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ORIGINAL COMMUNICATIONS.

A CONTRIBUTION TO THE STUDY OF PATHOLOGY OF ENAMEL.

BY J. LEON WILLIAMS, D.D.S., L.D.S., LONDON, ENG.

(Read before the New York Odontological Society, January 12, 1897.)

(Concluded from page 301.)

IN a paper recently read by Dr. Henry Gerhart before the Pennsylvania State Dental Society, on the "Etiology of Dental Caries," he asks Dr. Black how he knows that this zone, seen far in advance of the bacteria, is the work of the micro-organisms. The answer, of course, is perfectly evident from what I have just been demonstrating. The zone is caused by the action of acids excreted by the bacteria. That is so clearly shown by many of the illustrations accompanying this paper, where the appearance is produced artificially as well as naturally, as to make further comment on the point unnecessary.

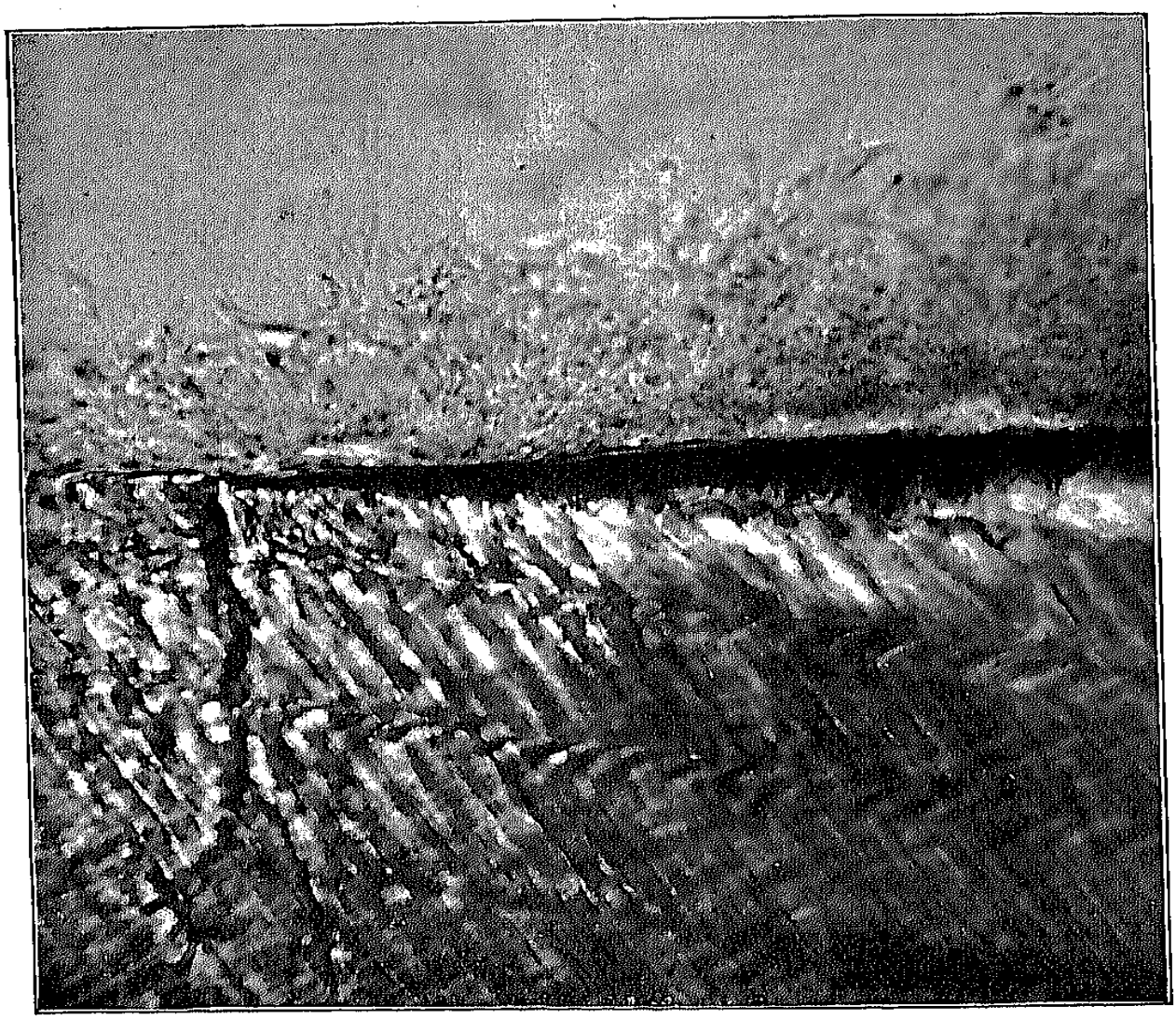
Fig. 69 shows bacteria attacking sound, well-formed enamel in the vicinity of a fissure into which no micro-organisms have entered, although the opening of the crevice is many times larger than the largest forms of bacteria. Throughout these investigations I have observed that the bacteria nearly always enter any fissures that may be present in backward, or what Miller calls "secondary decay" of enamel, while rarely entering any except very large fissures in direct decay.

In Fig. 70 it is seen that the acid has dissolved out channels between the enamel-rods and is splitting up the rods into their original formative sections for a considerable depth, and this effect is even more strikingly shown in Fig. 71, where the line of limitation between normal enamel and that penetrated by acid is very clearly demonstrated. The bacteria have been accidentally brushed out of the decayed spot in this specimen, but almost every phase of their action on the tissue is beautifully shown.

In Fig. 72 is seen the commencement of a cavity. In deeply pigmented and slow decay, such as is shown in this specimen, the acid penetrates but a short distance in advance of the point where the tissue is breaking down.

Fig. 73 illustrates one of the difficulties in making photographs of sections of this character. If sufficient exposure be given to bring out the detail in the deeply-stained enamel, the bacteria will often be so much over-exposed as to almost completely disappear. On the other hand, if the bacteria are stained, as in Fig. 74, and the

FIG. 69.



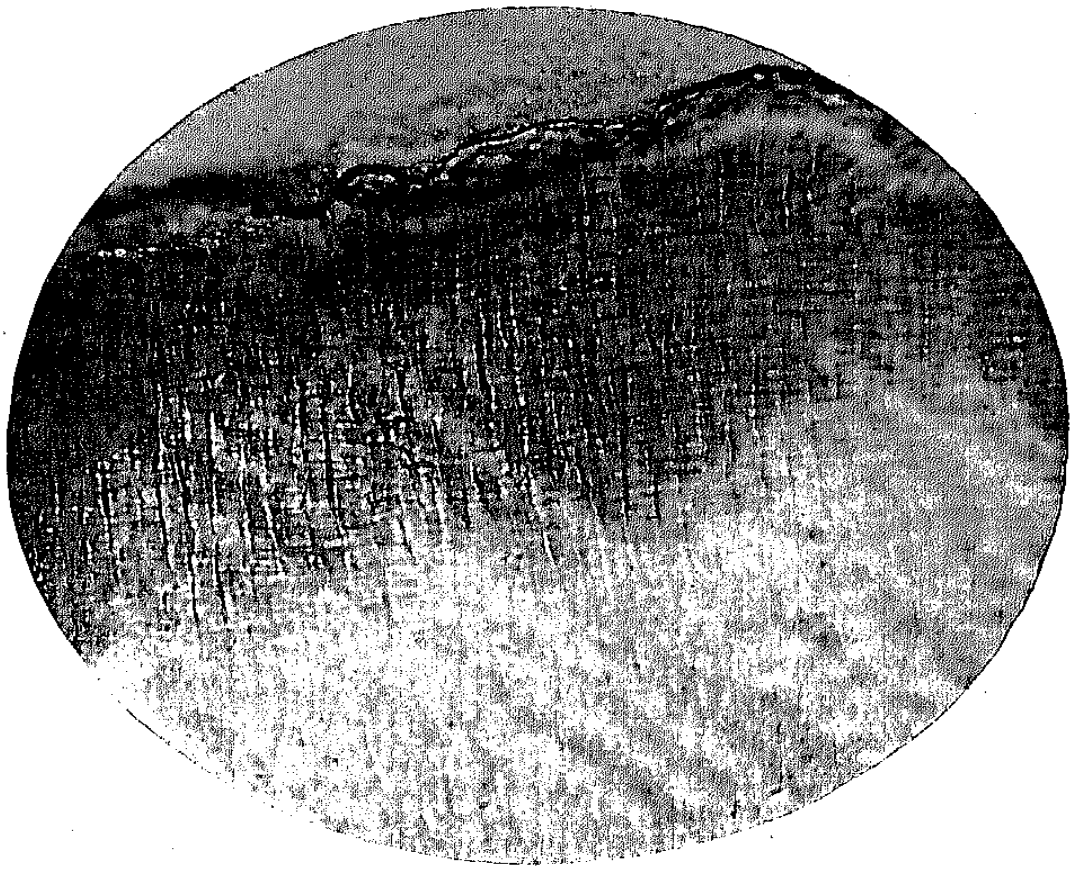
SECTION OF HUMAN ENAMEL, SHOWING MICRO-ORGANISMS DESTROYING NORMALLY FORMED TISSUE IN VICINITY OF FISSURE. × 500.

exposure made for the enamel, the deeply-stained mass of micro-organisms lying next to the enamel is much under-exposed. It will sometimes be found best to make two exposures, one for the enamel and another for the bacteria, and the two photographs, if properly made, will bring out all points. From the two illustrations which we have just seen we discover that the so-called granular layer of decaying enamel, which has been so often described, is simply a mass of densely-packed micro-organisms.

Fig. 75 shows the enamel nearly penetrated by decay. As is

usual in balsam-mounted specimens, the bacteria are slightly raised from the floor of the cavity. In this condition the micro-organisms are easily brushed away, and the appearances which are then shown are such as have led to the conclusion that bacteria are not directly concerned in caries of enamel. A curious and interesting phenomenon is shown in this and in the succeeding illustration (see Fig. 76). In both instances the bottom of the cavity, as shown, is bounded by a line of stratification of the pathological type, but in both instances the action of the acid of decay seems to have been arrested, at least temporarily, by this imperfection. The acid had probably penetrated along natural canals to

FIG. 70.



SECTION OF HUMAN ENAMEL, APPROXIMAL SURFACE OF BICUSPID. × 500.
Showing commencement of caries. Enamel-rods separated by solution of cement-substance and discolored by action of acid.

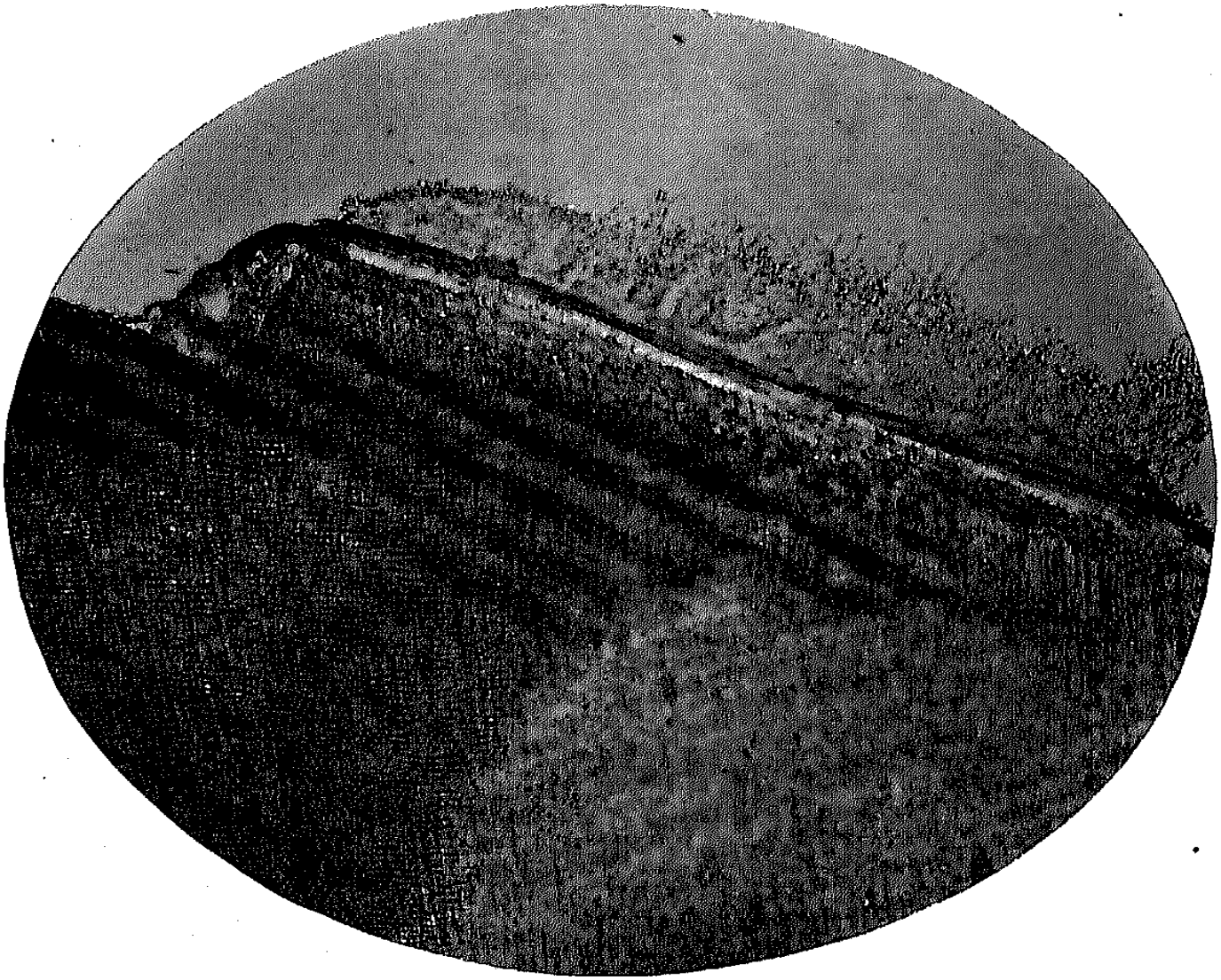
this point, and the termination of the canals here, or an abrupt change in their direction, has led to this temporary check in the penetration of the destructive agent.

In carefully-prepared specimens the ends of the enamel-rods at the borders of a cavity may always be seen sharply defined against the ever-advancing line of bacteria. From such appearances as are often shown at this point I have found that the destruction of enamel by bacteria is rarely accomplished by molecular disintegration, as claimed by Dr. Black, except so far as the cement-substance is concerned. The enamel-rods, as we shall see, break down in a more rapid manner because of their structural peculiarities. I should say, however, that this has reference solely to di-

rect or penetrating decay. In backward decay from the dentin it is probable that the enamel is largely destroyed by molecular disintegration, but this is because the loosened sections of the enamel-rods are prevented by the overhanging edges of sound enamel from being removed until they are completely dissolved.

In Fig. 77 we see the manner in which the enamel-rods are torn down at the commencement of decay by the solution of the cement-substance, which unites the sections of the rods and also the rods

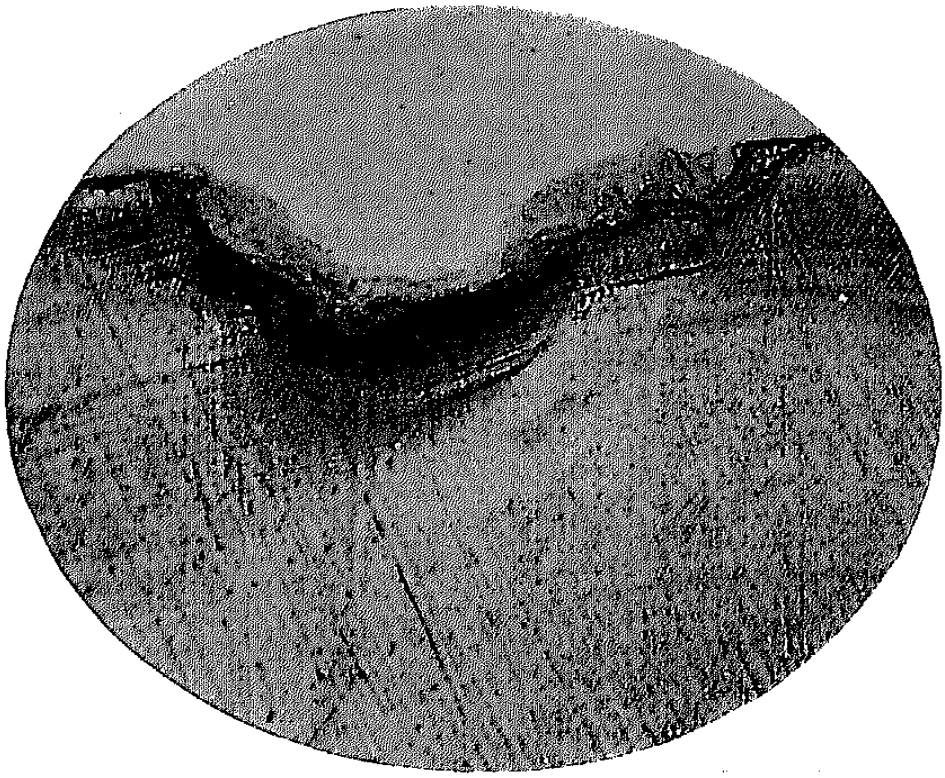
FIG. 71.



SECTION OF HUMAN ENAMEL, APPROXIMAL SURFACE OF INCISOR. × 250.
Showing micro-organisms of decay attached to the surface and marked effect upon tissue caused by the penetration of acid excreted by the bacteria.

to each other. The acid product of the bacteria, it is seen, has dissolved out the cement-substance between the rods for a short distance from the surface and is penetrating between the sections of the rods, several of which on the surface of the enamel are already loosened and falling away. As these sections fall away they are either completely dissolved in the mass of bacteria or are thrown out and washed away. The progress of direct enamel-decay, therefore, goes on, at least in many instances, much more rapidly than it would if the enamel were completely destroyed by molecular disintegration.

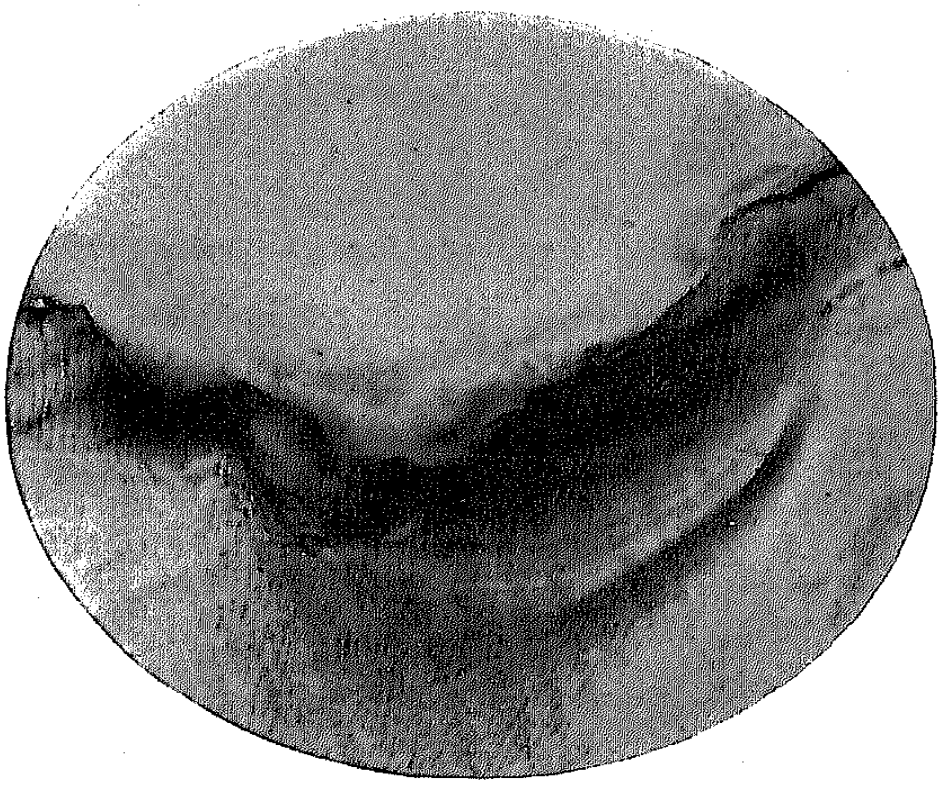
FIG. 72.



SECTION OF HUMAN ENAMEL, SHOWING COMMENCEMENT OF FORMATION OF CARIOUS CAVITY. × 200.

The cavity is everywhere seen to be lined by the felt-like mass of micro-organisms.

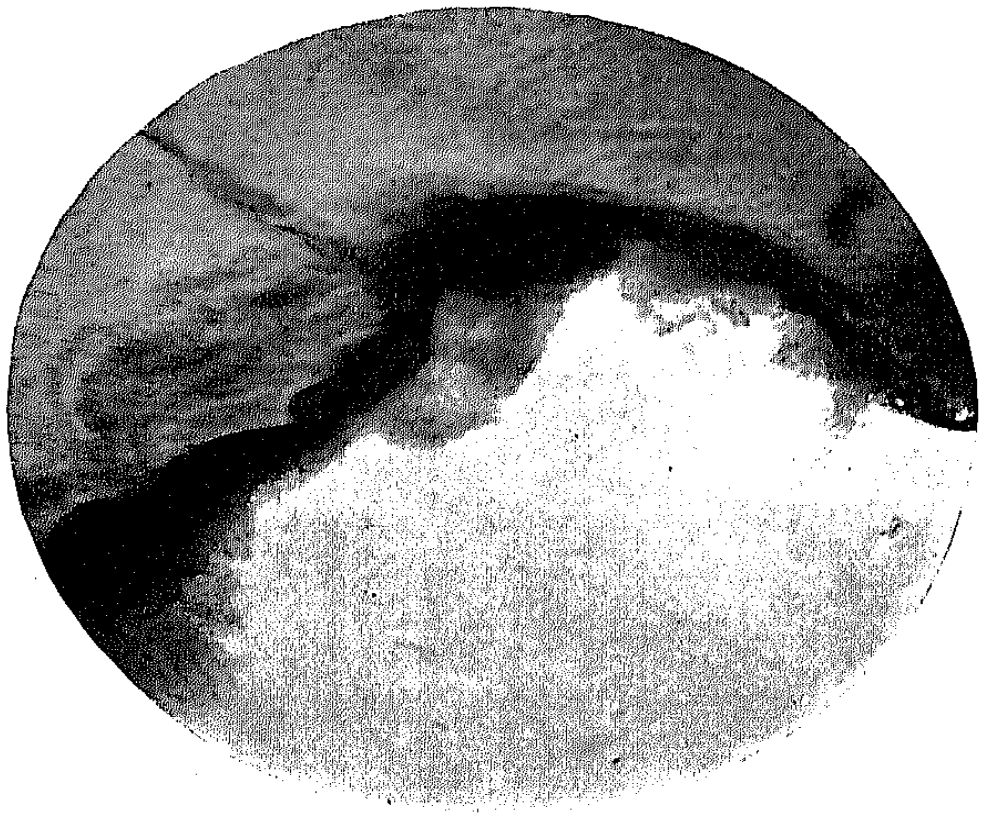
FIG. 73.



SECTION OF HUMAN ENAMEL SHOWING PROGRESS OF SLOW DECAY MARKED BY DEEP COLORATION OF THE TISSUE. CAVITY LINED WITH MICRO-ORGANISMS. × 250.

Fig. 78 shows this process going on in the deeper parts of a cavity which has nearly penetrated the enamel. The destruction of enamel in this manner may be compared to the method of tearing down a brick or stone building by the removal of the cement which binds the bricks or stones together. If we expose a section of enamel for a short time to a solution of lactic acid, we shall see that the effect is substantially the same as is shown in the mouth. From the illustration (Fig. 79) you observe the widening of the spaces between the rods and the separation of the rods into the original globular bodies of which they are composed by the solution of the cement-substance.

FIG. 74.

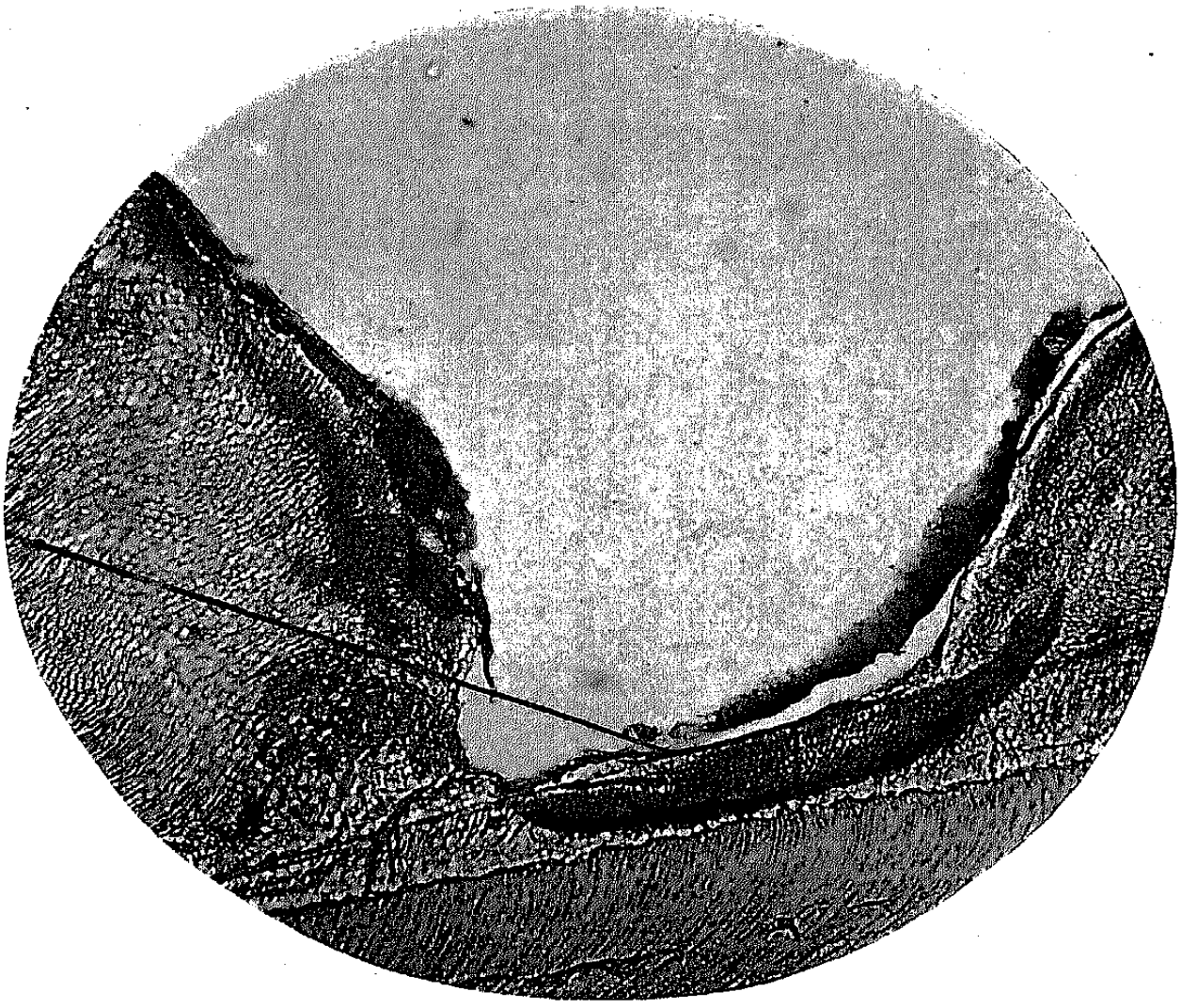


SHOWING CARIES OF ENAMEL. MICRO-ORGANISMS DEEPLY STAINED. × 200.

If, now, we carefully remove the bacteria from a few sections we may observe still more clearly the effects of their acid product upon the enamel. Although the appearances vary somewhat in accordance with peculiarities of structure (see Figs. 80 and 81), there are always to be seen the enlarged spaces between the enamel-rods and the separation or division of the rods into their formative sections. Fig 82, showing caries of enamel under a power of two thousand diameters, is a very instructive specimen from several points of view. The cement-substance is almost completely dissolved away, and the original organic matrix, the product of the ameloblasts, now, of course, completely calcified, is most strikingly exhibited. When this is compared with appearances which I have shown in and immediately beneath the ameloblasts in forming enamel, I entirely fail to see how any one can doubt the method of

the development of this tissue. There are many places where the organic connections, the radiating processes, which unite the globular bodies in each rod, and often those of contiguous rods, are plainly seen. Here is the full explanation of what has been called by the Heitzmann school "the return to an embryonal condition." But how different the processes by which this appearance is produced, and how different all the facts in connection with it from what Bödecker and Abbott have described. Their whole theory

FIG. 75.

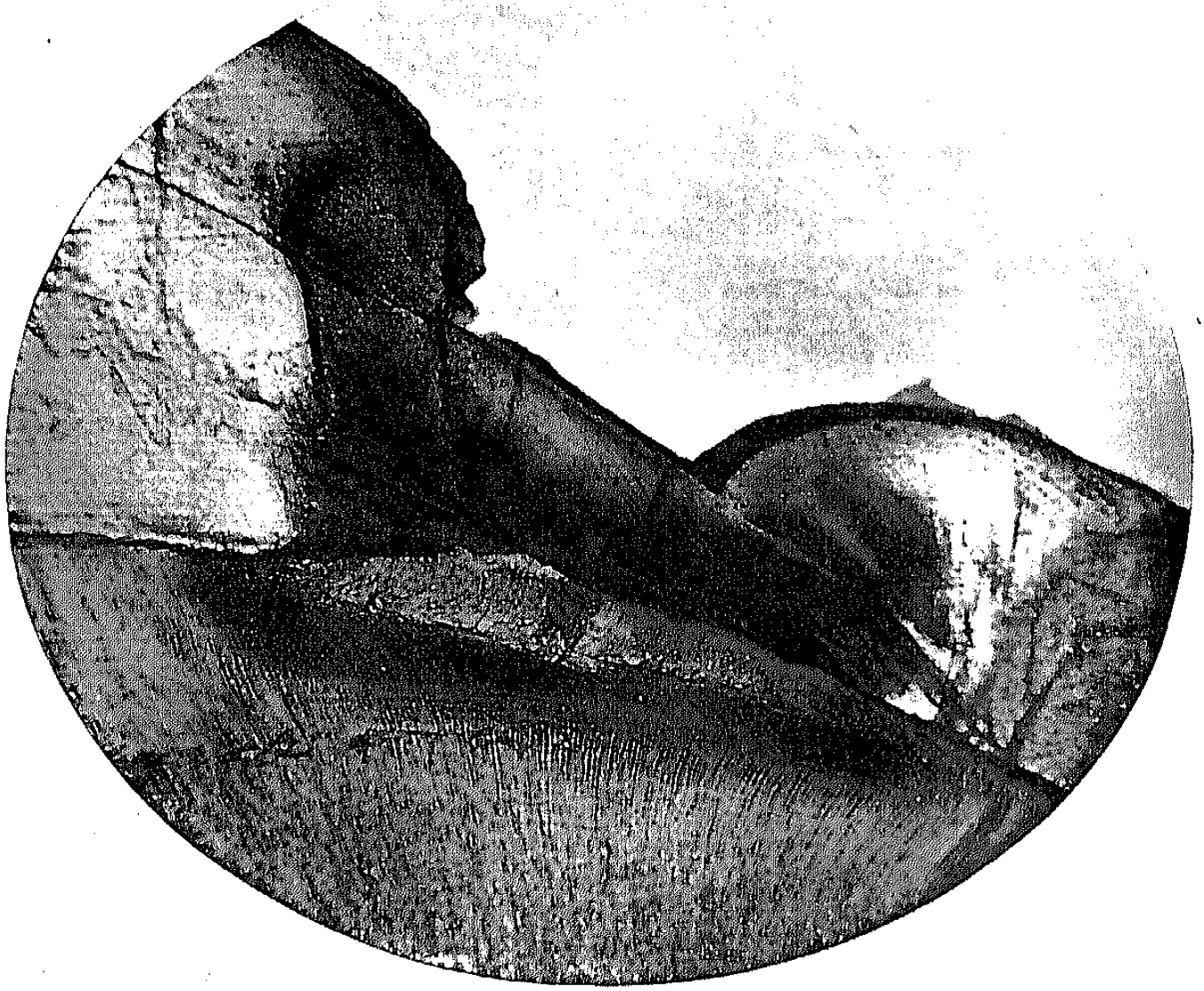


SECTION OF HUMAN ENAMEL, APPROXIMAL SURFACE OF INCISOR. × 175.
Showing enamel nearly penetrated by decay. The carious process apparently arrested by a line of stratification. Micro-organisms slightly raised from floor of cavity by shrinkage caused by mounting in balsam.

on this point is completely overturned by the simple fact that precisely the same condition of enamel as is here shown can be produced in a tooth that has been dead for a hundred years. In other words, it is purely a chemical process, and consists in the removal by an acid of the veil of cement-substance which always conceals the true structure of enamel. There is no vital reaction because there is nothing vital to react. There is no physiological or anatomical change. The structure which you see has always been there from the time the tissue was formed, but in normal enamel it

is covered up and hidden by the cement-substance which causes its calcification. Those who teach that enamel is formed without a definite structural matrix are just as far from the facts as Bödecker and Abbott have been,—farther, in fact, because these investigators saw the necessity for an explanation of appearances that could not be explained by the older teachings.

Fig. 76.

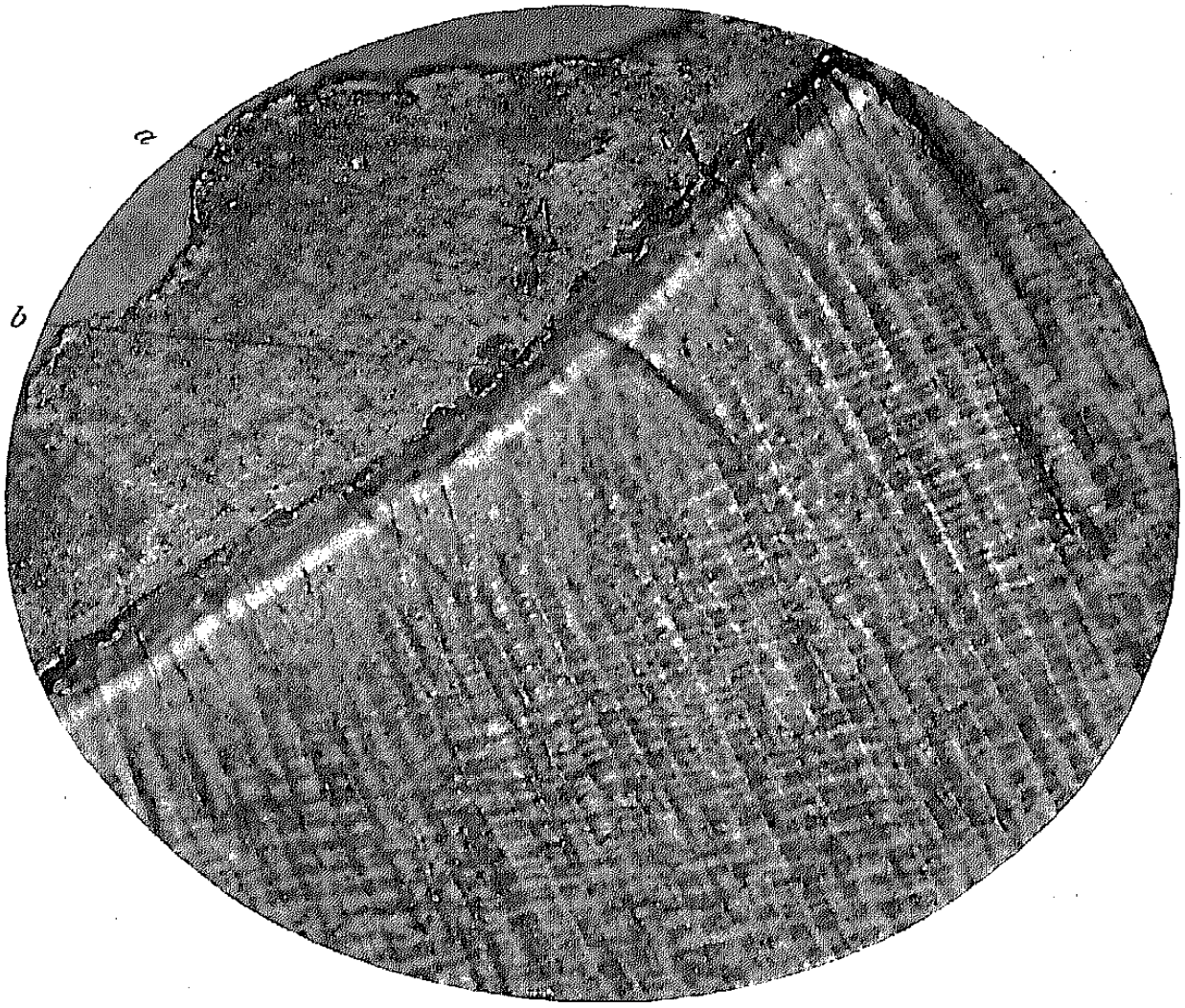


Section of Human Enamel, Approximal Surface of Molar. × 150.
Showing decay temporarily arrested by a line of stratification. Micro-organisms deeply stained.

After caries has completely penetrated the enamel, the progress of decay becomes much more rapid. The line of least resistance seems to be the exact point of union between the enamel and the dentin. This is what one might expect, as both tissues are usually more imperfect at this point than elsewhere. Whenever cavities or channels are found extending into the enamel they are filled with masses of bacteria or micrococci—chiefly the latter. This phase of caries is well shown in Figs. 83 and 84. A curious and interesting fact in connection with backward decay is that the bac-

teria seem far less adhesive than those which line the cavities in direct decay, so that in the preparation of the specimen all of the micro-organisms except such as are protected in cavities and channels are generally torn out and washed away. It is evidently a case of necessary adaptation to environment. In direct decay they must literally cling together or be worsted in the struggle for existence, but in the sheltered conditions of backward decay they can take life more quietly, serenely, and with indifference to mu-

FIG. 77.



SECTION OF CARIOUS ENAMEL, SHOWING DESTRUCTION OF TISSUE BY SOLUTION OF CEMENT-SUBSTANCE AROUND ENAMEL-RODS AND GLOBULAR BODIES. × 500.
a, *b*, Globular bodies of enamel-rods loosened and set free by action of acid excreted by thick mass of micro-organisms attached to the surface of the tissue.

tual relations. In direct caries I have only occasionally found small groups of micrococci and bacteria deep in the substance of enamel, where they had evidently penetrated by means of some channel communicating with the cavity of decay, but in backward caries fissures are nearly always present filled with micro-organisms, as shown in Fig. 85. If a section of enamel where backward decay is in progress be exposed to an anilin dye, the stain is quickly taken up (see Fig. 86), and the resistance of this stained enamel to the action of acid alcohol shows the presence of bac-

teria. If a little of this white, partly-decomposed enamel be scraped away with a spoon excavator and spread out on a cover-glass and stained in the usual way, we shall find on making microscopical examination many places resembling the views shown in Figs. 87 and 88. In successfully-prepared specimens certain forms of micro-organisms, chiefly micrococci, diplococci, and two or three forms of bacteria, are always to be seen lying between the

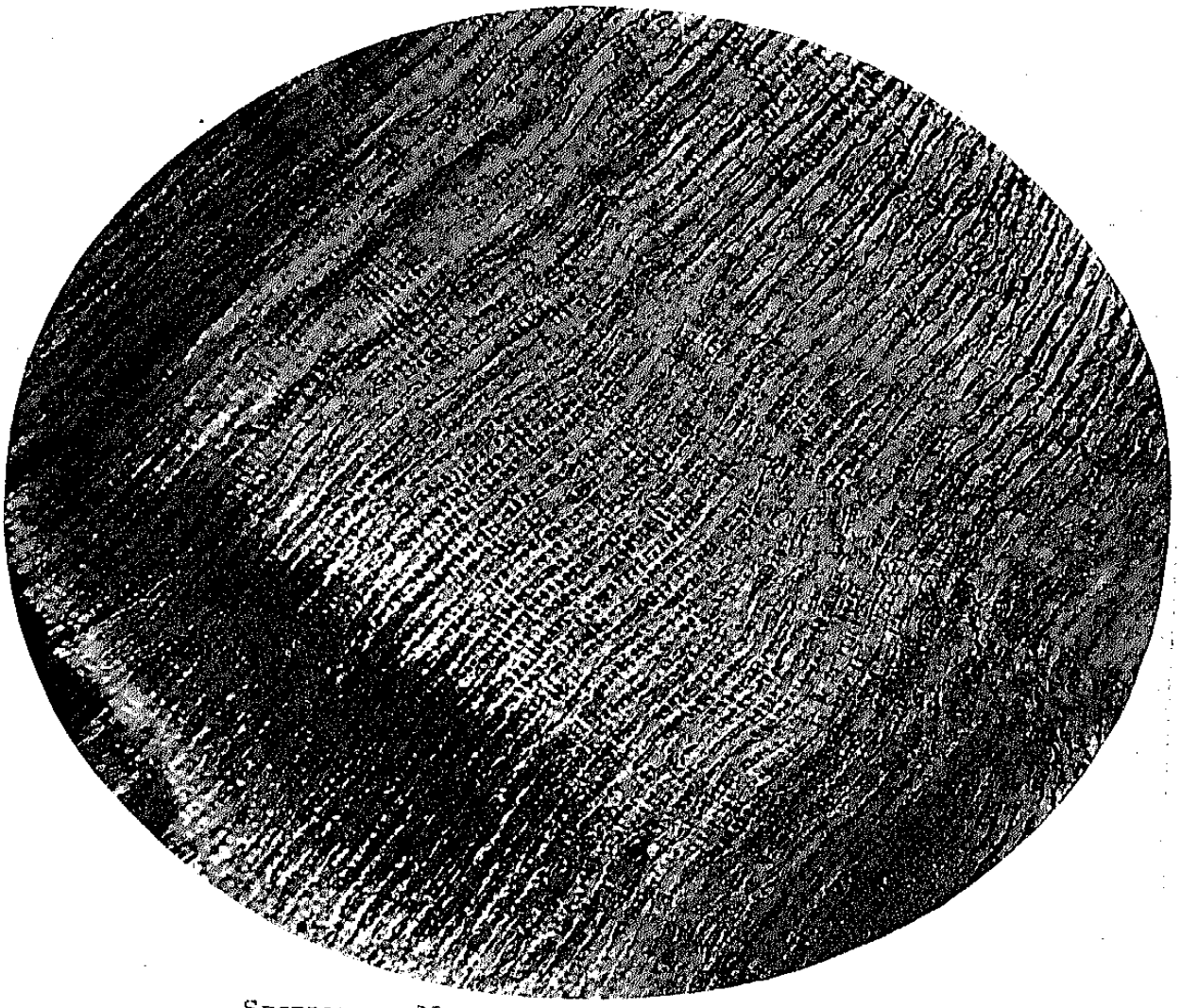
FIG. 78.

SECTION OF CARIOUS ENAMEL. × 500.

a, Ends of enamel-rods at margin of cavity. It is seen that there is no "granular layer" of enamel at the margin of decay, as has so often been described, but the enamel-rods end sharply at the surface where the micro-organisms are attached. The so-called "granular layer" of carious enamel has probably been produced by faulty methods of treatment by which the thick mass of bacteria has been converted into an appearance of granular decaying enamel; *b*, *c*, Globular bodies or sections of enamel-rods loosened and set free by action of acid of decay.

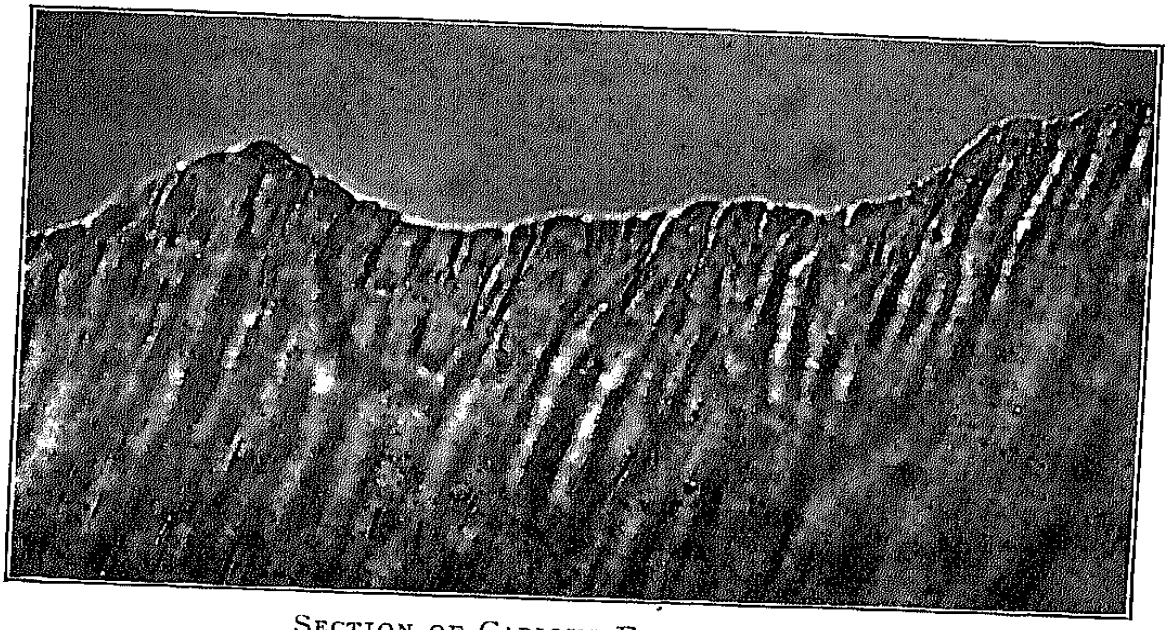
enamel-rods and sometimes between the sections of the rods. Here, in deep backward caries, the process is the same as in direct decay, although so much more rapid that there is usually little or no discoloration of the enamel in secondary decay. As the acid produced by the micro-organisms dissolves out the cement-substance between the rods, the bacteria insinuate themselves deeper and deeper in the depressions thus formed. The acid is continually

FIG. 79.



SECTION OF NORMAL HUMAN ENAMEL. × 250.
Treated with lactic acid to show solution of cement-substance between enamel-rods and globular bodies.

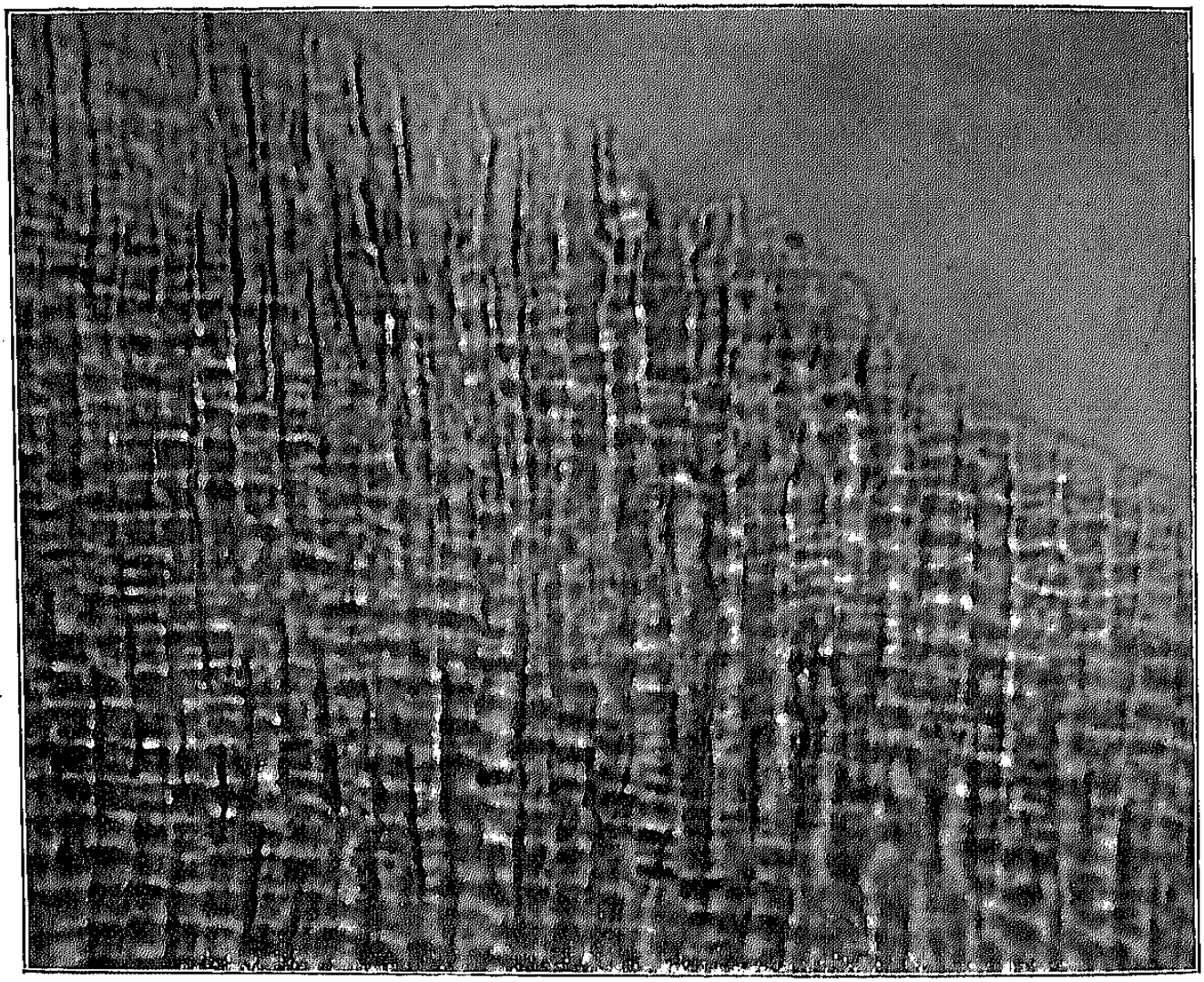
FIG. 80.



SECTION OF CARIOUS ENAMEL. × 600.
Bacteria of decay removed to show action of acids on ends of enamel-rods.

being formed and its full dissolving power continuously acting on the tissue. With the removal of the cement-substance the loosened rods and sections fall apart, and the work of destruction is finished (see Fig. 88). It will be interesting to you to know that the microscope reveals something in the nature of an explanation of one of the causes of the difference between slow and rapid caries. A comparison of Figs. 59 and 82 will show a very marked contrast in the structure of the enamel. In both the cement-sub-

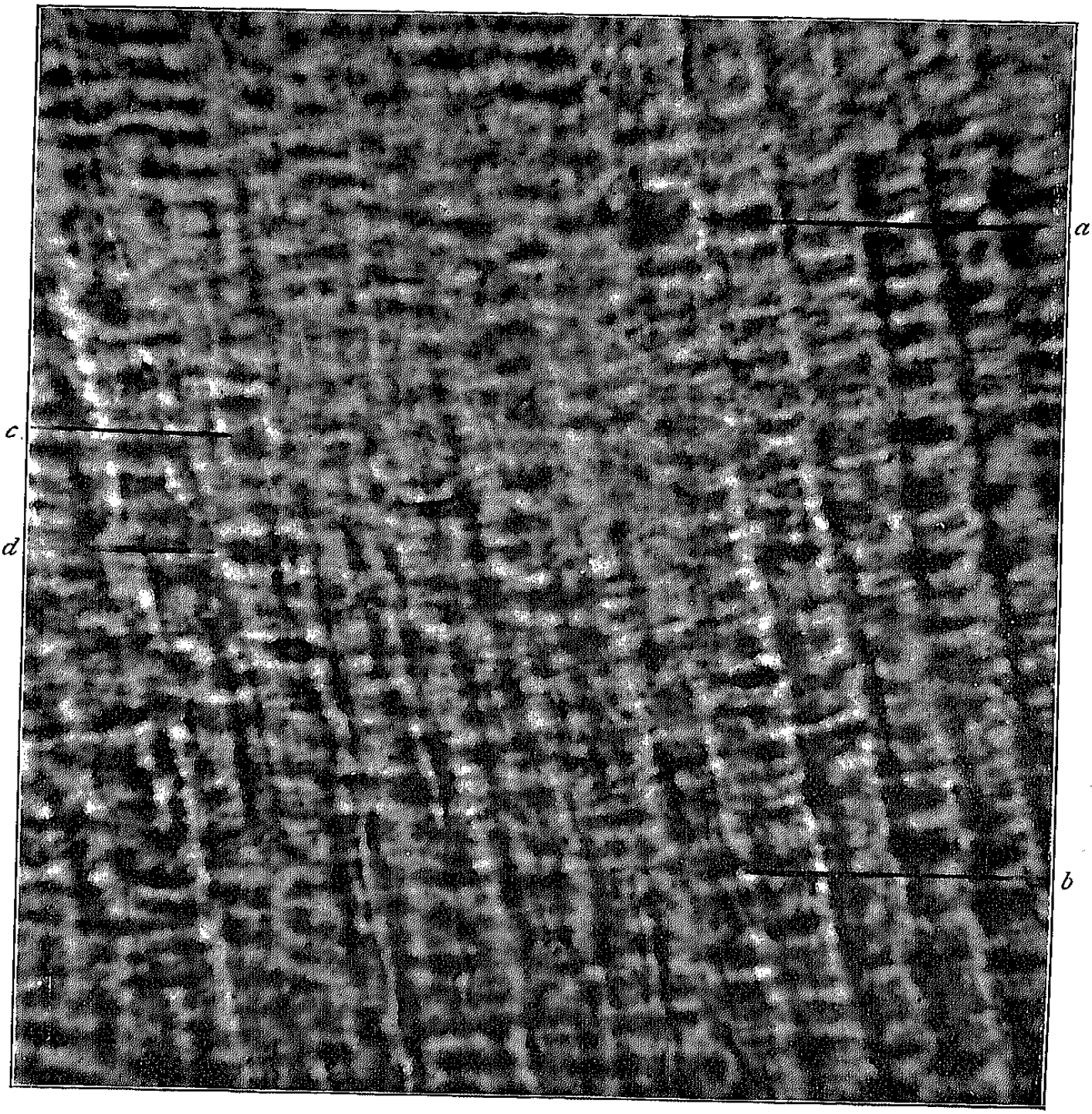
FIG. 81.



SECTION OF CARIOUS ENAMEL. × 550.
Bacteria removed to show action of acid on enamel-rods.

stance has been largely removed by the acid bacteria, and the structure of the basis-substance, representing the original organic matrix, is revealed. In the case of slow decay shown in Fig. 82, the globular bodies, the original formative sections of the rods, are everywhere seen to be firmly united to each other, both in the lateral and perpendicular aspects, by projecting processes, as I have already described. It is easy to see that this form of structure would resist the action of the acid longer than that shown in the case of rapid decay illustrated in Fig. 59. Here the removal of the cement-substance leaves the rods almost completely isolated,

FIG. 82.



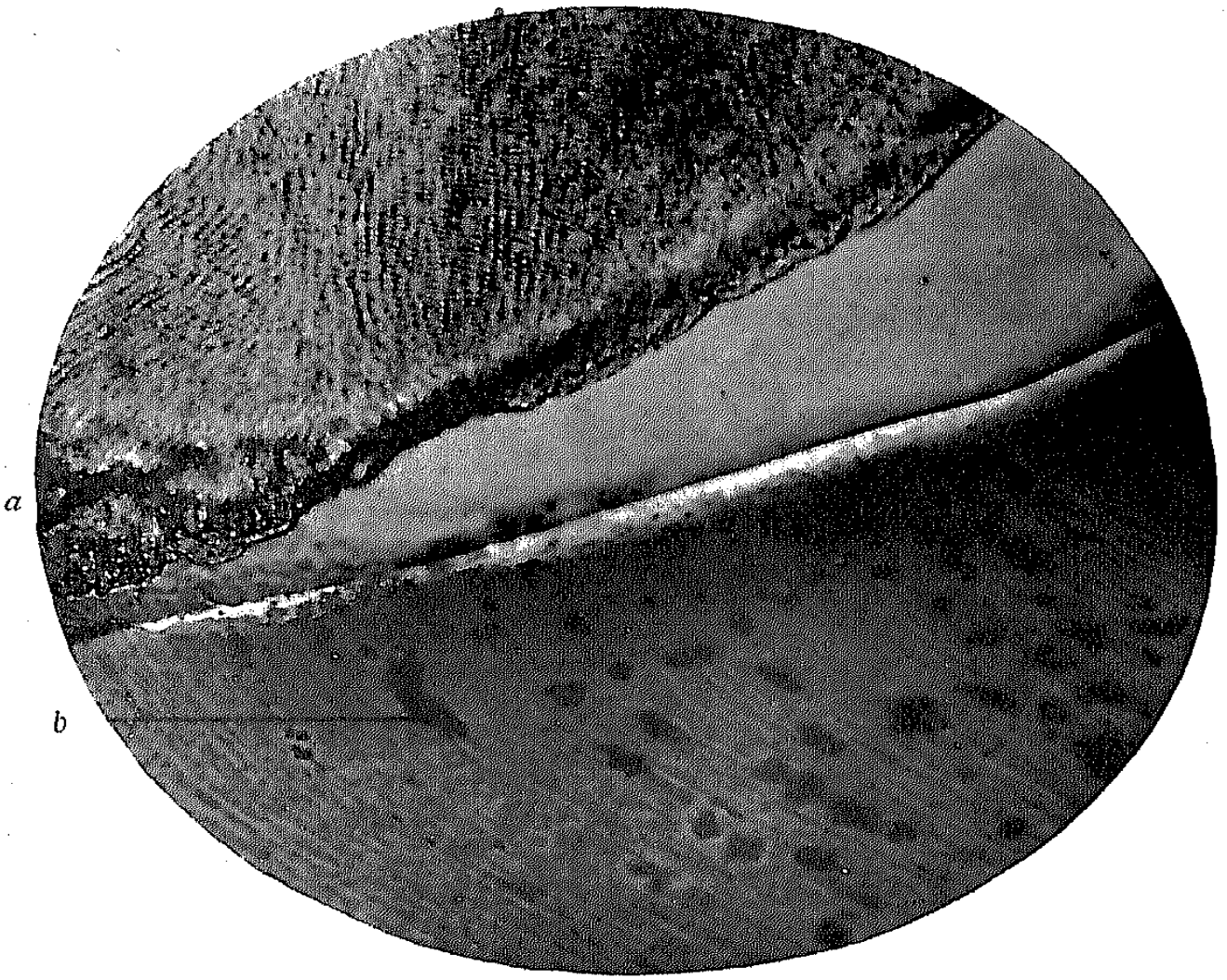
SECTION OF CARIOUS ENAMEL, SHOWING APPEARANCES OF TISSUE IN SLOW DECAY. × 2000.

The cement-substance has been dissolved away by the bacterial form of the acids, thus exposing to view the original organic matrix. The globular bodies or sections of the rods shown at *a*, *b*, *c*, *d*, and seen to be identical in general shape and character with those previously shown in the ameloblasts and on the surface of forming enamel.

and they therefore fall apart, and the structure of the tissue is destroyed before the complete solution of the lime-salts. Such structure as is shown in Fig. 82 evidently does not break down completely until the tissue is nearly destroyed by molecular disintegration.

I have further observed that there are marked differences in the ultimate granular structure of the enamel-rods, the granules being much finer in some specimens than in others, even when the specimens are quite normal in other respects.

FIG. 83.



SECTION OF CARIOUS TOOTH, SHOWING APPEARANCES OF DECAY IN ENAMEL AND DENTIN AT THE LINE OF UNION OF THESE TISSUES. × 250.

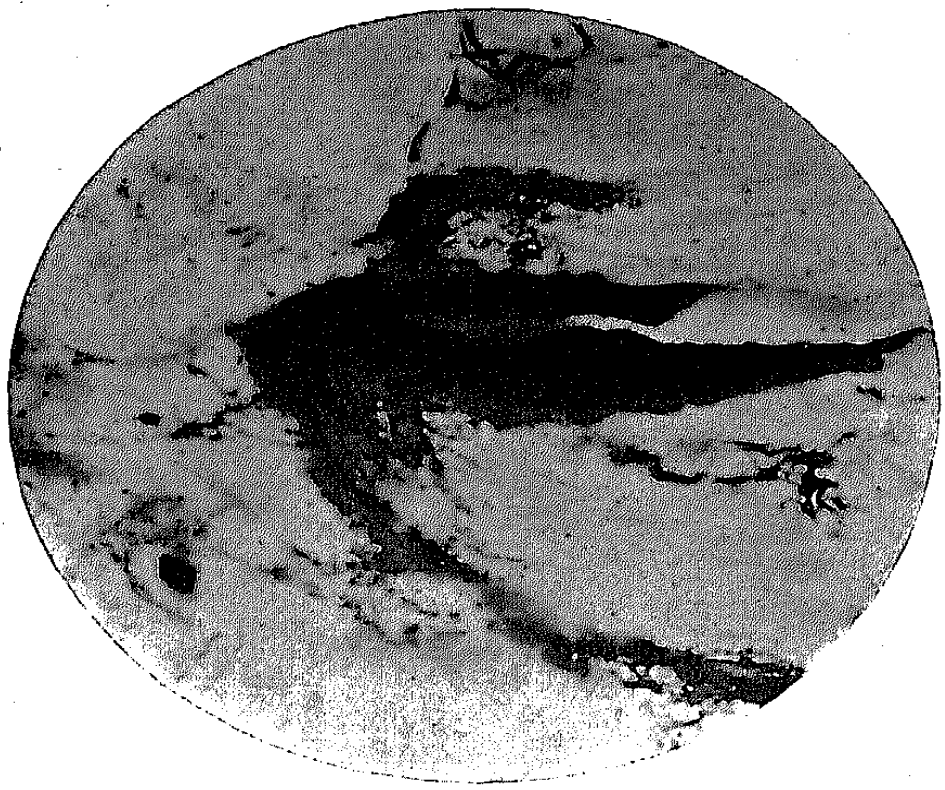
The dark spots shown in the enamel and dentin at *a* and *b* are masses of micro-organisms.

There may also be a difference in the resisting power of the cement-substance, but the wide variations in the conditions of environment and in the structure, as shown, seem to be quite sufficient to explain the marked differences which are clinically observed as to the rapidity or slowness of decay.

I had hoped to be able to make a more extensive report on the special forms of micro-organisms concerned in enamel-decay, but my paper has already considerably exceeded prescribed bounds.

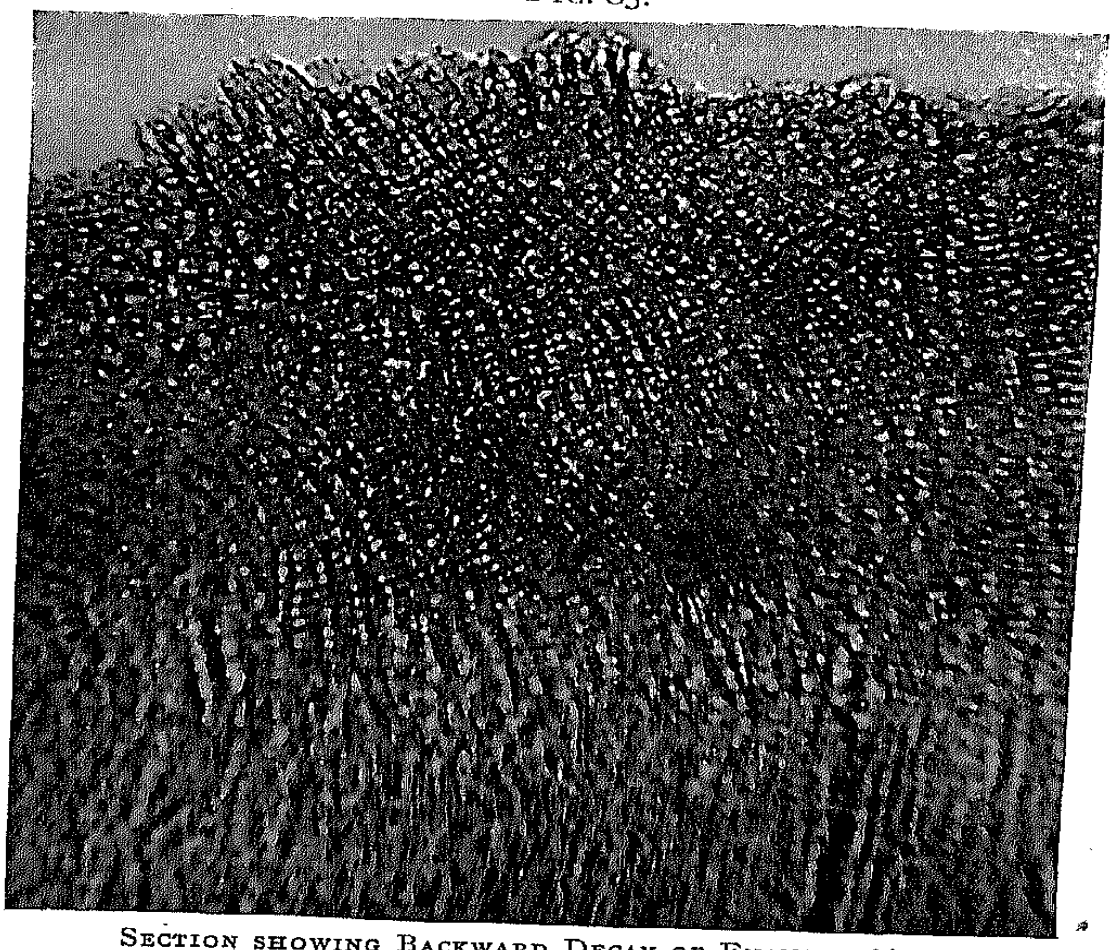
Investigations are in progress for determining, if possible,

FIG. 84.



TISSUES IN SECONDARY OR BACKWARD DECAY OF ENAMEL FROM THE VICINITY OF *a* IN THE PRECEDING ILLUSTRATION. × 750.
They are seen to be filled with deeply-stained masses of bacteria and micrococci.

FIG. 85.



SECTION SHOWING BACKWARD DECAY OF ENAMEL. × 350.
The stained area in the lower half of the illustration shows the depth to which the bacterial acids, and in many cases the bacteria also, have penetrated in advance of the actual breaking down of the tissue.

whether special forms of bacteria are invariably present in markedly rapid decay of enamel. In the few cases which I have had the opportunity of examining, I have invariably found that the streptococci shown in Fig. 89 far outnumber all other forms. But much careful work is necessary before forming conclusions on such points. It is a matter of common observation that teeth which have for years been comparatively free from caries are suddenly attacked, and for a time decay very rapidly. The opinion

FIG. 86.

COVER-GLASS PREPARATION FROM SCRAPINGS OF WHITE, OPAQUE DECAYING ENAMEL. × 450.

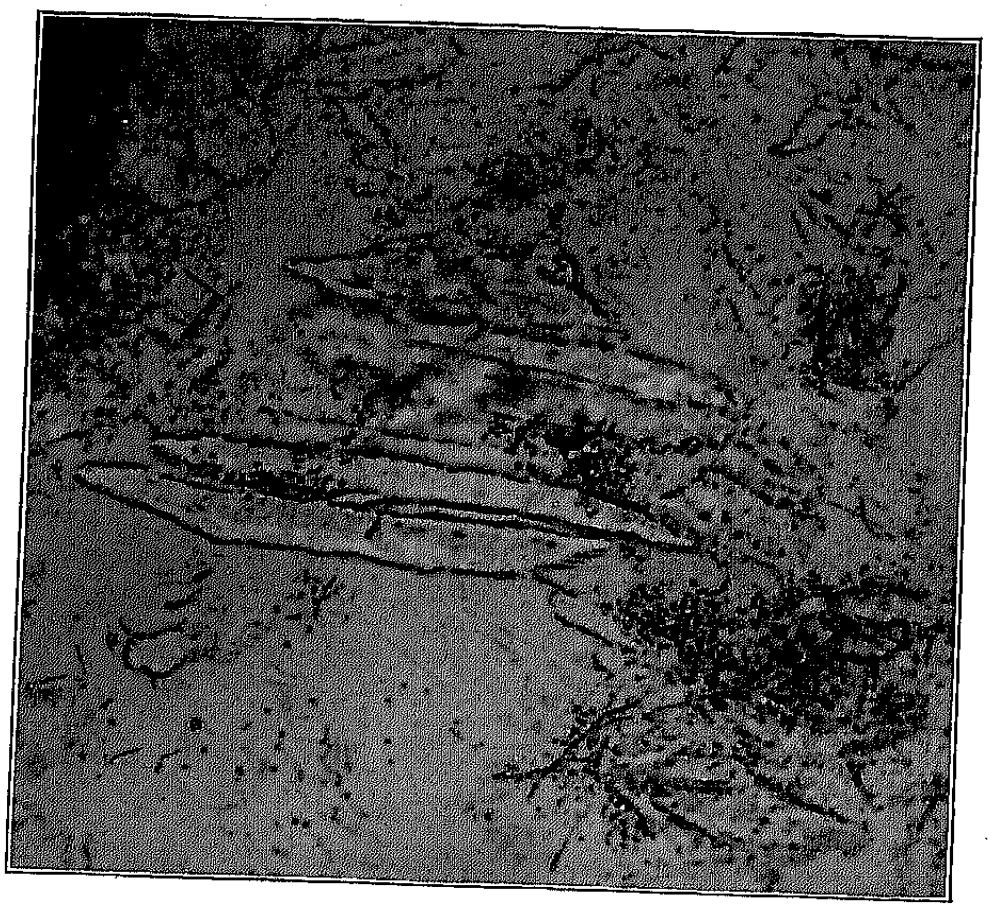
The cement-substance between the rods is seen to be dissolved away, and the crevasses thus formed are filled with round and oval forms of micrococci and bacteria. Stained by the Gram method.

has long been held by a majority of the profession that this change is due to the degeneration of the tissues of the teeth. I have shown that so far as enamel is concerned there is not the slightest foundation for this opinion. A careful study of this phase of caries demonstrates that persistent and rapid fermentation is always going on in such mouths. In all such cases it is evident that some change in the fluids of the mouth has occurred which decreases their inhibitive power over the development of micro-organisms,

and acid-forming bacteria seem to proliferate rapidly and to act with great energy. The observed differences in rapidity of decay, therefore, are primarily due to change in environment, somewhat accelerated or retarded by such peculiarities of structure as I have pointed out. Given a certain condition of the oral fluids which favors the development and activity of bacteria, and it is obviously true that poorly-constructed enamel will decay more rapidly than a solid and perfectly-calcified tissue.

In direct caries of enamel one finds the cavities always lined with various leptothrix and thread-like forms (Figs. 90 and 91). The

FIG. 87.

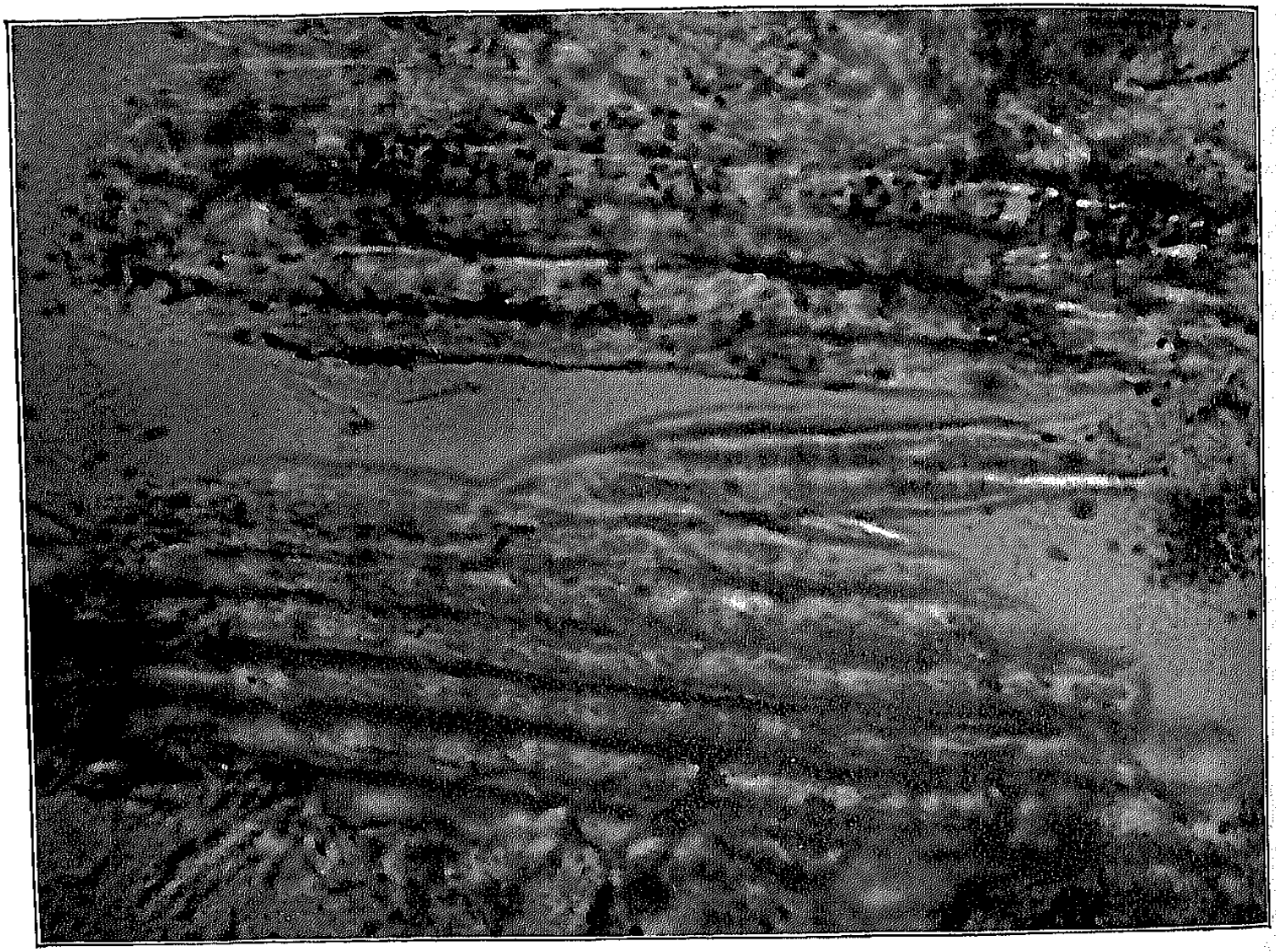


COVER-GLASS PREPARATION. × 600.
Same treatment as in the preceding specimen.

Leptothrix buccalis maxima and the Bacillus buccalis maximus of Miller are nearly always found, the former in large masses lightly stained, if the Gram iodin method has been used, and the latter more sparingly in numbers, but deeply stained (Fig. 92). I have invariably found beneath the thick felt-like mass of thread forms, and lying in contact with the decomposing enamel in direct decay, and also deep in cracks and fissures in backward or secondary decay, a curved bacillus which appears to be much smaller than Spirillum sputigenum, as figured by Miller, a short, thick bacillus usually constricted in the center, probably the second kind mentioned by Vignal and Galippe as being invariably present in carious teeth, but most abundantly large micrococci and diplococci

(see Figs. 93, 94). These will always be found between the enamel-rods in backward decay and lying in little depressions, caused evidently by their excretory acid, in direct decay. They stain quickly and deeply by the Gram method. The final result of the work of these micro-organisms is strikingly shown in Fig. 95, where the tumbled and broken ruin is all that remains of that once beautiful structure, the enamel of a tooth.

FIG. 88.



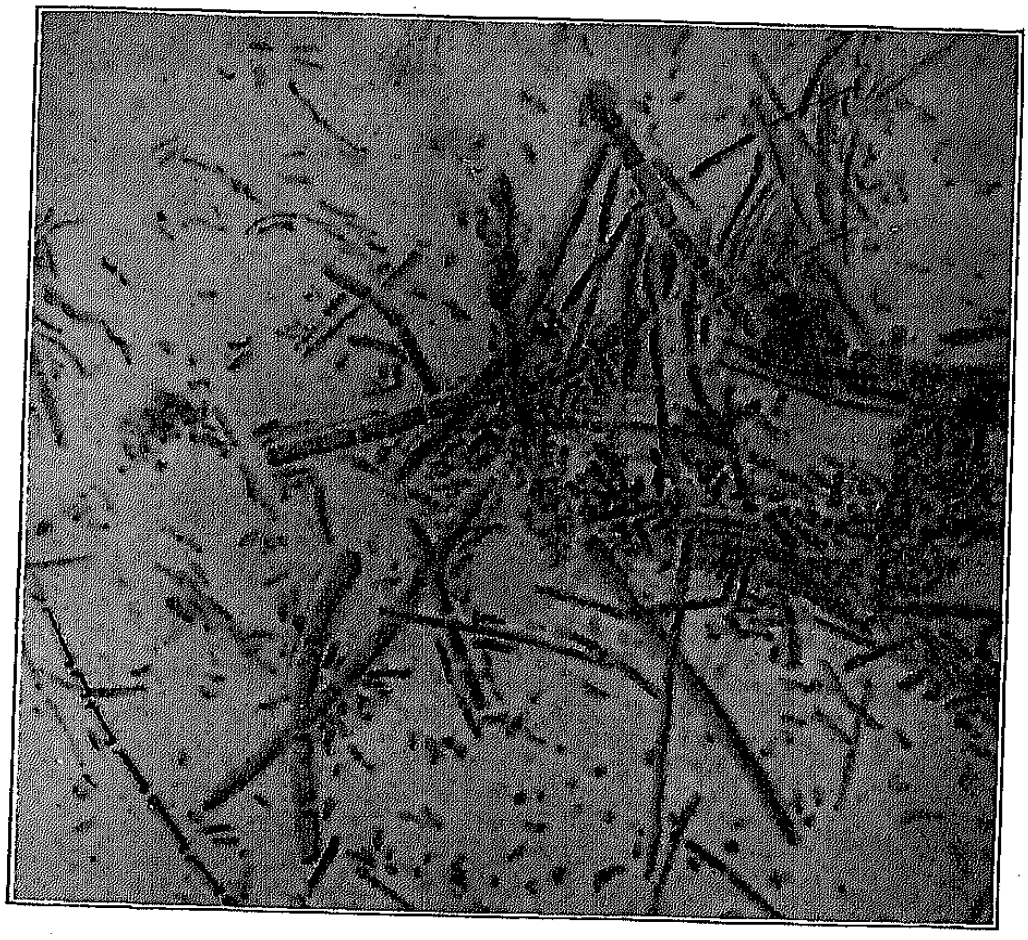
FROM COVER-GLASS PREPARATION OF DECAYING ENAMEL. × 1500.
Stained with Squire's carbolic fuchsin. Micro-organisms, chiefly micrococci and diplococci, are everywhere seen lying between the enamel-rods.

Gentlemen, my demonstration is finished. I have presented a long string of facts about which I have expressed few opinions, because opinion did not seem called for, as the facts explain themselves. The evidence, considered in detail and in mass, is simply overwhelming. There seems no reason why any rational man should continue to doubt that acid-forming bacteria are the sole active cause of dental caries, or that the predisposing cause is to be found in that "peculiar condition of the bodily juices and cells in which these are unable to repel the invasion of pathogenic

FIG. 89.

A FORM OF STREPTOCOCCUS FOUND ABUNDANTLY IN MOUTHS WHERE VERY RAPID DECAY OF THE TEETH IS IN PROGRESS. × 750.

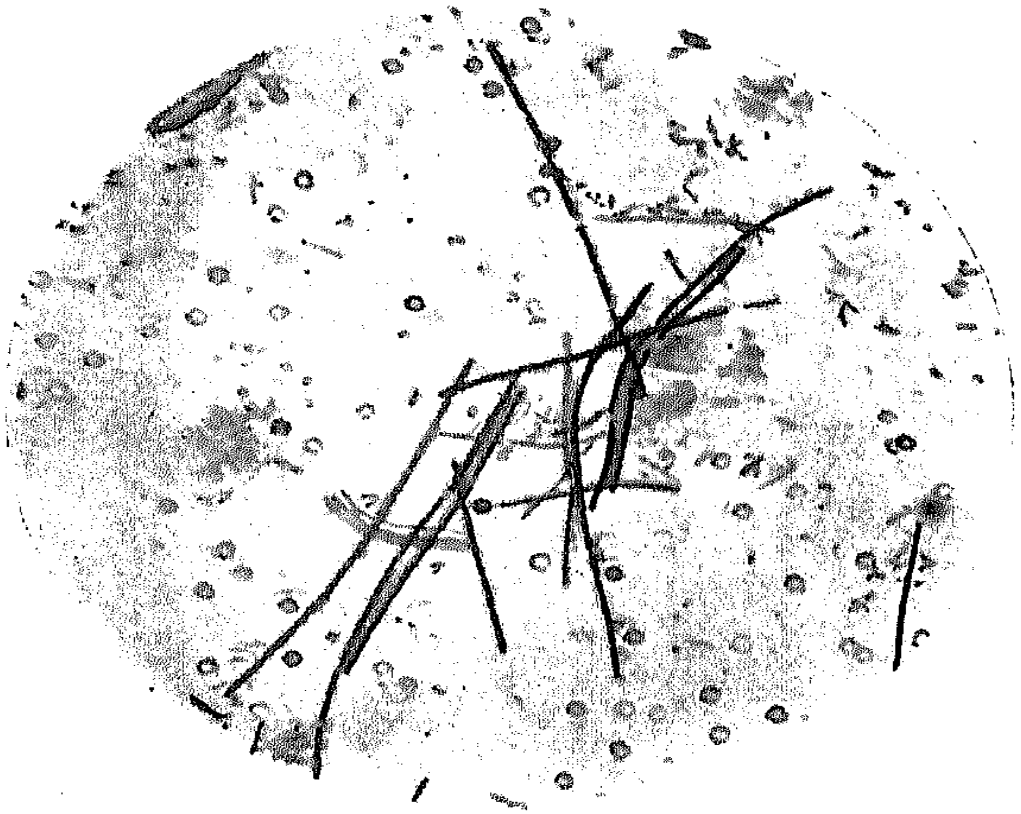
FIG. 90.



SCRAPINGS OF MICRO-ORGANISMS FROM THE APPROXIMAL SURFACE OF A DECAYING TOOTH. × 1500.

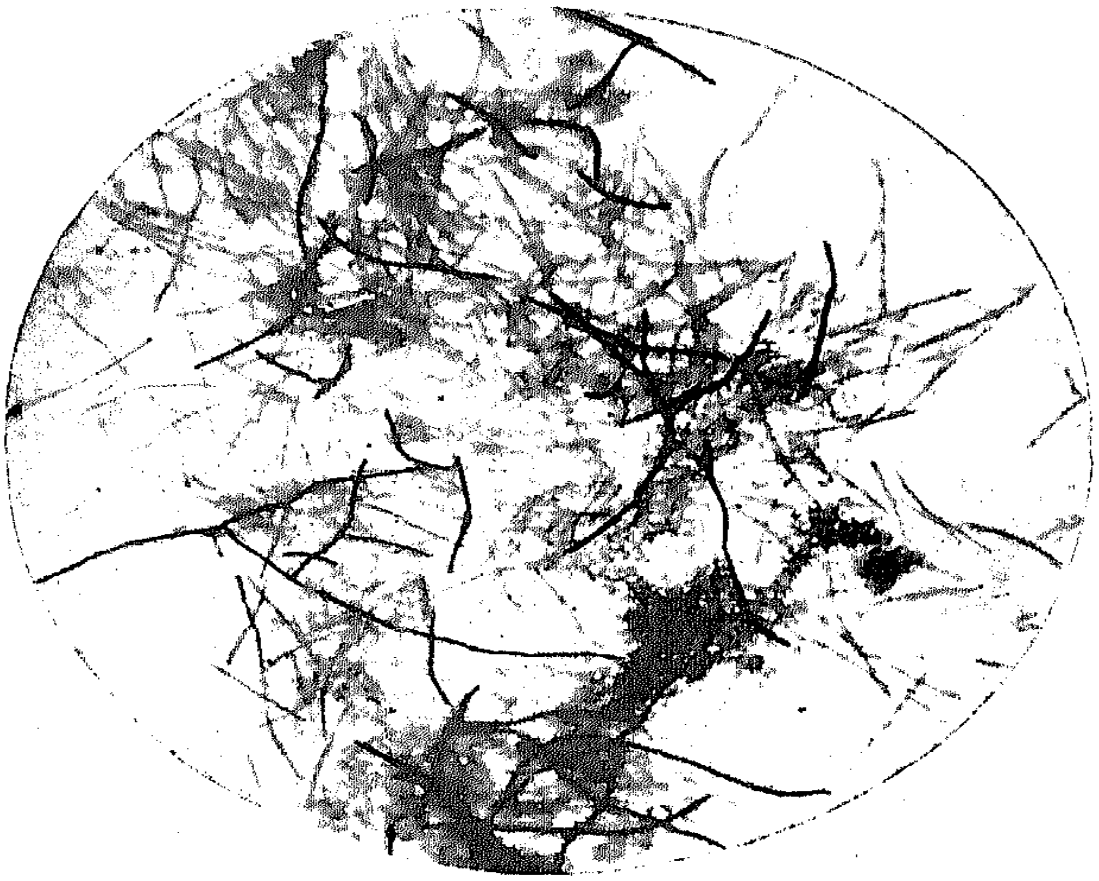
Shows the Leptothrix buccalis maxima and the Bacillus buccalis maximus of Miller.

FIG. 91.



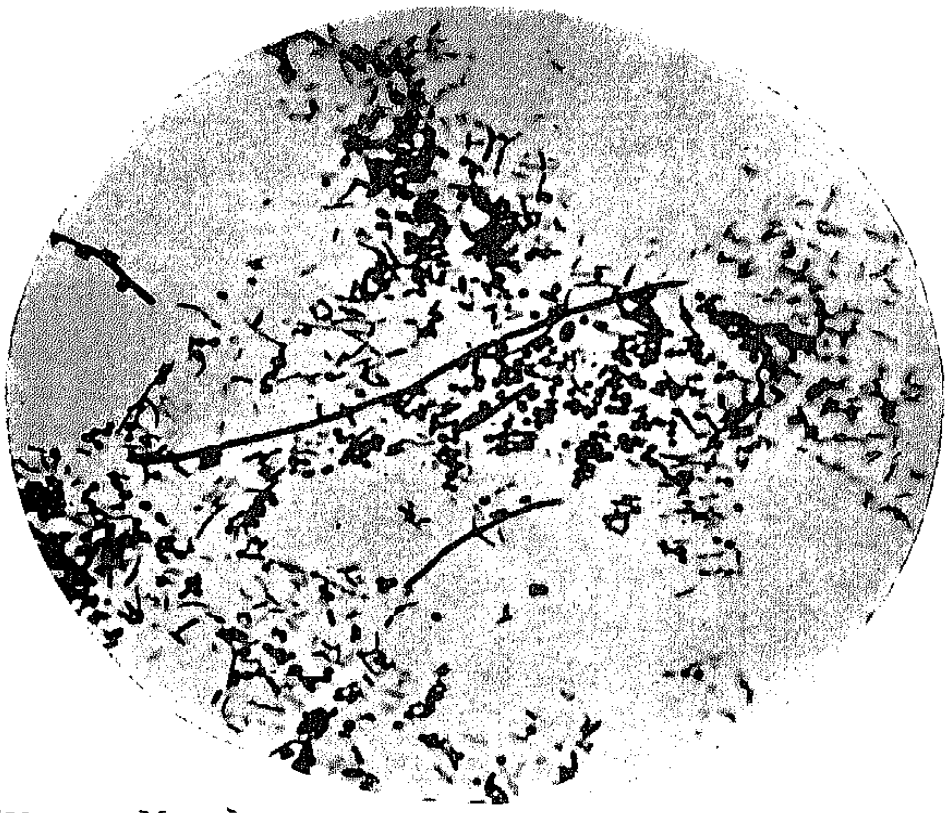
LEPTOTHRIX FORMS OF MICRO-ORGANISMS FROM DECAY OF ENAMEL. × 1000.

FIG. 92.



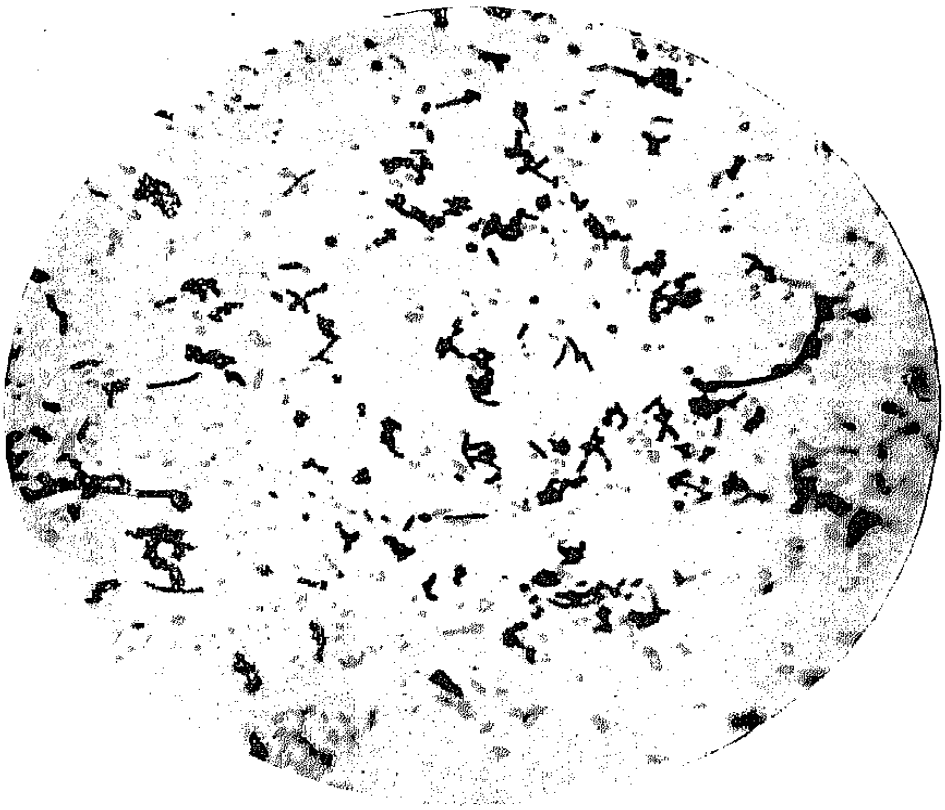
COVER-GLASS PREPARATION OF SCRAPINGS FROM DECAY OF ENAMEL. × 850.
Stained by Gram method. Shows Leptothrix buccalis maxima and Bacillus buccalis maximus of Miller.

FIG. 93.



VARIOUS FORMS OF MICROCOCCI AND BACTERIA FROM DECAYING ENAMEL. × 1000. Photograph by Mr. Andrew Pringle from author's cover-glass preparation.

FIG. 94.



MICROCOCCI, DIPLOCOCCI, AND BACTERIA FROM DECAYING ENAMEL. × 1000. Photograph by Mr. Andrew Pringle from author's cover-glass preparation.

micro-organisms." Tooth-structure is seen to play but a very subordinate part in the phenomena of decay, and to be of small consequence except in relation to the active and true predisposing cause of caries.

From the facts now in our possession we may, I believe, sum the whole question up by saying that if the environing conditions of

FIG. 95.

SHOWING FINAL DISRUPTION AND DESTRUCTION OF ENAMEL-RODS NEAR THE MARGIN OF A CAVITY OF DECAY. × 1500.

the teeth are such as to favor the development and activity of acid-producing bacteria, and if those bacteria are permitted to become attached to the surface of the enamel, it is doomed, although it may be the most perfect that was ever formed. On the other hand, if those environing conditions are not present the worst enamel will not decay.