extracted by Dr. J. E. Callow, of Antigo, Wis. Many of these teeth were so badly deformed that they could hardly be recognized as human teeth. We do not often see teeth so badly deformed as these are.

ance. Often when a mouth mirror is placed to the lingual of the incisal portion it will appear to be very thin. The tooth is more out of form than appears

whole of it may be of a dark color. The incisal portion, which appears when the lips are slightly opened, may be absolutely black, while the bulk of the crown

toward the gingivæ is large and stubby, and is liable to be more deformed by breakage of the thin portion described but normal in color.

FIG. 23.



This photograph is from a skull found in the anatomical laboratory of the dental department of Creighton University by Dr. E. H. Bruening. All of the teeth of this individual presented the same deformity as those shown in the illustration.

A section prepared from this skull was lost by accident. The scalloping was very regular in that case, and like the scalloping at c in Fig. 22. In this case the teeth presented an irregular wrinkling upon their surfaces, the wrinkles passing horizontally around the teeth. These wrinkled teeth have always a scalloping of the dento-enamel junction.

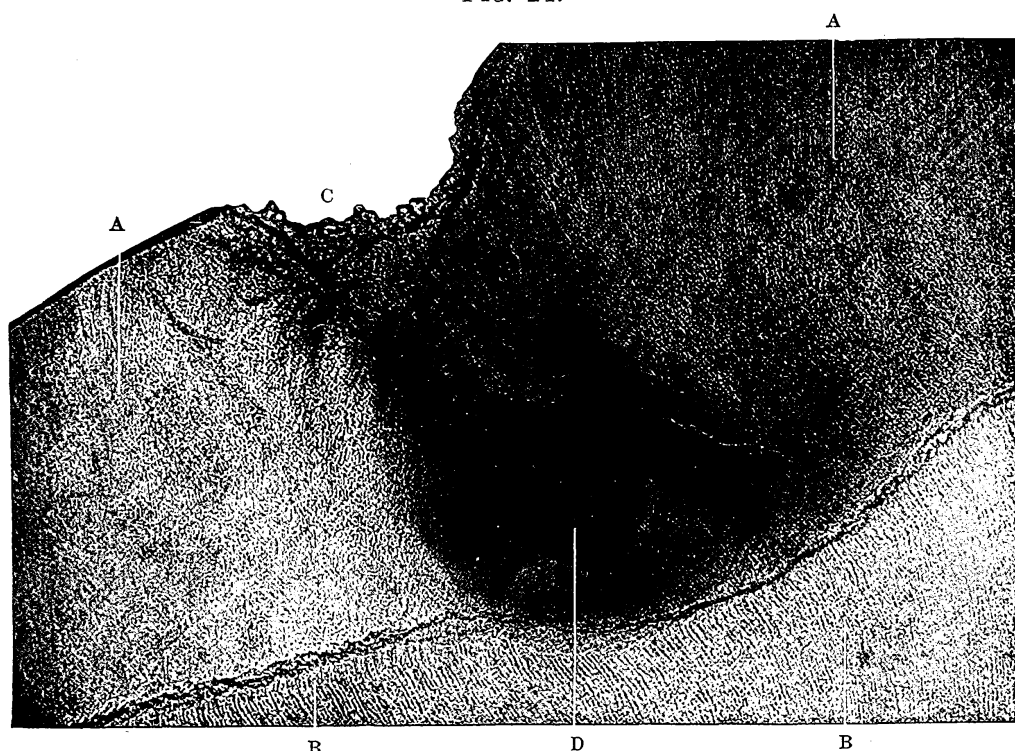
In very bad cases that occur in this scalloping of the dento-enamel junction the teeth go all to pieces. The enamel is lost from them very early. The junction between the enamel and the dentin seems to be almost completely broken up, but in cases that are not so bad, as in the Bruening skull, the scalloping of the enamel is often very regular and the teeth do good service. Singularly enough, very little decay has been observed in these wrinkled teeth.

In form the tooth is often much shortened, and the incisal end is too small above, so the tooth comes to be very much shortened. This shortening of the tooth

is actual, not simply apparent. The line mentioned may have occupied considerable time in forming while the tooth was growing; this particular part of the tooth failed to grow during that time, and the part that should have grown during that time is left out. The two parts—that which grew before the injury and

dystrophies are understood. In the illustration, Fig. 18, I have selected a section from one of the actual deformities in which the injury is slight and the colors are nearest normal of any in my collection. Consequently the marks come out clearer than is usual in microscopic specimens of this class of deformity.

FIG. 24.



An enamel whorl in the enamel near the dento-enamel junction, the surface of the enamel presenting a pit over the whorl. Normal enamel is marked A, A; dentin, B, B; the pit in the surface, C; the whorl, D. It will be observed that there is a heavy deposit of brownin in the deformed enamel, which lies next to the dentin. In fact there is a recurve of the dento-enamel junction to partially accommodate the whorl.

A little different direction in the cutting of the section so that the pit in the surface would be missed, would show only the dark spot in the enamel and the whorl in the direction of the enamel rod, which would appear if the spot was not so black as to interfere with seeing the enamel rods.

the part which grew after the injury—are fitted together in a very awkward manner frequently. The gingival portion, which grew last, is fitted over the incisal portion, which grew first. The incisal portion appears to be sunken into the portion subsequently formed.

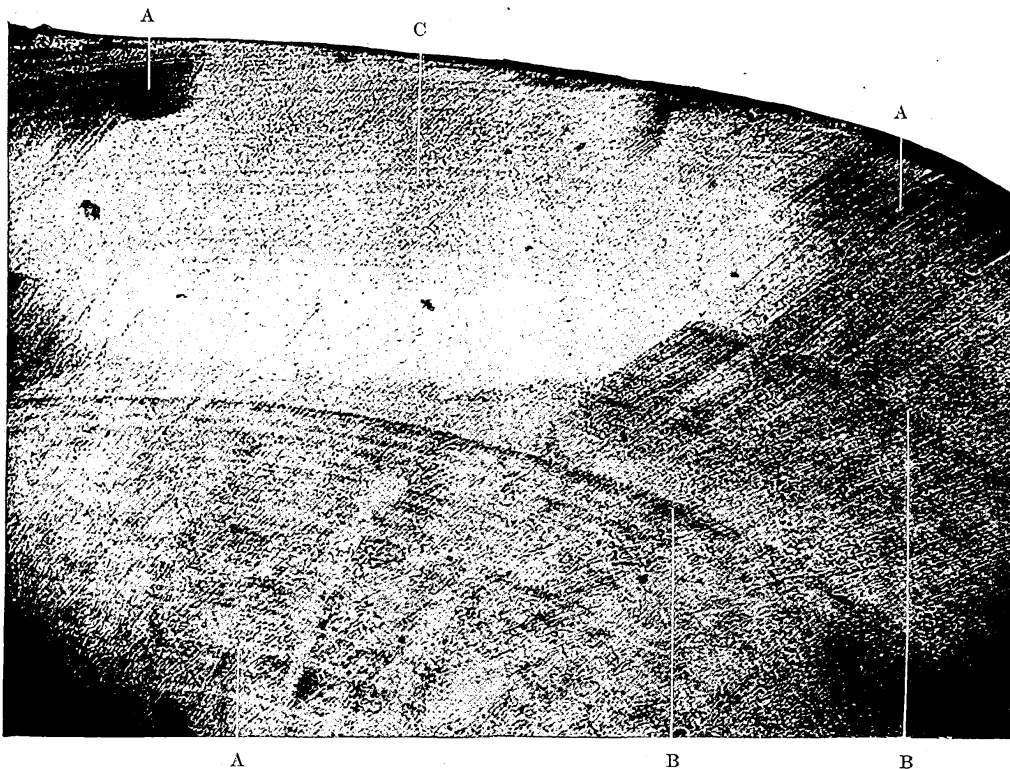
It is very difficult to determine the real nature of the deformity, unless the characteristic features of the various

It will be seen in this that the line, E, is a mark beginning toward the incisal portion of the tooth and entering the enamel, following a slightly curved line obliquely rootwise in the tooth crown, until it meets the dento-enamel junction. Then a mark differing in character, and composed of interglobular spaces, D, is reflected in the dentin toward the incisal edge, but going deeper

and deeper into the dentin in a somewhat curved line. This finally comes to the center of the tooth, where the hard tissue is not yet formed; therefore it skips a little. Beginning on the other side it follows a similar course in the opposite direction until it reaches the dento-enamel junction on the other margin of the section. (Not shown in the

ing of the dento-enamel junction. In each of these scallops there is a disturbance of the direction of the enamel rods. They are thrown into circles and whorls and not infrequently open cavities occur in the tissue. In some the disturbance is so great that a microscopist unfamiliar with the condition would not recognize the tissue as belonging to the teeth. In

FIG. 25.



White spot in the enamel. An area in which the cementing substance, which normally occupies the space between the enamel rods, is missing, although Nasmyth's membrane is intact. Normal enamel is marked A, A, A. Two lines of accretion are marked B, B. The white spot is marked c. It will be noticed that the line of the greatest depth of the spot is parallel with one of the lines of accretion.

illustration.) From this point again it is reflected in the enamel in a direction toward the incisal portion of the tooth, until it comes to the enamel surface.

*Wrinkled teeth, with scalloping of the dento-enamel junction.* (See Figs. 22 and 23.) This class is characterized by a wide disturbance of the usual regular line of the dento-enamel junction, which is often in the form of scallops, circles or half-circles being frequent. In some of these there is a very regular scallop-

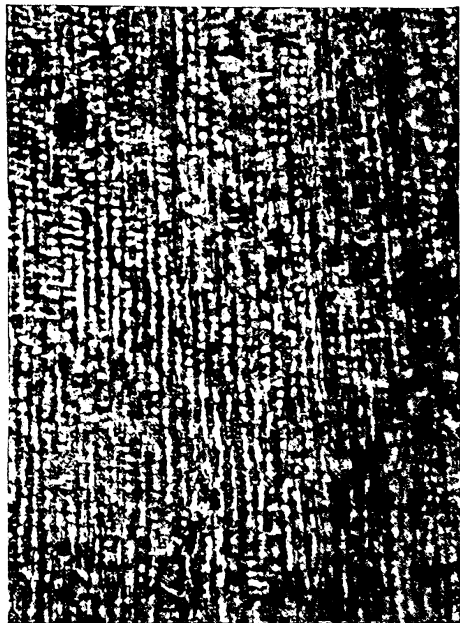
the milder sort there is simply an undulation of the dento-enamel junction, and even in teeth supposed to be perfectly normal there will be an occasional quarter-circle. In some of these cases the teeth were horribly deformed, while in others they might pass unnoticed. The changes upon the surface are usually in the form of wrinkles, passing horizontally around each tooth, the general tooth form being otherwise good. The enamel is the same as other enamel in

most of these, and the teeth seem to do good service. This type of injury does not follow lines of accretion, and, in the cases I have seen, is present in all of the

formities as the incisors, cuspids, and first molars, formed before the fifth year.

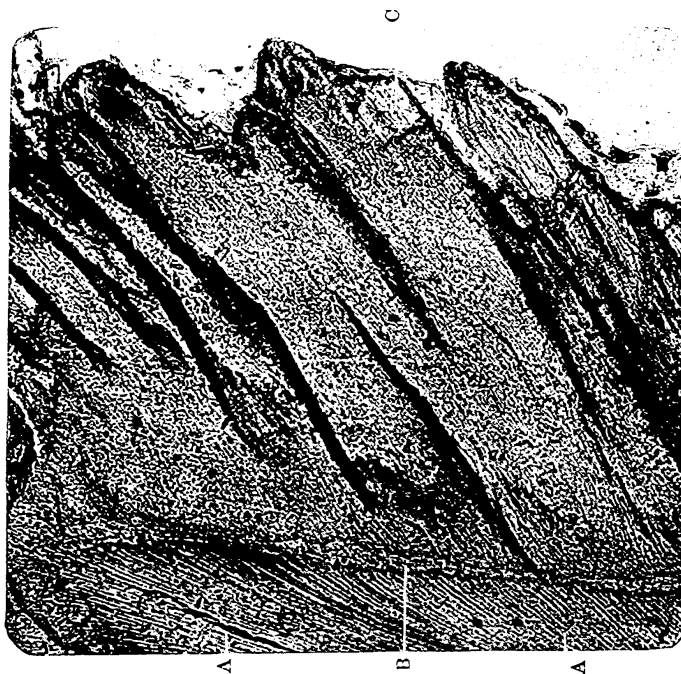
*The enamel whorl.* (See Fig. 24.) The enamel whorl is never seen as such

FIG. 27.



A section of enamel from the same case as Fig. 26. This section was mounted in yellow balsam, which filled the spaces between the rods and photographed dark. The formation of the enamel rods is shown to be perfect.

FIG. 26.



White enamel. A section from one of fourteen teeth extracted by Dr. John Prunty, of Boyd, Texas, and loaned to the author by Dr. D. J. McMillan of Kansas City, with the privilege of making sections. The enamel of all of these teeth was dead paper-white throughout its full thickness and the cementing substance was lacking. These teeth had been carried in the pocket for a number of weeks and were badly cracked because they had dried out. The surface of the enamel had been broken as shown in the illustration. Nasmyth's membrane was entirely lacking and an exploring time could be pressed deeply into the enamel in any position on any tooth. The dentin is marked A, A; the dento-enamel junction, B; the outer surface of the enamel, C. Fig. 27 shows a higher magnification of a section of the enamel of one of these teeth.

teeth of the individual. It is, therefore, not related to a particular time of life. The bicuspid and second molars, formed after the fifth year, present the same de-

by the naked eye, always being within the enamel. A pit upon a surface that is usually smooth may be the only indication of it. Yet when a section is cut

through this little pit in the usual direction of the enamel rods, we find an

every tooth and every part of the enamel of every tooth in the mouth being of the

FIG. 28.

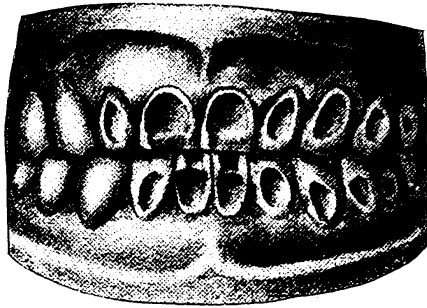


FIG. 29.



FIGS. 28 and 29. Two cases of erosion of the teeth. These are acquired deformities, occurring after the teeth have been normally formed, and should be differentiated from the various dystrophies. There are many other acquired deformities.

abnormality of direction of the enamel rods, and often it is very dark in color. It may be so deep in the normal enamel that this color is not seen, or occasionally it may show through, making a very slight change in the color of the enamel over it. In such cases, the coloring matter—brownin—is deep in the enamel, even touching upon the dento-enamel junction.

*White spots in the enamel.* (See Fig. 25.) One who is accustomed to scanning the teeth closely for abnormalities will occasionally discover small white spots in the enamel which will escape the casual observer; but occasionally these are larger, appearing somewhat prominently as paper-white areas. Microscopic examinations show these to be a form of dystrophy in which the enamel rods are normally formed, but the cementing substance which should occupy the spaces between the rods is missing. In some of the larger of these white spots Nasymth's membrane is absent over the central part, leaving a rough area in which an exploring tine will catch. These spots are not very frequent, and many of them are passed over without observation. They are of little importance.

*Paper-white enamel.* (See Figs. 26 and 27.) I have seen a number of cases in which the teeth of the individual were the color of ordinary dead-white paper,

same color. To know what this means one should hold a piece of dead-white

FIG. 30.



FIG. 31.

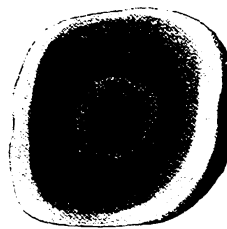


FIG. 32.



FIG. 33.



FIGS. 30, 31, 32, 33. Four illustrations showing abrasion of the teeth. This is an acquired deformity, and an occasional case might be mistaken for a dystrophy.

paper in the hand and turn it about to the light while in conversation with



somebody close by, and note the difference between the color of the paper and of the teeth in the mouth. What we call white teeth have nothing like the whiteness of white paper, but the teeth have that transparency or translucency about them which moderates the color of the teeth, harmonizing them with the countenance of the individual.

In the case described in Fig. 26 this dead-white color showed so prominently as something out of harmony in the individual's countenance that it could not escape the eye. A sharp exploring tine will glide over the surface of a normal tooth, but when tried upon this paper-white enamel will penetrate anywhere upon the surface of any tooth, and when it is removed there is no appearance of the hole where it came out. The surface is made up of enamel rods that are disconnected one from another, and these may be moved readily this way and that, and recover their positions again. Otherwise than this, the teeth are of good form. In these cases caries has not often occurred; indeed, as a matter of fact, I have seen very little caries.

This specimen was cut from one of several teeth that had been out of the mouth for a long time, and the surface of the enamel was broken and rough. In some of the teeth the enamel was practically all gone, and it was difficult to choose a tooth that would represent it. In the illustration it will be observed that there are splits and breaks in the enamel. At one point there is a slight appearance of a membrane, unlike Nasmyth's membrane, probably from the drying of mucus upon the surface.

A matter that should not be overlooked in this is the mental attitude of these persons. I have found it very difficult to obtain a good opportunity to examine these teeth in the mouth, because the persons have been so sensitive to such observation. One of them told me that he had almost completely retired from society because people stared at him as though there was something about his countenance that was uncanny. Otherwise than this, these teeth have always been normal in form, and observed with the lips closed, these people would not attract any especial attention. This class of cases has been very rare.

*Mottled enamel.* This deformity is distinguished especially by the absence of the cementing substance between the enamel rods in the outer fourth, more or less, of the enamel, and presenting great variety of color, rendering it totally different from anything else I have known. In certain areas of our country this is endemic and occurs in many thousands of persons, as mentioned previously in this paper.

*Acquired defects.* (See Figs. 28 to 33.) In order to emphasize the differences between the dystrophies, in which the deformity occurs during the growth of the teeth, and the acquired defects, which occur after the teeth have been formed, I have included a few illustrations of erosion and abrasion. In each instance these defects have occurred to teeth which were of normal form and structure, but which were subsequently injured. In all cases of dystrophy, the deformities occur during development and the teeth erupt in the malformed condition.

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# THE DENTAL COSMOS

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## ORIGINAL COMMUNICATIONS

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### **An Investigation of Mottled Teeth:**

An Endemic Developmental Imperfection of the Enamel of the Teeth,  
Heretofore Unknown in the Literature of Dentistry.

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By FREDERICK S. MCKAY, D.D.S., Colorado Springs, Colorado,

*IN COLLABORATION WITH*

G. V. BLACK, M.D., D.D.S., Sc.D., LL.D.

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( I. )

IT is the purpose of this paper to describe an investigation into the occurrence and prevalence of a lesion of the enamel that, until recently published by Dr. G. V. Black (DENTAL COSMOS, January 1916, vol. lviii, No. 1) has never before been described either accurately or comprehensively.\* The term "mottled enamel" was applied to it by the writer somewhat empirically, but has become probably the accepted designation, having been suggested by the appearance of the teeth.

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\* The histo-pathology of this lesion has been fully dealt with in a companion-paper by Dr. Black (as above noted), and Dr. McKay confines himself in this paper to a description of the clinical and other features and a detailed account of the investigation.

The remarkable thing about the lesion is that it is practically, if not absolutely limited in its distribution, in any large way, to certain well-defined geographical areas, in which it occurs in the teeth of only those individuals who were either actually born and lived continuously in any of these areas during the years of enamel formation; or in those who, although being born elsewhere, were brought into such districts for a continuous residence during the years of enamel formation. These circumstances indicate that we are dealing with a developmental dystrophy, and the term "endemic" is applied because the lesion is peculiar to a district or particular locality or class of persons—natives and those coming to the locality in early childhood.

An endemic disease is one constantly present to a greater or lesser degree in any place, and the investigation of this condition has left no doubt that a high percentage of those persons who conform to the conditions just set forth will exhibit mottled enamel upon the permanent teeth when they erupt. This seems to be a law pretty definitely determined, as will later be shown, as applied to all of such districts as can properly be termed "afflicted," "susceptible," or "endemic."

#### MACROSCOPICAL DESCRIPTION OF MOTTLED ENAMEL AND BROWN STAIN.

Normal enamel is a dense, homogeneous structure, in which the enamel rods are closely bound to each other and in turn into columns by a structureless calcified material, variously termed the "cementing" or "interprismatic" substance.

Mottled enamel is characterized by minute white flecks, or yellow or brown spots or areas, scattered irregularly or streaked over the surface of a tooth, or it may be a condition where the entire tooth surface is of a dead paper-white, like the color of a china dish. In many cases the surface of the tooth is dotted with irregular, shallow pits, which are usually darkly discolored because of the lodgment therein of *débris*. Such are spoken of as the "pitted" variety.

Any, or all, of the teeth may be mottled, or certain groups only, according to circumstances which are discussed elsewhere in this paper, and also in Dr. Black's paper; or the area of some teeth, either above or below a certain point, may be mottled, and the rest of the enamel of such teeth be practically normal.

In some slightly marked cases the white areas are found only on the points of the cusps, the rest of the enamel in these teeth being normal. The teeth present this appearance upon eruption, and the pits are present, when present at all, at this time. Perhaps the most frequent location for the pits is near the points of the cusps on the bicuspid

teeth. Upper and lower teeth seem equally liable to mottling, and upon all surfaces, although as a rule the labial and buccal surfaces have the most pronounced markings. If there is any difference, the upper teeth are most affected.

Mottled enamel, in my experience, has never been found upon the temporary teeth. In examining children in afflicted districts at ages when the permanent incisors and first molars have erupted, but the temporary molars are still in place, the contrast in the enamel on these two varieties of teeth is most pronounced. The white mottled enamel on the permanent teeth exhibits a marked contrast with the normal enamel on the temporary teeth, which has the customary almost bluish tinge. In explanation of this it is to be remembered that the temporary teeth are formed largely before birth, in an environment closely shielded against outside influences, with the nutritive supply dialyzed through placental osmosis.

This mottled condition, in itself, does not seem to increase the susceptibility of the teeth to decay, which is perhaps contrary to what might be expected, because the enamel surface is much more corrugated and rougher than normal enamel. It is recognized, however, by dental practitioners dealing with this sort of enamel, that, caries having occurred, it is difficult at times to find enamel sufficiently dense in which to lay cavity margins.

However, there is an associated phase of this lesion—the "brown stain"—and in this feature we come upon the serious and distressing part of the problem.

It has been pointed out in Dr. Black's paper that the initial or fundamental lesion is the failure of the cementing substance between the enamel rods, and it is the deposit of some sort of brown pigmented substance, termed by Black "brownin," in these otherwise empty spaces that produces the "brown stain." In only approximately 40 per cent. of cases of mottled enamel is any of this substance deposited, but this occurs in all grades of intensity, from the faintest

spots or tinge up to almost an ebony black. It is a most distressing and remarkable fact, also, that the discoloration is almost invariably located in the most conspicuous place—the labial surfaces of the upper incisors and cuspids. Rarely is it found upon the lower front teeth, and still more rarely upon the lingual surfaces of either uppers or lowers.

In its usual manifestation the stain is located upon the incisal half of the surface, and as a rule the central incisors will have the most, the lateral incisors somewhat less, and the cuspids still less and perhaps none at all. On the central incisors the stain may be about the middle of the labial surface; somewhat lower down on the lateral incisors, and just on the points of the cuspids.

It is extremely erratic in its distribution, although in general following the plan just outlined. I can recall distinctly only one case in which the molars were thus marked, this occurring in one of the Arizona districts; but cases have been seen in which the entire denture, including the third molars, was of a dirty, smoky appearance. The bicuspid are not often discolored in any typical way.

The same rule that applies to the freedom of the temporary teeth from mottled enamel, holds good regarding their immunity from the brown stain. Never, to my knowledge, has this been observed in the temporary teeth.

Because of the lack of any previously published description or records of such a condition, dental practitioners in afflicted districts could only theorize in casting about for possible causes; and what was no doubt the first systematic endeavor to investigate this lesion was undertaken by the Colorado Springs Dental Society soon after its organization in 1902. At that time it was generally supposed that a limited area of territory, measured by a comparatively short radius of miles, was the only area afflicted, and as a first step toward defining its limits, a series of letters was addressed to dentists practicing in various portions of the Rocky Mountain

region. The answers received brought very little information of value, and the matter of further investigation was allowed to rest for the next six years.

It is a curious fact that the earlier thought was directed toward, or confined to that phase of the lesion which was spoken of as the brown stain; and this is easily accounted for by its conspicuousness, being located as it is, almost without exception, upon the labial surfaces of the upper incisors. The white spotted or opaque appearance of the enamel of the entire denture seemed hardly to have been noticed, or at least it was rarely spoken of in discussions.

Early in the investigation it was recognized that it was only those persons who were born and reared in afflicted territory, and those who came during infancy or early childhood, who had the lesion, and inasmuch as our western communities were not old enough to have raised many adult natives, the lesion became associated principally with children.

In 1908 the work of investigation was commenced in an organized way, and the first work that seemed necessary was to locate other communities that were similarly afflicted, with the hope of finding some condition common to such localities that might be studied as the possible cause, and gradually to map out, as time went on, the entire area of distribution. This work has been steadily carried on up to the present time, and a detailed account of the examination of the various districts will be given later in the paper.

*Specimens.* One particularly difficult feature of the research has been to obtain specimens for examination, either histological or chemical, because of the lesion being found only in the permanent teeth; and so, in appealing for aid to those having special knowledge along these lines, it has been hard to provide material from which studies could be made.

#### THEORIES AS TO ETIOLOGY.

Some years ago, almost before any data had been collected, correspondence

was opened with Drs. R. R. Andrews, Kirk, and Broomell. Broomell replied that he believed the food supply was the place to look for the cause. In correspondence with Andrews, in 1908, the following opinions were elicited from him:

"If the stain is within the enamel substance it must have formed there while the enamel was forming; that is, some unusual chemical combination may be formed with the lime salts and the blood, and this abnormal substance may cause the stain by being deposited with the lime salts in the ameloblast, where it is elaborated into a pigmented structure. I am free to confess I have never seen just such a condition. If the stain is formed within, the color would be all over the whole surface, I think, and not in a certain location. Any unusual chemical combination must act on all of the forming tissue. There are certain organisms that etch the surface to quite a depth, and then die, and leave their characteristic stain, and if the application of iodine caused a dark dry stain, I should think it was caused by dead organisms."

In later correspondence, after examining a specimen which was sent him, he says:

"It (the stain) was not there when the tooth was forming, but is a stain that *penetrated* [*italics mine*] after the tooth was erupted. This I feel pretty sure of. I have never seen a stain penetrate the enamel so deeply before."

Kirk called attention to the articles of J. Leon Williams on the histology and development of the enamel, which ran through several issues of the Cosmos in 1896, in which it is shown that during the period of calcification the forming enamel lies in close conjunction with the capillary loops, and suggested that a rise in temperature at that period might cause a stasis in these blood-vessels, terminating in rupture with infiltration of the blood into the forming enamel, and thus account for the stain.

The attention of Dr. G. V. Black was directed to this lesion early in 1908 by Drs. G. Y. Wilson and Isaac Burton,

and his sympathetic interest was at once aroused. A statement of the condition was sent him by the writer soon afterward, and his reply was that there must be some error, as it was difficult for him to believe that there could be a dental lesion that would uniformly afflict any large proportion of the natives of any given locality and remain unmentioned in dental literature. Further correspondence resulted in his coming to study the condition in the field, during the summer of 1909.

It will be realized from the illustrations how extremely disfiguring a pronounced case would be to an afflicted individual, and time and again had the practitioners in these afflicted districts been appealed to for relief, only to be forced to confess their utter helplessness in removing these imperfections.

It was with commendable hesitation that the operation of excising the crowns of these disfigured teeth and replacing by porcelain substitutes was resorted to, but in extreme cases this was insisted upon by parents and patients themselves, and in this way some material was finally obtained and sent to Dr. Black for sectioning for histological examination. These studies are fully described by him in his paper recently published. In further preparation for Dr. Black's study, an examination of the public school children in one city was made during the spring of 1909 by Dr. Isaac Burton and the writer, in order that the exact condition might be known.

The method of conducting the examination was as follows: Cards were printed, of which a sample is here shown. These cards were distributed in each schoolroom previous to the examination, to be filled in by the pupils, with the aid of the parents when necessary. They were then returned to the teachers and redistributed to the pupils upon the day of the examination. The examiners went to each child, from desk to desk, and noted the condition of the teeth on the lines "Mottled" and "Stained." The entire school system was gone through—excepting the lowest primary grade, as these children as a rule had

Name ..... Age .....

Address .....

Where born .....

If not born here, at what age did you come here to live? .....

At what other places have you lived? .....

.....

.....

.....

.....

Mottled .....Stained .....

no permanent teeth. Twenty-nine hundred and forty-five children were thus examined in one city.

In this way was established for the first time any definite idea of the prevalence of this lesion among the natives of any community. In the city examined, L—, the percentage of native children afflicted was found to be 87.5.

#### APPEARANCE.

The accompanying series of illustrations has been gathered with the view of conveying, as far as possible, an adequate idea of the various phases which this lesion assumes.

Fig. 1 illustrates a case in which the surface is irregularly speckled or mottled. In this case very little of the brown stain is present, but the enamel is very much mottled and somewhat pitted, as shown on the point of the cuspids. The entire denture is of this character. This person is a native of L—, which community is described later in the paper.

Fig. 2 illustrates a pronounced case of the pitted variety, in which the teeth are of a dirty or smoky color, and the pits are very much darkened. In severe cases these pits often become the seat of caries,

hence are a distinct menace, it having occurred in several pits in this illustration. This case is very badly disfigured. The darkening of the pits somewhat overshadows the brown stain, which is present to some extent, and the enamel is very rough. We see the opaque white appearance of the lower incisors, upon some of which are the brown marks, which is quite unusual upon these surfaces. The enamel of the entire denture is of this character. He is a native of L—.

Fig. 3 shows just the slightest tinge of brown upon the central incisors, the left one having the most. The enamel of all the teeth is white, but the lower incisors are not stained. The pitted appearance of the right first bicuspid is just shown in the photograph. This child is a native of L—.

In Fig. 4 we see the opaque whiteness of the enamel as before described, and upon the prominent mesio-labial surface angles of the central incisors are brown spots. The lateral incisors have just a trace at the mesio-labial corners. Many cases show just such a symmetrical location of the brown spots occurring at the same corresponding places on teeth of the same class. The entire denture is

of this opaque white appearance, and the bicuspid and molars are pitted somewhat. This child is a native of L——.

The location of the brown stain in Fig. 5 is at the extreme labio-incisal

denture is mottled, and the bicuspid and molars are pitted. The child is a native of L——.

Figs. 6, 7, and 8 are typical cases made from ordinary black-and-white negatives. They all show marked symmetry

FIG. 6.

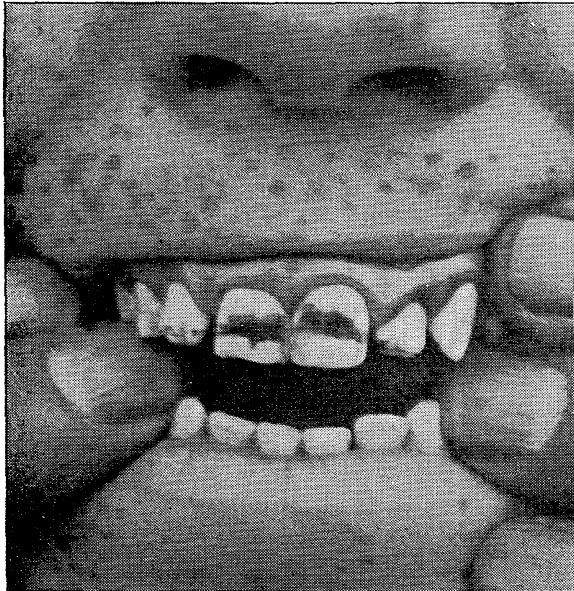


FIG. 7.

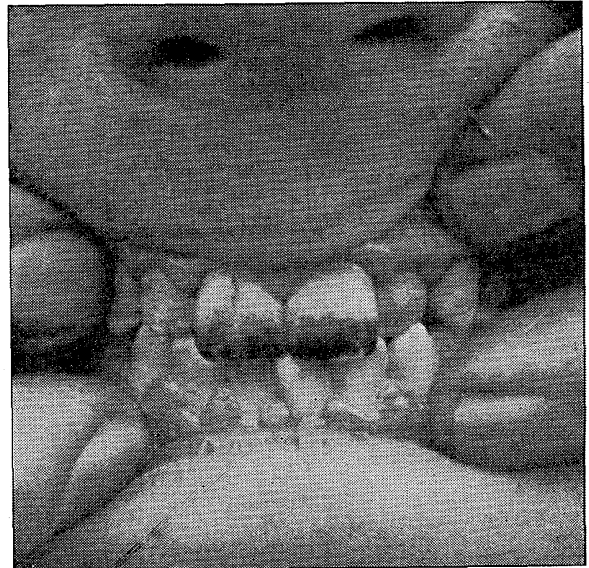
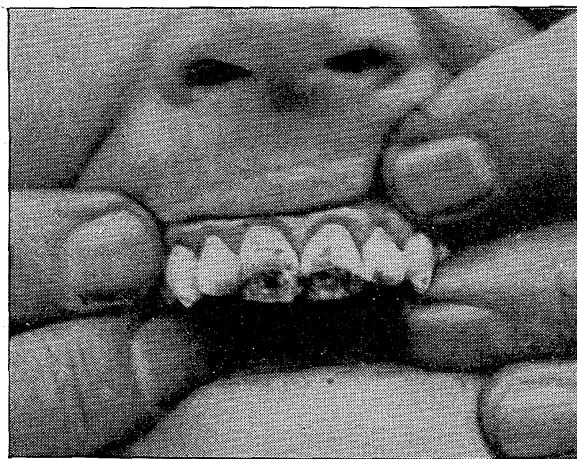


FIG. 8.



edge of the central incisors, and it is most peculiar that it stops just at the incisal edge, and does not extend over on to the lingual surfaces of these teeth. The writer has never seen a case where the stain continued over the incisal edge from the labial surface on to the lingual. The lateral incisors and the lowers are not stained, but the mottled character of the enamel is well shown. The entire

in the distribution of the stain. The children are all natives of L——.

In Fig. 9 we have a more pronounced stain, which is located somewhat symmetrically upon the central incisors. No other teeth are thus marked, but the opaque whiteness of the enamel is noticeable. The entire denture is of this character. The child is a native of L——.

Fig. 10 shows a darker discoloration than any previous case, it being almost black upon the central incisors and symmetrically arranged. The labio-incisal edges of the lateral incisors are also stained. This case is one of those rare ones that show the stain upon the lower incisors. The opaque whiteness of the uppers is well shown, and the mottled appearance of the lowers. A pit is noticed at the point of the left cuspid. The boy is a native of L——.

Fig. 11 is badly pitted and stained, although the lowers show only the mottling. The boy is a native of L——.

Fig. 12 shows a very pronounced case in which the stain occupies almost the whole labial face of the upper central incisors and a part of the lateral incisors. Here also we see a slight stain on some of the lowers. It is curious that when the stain does occur on the lowers, it is never so pronounced as upon the uppers. This girl is a native of L——.

Fig. 13 shows a symmetrical location of the stain on the upper central incisors almost in the form of a band across from mesial to distal. The laterals are also stained, but the lower teeth have escaped. These latter show the mottled appearance, with pitting of the cuspids.

Fig. 14 is a side view of the preceding case, and illustrates the pitted appearance of the teeth. The boy is a native of L——.

During the early part of this investigation the opinion was current that the brown discoloration was present at the time of the eruption of the teeth, but since close observation has been made enough young cases have been watched to lead us to the conclusion that while the teeth erupt in the mottled condition, the brown color does not make its appearance until some considerable period afterward.

It is a fact that in the very large number of partly erupted teeth observed, there is very little distinct recollection of the stain being present upon such teeth.

Fig. 15 shows a case in which I am

positive that the child, who has been under constant observation during the past two years or more for orthodontic treatment, has been subject to a very gradual appearance of the brown discoloration—at this time comparatively faint spots being visible upon the upper central incisors, more upon the left than upon the right. This case can also be used as evidence tending to show that advantages of wealth, as reflected in the care and quality of food, are not factors contributing toward immunity if nativity has occurred in an afflicted district.

All through this investigation it has been a common experience to find a confusion in associating this lesion with the various forms assumed in what have been commonly known as “atrophies” of the teeth. The distinction is sharply drawn between the two by Black in his paper, but an opportunity is afforded by Fig. 16 to illustrate the two lesions in combination in the same individual.

In some thousands of individuals examined, many of whom presented “atrophy” alone, and a multitude, of course, mottled enamel alone, this illustration and the one to follow (Figs. 16 and 17) are two out of a total of four cases that I can recall in which the two lesions are associated.

A peculiarity about these two is that they are twins, a boy and a girl, and I can get no history beyond the fact that they both were exceedingly delicate children and reared with difficulty. A moment's study of these illustrations will be of interest. It will be noted that the “atrophy” marks upon the upper central incisors are pronounced and typical, and that the brown stain is located upon the usual areas of these teeth, in close conjunction with the “atrophied” areas. The “atrophy” marks upon the lower incisors are just as typical, but curiously enough the brown stain is absent, as usual, upon these latter teeth—which seems to signify that these two lesions have an etiology entirely apart and distinct. The mottling of the enamel is also more apparent upon the upper in-



cisors; in fact, the enamel upon the lowers appears quite normal.

Much the same description can be applied to both cases, but Fig. 17 gives an opportunity to contrast the usual location of the brown stain with the ordinary superficial discolorations such as are frequently found near the gingival margins of the incisors. We note again the similarity of the "atrophy" marks on uppers and lowers, but with the absence of the brown stain upon the lowers. The mottled appearance is also pronounced upon the uppers and the lowers as well.

I consider these two illustrations (Figs. 16 and 17) as among the most interesting in my collection.

Fig. 18 serves admirably to illustrate the symmetrical distribution of the stain upon the upper central and lateral incisors. The absence of stain upon the lowers is to be noticed. The case is typical in many ways.

Fig. 19 is extremely interesting, in-

asmuch as the subject is a colored person and the case very typical.

I will call attention to the general mottled condition of the upper and lower teeth, the pitted cusp of the lower first bicuspid on the right side (which condition is present upon other teeth, but not shown in the illustration), and chiefly to the irregular distribution of the stain upon the upper central incisors, and the symmetrical staining of the upper lateral incisors. The lowers are not stained.

This case effectually disposes of the question of nationality in its bearing upon this lesion, and emphasizes that its acquisition disregards nationality, social status, and condition of physical health—in fact, all other circumstances except the one essential, namely, residence in an endemic district during enamel formation.

*(To be continued.)*

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## The Use of the Clasp and Lug as Attachment for Short Bridges and Partial Dentures, and Methods of Making Lugs.

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By F. R. GETZ, D.D.S., New York, N. Y.

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(Read before the union meeting of the Fifth, Sixth, Seventh, and Eighth District Dental Societies of the State of New York, at Syracuse, November 25, 1915.)

THIS paper has to do with a subject in which I am very much interested, namely, the restoration to the arches by artificial means of such teeth as from any cause are missing, and the maintenance of the arches in as nearly a normal functional condition as may be possible.

It is not necessary to emphasize the vast amount of restorations that should and could be made, if all of our patients, and those also who are not regular patients, could be made to understand how important a matter for their general

health and for their comfort and happiness it is to have full arches and a complete and efficient masticating apparatus. They do not know as well as the dentist that an increase of weight, better appetite, and improved health immediately follow in some of the larger restorations. In a percentage of cases, it is not going too far to say that the fullest restoration of the arches as food-preparing organs is necessary for the full recovery of health and vitality that have been impaired by insufficient nutrition due to poorly masticated food.



## **An Investigation of Mottled Teeth :**

**An Endemic Developmental Imperfection of the Enamel of the Teeth,  
Heretofore Unknown in the Literature of Dentistry.**

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By **FREDERICK S. McKAY, D.D.S.,** Colorado Springs, Colorado,

*IN COLLABORATION WITH*

**G. V. BLACK, M.D., D.D.S., Sc.D., LL.D.**

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(Continued from page 484.)

### **( II. )**

**A**LTHOUGH Dr. Black has described carefully the histological characteristics of this dystrophy, it is perhaps well to consider briefly one or two points concerning them.

#### **ETIOLOGY.**

So far as histologists are able to determine, the enamel rods and the cementing substance are both laid down by the same organ, and why this secreting organ should build the one tissue perfectly and fail in the other is declared by Dr. Black to be one of the strangest things in dental pathology. What is the difference between the enamel rods and the cementing substance? Noyes ("Dental Histology and Embryology") answers this as follows:

"While the cementing substance and the substance of the rods are both entirely inorganic, or, more correctly, are composed entirely of mineral salts, they differ in physical and chemical properties as follows:

"(1) The cementing substance is not as strong as the prismatic substance.

"(2) The cementing substance is more readily soluble in dilute acids than the rod substance. The causes of the difference in solubility between enamel rod and cementing substance cannot be

answered. Both rods and cementing substance are normally composed entirely of inorganic salts."

Black's conclusion that the mottling and stain is mostly upon the superficial areas of the teeth has been amply borne out by many observations and experiments made upon living subjects. It is very often noted that on those surfaces of the molars and bicuspsids which receive wear in occlusion the white layer is entirely worn through, and the bluish color of the underlying normal enamel is clearly apparent. It is probably true that this underlying enamel is not entirely homogeneous in structure, although it appears so to the unaided eye.

During the early part of this investigation observations had not been made with sufficient care to determine whether or not the brown stains were upon the teeth when they erupted, and the general opinion was that they were. Since that time, however, this point has been carefully noted, and now there seems to be little question that the discoloration is not present when the teeth erupt, but that it gradually makes its appearance afterward. This opinion has been arrived at by the fact that partly erupted incisors in the mouth of a child say of seven or eight years of age are rarely seen with the stain present. They will

erupt mottled or white, but with no stain.\* The only observations contrary to this were made at V—, a very pronounced endemic district described elsewhere, where partly erupted teeth were in many cases stained. Enough cases have since been recorded to warrant the conclusion that the discoloration, if it appears at all, does so in a very gradual manner, very faint at first and gradually becoming darker. This does not necessarily imply that the permeability of this enamel is thereby proved, although this possibility is not hereby disputed, but it is hard to conceive, for the reason that the outer glazed surface, Nasmyth's membrane, is almost invariably found to be as perfect as that upon normal teeth, and in no sense porous or defective. With photographs now on hand, and to be taken later, of young cases, and these again to be photographed two, three, or four years later, we shall in time have evidence that will positively determine the time of the appearance of the stain.

In reviewing the available literature upon the subject of enamel formation, it is evident in reading the exhaustive series of articles by Dr. J. Leon Williams, running through several issues of the DENTAL COSMOS in 1896, that previous to that time there had been controversies among the various authors dealing with this subject, and I gather that this whole question was fraught with error and misconception; so we are indebted to him for the establishment of a definite and rational basis from which to study the pathology of this tissue. At the conclusion of this series of articles Williams promises that a study by him of "Imperfections in Enamel Structure"

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\* To account for any difference of opinion in the text of this paper and Dr. Black's conclusions relating to the time or period during which brown discoloration makes its appearance, it should be pointed out that Black's observations were limited to the histological examination of certain teeth. It has certainly been most conclusively demonstrated since his studies were made that these teeth erupt white, and do not at that time exhibit the deposit of brownin.

would be forthcoming. If such a paper has ever been published it has not been my good fortune to see it, and in the light of the present research it would be of great value and interest to know if Williams is familiar in any large way with, or has reached any conclusions regarding, such a lesion as the one described.

Black's work on "Operative Dentistry" was written before his attention had been called to the existence of this lesion in any endemic way, and from what he has contributed to this paper the reader can readily agree that had he known of this condition previously, certain chapters of Vol. I, devoted to the pathology of the hard tissues, would have been very much enlarged, as is indicated by what follows. In discussing "white enamel" as illustrated by Dr. Prunty's case from Boyd, Texas, Black uses these words:

"These cases, taken together with the frequent occurrence of white spots, lead me to the supposition that the failure of the cementing substance between the enamel rods is a special form of atrophy or abnormality in formation to which the enamel is liable. The occurrence of this in isolated spots, which are usually of an ashy white color, is not very uncommon, but its occurrence in the whole of the enamel in the teeth of a person is certainly extremely rare. I have seen this in but the two cases mentioned, in the one with abnormal form, in the other with normal form. . . . Nothing seems to be known of the pathology that brings about this condition."

Black's studies of this condition in 1909 had an influence upon Noyes' book, "Dental Histology and Embryology," published soon after, for this author says, in chapter iii: "The most recent work of Dr. Black shows the brown and mottled enamel of certain localities to be found associated with greatly freckled skin."

This influence of Black's work is again noticed when, farther along, Noyes says:

"In certain restricted geographical

areas there seems to be a tendency to imperfections in the formation of the enamel. In these places the teeth of many children present, when they erupt, white or mottled areas. These may be only a few spots on a few teeth, or may involve all of the enamel of all the teeth. In some places a large proportion of all the children born and brought up in the district have teeth more or less disfigured. These mottled teeth seem to be often accompanied by greatly freckled skin. Nothing is now known as to the cause of this condition, or how the enamel organ is affected to produce this result. The study of this enamel has shown that the enamel rods are perfectly formed, but that the cementing substance is entirely absent in the mottled area. When the spots are white, the space between the rods is entirely empty; when they are brown, or a dark color, they are filled more or less with some sort of coloring matter. In many cases there is more or less pigment in these spaces before the teeth erupt, and in some cases they grow darker with age."

One statement occurring in this quotation, that in which there seems to be an attempt to associate the occurrence of this lesion with a freckled skin, requires some attention in passing. Doubtless this association is suggested by the fact that both of these tissues, enamel and skin, are epithelial in origin, but the clinical experience during this investigation does not confirm or support this association.

*Color.* In reading Hopewell-Smith's exhaustive work on the "Histology and Patho-histology of the Teeth," the pigmentation observed in association with hypoplasia, or "atrophy" as commonly called, is carefully described—and therefore is not to be confused with what he describes in another place as "pathological pigmentation"—as follows:

"This, which is a natural condition in the enamel of some of the families of Rodentia, *e.g.* coypu, or certain cetacea, as in the persistently growing incisor (tusk) of the narwhal, is seldom observed in human enamel. It must be

distinguished from the green deposits constantly observed on the labial or buccal surfaces of the teeth of young children, due to the agencies of chromogenic bacteria, which probably primarily affect Nasmyth's membrane. Definition: A brownish discoloration of the enamel of teeth. Etiology: Unknown. The tissue changes most probably have their origin as a congenital defect. Macroscopical appearances: The enamel is bright and polished, but is stained a deep brown color."

While in some slight respects the condition as thus described tallies with our lesion, in giving the histology Hopewell-Smith says that the rods have a "yellowish cementing substance between." This feature stands in direct contrast with the "brown stain," which is deposited in the empty spaces between the enamel rods in which the cementing substance is lacking according to Black.

Pigmentation of the enamel is thus spoken of by J. Leon Williams in his articles on "Formation and Structure of Dental Enamel" (Cosmos, June 1896):

"Pigmentation and granulation of the enamel are not necessarily evidence of imperfect formation. The ultimate structure of all enamel is granular, as I have abundantly demonstrated in this article, and pigmentation is frequently found in the most perfect enamel. At the same time it is true that coarse and deeply colored granulation is characteristic of certain phases of imperfectly formed enamel."

Williams' articles are not on pathology, but yet he leaves us very much in the dark as to whether, in writing the above, he was at that time familiar with such a lesion as is dealt with in this paper. His attention was called to it by the writer during the meeting of the National Dental Association in 1910, but so far as I know, his writings since that time have not dealt with it.

#### RESULTS OF EXAMINATIONS.

The results of the examinations of the towns X—— and Y——, both ad-

jaacent to L——, are included in Black's Tables I and II.

native children are stamped by this defect of the permanent teeth.

TABLE I.  
TABULAR STATEMENT OF THE RESULTS OF AN EXAMINATION FOR MOTTLED AND NORMAL TEETH AMONG  
THE SCHOOL CHILDREN IN L—— AND VICINITY.  
(Prepared by Dr. G. V. BLACK, July 12, 1909.)

CITIES.	Children in schools.	Absent or refused examination.	Deciduous Teeth only.	Persons with permanent teeth.	Native-born.			Born elsewhere in Rocky Mtn. region.			Born in other states.			Totals.
					Mottled.	Normal.	Per cent. mottled.	Mottled.	Normal.	Per cent. mottled.	Mottled.	Normal.	Per cent. mottled.	
"L."	3,254	131	126	2,945	811	116	87.5	231	162	57.2	410	1,215	25.2	2,945
"Y."	135	0	17	118	29	3	90.6	17	8	68.0	9	52	14.7	118
"X."	178	1	1	176	71	4	94.6	14	9	39.1	14	64	17.9	176
	3,567	132	144	3,239	911	123	88.1	262	179	59.4	433	1,331	24.5	3,239

Of cases with teeth mottled, 40 per cent., or 642 children, have brown stains also. The deciduous teeth examined (132 children) were found normal.

Note: First, there is a statement of the number of children in the schools in which examinations have been made. Second, those examined are divided into three classes—Native-born; born elsewhere in the Rocky Mountain region; born in another state. In case of the latter two classes, the age at which they became residents here is given in Table II. The examination is not yet complete. [G. V. B.]

To fully understand the astounding facts thereby disclosed, it is necessary to examine these tables in detail. The rule therein established is that in endemic areas a very high percentage of

The percentage of defects in those born elsewhere is very much lower, diminishing to zero. In the afflicted persons born elsewhere it is usually found that many had come from other known en-

demio localities, perhaps not far away from the community being examined, and that the afflicted cases born in *non-*

In discussing the three cities named, L—, \* X—, and Y—, the physiography needs some description.

TABLE II.

DETAILED STATEMENT OF RESULTS OF EXAMINATION FOR MOTTLED AND NORMAL TEETH AMONG THE SCHOOL CHILDREN WHO BECAME RESIDENTS AFTER BIRTH ELSEWHERE.

(Prepared by Dr. G. V. BLACK, July 12, 1909.)

		Incisors, cuspids, and first molars.																			Bicuspsids and second molars.										Third molars.					Out of danger.					Age not noted.																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																									
"L."	Years .	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																														</

endemic districts almost invariably are found to have come during infancy or early childhood into the endemic district where found.

All are on the same watershed and on the same watercourse, namely, Foun-

\* The city of L—, whenever mentioned, carries the idea of high susceptibility.

tain Creek, which rises in the front range of the Rocky Mountains and flows in a southerly direction, out on to the plains to join the Arkansas. L—— and Y—— are located out on the plains from six to eight miles from the base of the mountains, while X—— is in a defile, just at the point where this creek emerges by two branches from the mountains.

The population of this valley is sparse, and with the exception of Y——, only small hamlets are to be found until it reaches the Arkansas River.

The schoolhouses along this valley were examined and some very curious facts gathered, which I will describe in some detail.

#### *Examination of the School at C——.*

Five pupils were present, giving the following data:

No. 1. Born in New Hampshire; came to L—— at the age of four; bicuspid and second molars mottled; enamel on the other teeth normal; third molars not erupted.

Enamel development in this case was evidently rapid, as the incisors were not injured by residence established in L—— at the age of four, while the bicuspid and the second molars, being then forming, exhibited the lesion. New Hampshire is understood to be immune territory.

No. 2. In the same family, born in New Hampshire; came to L—— at age of one year, returned East at the age of seven; returned to C—— at the age of seven and one-half. All teeth were mottled except the first permanent molars. All incisors were stained, *including lowers*.

This is a very interesting case. Born in immune territory, he came into afflicted territory (L——) at one year of age, or, in other words, just at the time that enamel development of the incisors was beginning, and the result was the typical lesion when these teeth erupted. The damage was already done when the trip East was made at seven, and the stay was so short—about six months—

that no inhibition of the lesion was possible. The first permanent molars were normal, which means that their enamel was completed previous to the age of one year. This is one of the very rare cases in which the brown stain appears also on the lower incisors.

No. 3. Born at L——; remained until age of nine; came to C——. Mottling general; stain on upper central incisors. This case is one strictly chargeable to L——, as residence was continuous there during the years of enamel formation.

No. 4. Born at L——; came to C—— at the age of six. Mottling general. Stain on upper centrals. This case is exactly similar to No. 3.

These cases illustrate the extreme care necessary in obtaining accurate early histories, particularly the ages at which and the localities to which migrations have been made. It was the experience of the examiners time and again that children would be found in certain localities, exhibiting the typical lesions, whose records showed that the damage had been done elsewhere and usually in areas of known endemicism, and that the localities in which these children happened to be living when examined were in no way responsible for the presence of these lesions. Thus the records made at C—— show nothing that would determine its susceptibility, for the reason that no native children were found there.

For those of our readers to whom the idea of an enamel lesion which follows definite geographical areas as strictly as does this one is new, I direct attention next to the

#### *Examination of School Children at T——.*

This school also had but a few pupils, twenty in all. The typical mottled and stained enamel was found in eight children, each one of whom was born and reared in this locality. Here, then, is a district, of small population to be sure, that exhibits an endemic percentage of 100 in its native children. Three of the

remaining twelve normal cases were eliminated, having no permanent teeth, and the other nine give the following histories:

Three came to T—— from other states. Three others were native to T——, but were taken away into non-endemic territory after the ages of two and four, and did not return to T—— until enamel growth was completed. One other child did not come to T—— till eight years of age. One came from known immune territory at the age of seven.

The last one of the twelve normal cases was migratory in known immune territory during the early years.

Here again it seems absolutely certain that acquisition of these lesions requires that the years of enamel formation be spent in some endemic district.

The idea has sometimes been advanced that removal from afflicted into immune territory would cause the lesions, particularly the brown stain, to disappear. No reliable evidence of this sort has ever come to the writer, to whom, on the contrary, such a phenomenon is unthinkable, and there is considerable evidence available to disprove it. One instance will suffice: Just recently a traveling salesman was interviewing the writer, and it was noticed in conversation that his teeth seemed to show the typical brown stain. He was an adult of at least thirty-five years, and on questioning him I found, much to my surprise, that he was born and reared in the very town, T——, just described. He had been traveling over a large part of the United States for several years, and it seemed to me that ample opportunity had thereby been afforded for the stain to disappear, if such a thing were possible.

When our examination had reached this point it was realized that the data of greatest value was to be obtained from the native children of a community, and these alone were selected in the next place, which was W——, a city of considerable size.

#### *Examination of Children at W——.*

Five different schools were gone into, and the seventh and eighth grades se-

lected in order that temporary teeth might be eliminated. Of native children 125 were seen, and the lesions were found in 23. At once it is seen that a susceptibility attacking 100 per cent. of native children at T——, just described, which is but 15 miles from W——, has dropped to 18+ per cent. We have been coming down through the Fountain Valley, starting at X—— with 94.6 per cent.; then L—— with 87.5 per cent.; Y—— with 90.6 per cent.; then T—— with 100 per cent., and now, somewhere in the last fifteen miles, we cross the mysterious dividing line and find ourselves in a community in which the problem becomes almost negligible.

The only physical difference discernible in this short strip of fifteen miles is that the Arkansas River has been crossed when the drop to 18 per cent. is encountered.

A special class of 44 children was brought to the examiners, and 26 who were natives were separated. Three of these were afflicted. The remaining 18 of the 44—non-natives—were all afflicted in some degree, but had acquired the damage in various other localities, mostly in the state, some of which were later found to be susceptible territory.

It has been in this way, by finding children in a given community who had been stamped, I might say, by this lesion in some other community in which they had spent their infancy, that the boundaries of the endemic area have gradually widened. Our attention has been called to several badly afflicted districts by observing their products in other places. As fast as these new suspected districts came to our attention, examinations of them were made as soon as possible.

Fountain Creek is joined at L—— by a tributary named Monument Creek, which comes from the north and drains the southwesterly slope of a timbered spur of the front range that extends out on to the eastern plains. This spur is spoken of as the Divide, separating, as it does, the Arkansas watershed from that of the South Platte. No communities of any size occur up Monument Creek until the town of R—— is



reached, and as a contrast to what was found in the lower end of the valley, attention is directed to the data obtained by the examination at R——.

#### *Examination of R——.*

Thirty children were present. Twelve of these were natives, and only two of these exhibited lesions. Later another adult, age twenty-nine, was observed, who had lived in R—— since the age of two weeks, and no lesions were present. Here again is a lowering of the percentage to a negligible quantity, and although a small community, what a contrast with the still smaller village of T——!

The altitude has been increasing as the valley is ascended, and R—— is about 6800 feet above sea level. Four miles farther up, and just at the top of the Divide, at 7200 feet altitude, is another village, S——.

#### *Examination of S——.*

Only ten children were in this school, and eight of these were natives. All native children who were old enough to have the permanent teeth were afflicted.

In four miles, here, we pass from a community which is almost immune to one in which the susceptibility becomes high. What can be the difference in these two places? So far as the physical location is concerned, S—— is situated just as close to the base of the mountains as it is possible to build a town, and like X——, before spoken of, just at the point where a creek comes out of the mountains. R——, however, is on the opposite side of the creek, and on the slope from the creek up toward the timbered Divide. In the case of S—— the drainage or water supply is in relation with the mountain range, but that of R—— is in relation with the Divide; two separate watersheds, in fact.

Finding R—— so nearly immune held out the suspicion that some interesting data could be secured by going carefully over the whole Divide territory, and the beginning was made at the

hamlet I——, thirty miles out on the eastern plains. Unfortunately many of these little places had only a handful of children in the schools, but the data obtained is nevertheless valuable.

#### *Examination of I—— and the Divide.*

There were in the school only fifteen children, nine of whom were natives. The others were from the surrounding country or had come to I—— when young. No trace of this lesion was to be found in this community, and the examiner felt some satisfaction in locating here, for the first time, a boundary of the local endemic area.

The examination of the rest of the Divide country was much more difficult, as the schools were closed on the day the examining trip was made, so the main road was followed for twenty-five miles from I—— to R——, and as the different ranches came into sight, or families were heard of who lived on the side roads, a house-to-house canvass was made, particularly in search of persons native to that territory. It probably needs to be said that native persons in some of this western country are not numerous, as many of the people have emigrated from other states. However, in our day's search we found eleven natives, none of whom showed the enamel lesions.

An interesting incident was the finding of several children at a ranch some miles off the main road, who showed very typical lesions. Inquiry, however, brought out the fact that they had all been born in, hence had acquired the lesion in, L——, with the susceptibility of which we are familiar.

#### *Cummings' Ranch.*

Another bit of valuable evidence was obtained at the ranch of John Cummings, which was visited in the course of the day's search. On this ranch were found several children who were born and raised there, and the mother herself had maintained a continuous residence there since the age of two years. She

was a woman not far from forty at the time of the examination. No trace of this lesion was to be found in any of this family.

The water supply was from a well in the yard, and a sample of the water was taken for analysis, which showed the following:

*Analysis of Cummings' ranch water.*

Ions.	Pts. per million.
Sodium (Na),	4.92
Potassium (K),	2.67
Calcium (Ca),	10.50
Magnesium (Mg),	2.34
Iron (Fe),	1.04
Aluminum (Al),	2.32
Chlorin (Cl),	2.40
Sulfuric acid ion (SO <sub>4</sub> ),	4.85
Carbonic " " (CO <sub>3</sub> ),	52.86
Silicic " " (SiO <sub>3</sub> ),	
Organic matter,	
Total solids,	83.90

This work established the fact that in some way the entire Divide was different from the country lying in the Fountain Valley to the south, and that it must be considered a region of total immunity.

THE "WATER SUPPLY" HYPOTHESIS IN THE ETIOLOGY.

Before continuing the account of examinations of additional territory it seems wise to digress, and take up next a consideration of the prevailing theory as to the cause of this lesion, namely, the question of water.

Even from the very beginning of the notice taken of this lesion and before any definite steps were taken to study it, the sentiment of both the profession and the laity in the areas of susceptibility was that the water was in some way responsible. Indeed, it was hardly possible to mention this condition without at once encountering a question, and often a dogmatic assertion, indicating the water as the cause. Hence it has been found necessary to examine the water conditions as thoroughly as has been possible under the circumstances, as will later be shown.

Dr. Black, who has been in close touch with the investigation, has urged again and again that this water relation be followed to its very source, so far as possible, in order to eliminate it.

In order to establish a basis for comparative studies, a description is given of the water supply of L——, which is an area of high endemic percentage. This community is situated on the plains near the base of the mountains, at an altitude of about 6000 feet, and boasts one of the finest supplies of pure water that can be imagined. The water has its origin in the melting snows of the mountain range, where it is collected in a chain of lakes at an altitude of about 11,000 feet. With such a source, and in such a locality, the liability of pollution is almost negligible. From here it is conveyed to the city below, and distributed in the usual way. As it flows from the pipes it is absolutely clear and cold the year round.

*Analysis of water at L——. (Fuller.)*

Ions.	Pts. per million.
Sodium (Na).	} 3.20
Potassium (K),	
Calcium (Ca),	5.70
Magnesium (Mg),	1.70
Iron (Fe),	} .49
Aluminum (Al),	
Chlorin (Cl),	7.29
Sulfuric acid ion (SO <sub>4</sub> ),	7.10
Carbonic " " (CO <sub>3</sub> ),	15.30
Silicic " " (SiO <sub>4</sub> ),	7.50
Organic matter,	9.50
Total solids,	57.78

Two other towns of an endemic percentage of about 90 derive their water from this same shed, on its north slope, while clustered about its base along the northwest side is a chain of hamlets, to be later described, whose percentage is equally high.

Coming around to the southwest side we find a group of metalliferous mining towns, grouped into a district through which the lesion is known to occur in high percentage, although never definitely examined, and one of these towns is an actual "tenant" water consumer from the system just described, owned

by L——. The entire inhabited portion of this watershed is almost a solid endemic area.

If the water is suspected as being the cause, is it because of the presence or lack of some ingredient? Many had argued that the deficiency in the enamel was because of the lack of sufficient lime for the needs of calcification, and a glance at the analysis shows that about 58 solid parts per million indeed denotes a water of extreme purity, and also that 5.70 parts of calcium is an extremely low content.

Lest the reader is tempted at this point to jump at a conclusion, I would counsel that judgment be suspended until other data, to be brought out later in the paper, has appeared.

Another fact that ought to be brought out is in relation to areas in which mineral springs occur. One of the communities at the base of this watershed is very plentifully supplied with various kind of such springs, and the lesion has a percentage there of over 90. No other community in this group has more than a trace, and most of them not even that, of mineral water in the ordinary sense—and their endemic percentage runs just as high. Also there are many other parts of the state in which the waters are highly "mineralized," and no lesions have ever been reported from any of these places.

To follow this matter a little farther in a comparative way, we will contrast the water at L——, drawn from the snows of the range, with that at Y——. This latter place is out on the plains about fifteen miles south of L—— and about the same distance from the base of the mountains. The water here is from a totally different source, being pumped by windmills from individual wells, which certainly can have but the remotest relation to the other water supply situated at timber line—11,000 feet. And yet the endemic percentage here is still higher (90.6) than at L—— (87.5).

We therefore leave this question of the water for the present—to take it up later in considerable detail—and

finish the examinations of school children in the remaining towns grouped around this same watershed.

We have been down the length of Fountain Creek and up its northern tributary, the Monument. We will now follow the main stream up through the famous old trail used by the Utes in times past, to its source among the higher peaks, commencing the examination again at the upper end of the pass or valley.

#### *Examination of B——.*

The upper end of this valley or pass ends at a village, B——, located on the summit of a divide which separates two watersheds, at an altitude of 9200 feet. Thirty-four children were in this school, only ten of whom could be classed as natives, and of these eight showed the lesions. Thirteen others were similarly afflicted, but had been migratory in other known susceptible territory. The endemic percentage, then, of the natives of this town is 80.

#### *Examination of J——.*

The next community down this valley is J——, and here were thirty-one children. Out of the eighteen natives only one had escaped the lesion. Only five children in this school exhibited normal enamel, and excluding the one native who had in some unexplained manner escaped injury, the others were from distant places. The endemic percentage here is close to 100.

#### *Examination of M——.*

A few miles below is M——, and of the ten children in the school every one was a native and every one had the typical lesion. Here is an actual endemic percentage of 100.

The towns just described lie in a narrow defile in the midst of rugged mountains, which are well timbered in contrast to the places previously described, which lie out on the barren, treeless plains.

To review briefly, we find that from its source in the mountains to its confluence with the Arkansas River, this creek valley along its entire length of about seventy-five miles presents an unbroken endemic affliction of high percentage.

Before leaving this region another examination, which brought to light what must be considered as almost a fundamental law, must be recorded. Many times the question had arisen as to whether the children from homes of wealth were afflicted to the same degree as those having fewer advantages. The idea presumably was related to the difference in the food supply of the two classes of children. To obtain data on this point, a private school was examined, whose pupils were drawn from wealthier homes, in a city of high affliction.

#### *Examination of San L—— School.*

In this school were twenty-six natives. Twenty-three of these presented the lesion, and of the remaining three it is of interest to note that one left the city at the age of five and returns each winter; another has left the city every summer, and the other has spent a part of each year in Minnesota.

The non-natives numbered twenty-three, of whom twenty-one had normal enamel, and the remaining two had slight mottling of the enamel, but these two came into the territory at the ages of four and five respectively.

A new fact is hereby established, namely, that removal from afflicted to immune areas for a portion of each year during enamel formation exercises in some way an inhibitive action upon the lesion. This fact was not at that time fully appreciated, but since that time this observation has been made over and over again in so many cases that the relation of these factors is undisputed. The exact reverse of this proposition can be shown in the case of a boy, now about fifteen, who has been a regular visitor to a certain afflicted locality, spending three to four months of each year there since early childhood, and his

upper incisors show a trace of the mottling. This but emphasizes the rapidity with which this peculiar influence attacks any forming enamel with which it may be brought into contact.

In describing in detail thus far the examinations and findings in these various communities, it is intended to give the reader a fairly comprehensive idea of the occurrence of these lesions, this being the most extensive endemic area known or studied up to that time. The descriptions of other areas which are to follow will omit detail, except in so far as may be necessary to bring out points of particular interest or of value in reaching conclusions.

One of the most astonishing phases of this problem is the way in which the lesion distributes itself in sharply defined areas. From the standpoint of the examiners of these various places, perhaps the most baffling experience is to be found in one of the larger cities of the region, and here the lesion shows decided preference for one particular section of this city, if indeed it cannot be said to be limited almost exclusively to that section.

This city is divided into two main sections by a river. The principal part of the city is on the east, and so far as I am aware this section is practically immune. Of many cases investigated, and records made, invariably it is found that cases observed in this city have had their origin on the west side of the river. How to account for this is a mystery. The water supply of both sections is identical and has its origin in various mountain streams which are impounded in a large lake in the mountains by means of a magnificent dam, some forty to fifty miles from the city.

The fact that some individual cases that have been investigated give a history of having used well-water during infancy makes a suspicious circumstance that needs to be recorded. The endemic percentage of this section of the city, however, is low—about 18 per cent., as shown by an examination of one of the large grade schools.

As bearing upon the susceptibility of the west side of this city, the curious history of the ten children of the M—— family will bear recital. Mary, the eldest, was born in another part of the city, and came to live at the present location—in the west side—at the age of three years. Her teeth are *slightly* marked. Tom, the next child, was one and one-half years of age when he came to the present homestead. His teeth are *typically* marked. Catherine, the third child, was three weeks old when the family came to the present home. Her teeth are very typically marked.

Margaret and James, the next two children, were born at the present location, one and one-half years and four years respectively after the family moved there. Both are slightly marked. The last five children, commencing with Joseph, who was born about seven years after the family came to the present location, have escaped the lesion.

It is evident that some influence was present at that locality when the family first came there which resulted in the occurrence of the lesion in the older children, and that this influence later disappeared, as is evident by the normal enamel of the younger children.

The only fact that could be learned was that the family depended upon a shallow well for its water supply in the early days prior to the advent of the city water, which was put in some years later. This circumstance tallies closely with the conditions found during the examination of H—— (see next page).

#### *Examination of F——.*

The necessity for great care in getting accurate histories of the early years when examining children was nowhere more strikingly shown than in this community, for the occurrence of the lesion in a given locality does not necessarily mark that locality as susceptible territory unless it can be shown that the lesions were acquired there.

It had been stated that the trouble was seen frequently in F—— children,

but the examinations showed that comparatively few had acquired it there—less than 7 per cent. The largest number were children who had spent the years during enamel growth elsewhere, most of them in known susceptible territory, and had come to F—— after the damage had been done.

F—— is an agricultural district, and many of the children had come with their parents from a mining district that is known to be highly afflicted, taking up small agricultural plots after the decadence of the metal-mining industry.

The real facts in connection with this community did not tally with reports previously heard. Many of the cases found at F—— had been born and reared on ranches scattered about in a radius of ten to twelve miles, but particularly in the strip of territory lying between this town and the base of the mountain range to the west. This draws attention again to the possible influence of well-water.

#### *Examination of Q——.*

In an attendance of 286 children, 119 natives were found, 20 of whom had the lesion. One curious case was a child who had lived in a nearby rural community until five years of age, and was the only one in a family of nine who was afflicted, and all had used the same water—at least this was the child's statement.

The endemic percentage of Q—— was 16+. By far the most valuable evidence found there was in the case of Mary Lawson, who presented a typical illustration of the lesion. Her home was on a ranch about three miles east of the town, and with several other children in the family she had been born and raised on this ranch, and they all had typical cases. Dr. Charles A. Monroe and myself visited this ranch, talked with the mother, and took a sample of the water from the well in the yard, which had been the sole source of supply for domestic use. The analysis of this water follows:

*Analysis of water from Lawson's well.*  
(Eckley.)

Ions.	Pts. per million.
Sodium (Na),	207.80
Potassium (K),	3.35
Calcium (Ca),	31.80
Magnesium (Mg),	37.75
Iron (Fe),	
Aluminum (Al),	
Chlorin (Cl),	31.00
Sulfuric acid ion (SO <sub>4</sub> ),	142.40
Carbonic " " (CO <sub>3</sub> ),	615.00
Silicic " " (SiO <sub>4</sub> ),	21.65
Organic matter,	
Total solids,	1,090.75

*Examination of School District No. 61.*

Another nearby town was to be visited that day, and we found this schoolhouse at a turn in the road. This was a one-room school, well filled with children from the nearby ranches, and we observed that over 80 per cent. of the native children in this district were typically afflicted, and had been born and reared on ranches on which their water supply was drawn from shallow wells.

We found also several children in the next town toward which we were then going, who were born and had spent their early years on ranches in No. 61 district, but later had moved into town, who showed typical cases. The Lawson ranch is really located in this No. 61 district, which must, according to the foregoing, be considered a highly susceptible area.

*Examination of H—.*

The present generation, as indicated by the children found in the school, was practically immune or unafflicted with this lesion. A totally different story, however, was told by the examination of several adult natives who were found on the streets and in various stores with the aid of the local dentist, Dr. Miller. Assistance was also rendered by Dr. Monroe. Some of the individuals presented the most pronounced cases of this lesion, particularly the brown discoloration, that we have ever seen. The instance of the Scholes family is notable.

The father and mother were past middle life and had come to H— to live in the early days. The enamel on their teeth was normal. The children, with the exception of a boy about twelve, were all grown to adult life, and were found employed in stores about the town. These older children had extreme cases, but the boy was only slightly marked. The family was still living in the house where the children were born, and had used water from a well in the yard until the past few years, when city water was put in. A sample of this water showed the following:

*Analysis of water from Scholes' well.*  
(Eckley.)

Ions.	Pts. per million.
Sodium (Na),	242.70
Potassium (K),	6.44
Calcium (Ca),	33.31
Magnesium (Mg),	33.60
Iron (Fe),	
Aluminum (Al),	3.35
Chlorin (Cl),	51.00
Sulfuric acid ion (SO <sub>4</sub> ),	250.00
Carbonic " " (CO <sub>3</sub> ),	530.00
Silicic " " (SiO <sub>4</sub> ),	18.12
Organic matter,	
Total solids,	1,168.52

Invariably these native adult cases gave a history of having used well-water exclusively during early life. In the earlier years there was of course no other source of water, but some twelve or fifteen years ago a city water system was built, using the water from a mountain stream which rises in the melting snows of the main mountain range some miles away. If this factor can be held responsible for the immunity of the present generation, how shall we explain conditions at L—, for instance, where water of the same or perhaps greater purity, and likewise drawn from melting snow high in the range, has always been used, and yet its endemic percentage is almost 90? Reservation of judgment is again counseled, as facts still more startling are to be shown later.

Another neighboring town, while not examined, also furnished rumors indicating its possible endemicism.

Another factor that may be found to have some bearing upon this problem is that the area just described is heavily underlaid with coal. In fact, several large coal mines are operating in this district, and the coal is found in association with shale. The surface of this district would be described as barren, and the soil is adobe or clay.

For a long time it had been the desire of the examiners to investigate other parts of the Rocky Mountain region, and attention had been directed to certain towns in the southern region and in one of the large intermountain valleys. Several of these places were examined in January 1912, in the following order:

#### *Examination of U——.*

The number examined was 338. Of these, 140 were natives and the lesion was found in 24. The endemic percentage is 17+. Many of these afflicted children gave histories of having spent their infancy on ranches in the surrounding country in contact with well and cistern water, which of course would lower the percentage of affliction of the city proper. Assistance was rendered by Drs. Marquardt and King.

Following this an examination was made for the first time in another state, when P—— was reached the next day. This was important not because the invisible state boundary line was crossed, but because this city is located on another watershed.

#### *Examination of P——.*

This city is in New Mexico, and no reports had ever been received regarding it. There were 432 children examined, and but 7 cases were found, all of which, with the exception of 3 very slight cases, were chargeable to other territory. This city has a number of coal mines in operation, and receives its water supply from the nearby mountains. Assistance was rendered by Dr. Engledow.

Children were observed here from

various parts of the state, and it was a surprise not to find more of the lesion, as the topography is very similar to some of the worst endemic territory previously and yet to be described.

#### *Examination of Z——.*

Returning again the next day to the other side of the watershed, it was an added surprise to find this city immune, particularly so because it was known that an endemic area lay in close proximity, and that coal-mining is extensively carried on. Of 238 children examined, 6 cases were found. None of these were natives, but all came from known endemic territory. It was stated that the coal mined here occurred in sandstone formation, in contrast with Q—— and H——, previously described, in which the coal occurs in shale. The water used at Z—— comes from the mountains.

The next community, N——, was one to which attention had been called in this connection many times, and it was with a feeling of great interest that it was approached by the examiner.

#### *Examination of N——.*

The number examined was 322. There were 58 cases of the lesion, 45 of whom were natives. The other 13 had been migratory in known susceptible territory.

During the forenoon's search in the schools, there came to notice several of the most pronounced cases of the brown stain phase of this lesion that I had ever seen, and inquiry invariably brought the reply that these cases had been born and had spent their childhood at a little coal-mining camp named V——, which was only two miles distant.

#### *Examination of V——.*

This place was examined during the afternoon, and there was revealed the most startling condition of affairs that had been realized during the investigation up to that time. There were 110



children in the school, and in this number were found 58 of the worst cases I have ever seen. Of these, 49 were born right there, being children of the coal-miners employed in the mine. This was the only industry of the place. In all, there were found, out of 79 native children, only 2 who had escaped this lesion in its most severe manifestation. This is perilously close to 100 per cent. All the cases associated with V—— were extreme. The color of the teeth was almost invariably dark and smoky, almost black in many cases, and the enamel so imperfect that the destruction of the labial surfaces of many of the incisors by caries had occurred. The hygienic conditions of these mouths was extremely bad. Also it was noted that partially erupted incisors in young children were badly stained, a condition which had heretofore not been observed.

The location of V——, in a barren basin on the prairie, devoid of vegetation, adjacent to the foothills, seems to exclude all other factors that might bear a causative relation except the water, or at least it seemed to fasten upon the water the chief suspicion, inasmuch as no home production of the food supply seemed possible. Investigating the water it was found that the sole source of domestic supply was from the mine, being pumped from there to a tank on the hillside and distributed through pipes. This water, as observed casually, was clear and cold, but had a pronounced smell of sulfur. Its analysis follows:

*Analysis of mine water at V——. (Cambier.)*

Ions.	Pts. per million.
Sodium (Na),	276.77
Potassium (K),	
Calcium (Ca),	89.75
Magnesium (Mg),	27.36
Iron (Fe),	nil
Aluminum (Al),	2.74
Chlorin (Cl),	47.37
Sulfuric acid ion (SO <sub>4</sub> ),	651.49
Carbonic " " (CO <sub>3</sub> ),	216.78
Silicic " " (SiO <sub>4</sub> ),	16.68
Organic matter,	100.00
Total solids,	1,428.94

After the return to N—— that afternoon a most peculiar circumstance was related by Dr. Lescher, who assisted with the examination. Several adult natives in this town, known personally to him, who had extreme manifestation of the brown stain, had during their childhood used the water from the V—— mine. It seems that before N—— had secured a municipal water supply the early residents had hauled the mine water in barrels for domestic use, as it was considered better than the available local supply, and the children in these families were brought up, it may be said, on this mine water. Here is a circumstance that is, to say the least, very significant, for so many of the adult natives had very pronounced cases. This circumstance is similar, it will be remembered, to that at H—— except that in the latter place the water used during childhood was drawn from wells. Taken all in all, the influence of V—— was extremely bad in relation to the production of this lesion of the enamel. A large area of adjacent country is given over to coal-mining, and some well-known mines are located there. Several other coal camps were mentioned in which the lesion was prevalent, but lack of time prevented their examination. The coal in all of these is said to be associated with shale rock.

*Examination of D——.*

This city is situated in one of the large open areas designated as parks in the Rocky Mountain region, devoted wholly to agriculture and grazing. To reach it from N—— it is necessary to cross one of the high mountain passes by rail.

Of 328 children examined, 50 per cent. of natives were found to be afflicted—in a very mild way, however. No pronounced nor extreme cases were found. The water supply here is from artesian wells of various depths, and according to the depth the water is perceptibly warmer or cooler, the warmer from the deeper wells. It is probable

that some other parts of this valley or park, which is several hundred square miles in extent, are afflicted to some degree, but no further examination was then possible.

Assistance was rendered by Drs. Davis and Stanwood.

The apparent association of these lesions with coal-mining districts rendered it imperative that all such districts which were under suspicion be investigated. This made it necessary to visit a coal camp, E——, which was one of a group of several, in another part of the Rocky Mountain region. Attention had been called to this locality by Mrs. Mayhall, who had become familiar with the lesion during a residence at L——.

While in this district examination was made of 85 children in a school at E—— City, and of 18 natives there, only 2 had the lesion. Another outlying school, at Park Center, was examined later in the forenoon, and of 18 children examined the lesions were found in 5, three of whom were of the same family, and curiously enough, had been raised at E——, the objective place of this trip. This emphasized again how the products of an endemic territory are to be found sprinkled about in various places, thereby seeming, to superficial observers, to designate the places where these persons are found as endemic territory, when in reality such places may be entirely innocent. Other scattering cases were found who had come from neighboring ranches.

#### *Examination of E——.*

Number examined 50, in 11 of whom lesions were found. Only 8 native children were present, 5 of whom were afflicted. Of the other 6 cases, 5 were from adjacent coal camps and the remaining one was from another known endemic locality.

One difficulty is found in the disposition of coal-miners to move, with their families, from one district to another as the industrial conditions change, so it is hard to find many children in a given camp who have had a continuous resi-

dence there. This accounts for the meager data obtained from such places, which have, in a general way, a fair-sized population.

Two important associations were established by the visit to the camp E——. One was that the coal here is mined from shale rock, and the other, more important, that the domestic water supply is derived from the mine, as at V——, previously described. The analysis of this water follows:

#### *Analysis of mine water at E——. (Cambier.)*

Ions.	Pts. per million.
Sodium (Na),	37.12
Potassium (K),	
Calcium (Ca),	74.40
Magnesium (Mg),	16.71
Iron (Fe),	trace
Aluminum (Al),	trace
Chlorin (Cl),	14.17
Sulfuric acid ion (SO <sub>4</sub> ),	104.66
Carbonic " " (CO <sub>3</sub> ),	239.60
Silicic " " (SiO <sub>4</sub> ),	
Organic matter,	84.00
Total solids,	570.66

Gaining this additional evidence was in itself of great value, but far and away of greater value was information that was placed at our disposal that day by Mrs. Mayhall. Up to this time absolutely nothing had been known of any other district outside the Rocky Mountain region in which this lesion existed, and the circumstances through which our attention was drawn to another area in a distant part of the nation in which a precisely similar condition existed are so curious that indulgence is asked for a recital in detail.

At the time that Dr. Black made his studies of this lesion in one of these endemic areas a short article commenting upon the matter appeared in one of the important daily papers of the Rocky Mountain region. This article was copied into the *Dental Brief*, and fell under the eye of Dr. W. H. Arthur of F——, a town situated in one of the Atlantic seaboard states of the South. This called forth a letter from him to the newspaper, in which he described briefly the condition in his district.

It is indeed curious that this published letter in a great daily newspaper, with wide circulation through this region, should have been overlooked apparently by all of those who were most interested. Certainly no one brought it to the attention of our committee of investigation until it was handed me that day at E—— by Mrs. Mayhall, who had seen it, cut it out, and saved it for many weeks. It is no more than fitting that at this time our profound gratitude to Mrs. Mayhall for her thoughtfulness be in this way publicly expressed. Correspondence was at once opened with Dr. Arthur, and his description of the conditions existing in his territory is contained in the following letter written by him:

April 22, 1912.

Dr. F. S. MCKAY, Colorado Springs, Colo.

*My dear Doctor,*—Yours of 4/18/12 to hand yesterday, and in regard to the discoloration of teeth in this section my observations have been about as follows:

My observations and experiments cover a period of about fourteen years. I have not gone deeply enough into the pathological end of it to know the cause or whys and wherefores of some of the symptoms as I am going to give them to you, but simply give you the pathological conditions as they present themselves to me clinically.

So far as I know it is confined to a little strip of territory in our own county between two little fresh-water rivers, principally to this town and our county seat ten miles away. We are on one side of the river and they on the other.

As nearly as I can ascertain it made its appearance here about twenty years ago.

It is confined exclusively to children and young people born in this territory. Exclusive of young people it is not confined to any set or class of people. It is in practically every family in town in which the children were begotten and born here. Some families have it in one, two, or three children, and probably as many more in the same family have escaped it. All of same parents, same table, same water, and same environments. Home and environments seem to have nothing to do with it. It is in the home of the \$1.00 a day laborer and in that of the banker and manufacturer, which would tend to eliminate the diet.

It cannot be due to bottle-raising, for many

of the patients are breast-fed babies. At first I thought probably it was due to some infantile disease, as measles, scarlatina, scarlet fever, or some skin trouble, but on taking stock I find that many of the worst cases never saw an hour's sickness, and furthermore, it is found from year to year in each succeeding year's crop of infants, and no history of any such epidemic in town.

Our town gets its drinking-water from artesian wells. Many of our people think the water responsible, but I have cases, only a few, which antedate the wells; furthermore not all of the children have it, even though they all drink the same water.

I have seen several analyses of the H<sub>2</sub>O by competent chemists, and they all pronounce it ideal for drinking purposes. These facts would tend to explode the water theory.

I have many children in my practice brought here in infancy as young as four weeks, and some whose mothers came here just before parturition who have not the slightest trace of it. It is confined exclusively to children born in the little strip of territory indicated.

It looks as though the trouble is done *in utero*, as it is confined to children conceived, carried, and born here, and not to foreign cases. Why this is I can't even offer a suggestion. Further, it never attacks the temporary teeth—they are as perfect as any I ever saw—but holds over to second dentition. Why the causes lie dormant until then I would not hazard a suggestion. But if the trouble is done after birth, why do not children brought here as sucklings acquire the trouble? They are certainly as liable as the others, yet I have never seen a case develop even in the slightest in those brought here after birth.

By observation and clinical experience I am forced to the belief that the brown stain is not a primary effect, but a secondary one. As we see the brown stain we are observing the secondary effect and not a primary one, varying in color from a light brown to one as dark as a Colorado cigar wrapper, depending almost entirely on the age of the patient and the length of standing of the case.

If you will notice a case in its incipience you will doubtless notice that there are several zones of discoloration, and that each one has its individual nucleus in the shape of a minute pit, and gradually enlarging until they merge one into the other.

With us the discoloration is most noticeable on areas of enamel which are constantly or periodically exposed to the atmosphere, and the more habitual the exposure the

greater the discoloration; for instance, it is more common on the labial surfaces of the incisors, tips of canines and bicuspid, gradually lessening from the centrals backward as the downward curvature of the lip leaves less of the tooth exposed, and the palatine surfaces of the bicuspid and molars. The discoloration is usually superficial. The appearance of the tooth in the primary stage is a dead opaque chalky white one; the enamel is soft and has little strength. This chalky look appears as soon as the tooth is fairly through the gum, and continues to appear during the process of development. Let me say here that this whitening is not beneath the free margin of the gum. This soft chalky layer, which is superficial, soon begins to disintegrate and fall away, resulting in little pits all over the surface of the tooth, which rapidly work toward each other, so that when we see a case of it the color is almost uniform, and the surface has returned to more or less smoothness of the enamel. But there is more or less tendency to form superficial surface cavities at the original nuclei of the areas of discoloration. I do not know that there is any abnormal amount of decay in these teeth, except in superficial cavities in the discolored areas mentioned above. Work when done stands about as well as in other mouths, except perhaps a malleted gold filling—the margins do not hold there so well. I have not any idea how many cases I have seen; got discouraged and lost count. . . .

(Signed) W. H. ARTHUR.

#### OCCURRENCE OF MOTTLED AND STAINED TEETH IN OTHER LOCALITIES.

An examination of some teeth sent by Dr. Arthur proved conclusively that the condition prevailing in his locality is identical with the mottled and stained teeth found in the different susceptible areas already described. In certain respects Dr. Arthur's description differs from what has proved to be the unvarying rule in our own territory, namely, the susceptibility of children born elsewhere but who have been brought into afflicted territory during the years of infancy, for we know that such children are liable to the lesion exactly in relation to the age at which they were brought into such territory—or, in other words, in re-

lation to whatever enamel was in the process of formation at that time. For this reason there is a strong element of obscurity in interpreting Dr. Arthur's findings, and it may be possible that upon closer investigation it will be found that an error in observation has crept in which will account for some of his statements.

In brief, the points of correspondence between his conditions and those I have described may be summarized as follows:

(1) Its localization in definite geographical areas, and its occurrence in the native children thereof.

(2) Its non-existence in the temporary teeth.

(3) The similarity of coloration.

(4) The opaque whiteness of the enamel present when the teeth are erupted.

(5) The superficiality of the pigmentation.

(6) The location of the colored areas on the teeth.

(7) The pitted condition in some cases.

(8) The absence of any unusual amount of decay.

(9) The suspicion which is thrown on the water supply in the causative relation.

Coming into touch with another area of country that presents so identical a condition was a great surprise, and at the same time a matter of immense interest from its likelihood of furnishing valuable data for comparative use in running down the cause of the lesion. After some correspondence the interest of Prof. Wortley F. Rudd, chemical department, University College of Medicine, Dr. R. L. Simpson, dean of the dental school, and Prof. E. C. Miller, department of bacteriology, at Richmond, was enlisted, and they, with Dr. Arthur's co-operation, made an examination of the afflicted district in April 1913.

(To be continued.)

## An Investigation of Mottled Teeth:

An Endemic Developmental Imperfection of the Enamel of the Teeth,  
Heretofore Unknown in the Literature of Dentistry.

By FREDERICK S. McKAY, D.D.S., Colorado Springs, Colorado,

IN COLLABORATION WITH

G. V. BLACK, M.D., D.D.S., Sc.D., LL.D.

(Continued from page 644.)

### ( III. )

#### EXAMINATION OF AN ENDEMIC FIELD LOCATED IN ONE OF THE SOUTHERN STATES ALONG THE ATLANTIC SEA- BOARD.

In order to determine as accurately as possible the limits of the territory afflicted, questionnaires were sent to 144 dentists, physicians, and druggists adjacent to the territory to be studied. The two cities, F— and C—, only ten miles apart, were found to be the chief centers of affliction, and the questions, with a summarization of the answers received with reference to these two places, follow:

(1) How common is it? How many cases are there in your town?

*Ans.* At F—: Very common; most of the natives, or those brought at an early age, affected. At C—: Affects all natives born since advent of artesian wells. Nearly all children born there in the last eighteen years afflicted.

(2) How long has it been observed?

*Ans.* At F—: From twenty to twenty-five years—since artesian wells were put down. At C—: For the past twenty to twenty-five years.

(3) What is the age of the oldest person in whom you have seen it?

*Ans.* At F—: About twenty-five years. At C—: Twenty-one to twenty-three years.

(4) Does it seem to be on the increase or decrease?

*Ans.* At F—: Increase (due to more inhabitants there). Nearly all children born there are afflicted. At C—: On the increase, since it affects all natives.

(5) Can you trace any connection between its occurrence and the following factors:

(a) The water or food used by family?

*Ans.* At F—: The water supply is thought to be chiefly responsible. It was not noticed prior to use of artesian water. Food has no effect, as it occurs in the homes of plenty, as well as in those of the poor. At C—: Artesian water is thought to be the cause.

(b) The social position of family?

*Ans.* At F—: No effects; rich and poor affected alike. At C—: No.

(c) The general health of patient?

*Ans.* At F—: No. Occurs in those in good health as well as those in poor health. At C—: No. Seen in all conditions of health.

(d) Any disease of infancy?

*Ans.* At F—: No. At C—: No.

(e) Any prenatal condition?

*Ans.* At F—: No connection, as lesion is not seen in temporary teeth. At C—: Probably not, as no temporary teeth are affected.

(f) The place where individual was born or raised?

*Ans.* At F—: Individual must have been born in the locality where artesian water is used; never seen cases in sections where artesian water is not used—and children from various sections have been examined; children must use the water while permanent teeth are developing. At C—:

Birthplace has an influence; children from outlying districts not affected; those born elsewhere or coming to C—— after three or four years of age are free from it. [Probably so far as incisors or cuspids are concerned.—F. S. M.]

(g) The care of the teeth?

Ans. At F——: No. Is in well-kept as well as in neglected teeth. At C——: No. One writer thinks it worse in badly kept teeth.

(h) Decay of the teeth?

Ans. At F——: No. At C——: Teeth seem to be average in quality.

(i) Race susceptibility (white or black)?

Ans. At F——: There seems to be some difference of opinion on this point, some thinking there is not much difference, while others believe that it is not prevalent in colored children—the reason, as given, being that the colored children are more apt to use water from the open or surface wells. At C——: Have not observed it in negro children. [This answer is by no means conclusive.—F. S. M.]

(6) Is artesian water used in your district?

Ans. At F——: All replied, Yes. At C——: Artesian water used exclusively, but only slightly in the country districts.

The reader cannot fail to have noticed points of general similarity between this region and the endemic districts in the Rocky Mountain region, and at the same time it is hard to associate water drawn from deep or artesian wells with that derived from melting snows on the range, or from surface wells, yet we have found that all three seem to be factors in association with the lesion.

Reports from other communities within a radius of one hundred miles show that as a rule the lesion is unknown, except that cases have been seen which came from the two endemic cities noted. Other scattering reports indicate that a few cases have been seen, and the general opinion is that artesian water is in some way to blame. It is generally noted that those places that are immune do not use artesian water.

Let us now make a closer analysis of the details of the examination of 31 children at F——. Of these children 18 were afflicted, and 14 of them were natives. In considering the water

histories of these 14, we must eliminate two children who gave no definite water data. Every one of the remaining 12 were users of artesian water. Of the other four of these 18 afflicted cases who were *not native* to F——, accurate data was not given.

Now, to reverse our method of stating the data, we will examine the *artesian water users*, and we find 16 individuals; 12 of these showed the lesion, the other 4 being all at the age of seven, and are recorded as showing “no trace.” This is not conclusive, because these children may have had no permanent teeth. These teeth might, and the chances are large that they will, bear the typical marks when erupted. Let us turn about now and examine the *non-afflicted* cases. There are 8 of these with a known history as to nativity, and every one was born outside the city.

What kind of water was used by these children? We eliminate one because of no data, and find that the remaining 7 all used water from a shallow [surface] well. These facts seem conclusive, or to say the least, significant, but we find many things hard to account for in Dr. Arthur's statements of the water conditions. I will quote what he says in this connection:

The water for drinking purposes is derived from artesian wells, which were sunk, the first two about twenty years ago, as an experiment. Since then the number has increased to about 100. This trouble made its appearance simultaneously with these wells, that is, as a general condition. Prior to that time the people took their water entirely from open wells, the water supply being almost entirely dependent upon the amount of rainfall. . . . The water in all artesian wells is not the same, differing both chemically and physically, depending upon what vein the well happens to strike. Some of these wells supply many families, being club wells, and many of the children drinking the same water escape, while many will be affected. In some families it attacks all of the children, while the children of their neighbors, using the same water, will be entirely free from the trouble.

In some families where both parents are perfectly healthy, and with good family history, with the same water, same food and

environment, one or more children will be afflicted, while the family next door, equally healthy, and with just as good surroundings, may have all children afflicted or they may escape the trouble entirely. In several families using the same water, a portion of one may have it, and the other escape entirely. An instance is the Parker family, from whose well the sample of water for analysis was taken. Two of his children have it slightly, one not at all [ages are not given—F. S. M.]; his next neighbor, using the same well, has four children, and all of them terribly marked. [Dr. Arthur does not state whether all these children were born and raised on the premises described.] Directly in front of this family were three children, and not the slightest trace of trouble in any of them. [The data in this sentence is also incomplete.—F. S. M.]

Considering the uniformity of conditions as given in detail some paragraphs back, one finds these conditions as described by Dr. Arthur hard to account for. In our western territory the most striking similar instance is that of twins in a family at L—, one of whom was afflicted and the other escaped (mentioned by Dr. Black in his description: see page 144 of February issue of DENTAL COSMOS). Also it might be noted that the only place in the Western territory thus far touched by the artesian influence is D—, where we found an endemic percentage of about 50, and artesian wells prevalent. In contrast with this, however, we found Y—, with an endemic percentage of 90, drawing a large portion of its water with windmills, and we found badly afflicted adult natives at H— who had used water from surface wells. Certainly these facts seem exactly contrary to each other in the causative relation, and conditions just as puzzling are yet to be chronicled.

Let us return, however, and follow Dr. Arthur's description farther. He continues:

The town has water and sewerage systems, taking its water from Blackwater River. This water system has been in operation only six years, and no one drinks this river water.

Touching the distribution of the lesion, he says:

It is not confined to any set or social stratum. It includes the whole range, from the child of doubtful origin and the plainest of fare to those whose family history is absolutely clean, and who are sumptuous liver. Nor can it be attributed to bottle-feeding, as many of the worst cases have been breast-fed babies. This would seem to eliminate dietetics to a very great extent, if not entirely. There is no history of any infantile epidemics, such as measles or scarlet fever. On the contrary, some of the worst cases of stain are in the healthiest subjects, while, on the other hand, some of the most puny are entirely free from the trouble.

The territory affected includes the two towns F— and C—, only ten miles apart, and lies contiguous to two freshwater rivers, the B— and the N—, which latter it follows to its mouth.

Invariably the temporary teeth are free from the trouble. No child brought from unaffected territory, no matter how young they were when brought here, has the trouble so far as I am able to determine.

This statement of Dr. Arthur's seems exactly in contradiction with the facts as observed in the western regions, as is plainly indicated by reference to the written descriptions and to Dr. Black's tables, found early in the paper [p. 630].

Professor Rudd reports that the children in the colored schools at F— showed the same average condition as among the white children. It is interesting, also, to note that Professor Rudd went carefully through the library of Columbia University in New York and found no reference to the condition under investigation.

During all this investigation the question has frequently been raised as to the occurrence of this lesion in the teeth of lower animals, and so far as the writer is aware no case has ever been observed, certainly never reported. No hypothesis in explanation of this fact has been formulated that I am aware of, but should the cause in humans be discovered, as I believe it will be, the explanation of the immunity of animals might become easy.

At the time the examination of the field I have just been describing took place, Professor Miller of the department of bacteriology, University of Vir-



ginia, made a study of the affected region, chiefly to find the lesion in animals, if possible.

In his report he states that—"We have found great difficulty in finding any definite, tangible thing to study. We have so far been unable to obtain any of the affected teeth for histological examination, and we greatly hoped that we would find the local domestic animals affected. If we could produce it experimentally in animals, we could then study it systematically, and perhaps solve the mystery. In I—— is an experimental farm, used by the railway. It has a deep well (artesian) as its only source of water supply, and we examined the teeth of hogs and other animals that had used this deep water alone, but they showed no signs of trouble. We did not examine many animals, as most of their animals were imported.

Near this farm is a sawmill that has a deep well. Many of the mill hands and their families use this deep water exclusively, but none of their children showed any trouble with their teeth. [Were these children born there, and were they in constant relation with this well as an exclusive supply, and did these children have permanent teeth?—F. S. M.]

"I——," he continues, "is only about twenty miles from C——, and I really expected to find the trouble here, but there was none. There are no deep wells in I——. [This is significant.—F. S. M.] In C—— we found the trouble common. There the town people use deep well water. I saw very bad cases among the children."

Dr. Miller went over the library of the Surgeon-general at Washington, hoping to find some literature on this subject. He found that the removal of the parathyroid glands from a rat had the effect of stopping the calcification of the growing incisor teeth, but the chief effect was on the dentin rather than on the enamel.

Referring for a moment to the matter of calcification, it will be remembered that Black in his description of the histology of this lesion distinctly shows

that the enamel rods are perfectly formed (calcified), but the cementing substance is missing. This fact should make us careful in our use of the term "calcification" as related to the enamel.

It is very fortunate indeed that this investigation has received such splendid co-operation from such men as Professor Rudd and Dr. Miller, as thereby our findings in the Western fields have received corroboration, which is made more valuable by the fact that these investigators worked in their own original way and with practically no reference to the work accomplished by the writer and his associates.

During our association with Dr. Black and in our correspondence with him he had many times mentioned the barrenness of dental literature regarding this phase of pathology, so it was a genuine surprise to find in the DENTAL COSMOS for March 1912, in an article by Dr. W. H. O. McGehee of Cincinnati, Ohio, entitled "An Experimental Study of the Tooth-staining Properties of Various Colored Dentifrices," a reference which led this investigation straight to another endemic field in a far-distant part of the world.

One cannot but marvel at the almost providential dispensation which caused Dr. McGehee to turn back the pages of dental history for us, and place his finger so accurately upon an obscure article that had been buried for exactly ten years, but which was of such absorbing interest to us in this work. Surely if it had not been for this instance, this added information might forever have been lost to us.

On page 290 of Dr. McGehee's article are these words: "The DENTAL COSMOS describes—under the name of 'Chiaie teeth'—cases of brown or black discoloration of the enamel of the teeth to be found in certain parts of Italy, due to causes not well understood."

Through Dr. Kirk's kindness I was furnished with a copy of the DENTAL COSMOS of March 1902, at page 300 of which is the reference noted in Dr. McGehee's article, as follows:

"*Chiaie Teeth*."—Dr. J. M. Eager, of the U. S. Marine Hospital service, reports from Naples, Italy, the frequency of a dental abnormality among the inhabitants of the Italian littoral, and known as "denti di Chiaie," this defect having first been described by Prof. Stefano Chiaie. This impairment of the teeth, often not amounting to more than a slight impairment, is of particular interest owing to the fact that Italians who are its subjects frequently present themselves before medical practitioners in the United States. This dental abnormality is an acquired condition, and is due to geological conditions and unsanitary surroundings. In Naples it has been attributed to the water supply, and since this has been changed the disease among infants has greatly diminished.

"Denti di Chiaie" is really a collective name for various enamel defects. In Pozzuoli, a suburb of Naples, the inhabitants are distinguished from the people of the neighboring places by their black teeth ("denti neri"). This defect is supposed to be caused by the noisome gases from volcanos. The theory most generally accepted in Italy is that these gases have a selective harmful effect upon enamel formation in early childhood, but that the growth of the other dental tissues is not interfered with. Where the cause is active during the entire period of second dentition the whole tooth is deprived of enamel and becomes perfectly black. If the growing teeth are exposed for only a short time at the commencement of their formation, only the cutting edges of the upper incisors are affected, and the appearance when the teeth are matured is as if they had been browned by tobacco. The "denti scritti" (the teeth appearing as if written upon) constitute another form of the Chiaie teeth. These cases are characterized by black markings crossing the incisor teeth in a horizontal direction.

In the light of this investigation the foregoing was intensely interesting, and correspondence with Dr. Vincenzo Guerini of Naples, with which was included ordinary photographic prints of American conditions, brought a reply which made some corrections in the article quoted from the *Cosmos*. He says:

I can assure you, before all, that the name "Chiaia" is not at all the name of an author, but that of a quarter of Naples, namely, of the most beautiful quarter, where are the public park and a splendid promenade on the quay. There is also a Chiaia st., and another named "Chiaia Shore."

In the Chiaia region there are, in close proximity to the sea, numerous sources of mineral water, sulfurous and ferruginous, and the fact that the people living near the sea, just in the localities where such sources are, present on their teeth the brown spots in question (Chiaia spots) clearly demonstrates that this alteration of the enamel depends upon the action of the gases emanating from the said mineral sources. This is confirmed by the other fact that not only the inhabitants of the Chiaia littoral, but also those of other localities forming a continuation of this littoral, and equally rich in mineral sources, present the same characteristic dental spots.

In Pozzuoli, where the sources are more numerous, the spots invade sometimes the entire free surface of the teeth, making their color like chocolate and sometimes nearly as black as ink.

As for the appellation of "denti scritti" (written teeth), this, among the Neapolitan lower class, is the usual denomination for the abnormality in question, and not for a special variety of it.

Dr. Guerini also calls attention to a pamphlet (*Odontologia Forense*), where he makes mention of the dental spots here spoken of.

If my readers have followed carefully thus far, they have become very critical in accepting statements or testimony as conclusive, and I can be reasonably safe in assuming that they are not ready to agree that this Italian lesion must necessarily be considered as the same lesion with which this paper has been dealing.

It is to be regretted that a careful description of these Italian conditions, together with a report of the examination of children and study of water conditions, could not have been obtained. By far the most valuable direct evidence was obtained from J. F. McConnell, M.D., of Colorado Springs, who is familiar with the lesion as it exists in the West, and who, writing from Naples, says: "The children in Naples do not show very much of the brown stain, but in Pozzuoli the 'denti scritti' are quite common; the markings are brown in a horizontal direction on the upper incisors. It was the consensus of opinion that illness during the developmental period had something to do with the

markings. All of them claimed that when the teeth erupted they were white, and subsequently became brown."

The last statement in the above tallies exactly with conditions as we know them, and reading the evidence right through it seems hardly possible that the Italian lesion can be any other than the one we have been studying. It is interesting to note the theories that are held as to the cause, and while Dr. Guerini seems quite confident in ascribing the cause to the gases emanating from the mineral springs, it is very hard to account for the trouble in this way in some of the American areas that have been described.

Further, in ascribing this lesion to the diseases of childhood, it is evident that there has been confusion with the "atrophies" with which Dr. Black's writings have dealt. The evident fact is that the cause of this condition is as mysterious in Italy as in our own territory, but as with us, the water seems in some way to be held responsible.

The horizon of the research was again, soon after coming in touch with the Italian field, materially widened by a report brought by Dr. Isaac Burton of this city, from Dr. Rice of S—— A——, Texas, of an endemic area at A—— in the Texas Panhandle. Dr. Rice kindly donated two incisor teeth from that district which exactly corresponded in appearance with those from previously studied districts. An account of the examination of this district follows.

#### *Examination of A——, Texas.*

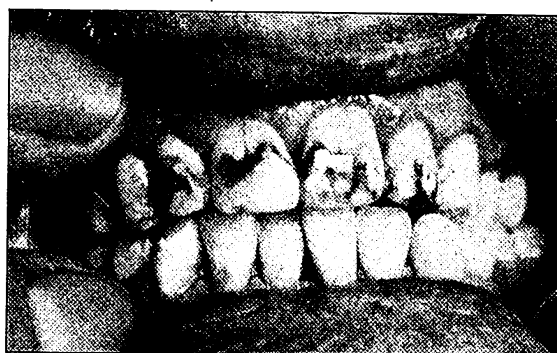
This was conducted by Dr. A. H. Ketcham of Denver, assisted by Dr. Bristow of A——, April 13, 1914. The data submitted were similar in character to those obtained in other places, and determined that this city had a high endemic percentage. There were 35 actual natives examined who exhibited the lesion, and 52 others who came there up to the seventh year who were afflicted. This is an artesian district, and most of these children used that kind of water. That fact associates this field with the South Atlantic area previously described.

It was evident from the data that the

surrounding territory could be termed one of "spotted susceptibility," on account of the number of cases found at A—— that had originated in adjacent territory and other parts of the state.

During the examination of A—— attention was in some way called to the city of W—— in another part of Texas, as a possible afflicted district, but no data were procurable. Just recently, however, a case originating there was called to my attention by Dr. Max

FIG. 20.



Giesecke of Denver, who also furnished the photograph (see Fig. 20) of the case.

The conditions shown in this illustration are typical in some respects, notably the distribution of the stain and its absence on the lowers, but a careful examination which I was privileged to make showed that the mottling of the enamel was not so general nor as widespread as would be found in typical cases from endemic districts, and particularly in cases in which the incisors were as badly stained as in this one. There is at present no evidence to indicate that any large proportion of the natives of that locality are similarly afflicted, and yet this young man was born there and had lived there until maturity. His detailed history is not available.

Reverting now to localities in the Rocky Mountain region: So far as is known, Dr. Waddell of Denver first called attention to certain parts of the valley of the P—— River as an afflicted district. The principal town in this district is A——, which was examined in the early spring of 1914, with the aid of Dr. Templeton.

*Examination of A——.*

The data secured here among school children were so similar to those in other like districts that recital in detail would be mere repetition. A large proportion of natives were afflicted, also many who came during early years. Comparatively few natives escaped, and most of the non-afflicted cases had come during later childhood. Some detail, however, with attention to particular cases, will prove interesting.

In one rural district school (No. 23) were 14 natives, 13 of whom were afflicted. The other one, who had normal enamel, used water at home from a shallow well. Another child was born in another endemic district (K——), but moved into this one at the age of three weeks, likewise used surface well water, and had normal enamel.

Another interesting case was that of a child who was born in this same valley and removed to the Pacific coast at the age of two years. He returned at five, and when examined showed the mottling on bicuspid and second molars. Any possible damage to the incisors and first molars that might have been inflicted during the first two years was evidently overcome by his being away until five. When returning, the bicuspid and second molars were growing their enamel, which showed these peculiar marks when erupted.

Another, Miss Rucker, was born at H——, an adjacent hamlet, and had used artesian water continuously, never having lived any place else. A brother of nearly the same age had the same history, and both had typical cases. An older brother was three years of age when he came under the identical conditions as above described, and has normal enamel.

A school used principally by children of German parentage gave some interesting data. Of 12 typical cases examined, every one was a native, and it was found that the use of artesian and surface well water was about equally divided.

This last fact was found to character-

ize the findings obtained through this entire district. In attempting to trace a connection between the lesion and the kind of water used it was found that (a) shallow wells had produced as many cases as artesian wells, and (b) as many non-afflicted children had used water from shallow wells as from artesian wells.

In no place so far examined have the examiners left the district in as confused a state of mind regarding the water relationship as here. No analysis of these waters has been obtained. This valley is in level, prairie country, and in total disrelation with the mountain range.

Certain districts as far out on the plains as 120 miles to the east were later examined, in company with H. L. Shantz of the bureau of Plant Industry, department of Agriculture, U. S. Government, and scattering results noted. The water supply at the principal town, A——n is from wells, and generally water is found at a depth of 100 feet after passing through the gravel layer, which is said to be a wash from the mountains during early geological periods. A shale formation underlies the gravel, and the water is said to be just above the shale.

The conclusion reached from examinations and reports is that the region embraced in the Great Plains can be described as being of "spotted susceptibility," the exact location of which spots is hard to determine, because of the very sparse population.

Reports have also been recorded of cases which have originated and been found in various scattered localities in the Rocky Mountain region, which add little to the value of the findings already recorded, unless it should be that later, as new facts are established, these places, usually of very scant population, should be subjected to studies of a very careful nature in order to check out on new lines of investigative procedure.

*Examination of the Sigle Ranch.*

To Dr. H. W. LeFevre we are indebted for calling attention to the Sigle

family, which brought us in contact with the most localized or circumscribed endemic area that had thus far been studied.

Attention has several times been called in this paper to the fact that these principal endemic localities were located out on the plains, and not within the mountain range. The one exception was the territory described as the headwaters of Fountain Creek, and the contiguous area designated as the K—— district. The Sigle Ranch, about to be described, is reached by a railroad that threads its way for fifty miles through one of the most rugged and picturesque gorges in the entire Rocky Mountain region, until the station E——k is reached. Then a wagon road is followed for two miles back into the hills, and there, in a beautiful meadow, is the homestead, right in

normal, but on the bicuspid and second molars was mottled, which set of conditions exactly corresponds with the rule that has been found to operate almost unfailingly in endemic territory.

The neighboring population, of course, was very sparse, but I could get no account of any other family in that locality that was similarly afflicted. At the foot of the sloping hillside just back of the house was a carefully walled-in spring of water that was absolutely clear and tasteless, of extreme purity, that had been running there for at least forty years, and it was from this spring that the family had derived its sole source of domestic supply. A gallon was taken, with great care, and the analysis follows. Parallel with it is the analysis of the Cummings Ranch water, for comparison:

<i>Sigle Ranch.</i> (Cambier.) (Endemic.)		<i>Cummings Ranch.</i> (Stewart.) (Immune.)	
Sodium (Na),	11.05	Sodium (Na),	4.92
Calcium (Ca),	21.32	Calcium (Ca),	10.50
		Potassium (K),	2.67
Magnesium (Mg),	5.41	Magnesium (Mg),	2.34
		Iron (Fe),	1.04
		Aluminum (Al),	2.32
Chlorin (Cl),	8.31	Chlorin (Cl),	2.40
Sulfuric acid (SO <sub>4</sub> ),	46.80	Sulfuric acid (SO <sub>4</sub> ),	4.85
Carbonic " (CO <sub>2</sub> ),	22.80	Carbonic " (CO <sub>2</sub> ),	52.86

Both of these waters are considered low in total mineral matter. (*Cambier.*)

the heart of timbered mountains and in utter contrast with the plains region heretofore described.

On this ranch a son and daughter, now adults, were born, and they maintained an absolutely continuous residence there until they were man and woman. I personally examined this son, and found as marked and typical a case of the combined lesion as is possible to describe. The daughter had removed to another state just previously, but she was described as having a condition just as pronounced. The older brother was born elsewhere, and commenced a continuous residence on the ranch at the age of about seven. The enamel on his incisors, cuspids, and first molars was

The various analyses which had been obtained up to this time were according to the standard form used in analyzing water, but it was requested that the Sigle Ranch water be tested in addition, for arsenic. The report was negative.

A moment's thought must make it plain that in the study of this ranch and its water supply the peculiar and mysterious influence which is responsible for this amazing condition of the teeth of these individuals must have been tracked very close to its lair, and it is my profound conviction that the proper kind of study devoted to this small bit of territory must determine exactly what the influence is, or in other words, the cause of this lesion. Certainly a similar com-

parative study of the areas equally circumscribed cannot fail to uncover the mystery. At present, excluding the Lawson Ranch, only one other similar endemic spot has been located (Keeton Ranch), but it has not been definitely studied. Neither of these, though, are strictly within the mountains.

In all the literature of dental science there is probably no one who has written more upon the food, water, soils, or other factors as related to the quality of tooth structure, or examined more individuals, over a larger area of territory than has the eminent investigator Dr. Carl Röse of Germany. And yet Dr. Black states that in all these published articles, of which there is volume after volume, no mention is made of a condition similar to the one we are studying.

A brief description of this lesion, accompanied by ordinary photographic prints, was sent to Dr. Röse, and his idea is given, somewhat literally as translated by Dr. Hillkowitz, as follows:

The cause of the teeth becoming black . . . . is not difficult of solution. I may tell you at once in advance that you have probably a *very soft drinking-water, poor in lime* [italics mine]. Secondly, the infants are probably not nursed by their mothers very long, and early receive artificial feeding. In this way are formed the badly calcified cases of your illustrations, who have hypoplasia of their teeth. One of your photographs shows a case that is absolutely typical in appearance of badly calcified teeth in the regions poor in lime.

Such teeth are found with us in Germany principally in lime-poor, hilly regions. The deposit is not quite a pure black, but rather a dark green. This dark green color consists principally of decomposed blood from inflamed gums which bleed easily. In your case the color is black, because the drinking-water certainly contains very fine carbon particles in the minutest division. Have a chemist treat your water with an aluminum sulfate in order to make the particles of carbon, which occur in traces, more evident.

Examine the teeth with a magnifying glass or with a microscope, and you will find that the surface of the enamel is not smooth but pitted, looking somewhat like a honeycomb. In these small excavations and pittings the black carbon particles are deposited, whereas with us it is the dark green coloring matter.

. . . . When the teeth are still concealed in the jaw they do not have this black or green coloring, but that grayish blue, mottled appearance, which arises from faulty calcification of the enamel.

This communication from Dr. Röse is, to say the least, disappointing, inasmuch as it seems to show plainly that he is not familiar with the lesion as we find it, at least he has in his mind and describes a totally different condition. In view, however, of the eminence of this investigator, his views as expressed above merit close analysis. In his first statement he attributes the discoloration to a "very soft drinking-water, poor in lime." What do we understand by a water "poor in lime"? Let us glance at some of the analyses of waters of some of the worst endemic regions and contrast their lime content. The mine water at V—, with its frightful endemic percentage of 100, has in every million parts 89 parts of lime. The Lawson Ranch well has 31; the Scholes well 33; the mine water at the E— mine has 74; T—, with an endemic percentage of almost 100, has 196; the Sigle Ranch spring has 21; and lastly, L—, with an endemic percentage of almost 90, has just over 5 parts of lime in each million parts of water.

How can we reconcile such a variation in the lime content of the water in these areas, all of high endemicism, and which one of these waters shall we say is "poor in lime"?

On the other hand, let us turn to the water at the Cummings Ranch, whose association with absolute immunity from this lesion is remembered, and we find a lime content of only 10+. If this water has sufficient lime to insure normal enamel development, why did T—, with 196 parts of lime, exhibit an endemic percentage of practically 100?

Second, regarding the effect of artificial feeding of infants on the prevalence of the lesion, it has been noted that the acquisition of the lesion depends absolutely upon the age during which an individual enters endemic territory, and many have become afflicted after they were long past the

period of artificial feeding as we understand this term. Surely the appearance of mottled enamel upon the third molars of an individual who had not entered an endemic area until the age of thirteen or fourteen, the enamel of all other teeth being normal, could not be related with the method of feeding during infancy. (See also description of Pima Indians, given later.)

Third, it is evident that in speaking of a "dark green" coloration, Dr. Röse has a condition in mind that is wholly unrelated with ours.

Fourth, in ascribing the dark discoloration to particles of carbon in suspension in the water, lodging in pits and excavations in the enamel, Dr. Black's description of the surface of these teeth states that as perfect a glazed surface exists there as upon teeth with normal enamel. There are no pits or crevices into which the finest exploring point will penetrate, or that will be revealed by the magnifying glass, except such as we have distinctly described as of macroscopic size, usually upon the bicuspid. Water was treated with aluminum sulfate by a chemist (Fuller) as suggested, without revealing a trace of carbon in suspension.

Pursuing further our study of the lime content of various waters in relation with the occurrence of this lesion, I find in the U. S. Geological Survey publication, "Water Supply" Paper No. 236—Part I, "Analysis of Waters East of 100th Meridian"—some very interesting and significant data.

The 100th meridian extends north and south through the Dakotas, Nebraska, Kansas, and Texas, and sixty-nine analyses are given of the principal rivers at various points between this meridian and the Atlantic. Not one of these gives as high a calcium content as that obtained at T— (196). The nearest is the Brazos River, at Waco, Texas, with 121. The next highest is the Rio Grande at Laredo, Texas, with 104. Also these two are the only ones showing higher lime content than the mine water at V—, with 89. Only six show more than the mine water at E—, with 74, and these are all west of and including

Indiana. Forty-six show an equal or higher content than the water from Scholes' well, and none of these are east of Ohio. Coming down now to the water at L—, which has a lime content of 5 and an endemic percentage of almost 90, we find but five analyses so low in lime, and these are every one from North Carolina, Virginia, or Georgia.

If it be a lack of lime, then, that causes this lesion, we find no waters, as reflected by these river analyses, that show anything like as high a lime content as some of our worst endemic areas, yet no reports have ever come from any of the territory drained by these rivers that would designate any degree of endemicism. Nor can we find but five rivers that presumably drain immune territory that have as small a lime content as one of our worst and most extensive afflicted districts. Comparing again the lime content right in the afflicted country, we contrast L—, with an endemic percentage of almost 88+ and 5 parts of lime, with Y—, having a percentage of 90+ and a lime content of 116 (Powers, chemist), and these two communities are only fifteen miles apart. Clearly the evidence regarding lime, as above shown, is absolutely contradictory and inconclusive.

The table of water analyses shown later [see August Cosmos] will show the predominance of the sulfuric and carbonic acid radicals in all these waters collected in areas having high endemic percentages, except L—, where they both drop in comparison with the other waters, and yet predominate in that particular water. The same is true of the Sigle Ranch water.

The only river east of the 100th meridian whose analysis shows anything like as high sulfuric and carbonic acid contents as these waters is the Brazos, which gave at Waco, Texas, 279 parts  $\text{SO}_4$  and 158  $\text{HCO}_3$ . This also is the same river that showed the highest lime content, and curiously enough it rises in and drains the so-called Panhandle (north-west) section of Texas, which section we found to contain at least one community of pronounced endemicism, and we



classed the area as one of "spotted susceptibility."

Turning to the west coast of the country, and studying the U. S. government analyses of the surface waters of California, we find in thirty-seven analyses only one river that exceeds the highest lime content in our table to be shown later. This is the Santa Maria, with 302 parts of lime. When we come to examine these California waters for  $\text{SO}_4$  and  $\text{HCO}_3$ , we find that the average content of these acids is far less than the amounts shown in our table of water analyses from afflicted areas. Again we note the curious fact that this Santa Maria River, which has the highest lime content, also carries the highest  $\text{SO}_4$  content (1253 parts) in which respects it is similar to the Brazos in Texas. This  $\text{SO}_4$  content is almost double that of any water shown from our worst afflicted areas. The  $\text{HCO}_3$  content of the Santa Maria is about the average of the waters in our table.

If the occurrence of the lesion is to be accounted for by some peculiarity of the water, then our suspicions might fasten on to this high proportion of the acid contents, but this theory seems to be nullified by the low content in the L— water.

Again, this same postulate would make it imperative that other districts having the same character of water supply should exhibit the same prevalence of enamel lesions. Apparently no density of population exists in the vicinity of the Santa Maria River in California, and so far no data are obtainable from that district.

Further studies of the California waters show the Salinas River and its tributaries, draining a large area, to carry an unusually high content of these same acid radicals and of lime, but so far as known no such enamel lesions exist in that territory.

The Ventura River is described as carrying an average of 226 and 251 parts per million of  $\text{HCO}_3$  and  $\text{SO}_4$  respectively, and the text states that this water is likely to produce unpleasant effects on persons not well accustomed to such

highly charged waters. The highest medicinal dose of  $\text{SO}_4$  in water is stated to be 150 parts per million, and such water is considered mineral water of therapeutic value.

It will be remembered that some of our endemic waters run as high as over 600 parts of  $\text{SO}_4$  per million. In describing the water of the Owens River, from which Los Angeles has taken its water supply by means of an immense engineering project, the government chemists give us an idea of what constitutes a good water for municipal use. The average of several analyses is given below:

Ions.	Pts. per million.
Silica ( $\text{SiO}_2$ ),	40
Iron (Fe),	20
Calcium (Ca),	15
Magnesium (Mg),	4.3
Sodium and potassium (Na and K),	40
Bicarbonate radical ( $\text{HCO}_3$ ),	111
Sulfate radical ( $\text{SO}_4$ ),	30
Nitrate radical ( $\text{NO}_3$ ),	1.2
Chlorin (Cl),	17
Total solids,	189

In reference to our lesion, then, is it an unusual purity as indicated by the water at L—, or an unusually high content of solid matter and high calcium,  $\text{HCO}_3$  and  $\text{SO}_4$  radicals, as indicated by the mine water at V— (both being areas of high prevalence of enamel lesions), that can be considered as the cause?

One cannot but be struck by the frequency with which various writers have associated the quality of the teeth with lime in the water. A notable instance is an article by Bunting in the DENTAL COSMOS for May 1912, who, on page 539, has the following to say:

Röse in Germany and Förberg in Sweden have made extensive investigations as to the condition of the teeth of the children. They both state that the children who live in localities in which the soil and water are rich in calcium salts have teeth which are well formed, are hard, and have little caries, while the inhabitants of communities in which the soil and water are poor in calcium salts have poorly formed teeth, which are very prone to caries.

Those who recall the literature of that period will remember the controversy between Rösé and Black over this question of the relative density or hardness—meaning calcification—of the teeth, and it will not be referred to here in any detail, but it seems necessary to emphasize the findings of the present investigation, as having determined that, given teeth of about the poorest quality imaginable so far as the enamel is con-

cerned, this quality of enamel seems to occur in the greatest possible proportion in localities which show the *highest* lime content, and also occurs in relatively as high proportion when the water is *very low* in its lime content. In other words, the enamel is equally badly calcified in the endemic districts, regardless of the lime content of the waters.

(To be continued.)

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## Prophylaxis at Different Ages.

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By J. SIM WALLACE, D.Sc., M.D.Glas., L.D.S.Eng., London.

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(Report to Section IX, Sixth International Dental Congress, London, 1914.)

### INTRODUCTION.

IT is generally admitted that the beneficent results of dental treatment are so great that the huge amounts of money spent annually for this purpose are amply justified. Nevertheless the expenditure of money on the treatment of dental diseases ought soon to be almost wholly unnecessary, because we now know full well how dental diseases may be prevented. Moreover, treatment is not always perfectly satisfactory in itself. If the causes which render treatment necessary at any particular time are allowed to continue, re-treatment is almost inevitably required annually. Furthermore, treatment alone does not keep a mouth in a hygienic state, and the evil results of oral mal-hygiene may continue even after treatment unless preventive measures are initiated. With regard to the treatment of the teeth of adults, it is often found that nothing short of the wholesale extraction of teeth can be done to relieve the sufferers from certain dental and consequent diseases. So much so, indeed, is this the case that one of the

first recommendations which a fashionable physician makes is to have all the teeth taken out of the mouth. Things have come to such a pass for want of early preventive treatment that frequently this is the only satisfactory method of procedure. For these and many other reasons it is easy to see that treatment is, compared with prevention, relatively most unsatisfactory. Even among school children it has been found that the restoration of the teeth to anything like a physiological standard is, except among the wealthy, at present a hopeless dream. Where accurate statistics have been taken, children at the age of five entering school have been found to have more than six decayed teeth, and, as has been pointed out, "It is quite impossible by treatment afterward to remedy this most disastrous start in life."\* We may say that views such as these are now officially recognized. Thus Sir George Newman in his annual report for 1912, as chief medical officer of the Board of Education, says:

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\* J. Wheatley, M.D., "Health Report, 1912, County of Salop."

## An Investigation of Mottled Teeth:

An Endemic Developmental Imperfection of the Enamel of the Teeth,  
Heretofore Unknown in the Literature of Dentistry.

By FREDERICK S. McKAY, D.D.S., Colorado Springs, Colorado,

IN COLLABORATION WITH

G. V. BLACK, M.D., D.D.S., Sc.D., LL.D.

(Continued from page 792.)

### ( IV. )

#### EXAMINATION OF CERTAIN LOCALITIES IN ARIZONA.

Starting, as the investigation originally did, with one known afflicted community, it has been with an increasing interest that we have watched the boundaries gradually widening and extending until, up to the time of the examination in Arizona, several distinct localities had been outlined in one state, and districts had been located in two other states and one foreign country. Another very curious phase has been the roundabout way in which the first information of these new districts often has been brought to the attention of the investigating committee. In just such a way did we come to consider certain districts of the above state as worthy of investigation, and we are indebted to Dr. H. H. Wilson of Phoenix for bringing the matter to the attention of Dr. Black, who promptly notified our committee.

Through Dr. Wilson the writer was put into communication with Dr. W. G. DeVore of Tempe, Ariz., and through his interest and co-operation arrangements were made for the examination of this territory early in January 1915.

Through Dr. DeVore's familiarity with this territory it was established beyond much doubt that the most concen-

trated endemic areas were at the towns of M—, Ariz., and F—, Ariz., but scattering cases were observed that originated at T—, Ariz., and at P—, Ariz., both of which places, although adjacent to and in the same general district with these other afflicted districts, must be considered as of low endemic percentage. In fact, there may be some question as to whether the last-named place is afflicted at all.

Regarding T—, just mentioned, Dr. DeVore states that the cases seen there had originated in those rural districts which are situated in the worst alkali belts. The city water system is about seven years old, and the water is pumped from a 300-foot well. The evidence gathered there seemed to make a detailed examination of the children not necessary. Accordingly, our interest was centered upon M—, about seven miles to the east.

#### *Examination of M—, Ariz.*

The Salt River Valley, in which both T— and M— are located, is one of the most productive and fertile irrigated districts in the country. Such products as cotton, the citrus fruits, alfalfa, and grains are raised in abundance, and to all visible appearances the two districts are similar, being bordered

by the typical Arizona desert just beyond the irrigated areas. The mountains are not closer than, I should judge, about thirty miles. The climate in the winter months is delightful and the land is bathed in unclouded sunshine from day to day.

Fig. 21 is one of the most pronounced cases of marking of the entire denture that I have ever observed.

The subject is a male, age twenty-one. He was born on a ranch just outside the town, upon which he has lived continuously until within the past year. The sole source of water for domestic use was from a sixteen-foot well. As is rarely seen, the lingual surfaces of

FIG. 22.



the upper incisors were also stained; the lower incisors were also stained, and even the first molars, which latter must be regarded as a most unusual manifestation of this lesion. The enamel on all these teeth was very imperfect, being badly pitted, particularly on the molars and bicuspid.

Fig. 22 shows another typical case indigenous to M—. His history in detail is not known.

An examination of the children in the public schools was made, Dr. DeVore assisting, and 565 pupils were seen. At the high school, with an attendance of 165, we observed 70 natives, of whom 19 were afflicted and 51 not afflicted, giving an endemic percentage of 27 in this school. The grade school, with an attendance of 400, showed 158 natives, of whom 93 were afflicted and 65 not, showing 59 per cent. of endemicism.

A brief analysis of conditions is necessary to bring out the significance of these figures.

In examining the younger children we were met by an increase in the endemic findings. In other words, this dystrophy seemed to be on the increase in the younger children.

A curious expression of this lesion was manifest here, which was dissimilar to anything heretofore observed in the many children examined in the various localities, as previously recorded, in that, in a surprisingly large number of these younger children at M—, the first group of the permanent teeth, namely, the incisors, cuspids, and first molars, had developed normal enamel, but the second group, the bicuspid and second molars, showed a distinct and sometimes a pronounced mottling of the enamel. I am speaking, of course, of native children, but this peculiarity exactly corresponds to that class of cases to which attention has previously been drawn, namely, those children who had lived in non-endemic areas during the formation of the enamel of the first group of teeth, which of course was normal, and who, later removed to endemic territory, exhibiting mottled enamel upon the bicuspid and second molars when these teeth erupted. Recalling now the lesser degree of prevalence of this condition in the older pupils in the high school, one is forced to the conclusion that some influence has crept into the environmental conditions of this community between the time of the formation of the enamel of group I and group II of the permanent teeth of many of its children.

It must be taken into consideration, also, in this connection, that the data presented herein is incomplete, and the statement of the percentage of these younger children is erroneous in that as we approached the lower grades there were necessarily an increasing number of temporary molars present, hence the condition of the bicuspid could not be observed, and the second permanent molars had not erupted. There is no question that many of such children who

at present show normal enamel upon incisors and first molars would later be found to have mottled enamel upon the bicuspids and second molars when they erupt, thereby raising the endemic percentage of the community.

The only condition observed that could possibly seem to account for this mysterious peculiarity was the fact that about four years ago a city water system was installed, and yet the cases were about equally divided between the town and the country, and many of the town children are still using well water. The wells are from 40 to 50 feet deep, while the city system is pumped from about 300 feet below ground. A large part of the food supply is produced locally. Some curious migrations were noted, one case in particular; the history is as follows: Born in A—, in Texas, an endemic district already described, he removed at the age of two to L—, Colo., another afflicted district, remaining there until six, then coming to M—, Ariz., the place where found. It looked almost like a deliberate selection of one endemic district after another, and it is little wonder that this child bore the typical marks upon the teeth. Others were seen who had lived in other of the known afflicted districts, and these cases were to be charged against the respective districts.

In considering this subject during the years past, the question has often arisen as to whether any of the Indian tribes which have inhabited this western and southwestern portion of our country had ever been found to have this lesion. Some few years ago the United States Government maintained an Indian school at Grand Junction, in Western Colorado, and Dr. Geo. R. Lindsay, then practicing in that city, reported to the writer that he had observed it among them. After this school was discontinued the pupils were scattered over various parts of the country, some sent to other Indian schools, and others to the various tribal reservations, so that it seemed a large undertaking to secure data upon the point in question. Consequently, when it was made possible through Dr. De-

Vore's kindness and co-operation to visit the United States Government Indian School at Sacaton, Ariz., it was an opportunity eagerly seized by the writer.

*Examination of Indians at Sacaton, Arizona.*

Here are gathered the Indian children and young adults of the Pima and Maricopa tribes, and through the kindness of the chief medical officer in charge of the various Indian schools of the country, Dr. Joseph A. Murphy, the resident physician Dr. Sims, and the superintendent in charge, we were accorded every courtesy in making the examination. We succeeded in examining 50 boys and 101 girls, and of these 151 individuals every one showed this lesion in some degree, and many of the cases were as pronounced as any that have been observed during this whole investigation. One of these Indian boys is illustrated in Fig. 23.

This case is among the most pronounced ever observed by myself. The illustration gives hardly more than a fair idea of its condition. The entire denture is of the mottled and pitted character and must inevitably break down in decay at several points unless radical and thorough treatment for the obliteration of this pitted and defective enamel is instituted.

When one looks through the mouths of more than 150 of the inmates of this school, as did Dr. DeVore and myself, and finds every one of this number similarly afflicted, case after case being observed fully as bad as this, his amazement is hard to describe, even to dental readers.

Never before had such a uniformity been observed, so far as this lesion is concerned, and never before had so large an aggregation of afflicted individuals been assembled at one time and place. The great value of this find at Sacaton is apparent when we consider that we have here a group of individuals, all of the same racial characteristics, same environment, same habits of life, same kind of food, using the same kind of

water, in fact living under as near precisely the same conditions as it would be possible for a group of individuals of that size. They had all been born and reared in a collection of Indian villages located on both banks of the Gila River, and all located in a strip of territory not over ten or twenty miles long up and down this river. They had always lived right there, and had scarcely ever been more than a few miles away from home. The Pimas have been a peaceful tribe and have farmed the river banks by means of irrigation, the surrounding country being absolutely an arid desert.

These Indians never dig wells, but use the water direct from the river or from the irrigating ditches; they may scoop out a shallow depression in the sand on the river bank, and use what water collects therein. They produce practically all of their food supply, and rarely if ever use milk or butter. Most of their cooked food is boiled. The fact that Indians use no milk compels breast-feeding of their infants. Certainly, it would be hard to conceive of a bottle-fed Indian infant. This fact disposes at once of the attempt sometimes made to associate this lesion with bottle-feeding during infancy. It also is in direct contradiction with Röse's idea that "calcification"—presumably of the enamel—bears any direct relation to bottle-feeding in infancy.

Digressing for a moment, I wish to bring out the fact that in no group of children have I ever observed more pronounced cases of malocclusion of the teeth than among these Indians, and I wish—in the light of what has just been stated regarding the total absence of bottle-feeding among the Indians—to respectfully direct this fact to the attention of those writers who believe that bottle-feeding in infancy bears a causative relation to malocclusion.

I will state also that in this group I recollect no cases that exhibited a mouth-breathing or tonsillar etiology in reference to the type of malocclusion. In other words, they seemed to be all in class 1 of the Angle classification.

Time did not permit any examination of adult Indians for the enamel lesion, but two adults were observed, both of whom showed a slight marking. It is not unlikely that the vigorous use given the teeth up to adult life would have worn off most of the superficial layers of imperfect enamel.

The discovery of this lesion in adult Indians on the Pima reservation raised the very interesting question as to what proportion of adults were thus afflicted. A question arose as to whether placing the children in the government school at Sacaton had brought them under some peculiar influence which had resulted in the general prevalence of mottled enamel, and whether the previous generation in the original habitat had escaped.

To answer this inquiry the resident physician, Dr. Sims, examined the first consecutive 100 adults, and reports as follows:

Of 53 men and 47 women I found both conditions—mottled enamel and brown stain—to exist to some extent in all. Of those examined none were under forty-seven years, and in many cases the approximate age was seventy-five. My observation leads me to believe that the civilization of the Pimas has little or nothing to do with these conditions.

It is significant that the Pimas have lived in this same locality for many years, and it has been the source of comment that they have succeeded in forcing a living for so long out of a region so absolutely barren and desolate.

Further testimony from Dr. Sims regarding his observations at the Pima reservation are of interest. Speaking of American families now resident there, he says:

There are three American families who have been here continuously for thirteen, ten, and nine years respectively. The teeth of all these adults are normal. One of the families has four children, ages eleven, eight, five and one-half years, and six months respectively. The eldest of these children was born in the vicinity of Fort Apache, Ariz., and came here when nine months old. The other children were born here. The eleven-year-old child has the brown stain and mottled enamel, also the enamel is pitted in many places just as many

of the Pima children's teeth are. The eight-year-old child has only four permanent teeth. There is a trace of brown stain on the teeth, also the chalky white or mottled enamel is evident, but neither condition is so pronounced as in the older child.

For purposes of this study this eldest child can be classed as a native of the Pima reservation, although there is some evidence to show that her birthplace was in an afflicted district (Fort Apache). Such damage as has occurred to her teeth can undoubtedly be laid to the residence at the Pima reservation.

Here is additional evidence going to prove that the existence of this lesion depends upon one thing and one only, namely, residence in an endemic district during the time of enamel growth, and disregards all other factors, including nationality.

Dr. Sims further continues:

These conditions do not show on the temporary teeth of the Pimas or Americans. My opinion is that the chalky-white or mottled enamel is caused by some metabolic process before the eruption of the permanent teeth, as many of them show the mottled enamel before fully erupted. Later on, the brown stain appears, and by the time dentition is completed the stain is fully developed. As far as my observations go, this condition does not become more pronounced during adult life. I am of the opinion that both conditions—stain and mottling—are due primarily to the water, but this is merely an opinion without a scientific foundation.

All Indians [Pimas] get their water from surface wells and irrigation ditches. The water is highly impregnated with various inorganic salts, and for this reason the water from many wells cannot be used at all.

Some of these latter statements are inserted merely as corroborative of what has been stated elsewhere in this paper.

Just preceding the writer's visit to the Pima reservation in January 1915, one of the field dentists in the Indian service, Dr. F. E. Rodriguez, had upon his first official visit to this reservation noted this condition of the teeth, and had officially brought it to the attention of the Indian Office by a descriptive letter which was included as a part of

a paper which he presented at the Panama Pacific Dental Congress at San Francisco in September 1915. His description of this lesion agreed in detail with that given early in this paper.

Having noted this condition for the first time at the Pima reservation, Dr. Rodriguez thereafter in his tour of duties among the various other Indian tribes of the Southwest made careful examinations, and I am privileged to present the results thereof in this article as follows:

*The Pimas.* During the course of my duties as field dentist I had occasion to examine 1300 Indian children at that particular reservation, and about 1000 adult Indians. Of these children about 1200 were affected, the lesion varying in degree as to intensity. As the first symptom noticed is a white, chalky appearance either in the erupting or already erupted permanent tooth, I have classified such as "stain" because this mottled surface seems to be the precursor of the eventual stain in some degree.

Among the adult Pima Indians the enamel lesion is present in about 80 per cent. of all observed. The intensity of the discoloration apparently does not increase with age, since I have observed the worst cases in all persons ranging in age from twelve to forty-five. Although a large percentage of young children are found whose teeth are already deeply pigmented, I believe that they are the minority, and that the average child only presents the mottling if the teeth are in the period of eruption, or if already fully erupted a faint yellowish stain.

*The Papago Indians* (near T—, Ariz.). Among the Papagos the stain is not very prevalent, considering the conditions found among the Pimas. It is present, nevertheless, in about 30 per cent. of all examined.

*The Mission Indians* (Southern California). From reports the Mission Indians are affected. Although personally I have not visited that territory, I have examined Indians born in that section. My inquiries among several Indians disclosed the fact that there is a district located about 60 miles from San Diego known as Warner's Ranch. This until a few years ago was the residence of many Indians. All born there have the stain. They have recently moved to P—, and it is a noticeable fact that the newborn do not present the stain. Warner's Ranch is the location of a sulfur spring.



The following is a *résumé* of my observations:

(A) The Pima Indians, occupying the southern part of Arizona, are the worst affected of the Indian tribes I have examined. The stain is prevalent in 100 per cent. of those children born and living around the headquarters of the government agency, and diminishing in extent or prevalence away from this point. The eastern section of the reservation is the least affected, falling in percentage as low as 10 per cent., and traveling either in a northern or western direction the percentage of prevalence gradually diminishes to about 30 per cent. One of the extreme borders of the reservation, located about 13 miles from P——, Ariz., and about 50 miles from the headquarters, does not show the condition unless the parties were born at or near the affected area within the reservation.

(B) Of 1300 children examined and originating in different points 1200 were found affected. Of this figure about 85 per cent. were very young children, the age ranging from five to twelve. Careful examinations of the permanent organs in the process of eruption disclosed an already mottled appearance of the enamel. Besides observations of thousands of teeth partly erupted, I carried my investigations into the conditions presented by permanent organs whose crowns were fully formed but unerupted, the majority having the deciduous still *in situ*. Whenever conditions justified the extraction of any temporary teeth, or other opportunities presented of observing the unerupted crown still in its formative wall, or well ahead in its course of eruption but not subject to outside influences as yet, in every instance, running into the hundreds, the mottled appearance was pretty well established.

(C) A weakening of the enamel structure, occurring as well-defined pits, generally on the labial surface, which seems to be the most affected portion of the tooth crown in the average case, and presenting well-defined disintegration of enamel prisms, has been noticed in a small percentage of the cases. As a rule the stain is not productive of premature decay. My belief on this point is due to the fact of having observed innumerable cases in adults who had had the stain for a lifetime, but who otherwise presented a sound, strong, and apparently healthy denture.

(D) That the stain is associated with the presence of ferruginous or sulfurous waters is quite well established. Analyses of the water supply show this fact. People living in the neighborhood of hot springs, irrespec-

tive of race, have the discoloration to the greatest extent. How the pigmentation occurs, whether by direct infiltration through the pulp tissues or by contact of the crown enamel with the surcharged tissues, remains to be solved. The chemical character of the stain, in my territory, has not been examined, due to lack of opportunity in securing specimens. As the teeth examined, although deeply stained, were otherwise sound and healthy or could easily be restored to usefulness by simple operative procedure, during my tour of duty I was not afforded the opportunity of obtaining a single one for examination. It would be against the established rules of professional ethics to recklessly proceed to the extraction of an organ of this character, although the end in this case would justify the means. Nevertheless, I found myself always loath to do so.\*

(E) Among the thousands of cases I have observed, not a single instance was seen where any of the teeth of the deciduous dentition were affected to any degree. It is purely confined to the permanent organs in all cases and under all circumstances. Wellings claims, and has proved by his experiments, that the circulation through the pulp can influence the tooth tissues to a great extent. By means of certain dyes he showed the penetration of foreign substances as far as the enamel layer through the circulation, claiming that—"Enamel takes a very brilliant color, which subsequently fades as calcification progresses." Although this does not exactly apply to this condition, which as a matter of fact is the reverse so far as the onset of the coloration is concerned, nevertheless his experiment is of value, since it shows the possibility of foreign agents gaining an access and depositing within the enamel and dentin. This may also elucidate why the deciduous teeth are so remarkably devoid of the stain, due to their transitory structure and poorly organized blood supply. But even so, why is the agent deposited as a rule on the labial surface and not uniformly around, as would be expected? Professor Pickerill demonstrated conclusively the remarkable porosity of enamel, especially in unerupted teeth, in his experiments of staining by simply rubbing silver nitrate and graphite against the surface. I believe these are valuable data which have undoubtedly been looked up, and which bring up two important questions:

(1) Is the stain acquired through simple

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\* See data bearing on waters in this article.—F. S. M.

contact of the crown surface with the surcharged (?) tissue fluids? or

(2) Is it—the staining agent—brought within the tooth tissues through the medium of the tooth's blood supply?

Dr. Rodriguez indicates his intention of still further examining Indian tribes on other reservations, and his findings will be anticipated with interest.

*Examination of F——, Ariz.*

This was the last community examined by the writer in that locality, and 185 children were seen in the public school. Of 101 natives, 87 were afflicted and 14 not afflicted, making an endemic percentage of 86. No facts were observed here that would assist in any conclusion.

Summing up the survey of the entire district, it can be stated that three localities of high endemicism were carefully observed, M—— in the Salt River valley, and F—— and Sacaton in the Gila River valley. Cases were found from a few other places in the first-named valley, but many were observed which had originated in communities scattered from one end to the other of the Gila River, and it can safely be asserted that this water-course, from its source to its outlet, constitutes, thus far, the most extensive district of possible endemicism yet outlined. Were this valley well populated it would, I believe, be a continuous afflicted territory from source to outlet.

Neither is there any question that, considering the wide distribution of the cases, almost the entire desert region can be viewed as one of endemic probability, lacking only the population with which to demonstrate it.

Other cases also were seen which extended the margins of the susceptible territory into old Mexico. Mexican children living in the territory which has just been described were found to be afflicted practically the same as whites. Later reports indicate that the endemic area follows the Gila River to its union with the Colorado.

In "New Trails in Mexico," by Carl

Lumholtz, M.A., published in 1912, we find in a description of the Mexican settlement, Sonoita, located on the Sonoita River in northwestern Mexico, only a few miles south of the Arizona line, the following interesting reference: "With many of the Indian children [in an Indian settlement of about a hundred living about a mile down the river below Sonoita] it was noticeable that the four upper front teeth were chocolate-colored, no doubt on account of the water. It appears that the coloring does not take place until the second teeth come. Some of the Mexican children [evidently at Sonoita] were disfigured in the same way."

This author also speaks of mineral salts evidently; he says that "carbonate of soda," which occurs in the soil, gives the agriculturist in that vicinity some trouble. We can infer from this that the country is what is commonly termed "alkali."

After the examination at Sacaton Dr. Joseph A. Murphy, medical supervisor of the United States Indian Service, issued instructions to the field dentists in the service to examine and report on the prevalence of this lesion among the Indians at the various other schools throughout the country.

Through the interest of Dr. Murphy I have been enabled to include the following reports from the field dentists in this paper:

Dr. Wm. J. Lanahan reports that—"Of 145 children examined at St. M——, Ariz., 18 are afflicted with mottled enamel. This condition," he says, "does not exist among the Navajo children, and is confined to the Papago children who are attending this school." The homes of these latter were distributed over what is termed the "Papago country," extending from Tucson to the Mexican border and beyond. This is practically the same territory in which the Pimas are found, and this finding in Dr. Lanahan's report serves to emphasize that the whole region which is embraced in the Papago country bears a high endemicism.

Other reports received from various

other sections contained nothing conclusive, except that such sections are not endemic, so far, at least, as the Indian population is concerned.

A very interesting observation was made by Dr. Murphy himself on the Salt River reservation, which is just north of M——, which town was examined and is described in this paper. He found there 100 per cent. of inmates of the school afflicted with this lesion. "These Indians," he says, "were practically exclusively Pimas, and their water supply either rather hard alkaline water from surface wells (20 ft.) or river water from the Salt River, which itself is rather salt, as its name implies. About 25 miles north of the Salt River reservation, at Camp McDowell, there is a band of 200 Apache Indians, or, more correctly speaking, Mojave-Apaches. The river water from the Verde River, which flows through their district, is sweet, and the water is fairly soft which they obtain from their wells."

Then this significant statement by Dr. Murphy relative to these people: "There was not a single case of this lesion found among the native children."

Here are two exclusively Indian populations residing only 25 miles apart, one of which shows 100 per cent. of affliction and the other is absolutely immune. Can the water at Camp McDowell, which Dr. Murphy classes as "fairly soft," be accountable for their immunity? If so, why do the cities of L—— and X—— (as previously described), which use a very "soft" water, exhibit endemic percentages of about 90? Recall also the very pure water from the Sigle ranch, and yet the Sigle children were very typically marked.

The fact is that the inhabitants at Camp McDowell were outside the confines of this amazingly mysterious influence, while those at Salt River reservation were within it.

Dr. Murphy also cites one girl who had come from the Papago district to Camp McDowell a few months previous, who bore on her teeth the typical marks of the lesion which we have found to operate so consistently and unfailingly

upon natives of that district. This is but another bit of evidence which goes to prove that the "rule" which was laid down in the early part of this paper operates with almost mathematical exactness.

#### FURTHER REPORTS UPON THE PREVALENCE OF MOTTLED ENAMEL AMONG THE INDIANS.

Dr. Harry L. Hale, field dentist in the Indian service, reports that—"From examination of the pupils of Cushman school, Tacoma, Wash., out of 315 pupils examined 141 were found to have mottled enamel, and in perhaps two-thirds of these cases the brown stain was present. All of these pupils have lived in Washington, in Oregon, a few in Idaho and Montana, and a few in Alaska."

Out of 177 pupils at Tulalip school, mottled enamel was found in 73, and in the majority of these the brown stain was present. These pupils have lived all their lives on the Tulalip reservation on Puget Sound.

Dr. Murphy reports that at Truxton Canyon Indian school (Valentine, Ariz.) of 90 pupils examined, 14 had mottled enamel, but only a few of these had the brown stain. The brown stain cases were typical, but the mottled enamel was not as characteristic as that among the Pimas. [It would be of interest to know where these children were raised. —F. S. M.] Also at Fort Mojave school, Mojave City, Ariz., he found a number of cases of the white mottling, and only one or two cases of the brown stain.

Dr. Geo. O. Newton, field dentist, reports that of 40 pupils examined at St. Mary's school on the Rosebud reservation in South Dakota, 2 had the brown stain and 8 mottled enamel. Also on examination of 241 pupils at the Rapid City boarding school, Rapid City, S. D., he finds 20 cases of mottled enamel, and brown stain in five cases.

This additional data is interesting in that it extends the distribution of this lesion into territory in which no thought of its occurrence had previously existed.

It is noted, however, that the intensity of its occurrence in these various other Indian populations bears little resemblance to its uniform prevalence among the Pimas.

Notwithstanding all that has been written concerning the non-vitality of enamel, and emphasizing the fact that when the teeth are thrust into the mouth the enamel is absolutely a finished and completed structure, there are still those who believe that this tissue is vital, and capable of still undergoing nutritive and other changes. Such arguments applied to the problem we are studying would seek to prove that the brown stain could be the result of absorption or metabolic processes in the enamel. Such a conclusion is unthinkable to the writer, who feels that his position is strengthened beyond assail by various authorities among writers in dental histology. For instance, Noyes says, in "Dental Histology and Embryology"—"The enamel is produced by epithelial cells, which are lost and destroyed after the tissue is completed. Any such thing, therefore, as a vital change in the tissue is biologically unthinkable. After the enamel is formed it can be changed only by chemical and physical action of its environment."

Broomell says, in his "Anatomy and Histology of the Mouth and Teeth"—"As soon, however, as the tooth passes through the surface tissue, carrying with it the external epithelium of the enamel organ as the enamel cuticle, the possibility of nourishment has been cut off, and after a little time it becomes a petrified dental epithelium, no longer nourished, and absolutely non-vital."

Williams says, "No physiological change, therefore, is possible in completely formed enamel." (Cosmos, June 1896.)

In inquiring, also, as has often been done, into a possible relation which might exist between this enamel lesion and some corresponding lesion in bony development, among natives of the endemic districts, it is probably true that there has not been a clear differentiation between the processes of enamel and

bone formation. Noyes makes it clear in Chapter III of his text-book, in the following words:

The enamel is the only calcified tissue derived from the epithelium. All other calcified tissues are connective tissues. Histogenetically, then, the enamel is ultimately derived from the epiblastic germ layer, while all other calcified tissues arise from the mesoblast. Thus, even at the first step in the differentiation of cells, the enamel is different, and independent from bone, cementum, or dentin. It is natural, therefore, to find the enamel differing from bone in every other respect. On the other hand, the relation of the enamel to the epithelium becomes more and more apparent. For instance, imperfections in the structure of the enamel during its formation are most likely to be produced by systemic conditions which affect the epithelium.

Quoting again from the same author, he says:

All other calcified tissues are formed by connective tissue, and remain in vital relation with connective tissue of undifferentiated character. Bone and dentin matrix are therefore simply calcified intercellular substances containing living cells in the spaces of the matrix, which maintain its chemical quality. A change in the character or amount of the matrix might possibly, therefore, be brought about by the vital activity of these cells. Moreover, the formed matrix is always in vital relation with undifferentiated connective tissue, which may at any time destroy or rebuild it. There is therefore no basis for comparison between pathologic conditions of bone and enamel.

We may therefore conclude that the existence of this lesion of the enamel does not in any way imply any similar correlated bony lesion.

Having reviewed the investigation from its beginning up to the present time and set forth the various facts which have been brought to light, we return again to the question of *water* in an attempt to arrive at some sort of finality of decision which can at least be used as a starting-point from which to continue the investigation in the future.

Water analyses of the principal endemic areas have so far as possible been collected, and these have been inserted

in the paper at the places where the districts were described, that they might be studied in relation with the text.

For convenience of comparison, the most notable of these analyses are now inserted, so that a brief comparative study may be made.

the analysis obtained at L—— (see last column), this theory seems to be completely overthrown.

Another theory was that the brown stain was considered to be of iron origin, and hence could be associated with water heavily charged with this element.

TABLE OF ANALYSES OF WATER FROM ENDEMIC DISTRICTS.

*Given in parts per million.*

Constituents. (Ions.)	Mine water at V——.	Lawson ranch well water.	Scholes' well.	Mine water at E——.	Sigle ranch spring.	City water at L——.
Sodium . . . . .	276.77	207.80	242.70	37.12	} 11.05	3.20
Potassium . . . . .		3.35	6.44			
Calcium . . . . .	89.75	31.80	33.31	74.40	21.32	5.70
Magnesium . . . . .	27.36	37.75	33.60	16.71	5.41	1.70
Iron . . . . .	nil		3.35	trace		} .49
Aluminum . . . . .	2.74			trace		
Chlorin . . . . .	47.37	31.00	51.00	14.17	8.31	7.29
Sulfuric acid . . . . .	651.49	142.40	250.00	104.66	46.80	7.10
Carbonic " . . . . .	216.78	615.00	530.00	239.60	22.80	15.30
Silicic " . . . . .	16.68	21.65	18.12			7.50

There are several interesting things to be seen in a comparison of these figures. In no way could the first column be said to be similar to the last, and yet the endemic percentage in both these places is very high, as previously recorded—100 and 87.5 respectively.

The theory has many times been advanced that mottled enamel might be caused by a lack of lime in the water. V—— has 15 times more lime than L——, yet the enamel is worse there than at the latter place.

The most uniform feature of these waters is the high content of the salts of sulfuric and carbonic acids, as instanced in the first four columns, and for a time it was thought this might prove to be a causative factor, but from

Physiological facts would discredit this, but it is rendered null and void by the fact, as shown, that these waters are all low in iron content, and that at V——, where the lesion has an extreme manifestation, it has not a trace of iron.

Comparison of these with the water from the Cummings ranch, which has been shown to be in immune territory, can be made by referring to page 635.

The question of radio-activity as bearing a causative relation has been advanced, but so far seems to be a negative factor. No definite inquiries have been made, but certain districts declared to be high in radio-activity of waters have never been reported as being endemic to this enamel lesion. The question cannot, however, be considered closed.

Many other analyses of waters from endemic districts have been secured, but their inclusion here would not add to the value of the paper. The most striking ones have been given.

Our complete Table of Analyses has been submitted to chemists for examination, and their opinions have been that no definite conclusion can be reached from it. Notably, Professor Strieby of Colorado College declares that the analyses arrive at nothing, but are contradictory.

It is to be explained that these analyses as herein given were made according to the standard quantitative form.

There are present, however, in waters certain other elements of rarer varieties that exist only in traces, the determination of which requires much more elaborate technique and spectroscopic and polariscopic tests, which are beyond the capacities of the ordinary chemical laboratories. Strieby declares that in future chemical examinations of waters, the "standard" analyses should be abandoned, and the work confined chiefly to searching for "traces" of these rarer elements. In view of the contradictory evidence given by these "standard" analyses, it seems logical to assume that if the cause of this lesion is to be found in the water, it must be in the presence and influence of some constituent or

group of constituents heretofore undetermined.

Future work on this problem, then, must be in the more critical examination of the endemic areas already located, and the writer believes that with the collection and presentation of the mass of evidence in this article the subject has passed beyond the strictly dental realm, and must now be examined from the standpoint of some collateral branch of science.

That the problem is a chemical one, there seems to be little doubt, but that it is also physiological is just as certain.

Noyes very well expresses the thought of future work in the following, having reference to this investigation: "Still more recently the investigation of dystrophies of the enamel occurring in certain prescribed localities showed perfect rod formation and entire absence of the cementing substance. These facts suggest the hypothesis that the enamel rods and the cementing substance have a different origin, or are formed by different cells, and that pathological conditions may prevent the formation of one and not the other. In view of these factors, it is very necessary that a new investigation of the process of enamel formation be undertaken, as present knowledge of the process does not explain such conditions." ("Dental Histology and Embryology.")

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