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ORIGINAL COMMUNICATIONS.

A CONTRIBUTION TO THE STUDY OF PATHOLOGY OF ENAMEL.

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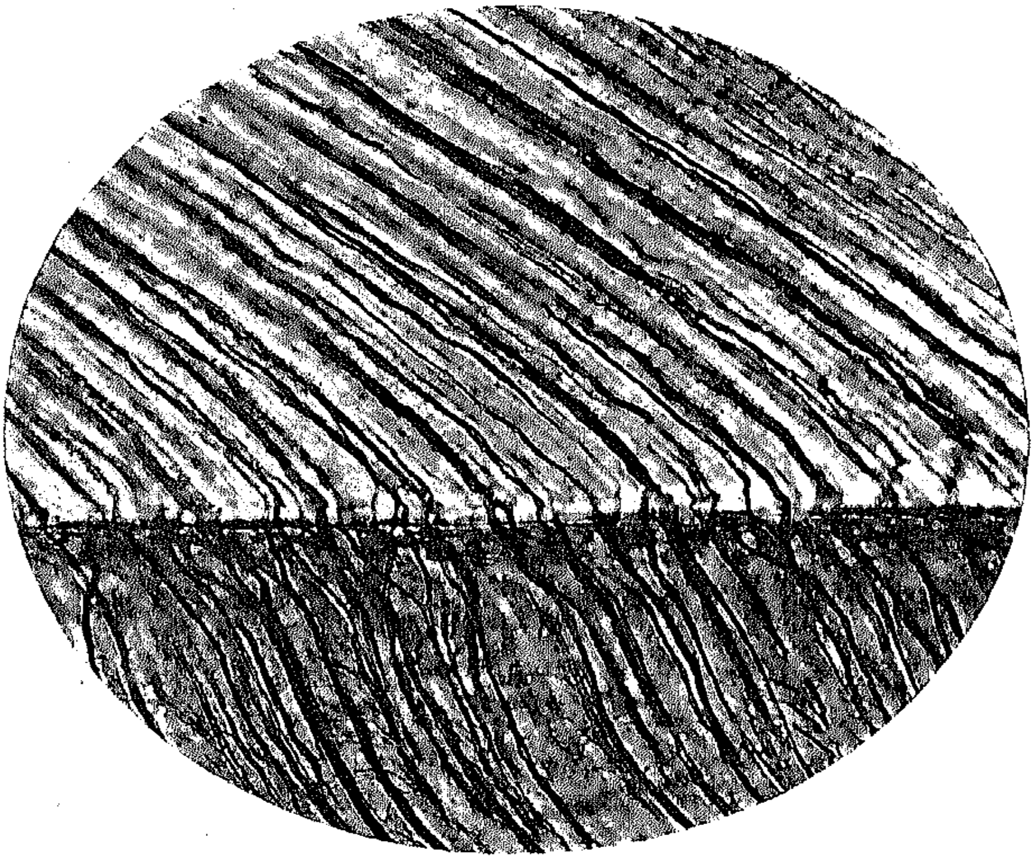
(Read before the New York Odontological Society, January 12, 1897.)

(Continued from page 196.)

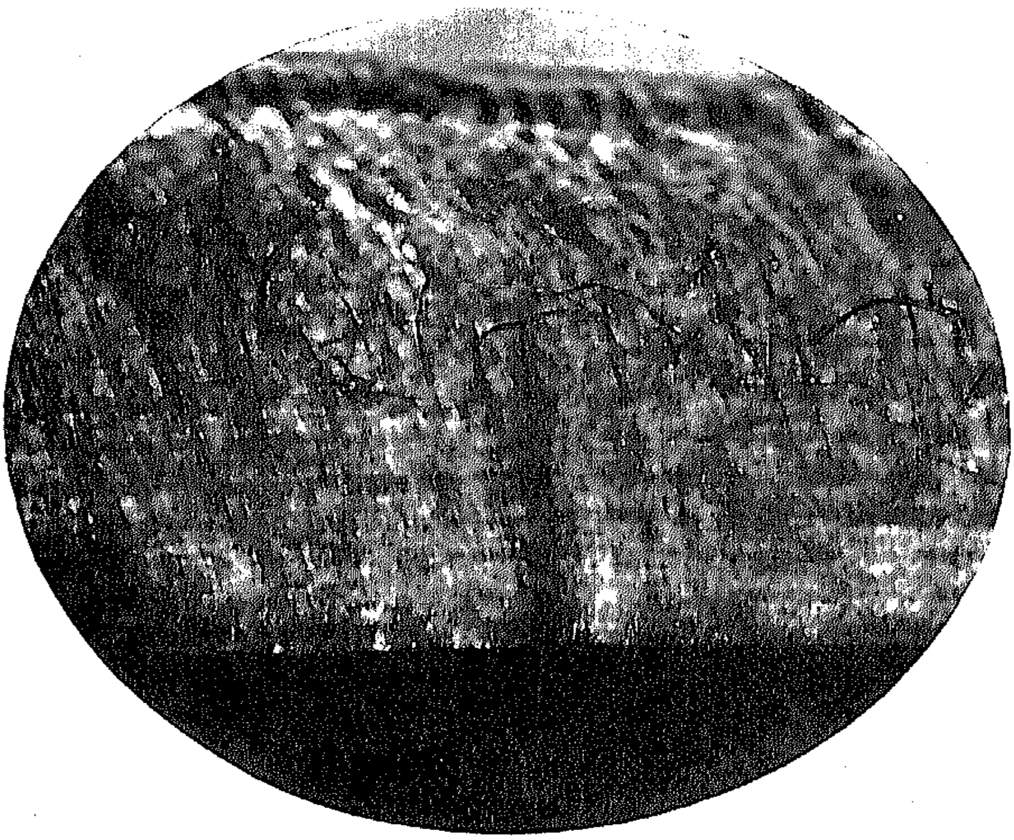
THE Heitzmann school of histologists have made the appearances of organic or living matter a distinctive feature of their representations of enamel. Let us see what foundation can be discovered for their claims in this direction. If we examine a section of a marsupial tooth under the microscope, we shall probably see most of the dentinal canaliculi passing over into the enamel and usually continued through this tissue to the surface (see Fig. 31). It is not such an easy matter as might at first appear to prove that these canaliculi contain fibers. The staining methods adopted by Drs. Bödecker and Abbott are very unsatisfactory and inconclusive, as I shall presently demonstrate to you. If we remove a tooth from the jaw of a kangaroo and immediately grind a section under water, and then partially decalcify the section, stain and mount in glycerol, we shall see that some of the fibers in the enamel have partly floated out of their canals, as shown in Fig. 32. Thus we have the most positive proof of the presence of living matter in enamel. But these fibers have no relation to the enamel-fibers of Dr. Bödecker. One occasionally finds specimens of human teeth in which the dentinal canaliculi are apparently continued into and sometimes nearly or quite through the enamel. Such appearances are shown in Figs. 33 and 34, the former from a human tooth and the latter from the tooth of a monkey. Careful experiments show that while the canals sometimes penetrate the entire thickness of enamel, the fibers are usually continued but a short distance into the tissue. Sometimes a few granules appear farther on in the canals, but for the most part they seem to be empty or filled with

FIG. 31.



SECTION OF INCISOR OF KANGAROO. × 400.
Showing dentinal fibrillæ penetrating enamel.

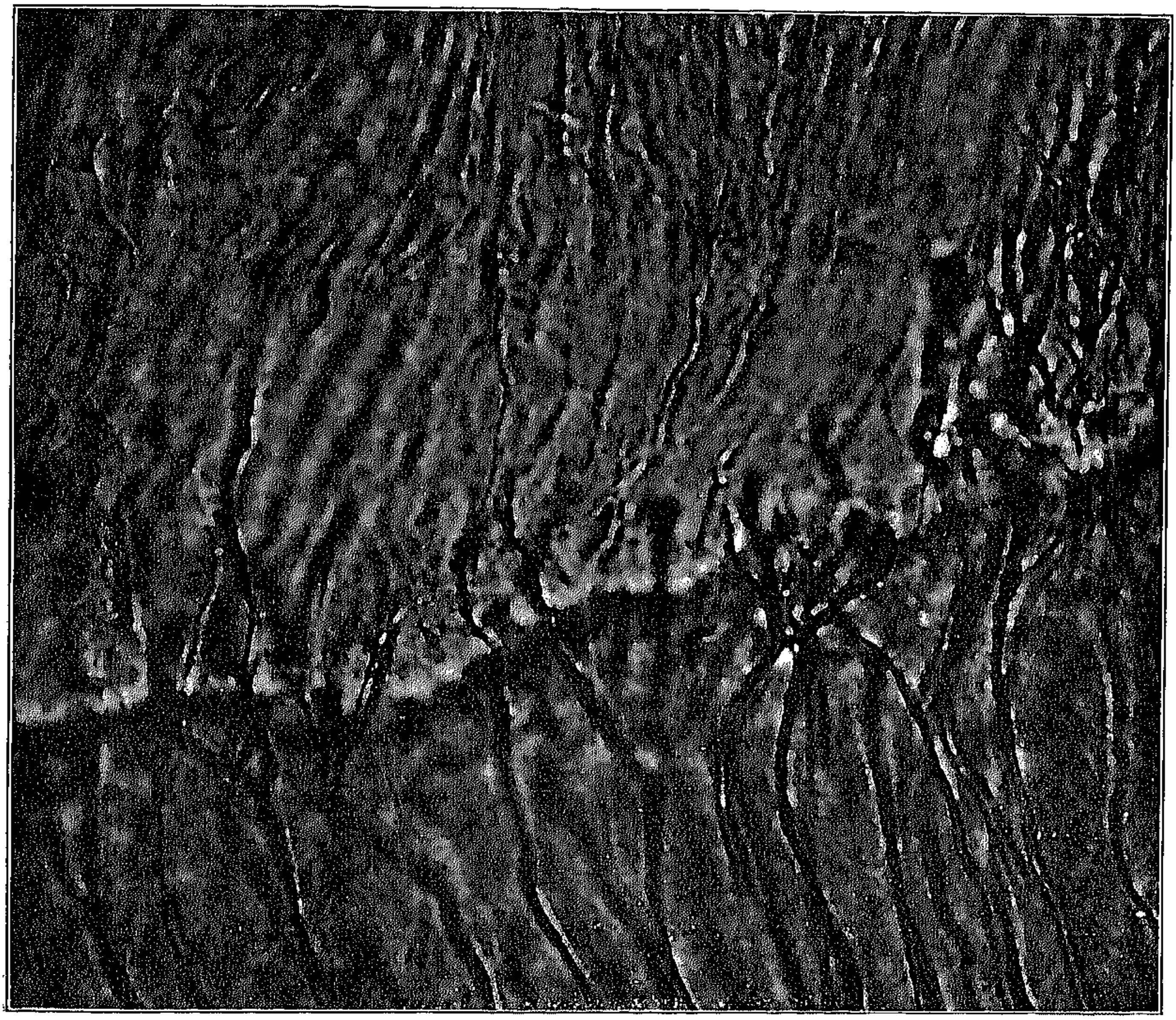
FIG. 32.



SECTION OF PARTLY DECALCIFIED ENAMEL FROM INCISOR OF KANGAROO, SHOWING STAINED FIBERS IN ENAMEL. × 300.

fluid. If we examine these canals under high power with oblique light and a rotating stage, we shall find that the appearance of the fiber is nearly always on the *shadow* side of the canal. If now we stain one of these sections with an anilin dye and fix the stain with a mordant, and then submit the section to the action of slightly acidulated alcohol, we shall find that all color is speedily removed from the enamel, except from the surface, when the

FIG. 33.

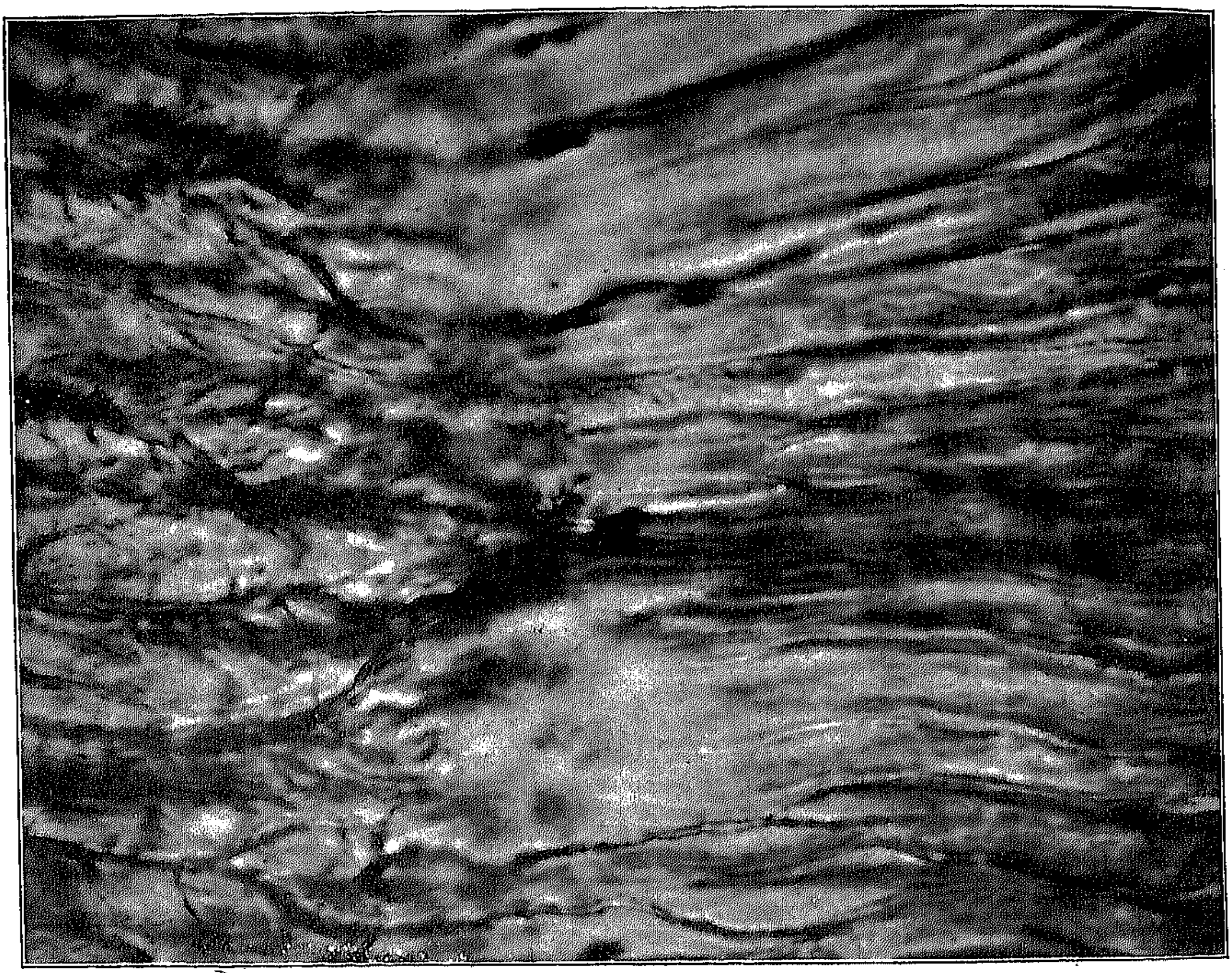


SECTION OF HUMAN MOLAR, SHOWING DENTINAL FIBRILLÆ PENETRATING ENAMEL. × 600.

organic matter of micro-organisms is present. Here the color is held very tenaciously, as it is also in the dentin. From these and many other experiments I conclude that the dentinal fibrillæ, although sometimes penetrating for considerable distances into the enamel, generally become atrophied with the complete calcification of this tissue. Canals are thus not infrequently left in the enamel into which staining fluids easily pass, and the appearances thus caused are very deceptive. Chlorid of gold is, in this respect, one of the most deceptive and unreliable of stains.

Fig. 35 is from a dried human tooth, and Fig. 36 from the fossil tooth of a mastodon. Both specimens have been stained, and both appear to contain fibers which have taken the stain, but it is quite safe, I think, to assert that there are no fibers of living matter in the fossil tooth of a mastodon.

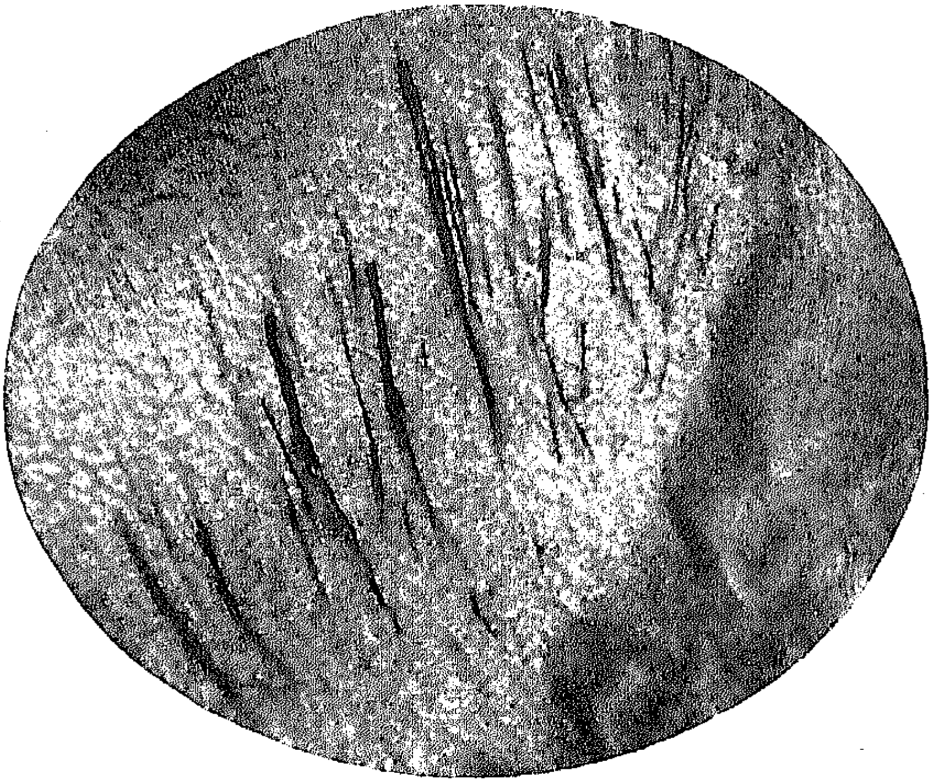
FIG. 34.



SECTION OF TOOTH OF MONKEY, SHOWING DENTINAL FIBRILLÆ PENETRATING ENAMEL. × 800.

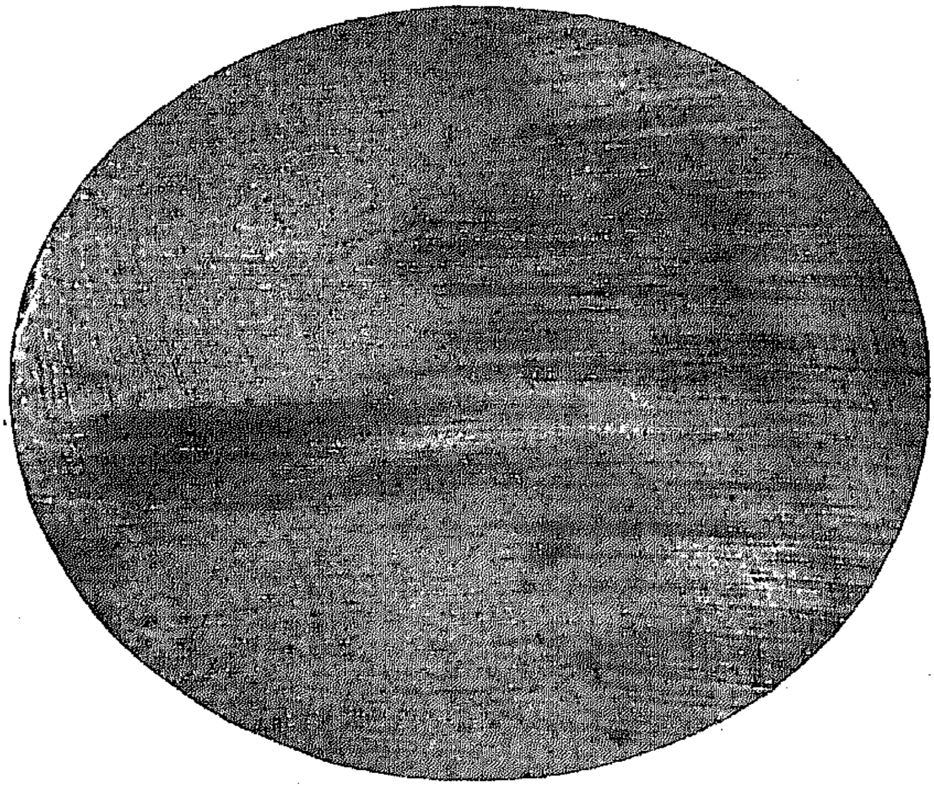
During the course of these investigations, I mounted a specimen of partially decalcified enamel which I at first thought showed unmistakable evidence of fibers passing from the dentin quite through the enamel. The specimen was ground so that the outer surface came on the beveled slope of a cusp, thus producing a knife-like edge, and the acid, acting on this very thin margin, has effected almost complete dissolution of the enamel-rods. The center of some of the rods still remains, but so small and as to look like a fiber. Very close inspection one day enabled me to trace

FIG. 35.



SECTION OF ENAMEL FROM HUMAN INCISOR, SHOWING HOW CANALS CAN BE IMPREGNATED BY A STAIN SO AS TO PRODUCE THE APPEARANCE OF FIBERS. × 150.

FIG. 36.

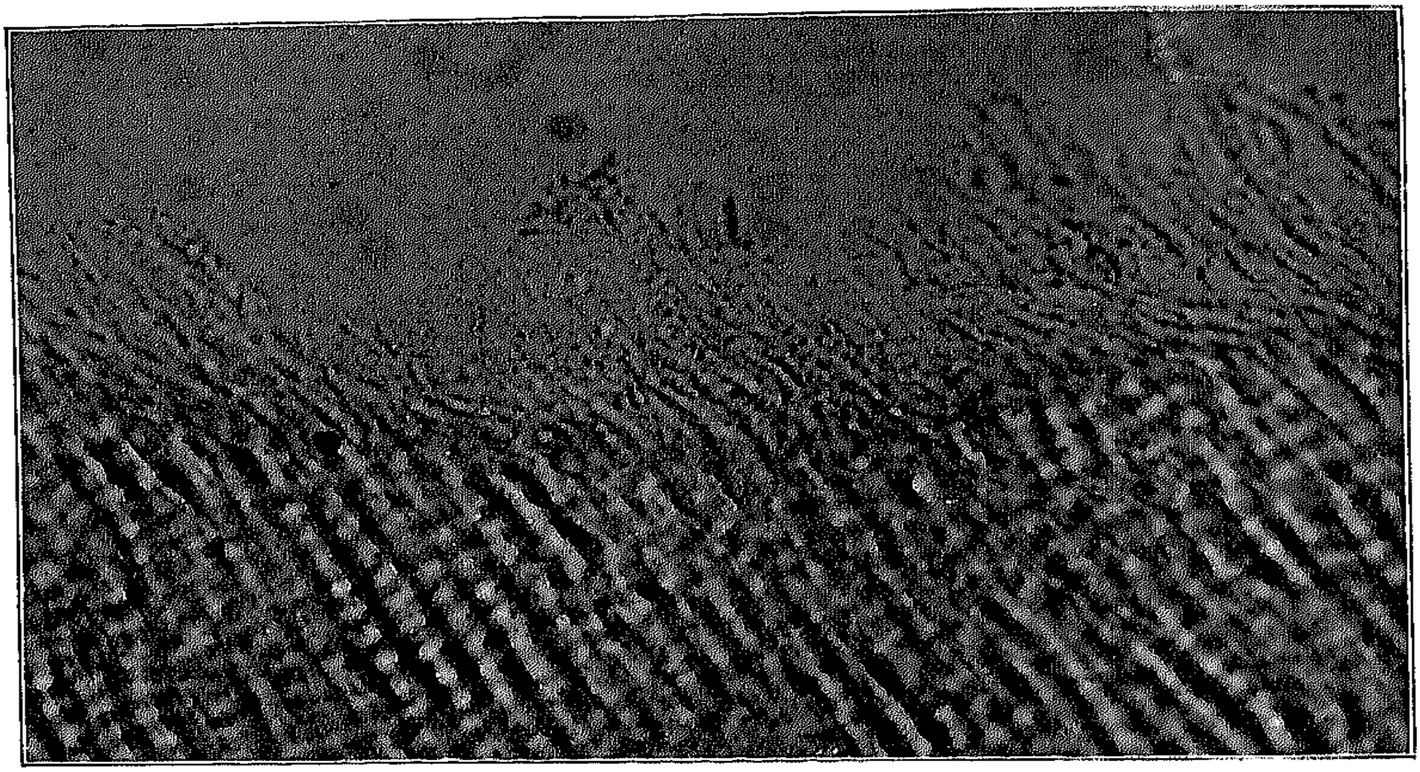


SECTION OF ENAMEL FROM FOSSIL TOOTH OF MASTODON. × 150.
Canals filled with a stain producing the appearance of fibers.

these fiber appearances from the edge inward to the thicker part of the tissue. I then saw each fiber gradually enlarge until it became an enamel-rod. Looking again at the finer continuation of the rod, I could in places see the last disappearing traces of the globular bodies along what I had at first taken for a fiber. (See Fig. 37.) There is no doubt, however, that during the developmental period the dentinal fibers sometimes penetrate the entire thickness of the enamel, and it is possible that these fibers may not always become completely atrophied.

Cope has shown that reversions to ancestral types are not infrequently found in human teeth, as, for instance, in the lemurian trituberculate form of molar teeth. It is somewhat more surprising, however, to find a reversion in the minute anatomy of the human tooth to the form of structure which is only fixed or permanent in the far-off marsupial tooth, for that is what we seem to have in the specimens I have just been exhibiting.

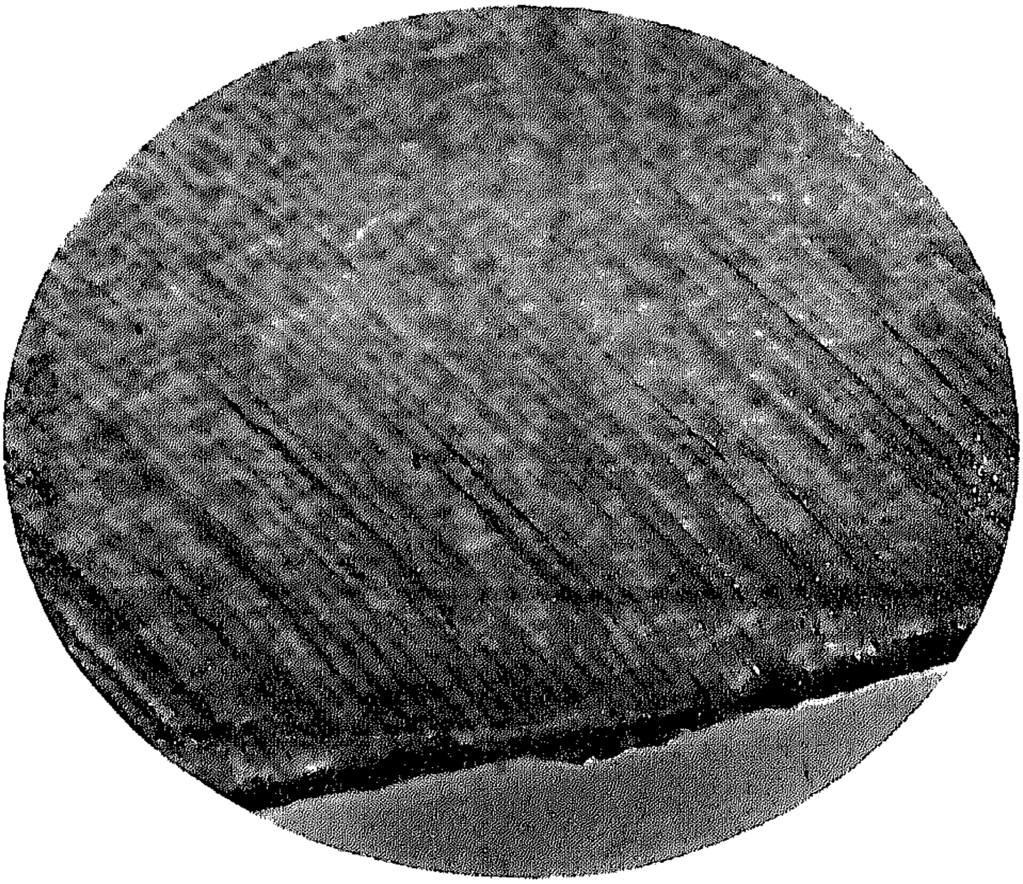
Fig. 37.



From Section of Normal Human Enamel Treated with Hydrochloric Acid. × 500. The acid, acting on a natural bevel on the upper margin of the specimen, has almost completely decalcified the enamel-rods, the fine remains of which present the appearance of fibers.

I have not infrequently found numerous canals near the surface in enamel that would be considered from its external appearance to be of the finest quality (see Fig. 38). But, as Dr. Black has pointed out, the habit has been formed by most dentists of looking upon the enamel of teeth which have escaped caries up to the fortieth or fiftieth year as being of very fine quality. As we proceed with our microscopic investigations it more and more becomes evident that there may be great fallacies attached to such conclusions. If such specimens as are shown in Figs. 35 and 38 had been prepared from rapidly decaying teeth, they would have been considered by most dentists as supplying a striking illustration of the significance of a strong predisposing cause of caries. Figs. 39 and 40 are from a syphilitic tooth, and this, as also the tooth from which the specimen shown in Fig. 33 was ground, were from the mouths of patients past fifty years of age. In both instances the teeth were removed because of extreme looseness, and in both instances the remaining teeth were nearly free from caries and also from filled cavities. The micro-organisms which fill the pit in the enamel in Fig. 34 had, before staining, that peculiar red-

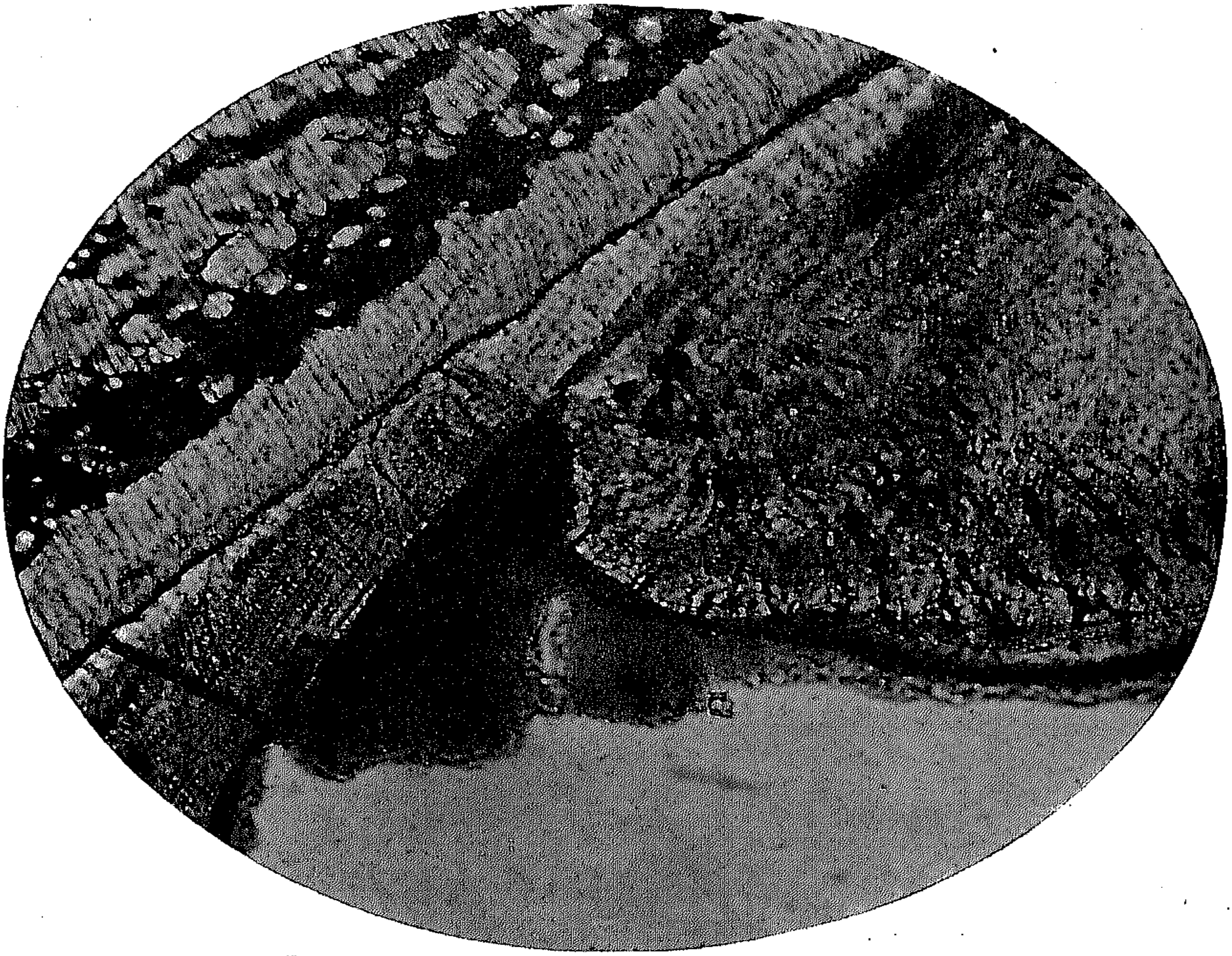
FIG. 38.



SECTION OF ENAMEL FROM HUMAN INCISOR. × 500.
Shows imperfect calcification and appearance of canals near the surface.

dish-brown color which I have always observed where caries is not in progress. The structure of the tissue in this specimen when seen under a magnifying power of eight hundred to one thousand diameters (see Fig. 41) looks much like cementum, for which it might easily be mistaken but for the indications everywhere of badly calcified enamel-rods. Large lacunæ-like spaces, which appear to be filled with organic matter, are seen, some of which have radiating processes and others seem to communicate with the dentin by means of canals. In other parts of the enamel of this tooth large cavities of various shapes appear, some of which communicate with each other (see Fig. 41). This specimen was temporarily mounted in glycerol, and after the photographs just shown were made I removed the specimen, washed it and placed it in a strong solution of picro-lithium-carmin, where it remained twelve hours. It was then washed in absolute alcohol and mounted in balsam. The basis-substance of the dentin is stained yellow, the interglobular spaces in the dentin and the micro-organisms on the surface are stained deeply with the carmin, but there is not a trace of stain in the substance of the enamel. I do not, therefore, believe that these large spaces contain living matter. It is of course perfectly plain that if the true

FIG. 39.



SECTION OF HUMAN INCISOR, SYPHILITIC. × 175.
Showing extremely imperfect enamel with appearance of masses of organic substance which does not, however, retain stains as living matter does.

predisposing cause of caries were present in such cases, the enamel would yield very rapidly to the attacks of decay-producing bacteria.

Nearly all writers on the pathology of the teeth have referred to the presence of interglobular spaces in the dentin as a special evidence of the degeneracy of tooth-tissue and as usually accompanying markedly faulty enamel. This certainly seems to be the case in human teeth. Fig. 42 shows a territory of dentin from the syphilitic tooth just mentioned. But interglobular spaces are found more frequently in the teeth of certain animals than in human teeth. I have often observed them in the teeth of the larger monkeys.

Fig. 43 is from the dentin of the Australian opossum (*Phalangista Vulpina*). The uncalcified spaces are more evenly distributed throughout the dentin, but the total amount of uncalcified area is probably quite equal to that shown in the specimen from the syphilitic tooth.

Fig. 44 shows granular pigmented enamel and poorly calcified dentin from the tooth of the dugong.

The photographs shown in Figs. 45 and 46 are, to me, in some respects the most interesting ones accompanying this paper. They tend to confirm all that I have previously written on the subject of

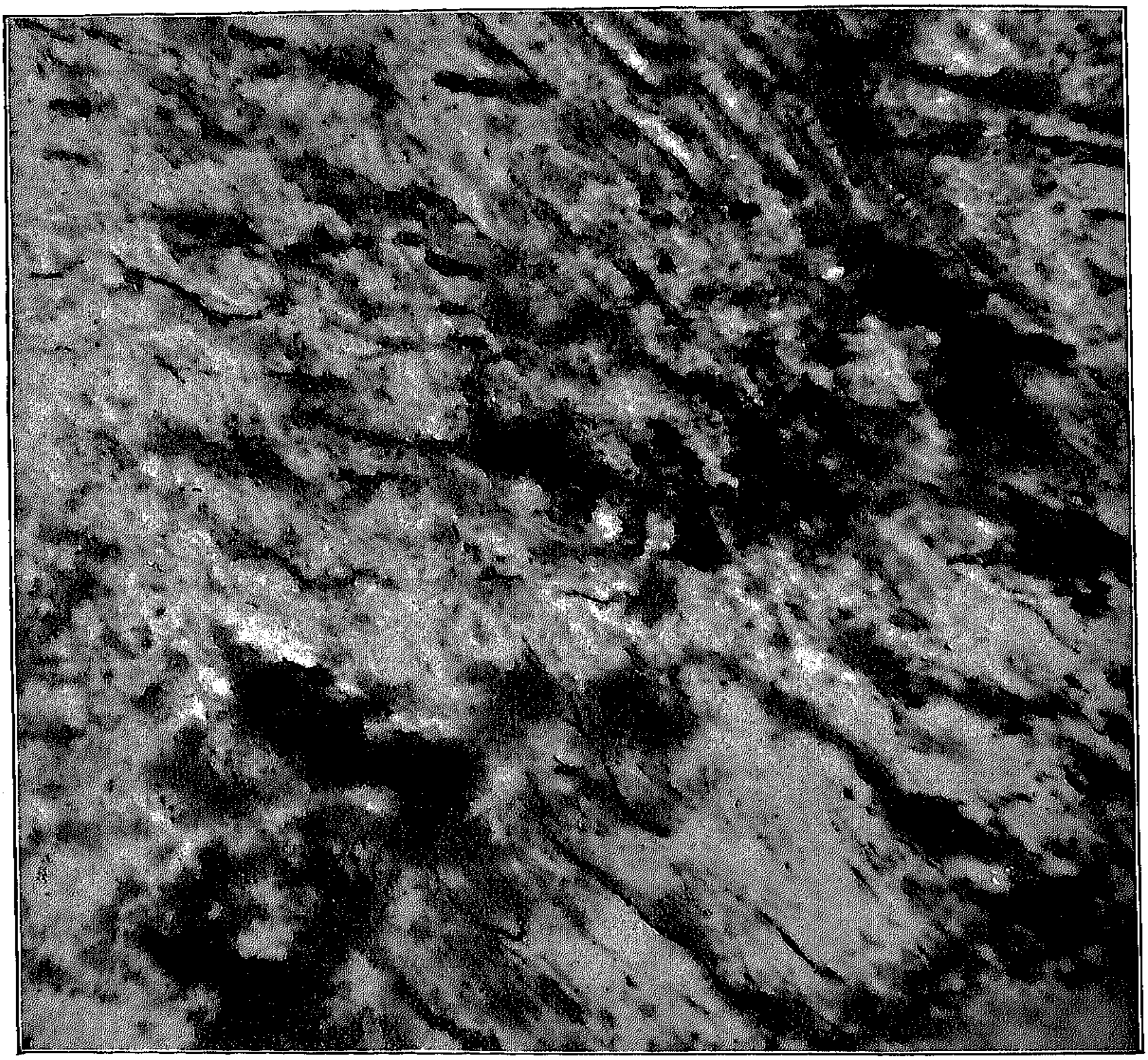
FIG. 40.

SECTION OF ENAMEL FROM SYPHILITIC TOOTH. × 600.
With appearances resembling the lacunæ of cementum.

enamel formation, and also to prove the fallacy of the teachings of the Heitzmann school concerning the arrangement of organic matter in enamel.

Bödecker and Abbott have taught and illustrated the presence of a delicate reticulum of living matter in enamel formed by a minute fiber passing between the enamel-rods and sending out very fine thorn-like processes, which processes produce the striated appearance of the rods. I have shown the most abundant evidence that the striation of the rods is due to a totally different cause. Fig. 45 is from a specimen of nearly decalcified enamel. The light line on the left side of the specimen is a line of striation caused by imperfect calcification. This specimen was mounted in glycerol, and pressure upon the cover glass showed that the portion outside of the line of striation moved slightly, but was held to the main mass by delicate fibers, which were not *between* the rods, but which constituted the organic basis of the rods themselves. At one point on the margin of the specimen the loose and curled-up ends of a few of these fibers can be distinctly seen.

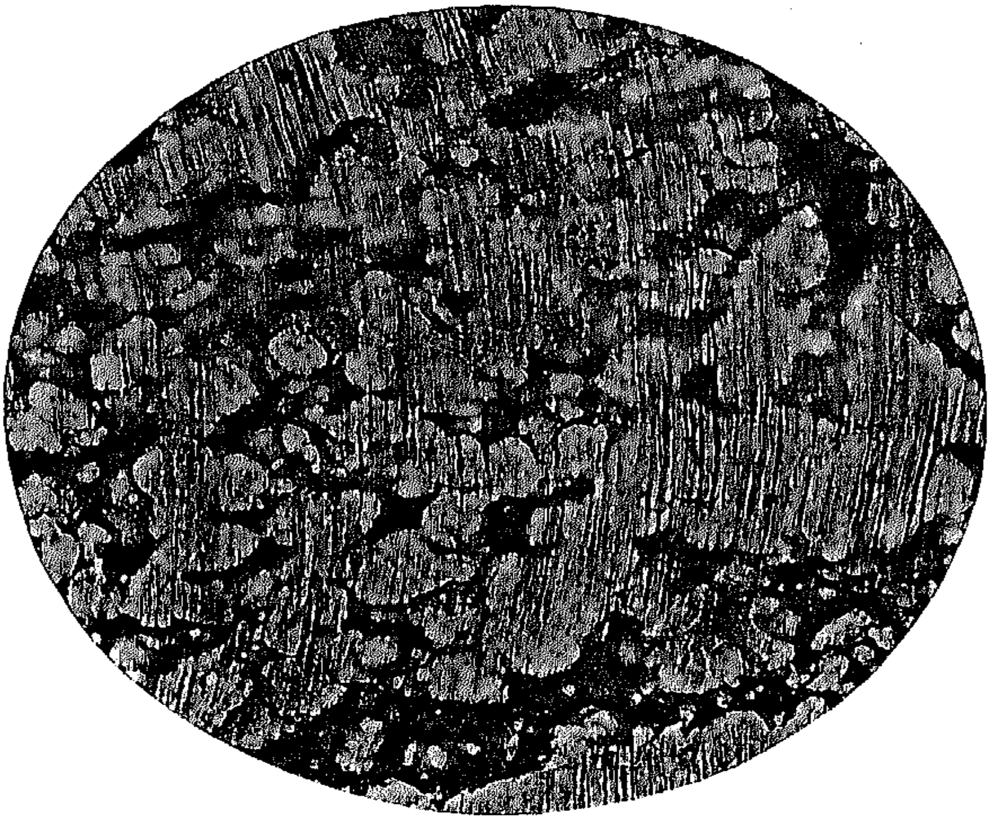
FIG. 41.



SECTION OF ENAMEL FROM SYPHILITIC TOOTH. × 800.

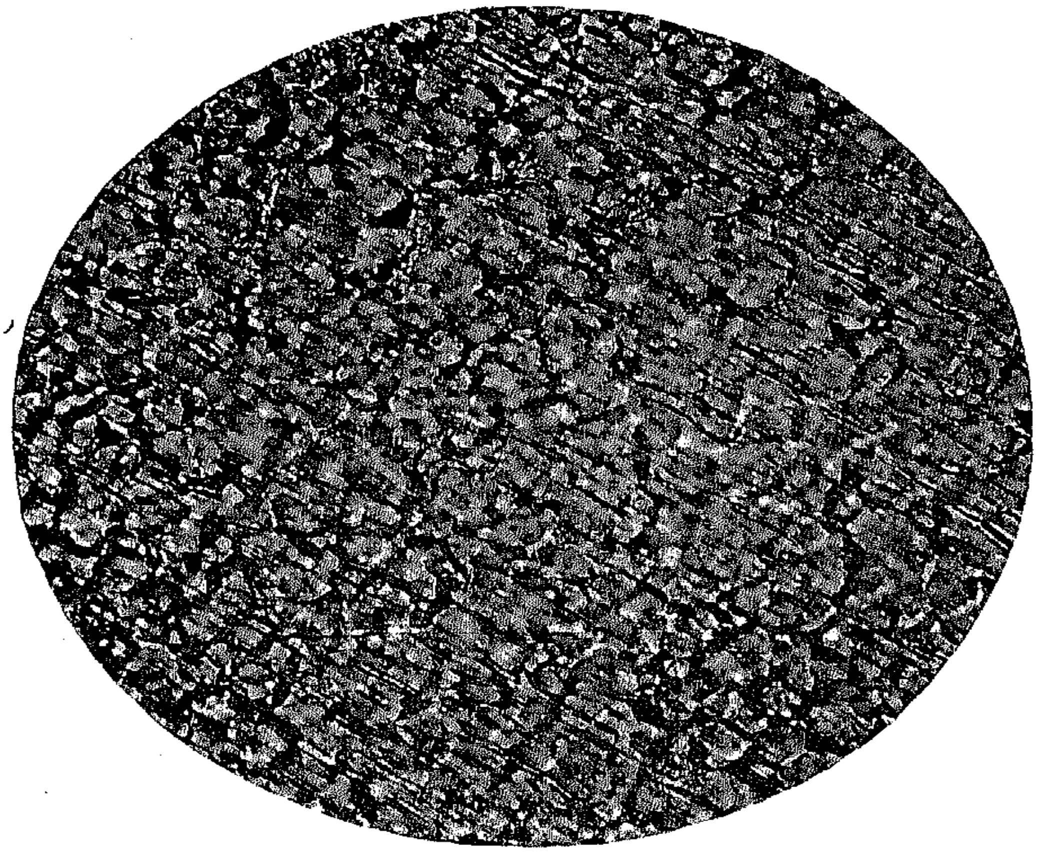
Fig. 46 is even more convincing than the foregoing. Here the rods are decalcified at their ends only. One can clearly see just where the last calcific remains of the globular bodies are disappearing, and projecting beyond these points are seen the faint ghost-like forms which constitute the organic substructure of the enamel-rods. The specimen is much more striking under the microscope, because the globular bodies on the border of the decalcified area

FIG. 42.



SECTION SHOWING INTERGLOBULAR SPACES IN DENTIN OF HUMAN TOOTH. SYPHILITIC. × 250.

FIG. 43.

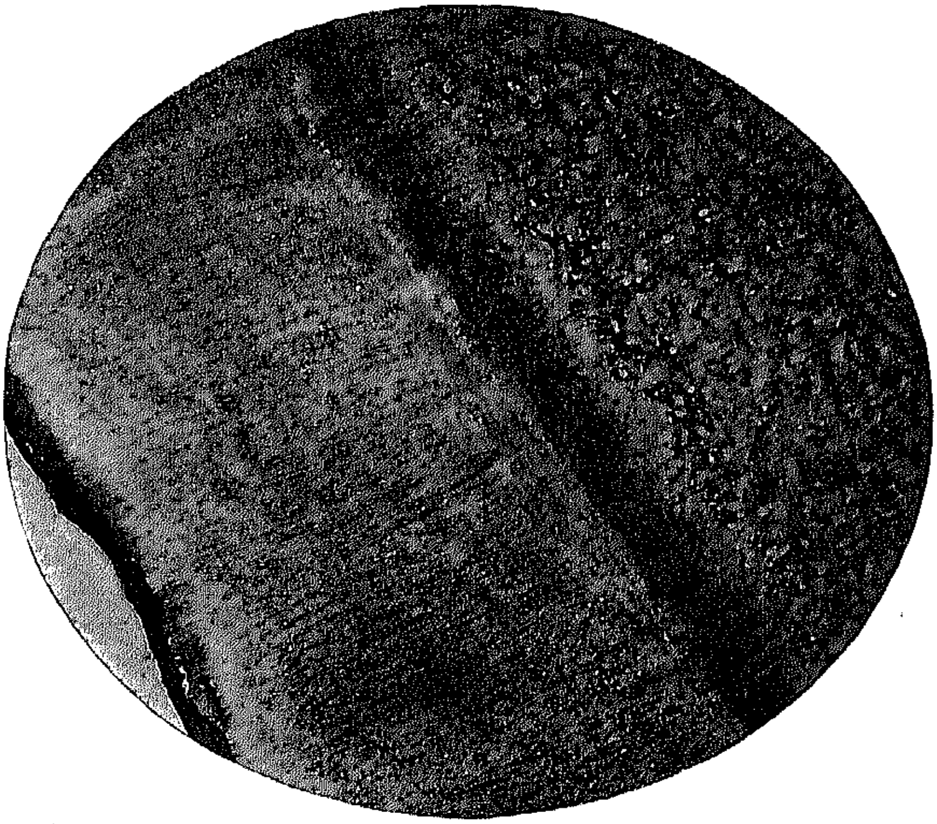


SECTION SHOWING INTERGLOBULAR SPACES IN DENTIN OF TOOTH OF AUSTRALIAN OPOSSUM. × 250.

are powerfully refractive and shine like jewels, while the organic substructure beyond is very dull and dim. Both specimens were photographed while temporarily mounted with a loose cover glass. Unfortunately, the one shown in Fig. 45 was lost in the attempt to remount it, but the other one I still have.

I have decalcified more than two hundred specimens of enamel, but these two are the only ones in which I have obtained any trace of an organic substructure in fully formed enamel. This substructure corresponds perfectly with the organic matrix which I have previously shown as being formed by the ameloblasts, and it is, in structure and position, exactly the reverse of what has been claimed by Drs. Bödecker and Abbott. But it is true, however,

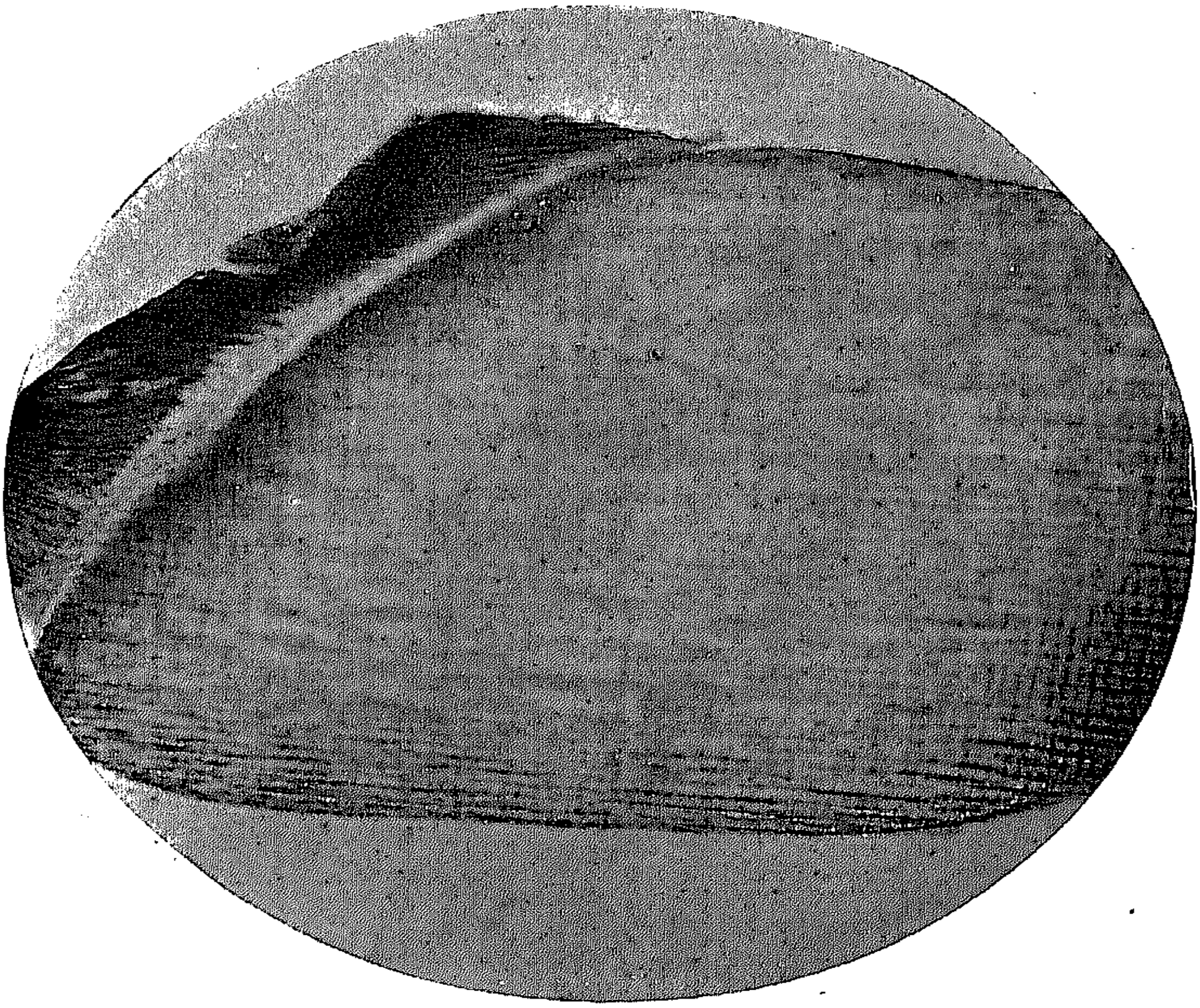
Fig. 44.



Section from Tooth of Dugong, showing Imperfectly Calcified Dentin and Enamel. × 250.

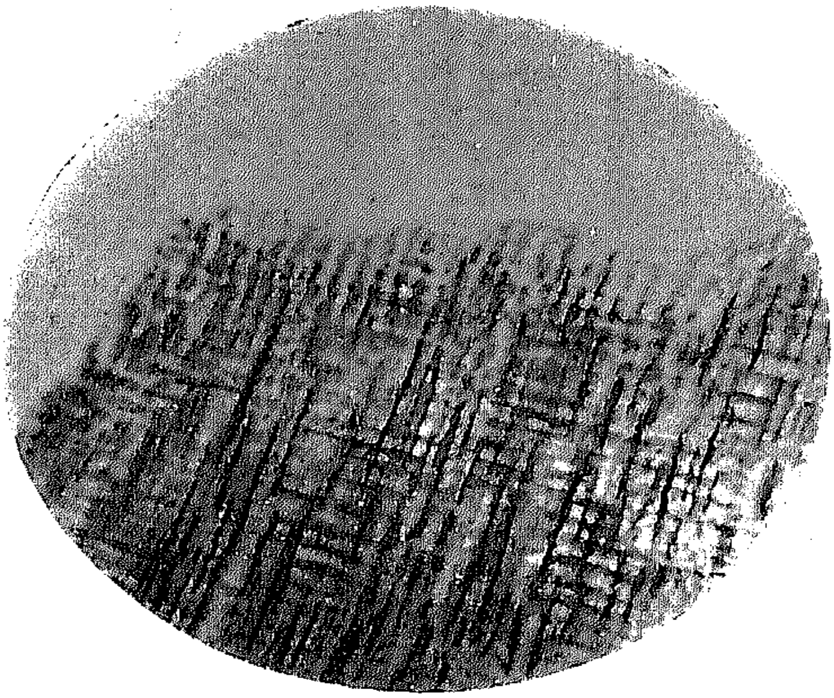
that there may sometimes be seen the appearance of a delicate fiber passing between the enamel-rods and sending out thorn-like branches into them. Fig. 47 is a photograph of enamel from the tooth of a South American rat (*Uromys macropus*). I selected the tooth of this little animal for showing this particular feature, because the enamel-rods are very distinct and clearly defined from the inter-rod substance. So far as I am aware, the appearance of a fiber with thorn-like projections between the enamel-rods has never before been so strikingly shown, certainly not in a photograph. I will not say that if Dr. Abbott or Dr. Bödecker had presented this photograph before this meeting, as a proof of their contention on this point, they would have converted all of you to their theories, but I think they would probably have staggered some of you and convinced not a few. It certainly does look like a convincing bit

FIG. 45.



SECTION OF HUMAN ENAMEL, NEARLY DECALCIFIED, SHOWING FIBROUS MATRIX. × 300.

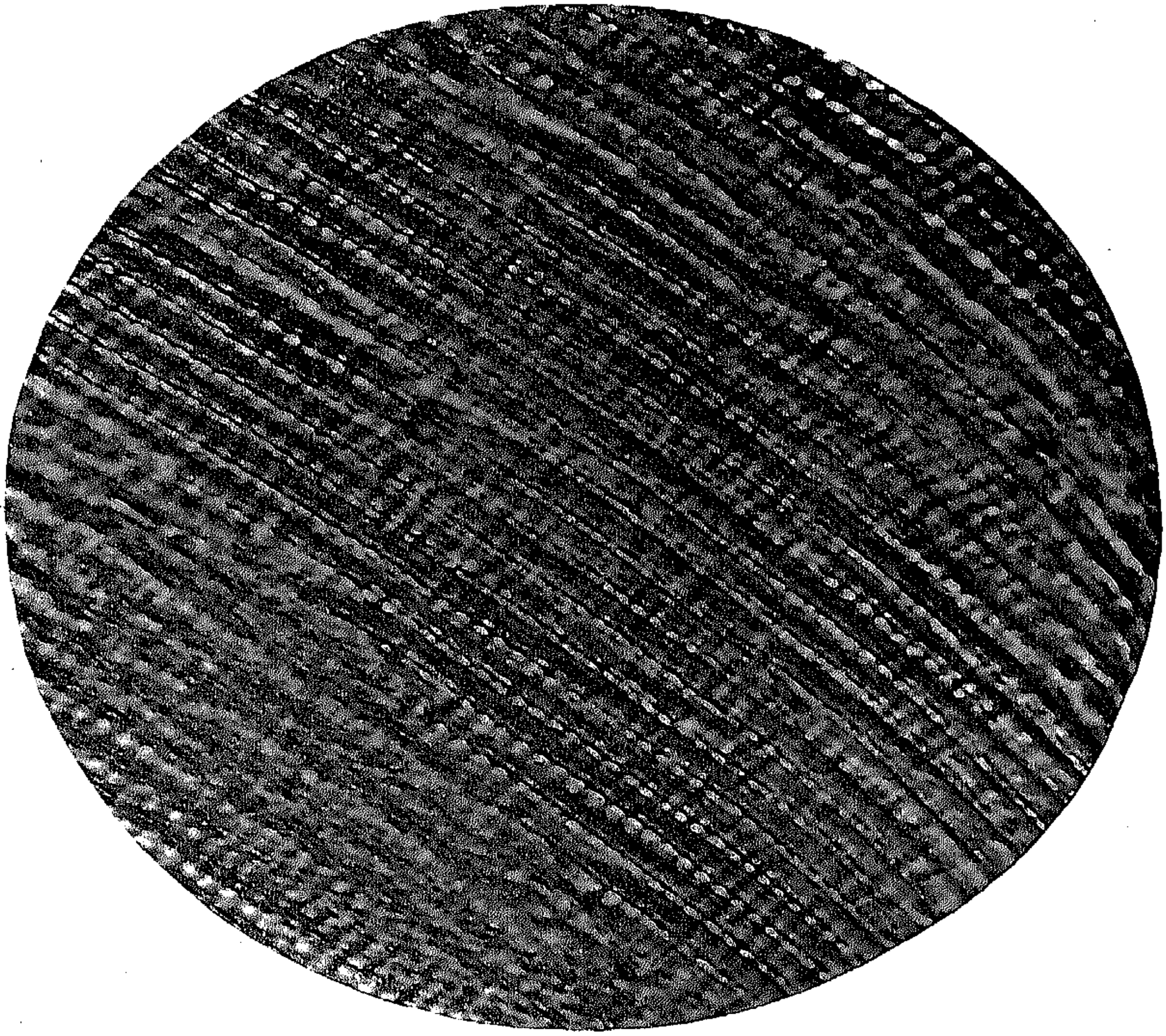
FIG. 46.



SECTION OF HUMAN ENAMEL, SHOWING EFFECT OF DECALCIFICATION. × 400.
A fibrous matrix is seen at the ends of the enamel-rods where the calcium-salts have been completely removed.

of argument in their favor. But we really have here only the outward form and semblance of a truth, and so we must, perforce, consign it to that great limbo which has swallowed up so many human delusions. It is a mere appearance, intentionally produced in this instance by manipulating the rays of light which illuminated the section at the time of photographing it. The sub-stage condenser of the microscope was racked down a little to increase the shadow effect, and the light was thrown obliquely upon the enamel-rods,

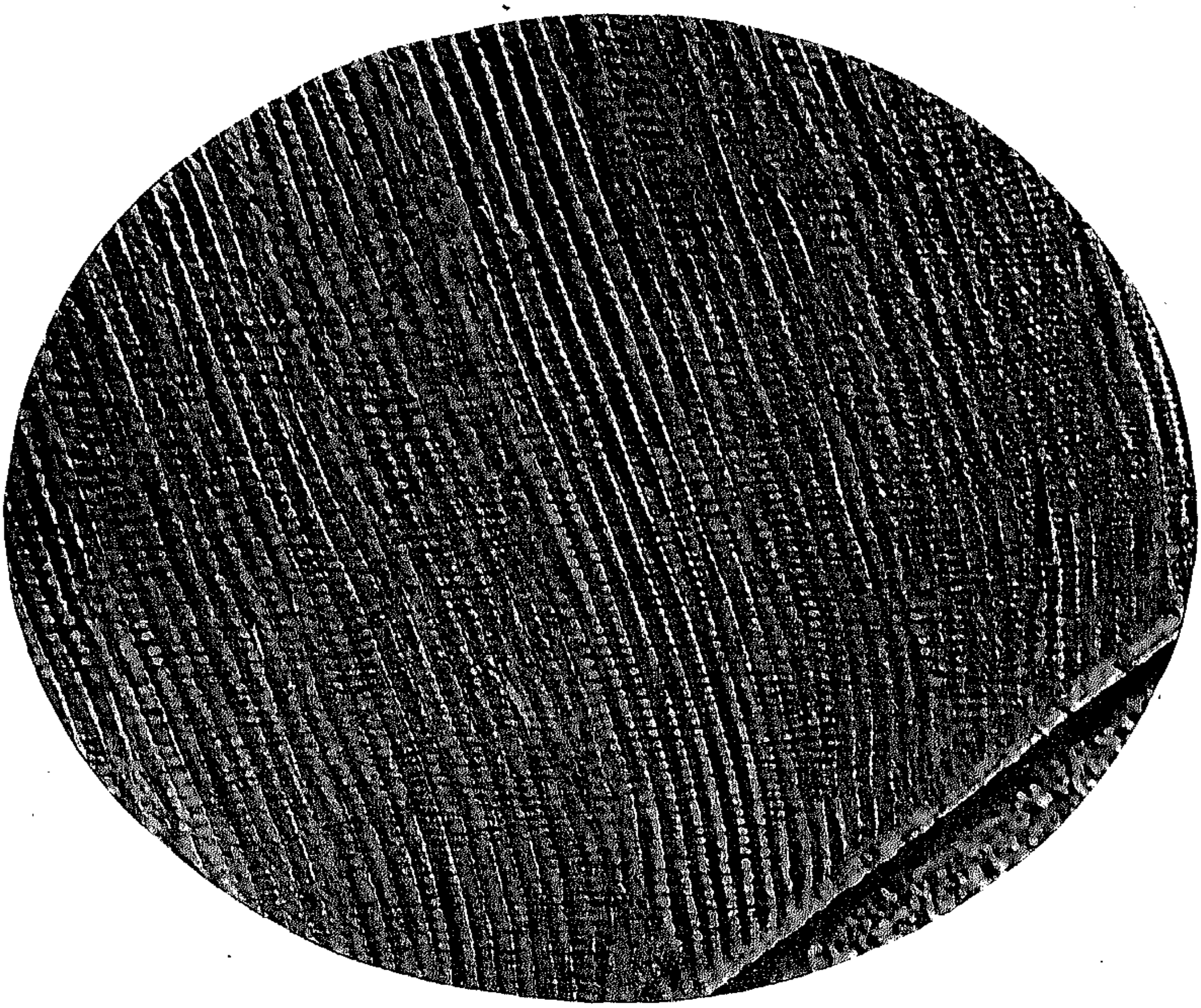
FIG. 47.



SECTION OF ENAMEL FROM TOOTH OF SOUTH AMERICAN RAT, SHOWING APPEARANCE OF FIBERS BETWEEN THE ENAMEL-RODS. × 800.

with the result that we have in the photograph a fine "diffraction" fiber. The thorn-like projections of the fiber are produced by the light breaking over the round edges of the enamel-globules of which the rods are built up. This manipulation of the condenser and the light is often resorted to by experienced histologists in their attempts to get different views of difficult subjects of study such as enamel is. It is also a method more frequently unconsciously used, with the result that wonderful discoveries are announced which nature is quite innocent of. In all critical tests of structure a different method of procedure must be adopted. Fig. 48 embraces the same field and a little more than is shown in Fig. 47. The lens used was slightly lower in magnifying capacity, but with a power of resolution or definition of a little over 181,000 lines to the inch. This is very near the present limits of the resolving power of microscopic lenses. The condenser was placed in "critical" focus and a central light thrown on the field, with the result, as you see, that every trace of the famous "fiber" has disappeared.

FIG. 48.

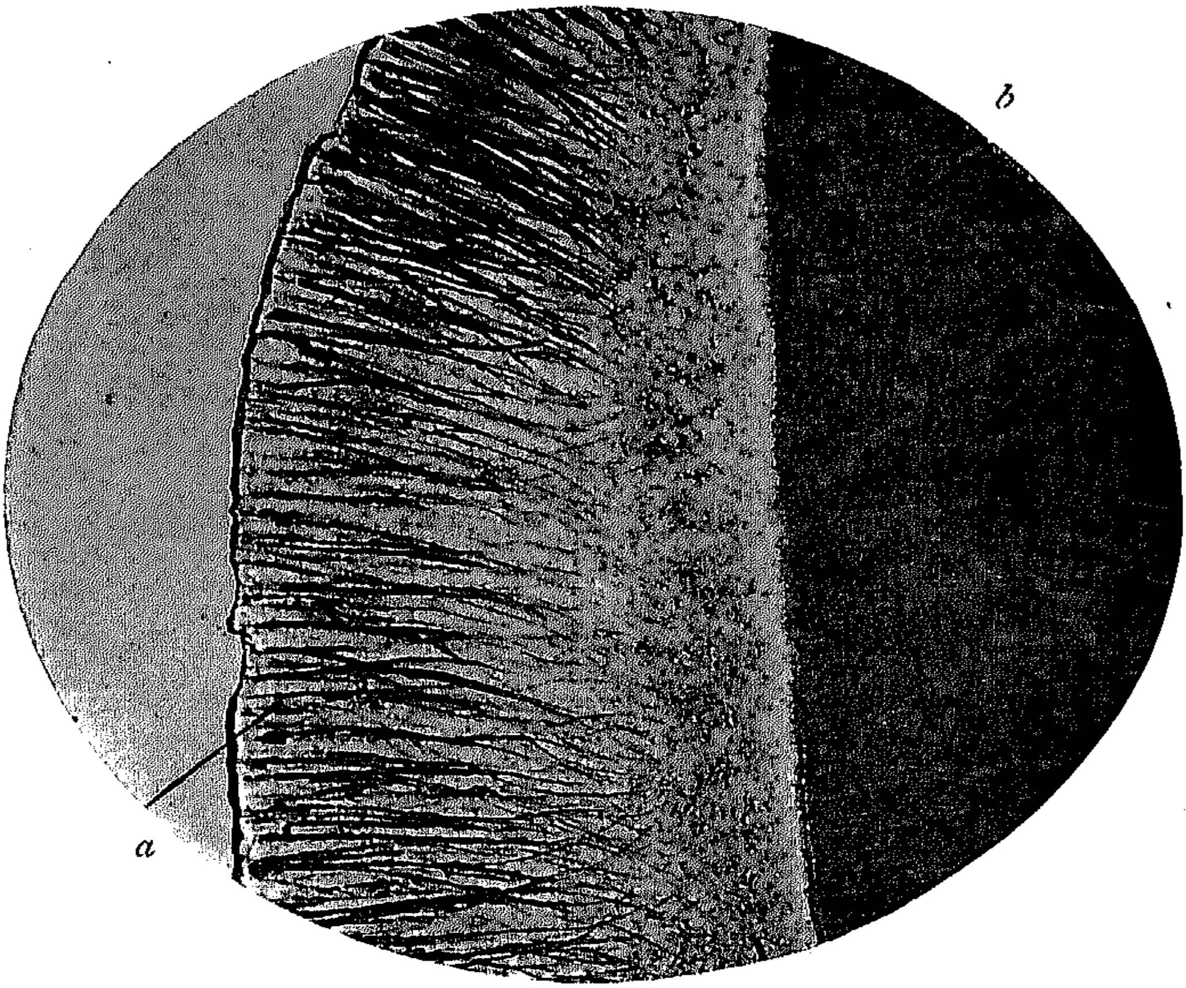


THE SAME FIELD AS SHOWN IN THE FOREGOING ILLUSTRATION. × 500.
Taken with a lens of lower magnifying, but higher resolving power, and with sub-stage condenser in "critical" focus and central illumination. All traces of the fibers shown in the preceding figure have disappeared.

This may serve not only as an explanation of Bödecker's enamel-fiber, but also as an illustration of one of the many technical difficulties which must be encountered in a critical microscopical study of enamel under high powers.

We are still far from having exhausted the subject of imperfections or variety in the minute structure of enamel, but we have taken a fairly general survey of the field. The facts brought out show that we may frequently find enamel of a markedly imperfect structure which has run the gauntlet of time for fifty or sixty years, and is free from decay. We may frequently find markedly imperfect enamel in the teeth of animals which very rarely or never suffer from caries. We frequently find enamel decaying rapidly which, from every test that can be applied to it, seems perfect in structure and composition. In the face of an overwhelming mass of facts of this kind, I think the only logical conclusion that can be reached is that *in teeth which decay* faulty structure may be regarded somewhat in the light of a predisposing cause of caries, while imperfection of structure in teeth which do not decay cannot be so regarded. This is nearly equivalent to saying that railway

FIG. 49.



FROM SECTION OF TOOTH OF SARGUS. × 150.
Specimen from Mr. Charles Tomes's collection. *a*, Enamel; *b*, Dentin.

traveling, for instance, predisposes to nervous shock, concussion of the brain, or broken limbs *if the train goes off the track*. I have no wish to over- or under-estimate the value of any fact in this connection. My whole aim in this first part of my paper has been to show the proper value and the true relation of a series of facts that have hitherto been vastly over-estimated in considering the problem of dental caries.

The utmost, as it appears to me, that can be said upon the point is this: Any form of imperfection in enamel-structure which implies a deficiency of calcific material makes less work for the true destructive cause just to the extent of such deficiency. But it is simply not true that all rapidly decaying enamel is deficient in calcific material or otherwise imperfect in structure. The canals, channels, or tubes which we find in the teeth of the sargus, spherodus, pycnodus, and other recent and fossil fishes cannot be said to predispose to caries, because the conditions of the environment of these teeth are such that they never decay. But place enamel of such structure as is shown in Figs. 49 and 50 in the average human mouth, and it would doubtless decay much more rapidly than the same bulk of enamel from a human tooth, for the simple reason that bulk for bulk the enamel from the teeth of these fishes contains much less calcific material for acids to dissolve than is found in human

FIG. 50.

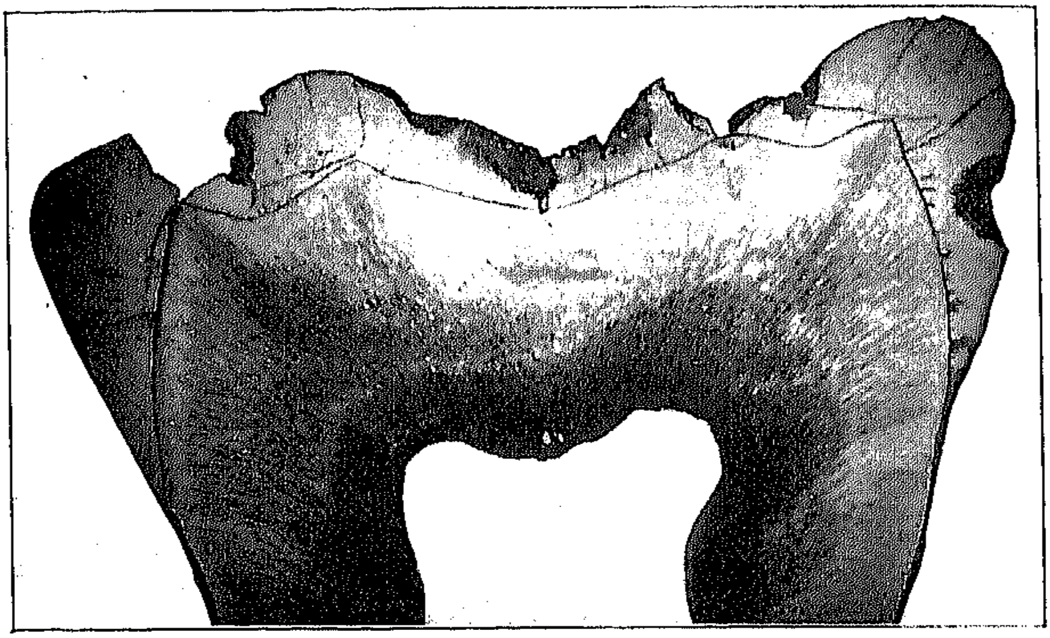
FROM SECTION OF FOSSIL TOOTH OF PYCNODUS. × 150.
a, Enamel; *b*, Dentin. The dentinal fibers are seen to pass into the enamel, some of them branching and turning abruptly to right and left, and others passing through the entire thickness of the tissue.

enamel, and also because channels and fissures of all sorts offer an increased surface for the acid of decay to act upon. In view of what has been previously demonstrated and of what is clearly shown in the illustrations accompanying this paper, I do not see how any one can take up any other position than this.

We will pass now to an examination of the active cause and the phenomena of caries of enamel. All previous writers have treated this subject very briefly, and have especially remarked the extreme difficulty they have experienced in preparing sections of carious enamel. Dr. Miller, while having most thoroughly worked out the problem of decay of dentin, gives only three pages in his valuable book to appearances under the microscope of enamel in decay. He says,—

"The preparation of specimens of enamel suited for a study of the process of decay is very difficult."

FIG. 51.



ANTERO-POSTERIOR SECTION OF UPPER HUMAN MOLAR. × 10.

FIG. 52.

SECTION THROUGH APPROXIMAL CAVITY SHOWN IN PRECEDING ILLUSTRATION. × 100.

His conclusions are that—

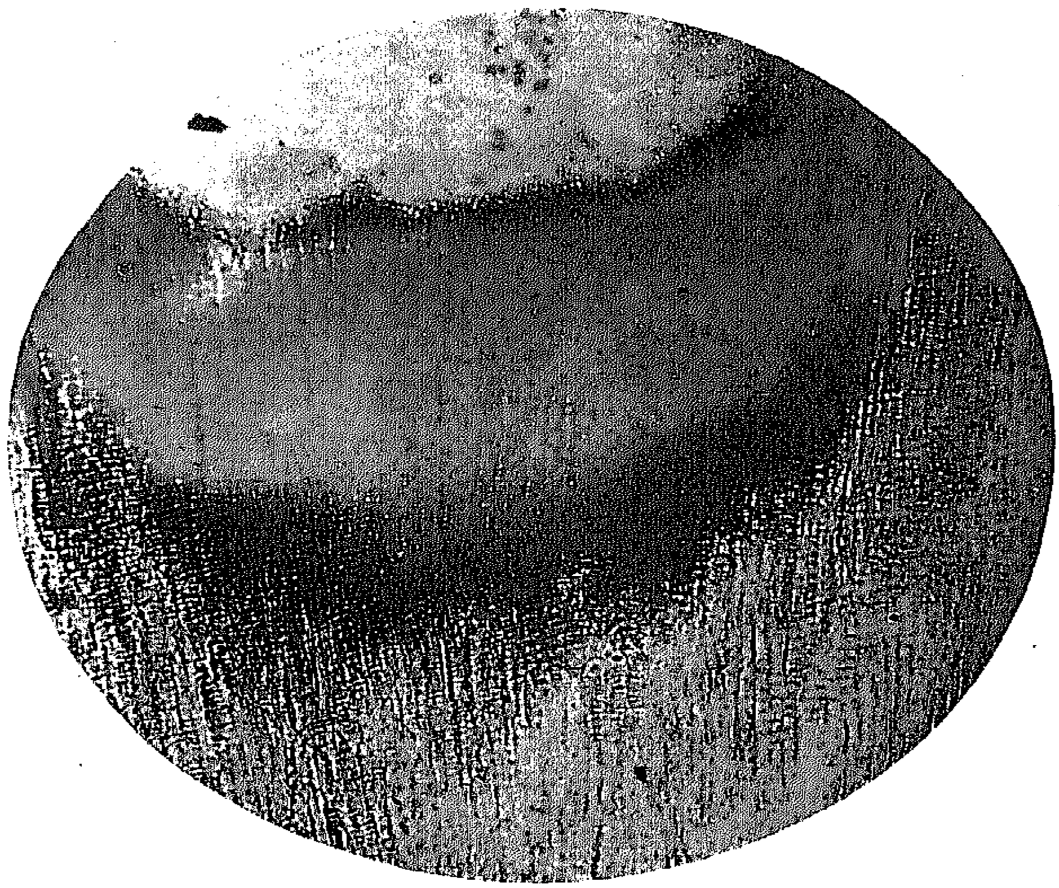
"The destruction of the enamel as it occurs in decay must be regarded as essentially a parasitico-chemical process. The loosening of the enamel-prisms is caused by acids concerning whose origin there can be no doubt; they arise in the mouth by fermentation of the carbohydrates. . . . The bacteria directly participate in the process, inasmuch as they invade the broken-down enamel, perhaps drive the prisms farther apart, and destroy the remnant of organic matter. Micro-organisms do not exert a direct influence on normal enamel."

Mr. Henry Sewill in treating this subject in his book says,—

"To cut a section of carious enamel sufficiently thin for examination under high microscopical power is impossible."

Wedl, in the "Atlas of Dental Pathology," gives but one illustration of the appearances of carious enamel under high magnifying

FIG. 53.



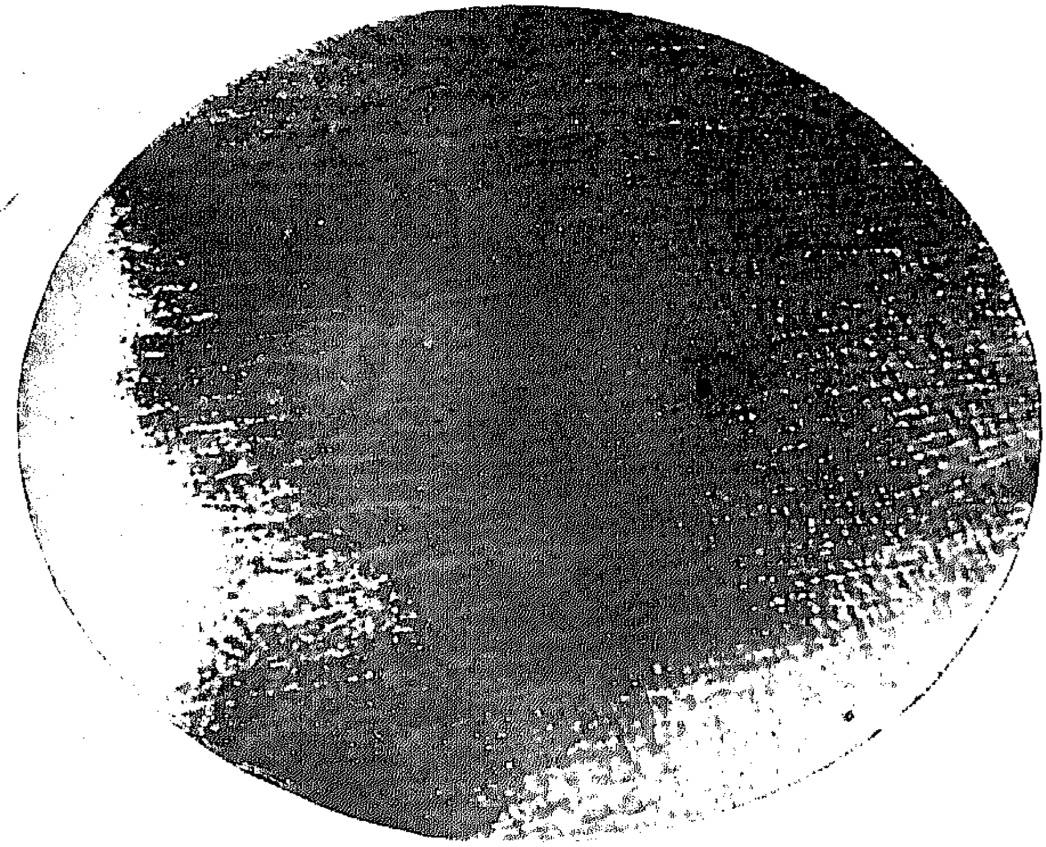
SECTION OF CARIOUS ENAMEL PREPARED BY THE WEIL METHOD. × 300.

The deep natural stain and the general appearance of the enamel indicates very slow decay. In printing, the thinnest part of the negative, where the stain was deepest, has been "blocked out" to prevent entire loss of detail at this part. It is seen that the enamel-rods are not broken down in this deeply-stained part and that there is no granular layer. The only appearance of this sort is on the surface of the cavity, where a thick mass of bacteria is shown.

power, and that one shows nothing of the process by which the disintegration or staining of the tissue is brought about. The only illustration on this point in the last edition of Mr. Charles Tomes's "Dental Surgery" is a reproduction of the engraving which accompanied Dr. Abbott's article on the subject in the DENTAL COSMOS in 1879.

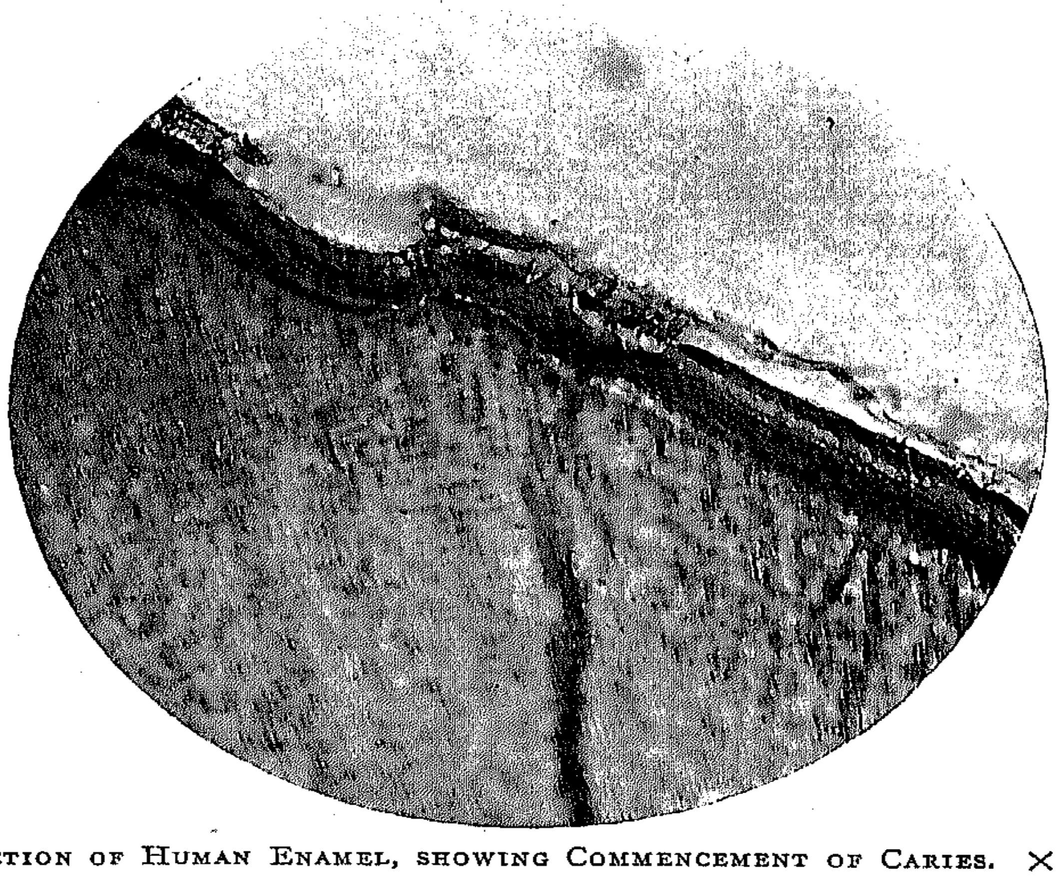
Mr. Tomes's conclusion concerning the process of caries is in harmony with those of the most advanced investigators and writers

FIG. 54.



FROM A SECTION OF CARIOUS ENAMEL. × 800.
The mass of micro-organisms, which has often been spoken of as a granular layer of decomposing enamel, has been torn away from the surface in mounting.

FIG. 55.

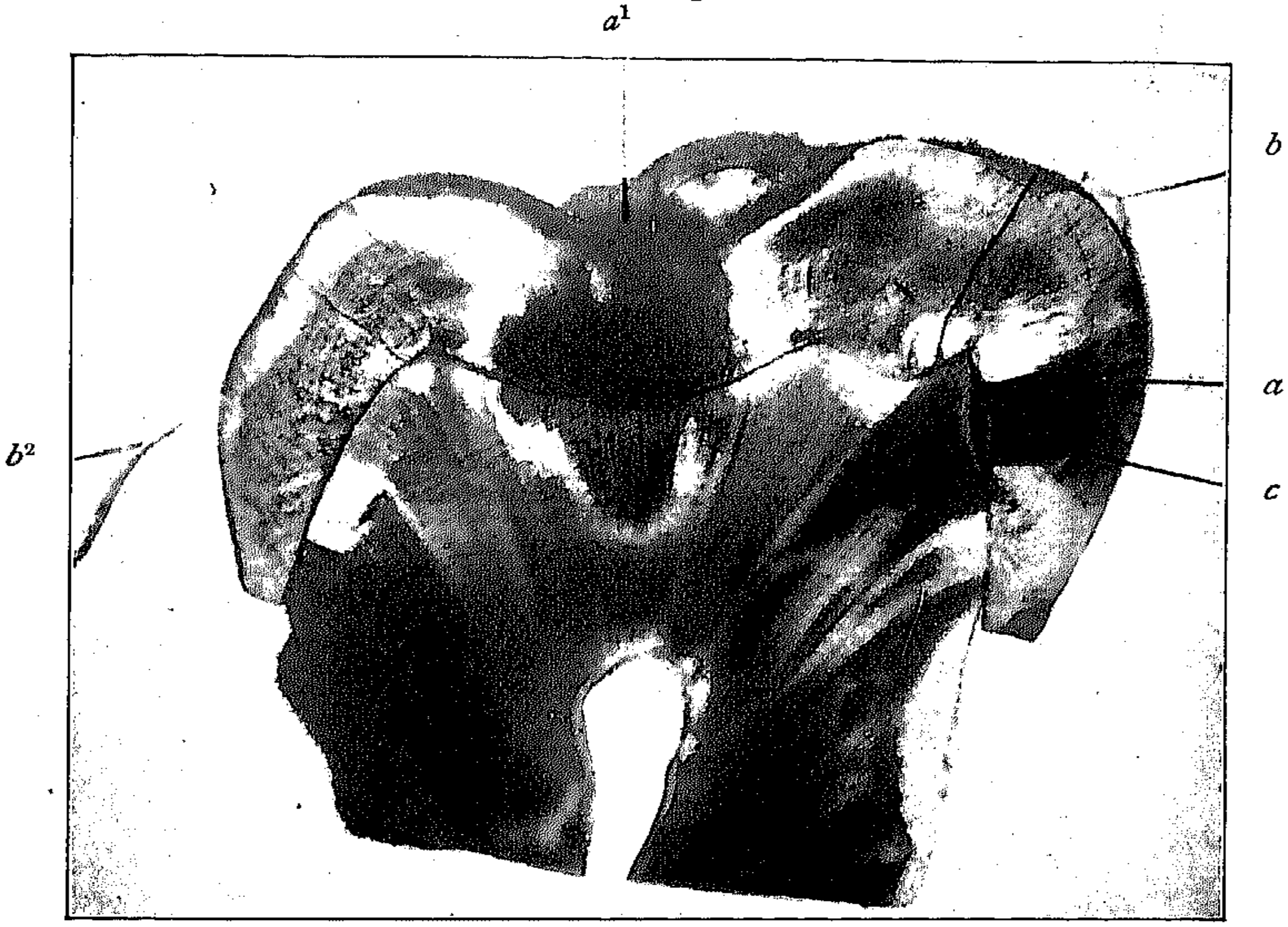


SECTION OF HUMAN ENAMEL, SHOWING COMMENCEMENT OF CARIES. × 250.

in this field, which is that it "is due to the solvent action of acids which have been generated by fermentation going on in the mouth, organisms having no small share in the matter."

There are no drawings or photographs of carious enamel in "The American System of Dentistry." Dr. Black's contribution to this work is a masterly presentation of the argument, and a lucid summing up of the whole subject, but it contains no definite statement as to the exact process of the inception of caries. Dr. Abbott, who says that he has studied this subject more or less continuously for sixteen years, gives in his recently published work on "Dental Pathology and Practice" the engraving to which I have already re-

FIG. 56.

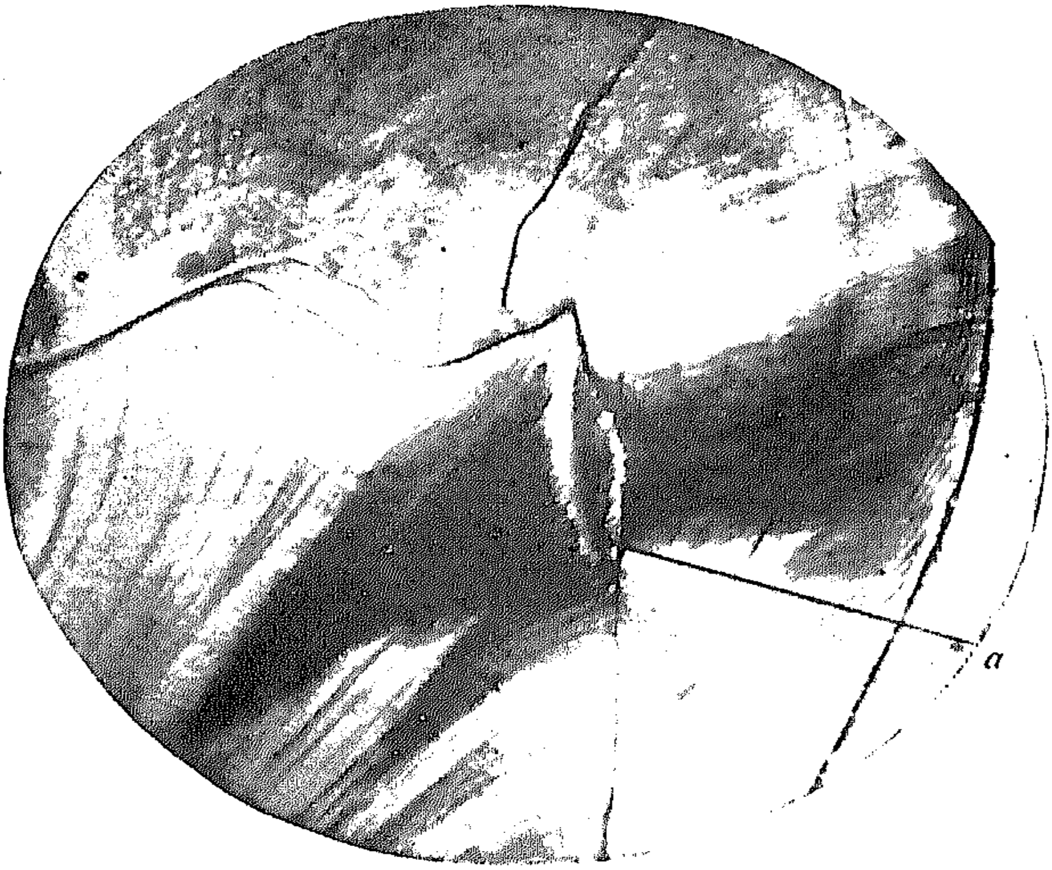


SECTION OF HUMAN BICUSPID, SHOWING COMMENCEMENT OF CARIES. × 12.
a and a^1. Appearances caused in enamel and dentin by the acid of decay; *b* and b^2, Shreds of a felt-like mass of bacteria raised from the surface of the enamel; *c*, A cavity, more distinctly shown in the illustration following this.

ferred and one photograph of decaying enamel, but neither of these conveys any information as to the real cause of caries. His conclusion, however, is that micro-organisms "do not play any important part in the process of caries, at least, do not materially interfere with the tooth in its normal condition." This opinion, judging from the context, is based upon the fact that no micro-organisms are shown in the drawing or, presumably, in the specimen from which the drawing was made.

The references which I have mentioned sufficiently indicate the present information and opinions on the subject, and I doubt if it

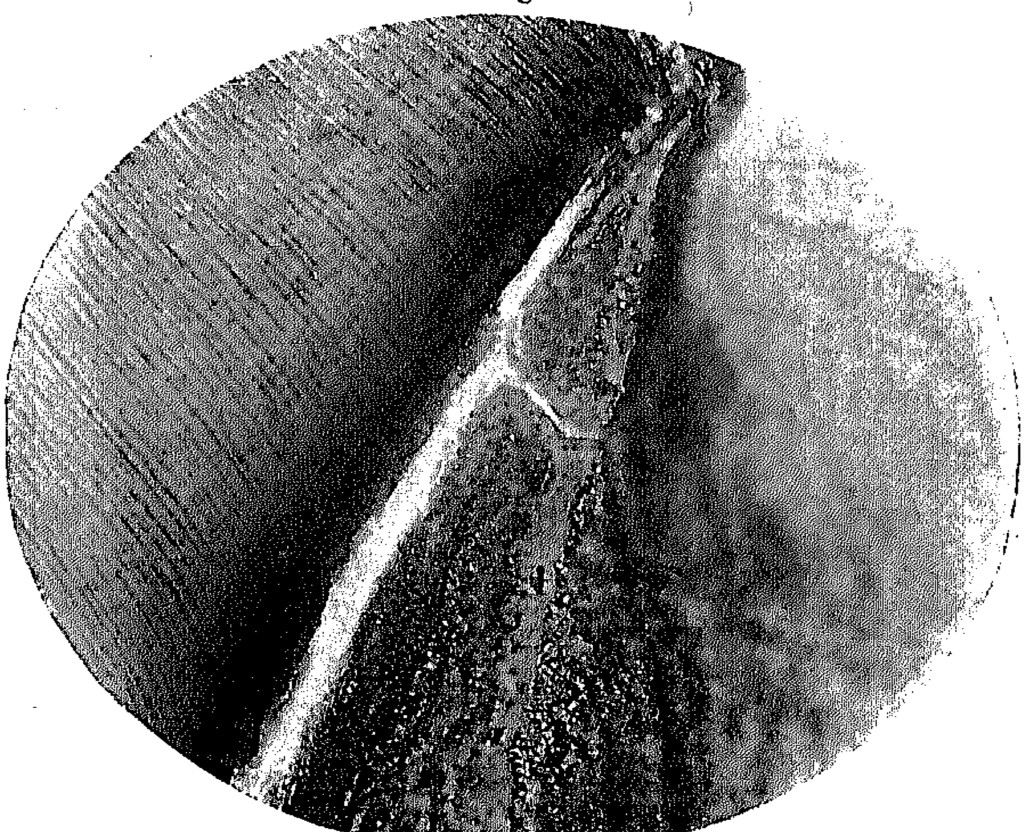
FIG. 57.



STAINED AREA OF ENAMEL AND DENTIN SHOWN AT *a* IN THE PRECEDING ILLUSTRATION. × 50.

a, A cavity which has been formed by the acid of decay at the line of union of the enamel and dentin. The only means of communication between this cavity and the surface of the enamel is through the microscopic canals formed in the enamel by acid excreted on the surface by bacteria.

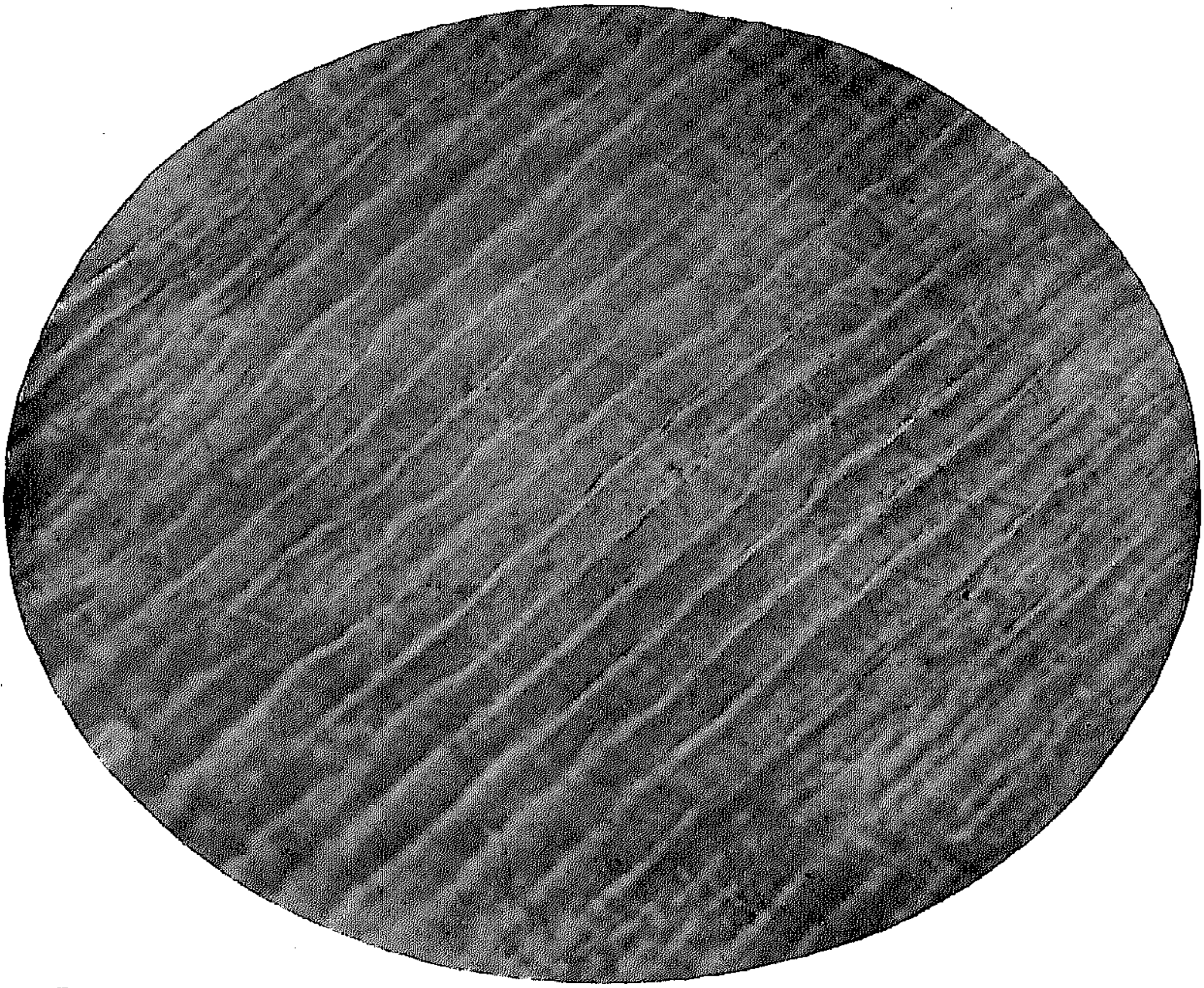
FIG. 58.



SHOWING CAVITY, SEEN AT *a* IN PRECEDING ILLUSTRATION, NEARLY FILLED WITH PARTLY DECALCIFIED BITS OF ENAMEL AND THE DEBRIS OF DECAY. × 250.

is possible to obtain any further information from specimens prepared in the usual way. Fig. 51 is a photograph of an antero-posterior section of an upper molar showing the commencement of caries of the enamel on the grinding and approximal surfaces. If the small approximal cavity be examined under a power of two hundred and fifty diameters we have such appearances as are shown in Fig. 52, and which have been described in most of the text-books treating the subject. One notes the usual staining of

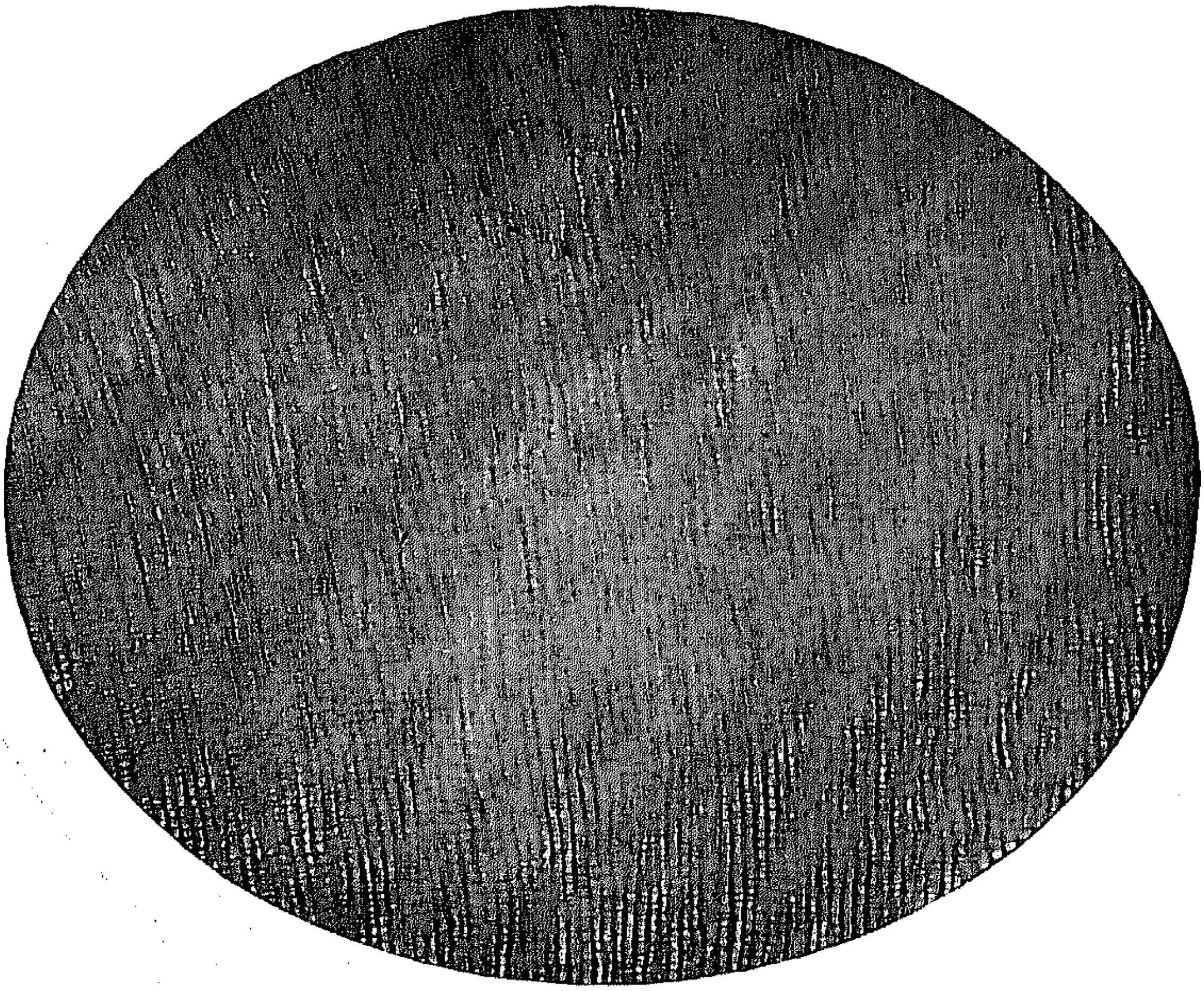
FIG. 59.



SHOWING CHANNELS OR CANALS BETWEEN THE ENAMEL-RODS FROM THE TERRITORY SHOWN AT *a* IN FIG. 56. × 1000.

the enamel and the marked definition of the rods and the sections of which they are composed as the result of the penetration of some acid. On the margin of the cavity is seen what has sometimes been described as the granular layer of nearly decomposed enamel. Fig. 53 shows a section of deeply pigmented, slowly decaying enamel. It is seen that the rods do not at any point break down into a granular appearance. The ends of the rods which form the floor of the cavity have the usual appearance of enamel which is being acted upon by acids. The granular appearance above the enamel is caused by a mass of unstained bacteria which lines the cavity. More frequently than otherwise this so-called granular layer is absent, as in Fig. 54, which shows the border of decaying enamel as magnified about one thousand diameters. In this specimen we observe that the cement-substance between the rods and also between the globular bodies or sections of the rods has been partly removed by acids, which have evidently penetrated deeply into the substance of the enamel. On completing our

FIG. 60.

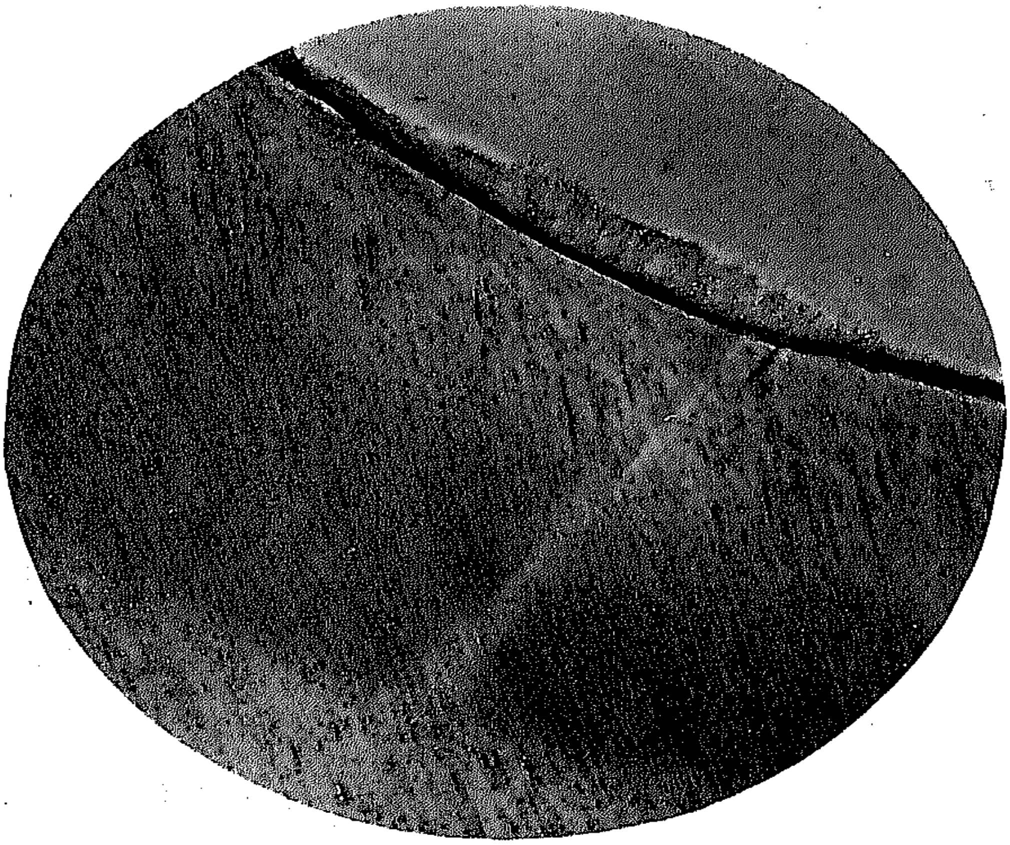


SECTION OF HUMAN ENAMEL, NORMAL, SHOWING EFFECT OF ACTION OF LACTIC ACID. × 200.

study of this specimen we can say with Dr. Abbott that "not a trace of micrococci or leptothrix is visible in or above the decayed pit of enamel."

When I began the study of this subject I examined several hundred specimens of decaying enamel mounted by the most expert preparers in this kind of work. I saw, as one might expect, a great variety of appearances, but nothing to indicate the exact manner in which those appearances were produced. On attempting to grind sections I found, as Dr. Miller and others have stated, that it was an extremely difficult task to get sections of carious enamel sufficiently thin for study under high powers. In examining comparatively thick sections in water or glycerol during the process of grinding, I often saw that the cavities in carious enamel were lined with micro-organisms, but if I succeeded in getting the section sufficiently thin and mounted in balsam I found that all traces of the bacteria had usually completely disappeared. Occasionally, in specimens selected to show the beginning of caries, such appearances were seen as are shown in Fig. 55. A slight amount of enamel at one point has been destroyed, and on each side of this Nasmyth's membrane is shown raised from the surface of the tooth and, adhering to the membrane in places, what appear to be bits of partly decomposed enamel. This is the most interesting and instructive balsam-mounted section of the commencement of caries

FIG. 61.

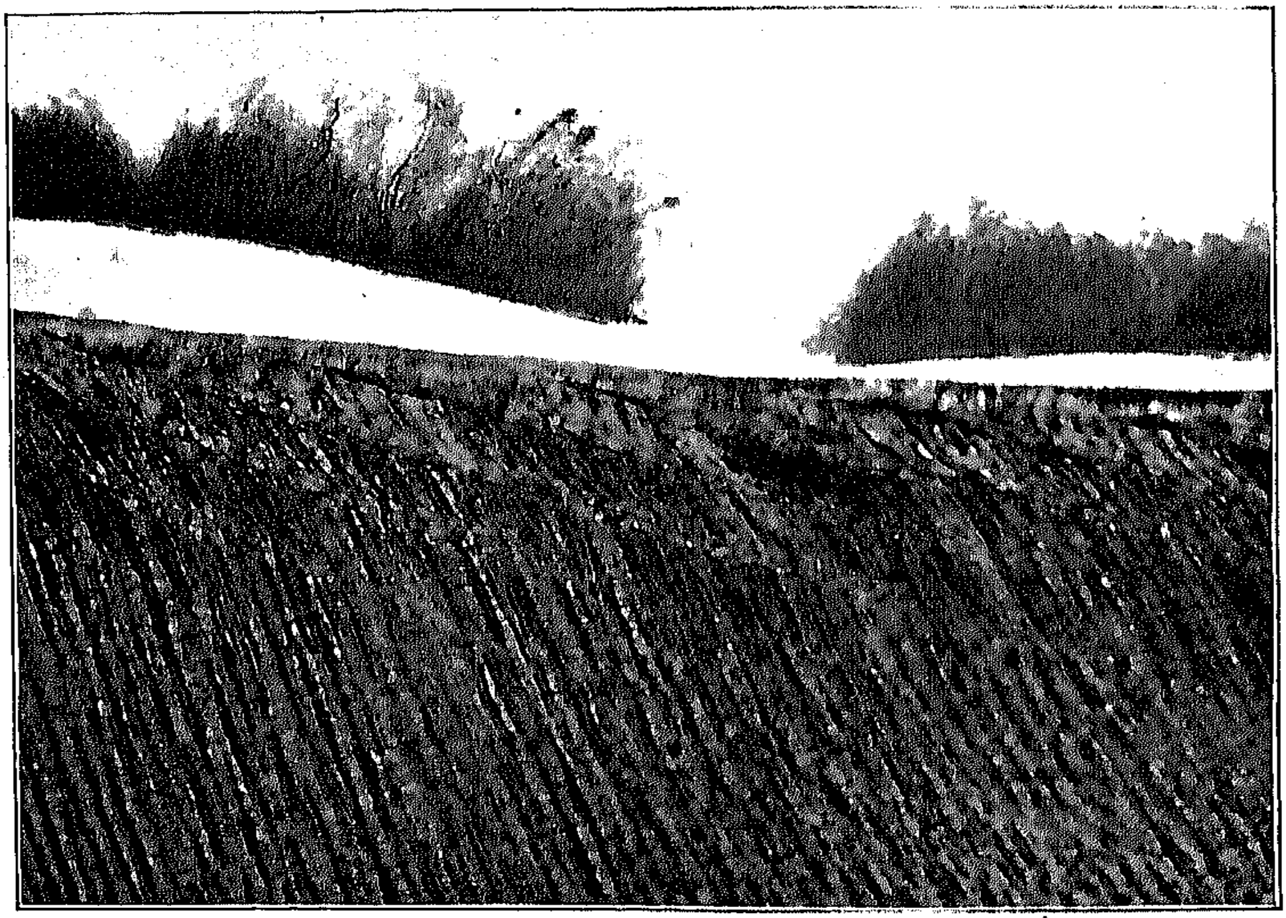


SECTION OF NORMAL HUMAN ENAMEL FROM APPROXIMAL SURFACE OF BICUSPID, SHOWING MICRO-ORGANISMS ATTACHED TO NASMYTH'S MEMBRANE. × 200.

that I have ever seen. It perfectly illustrates the statements of various authors to which I have referred, that caries of the enamel is caused by acids generated in the mouth. Experiments out of the mouth with acids demonstrate that Nasmyth's membrane may be raised so as to produce appearances almost identical with what is shown here. This, however, does not bring us much nearer a solution of the problem. As I was preparing this particular specimen I saw that the little depression shown on the left was filled with leptothrix and thread-like forms of micro-organisms, and the question which has often been asked, but never satisfactorily answered, at once occurred to me: Were the bacteria present merely as an accident because they found in some congenitally defective spot, or in a depression caused by the action of free acids in the mouth, the opportunity for undisturbed development, or was the defective spot in which they were seen solely caused by them?

A very interesting and suggestive fact was several times observed near the commencement of this work; it was that decay often seemed to be rapidly progressing where the enamel was most perfect, while various defective spots in the tooth well calculated to offer points of attack for free acids had been passed over. The appearances, especially such as show the sharply circumscribed area to which I have called your attention, all indicated that decay was *the result of some specific cause acting continuously at some particular point in a manner impossible to free acids in the mouth.* Being convinced of this, I set about devising some method of grinding thin sections with the least possible disturbance to the partially decomposed enamel or to anything that might be attached to its surface. The Weil-Koch method, which I tried thoroughly, gave me only mediocre results. It consumes much time, and it necessitates the treatment necessary for mounting in balsam,—an almost fatal objection for this particular kind of work from my point of view. To the discovery of a simple and effective method of grinding specimens whereby sections of carious enamel can be prepared in ten or fifteen minutes sufficiently thin for examination under the

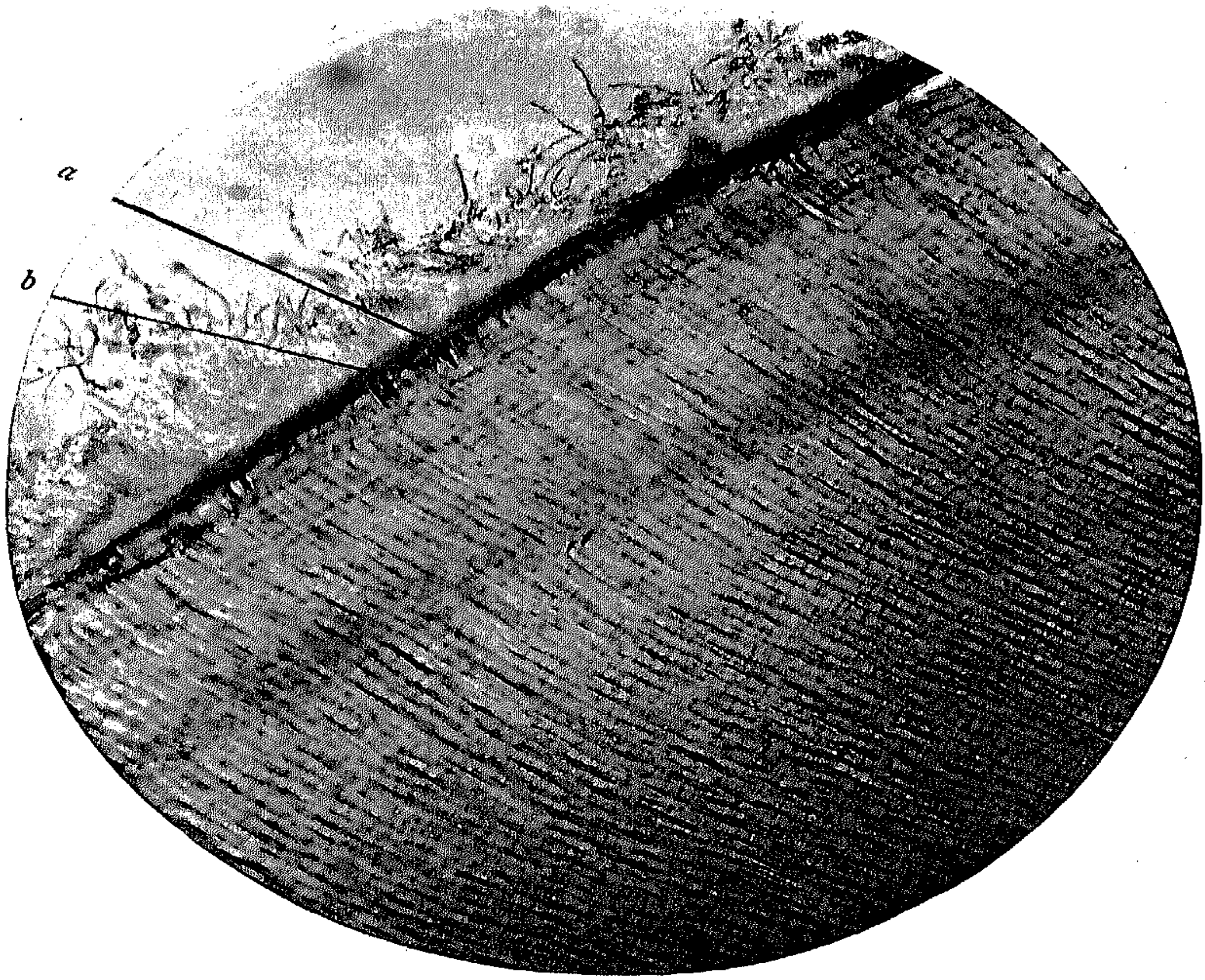
FIG. 62.



SECTION OF NORMAL HUMAN ENAMEL. × 350.
Showing thick, felt-like mass of micro-organisms slightly raised from the surface of the tissue by pressure of the cover-glass in mounting.

highest powers, is due whatever of interest the following part of this paper may contain. Many of the sections from which the photographs were made are less than half the thickness of the paper used in the DENTAL COSMOS. To this extreme thinness is also added the perfect preservation of every feature of the processes of decay. The teeth from which the specimens were made were placed, immediately after extraction, in a fixing and preserving

FIG. 63.

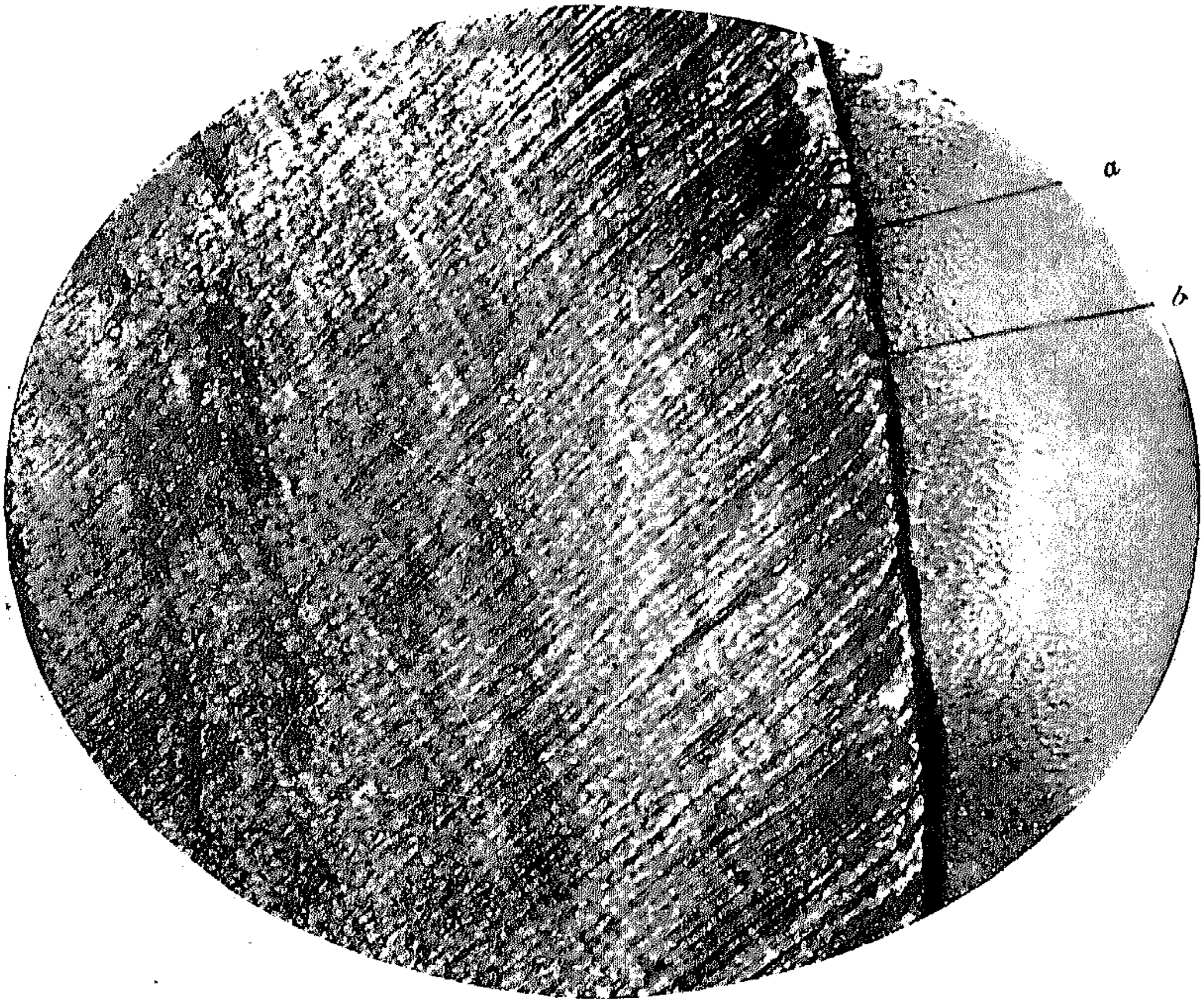


SECTION OF HUMAN ENAMEL SHOWING MICRO-ORGANISMS ATTACHED TO APPROXIMAL SURFACE OF MOLAR TOOTH. × 200.
a, *b*, shows commencement of the process of caries by solution of the cement-substance.

fluid. The sections were all ground under water and the most of them mounted in spirit and glycerol, thereby insuring the utmost naturalness of appearance and freedom from shrinkage.

During the past two years I have ground more than four hundred sections of enamel in every stage of decay from teeth of almost every description, some of which have been sent from different parts of the world. In one respect every specimen has shown precisely the same appearance. Lining the cavities or covering the surface where decay has commenced there is always to be seen a thick felt-like mass of acid-forming micro-organisms. *This mass of fungi is so dense and adhesive as to make it highly improbable that the enamel is affected, except in rare or special instances, by any acid other than that which is being excreted by the bacteria at the very point where they are attached to the enamel.* The thick glutinous-like mass of fungi also prevents the excreted acid from being washed away, so it exerts its full chemical power upon the calcific tissue.

FIG. 64.

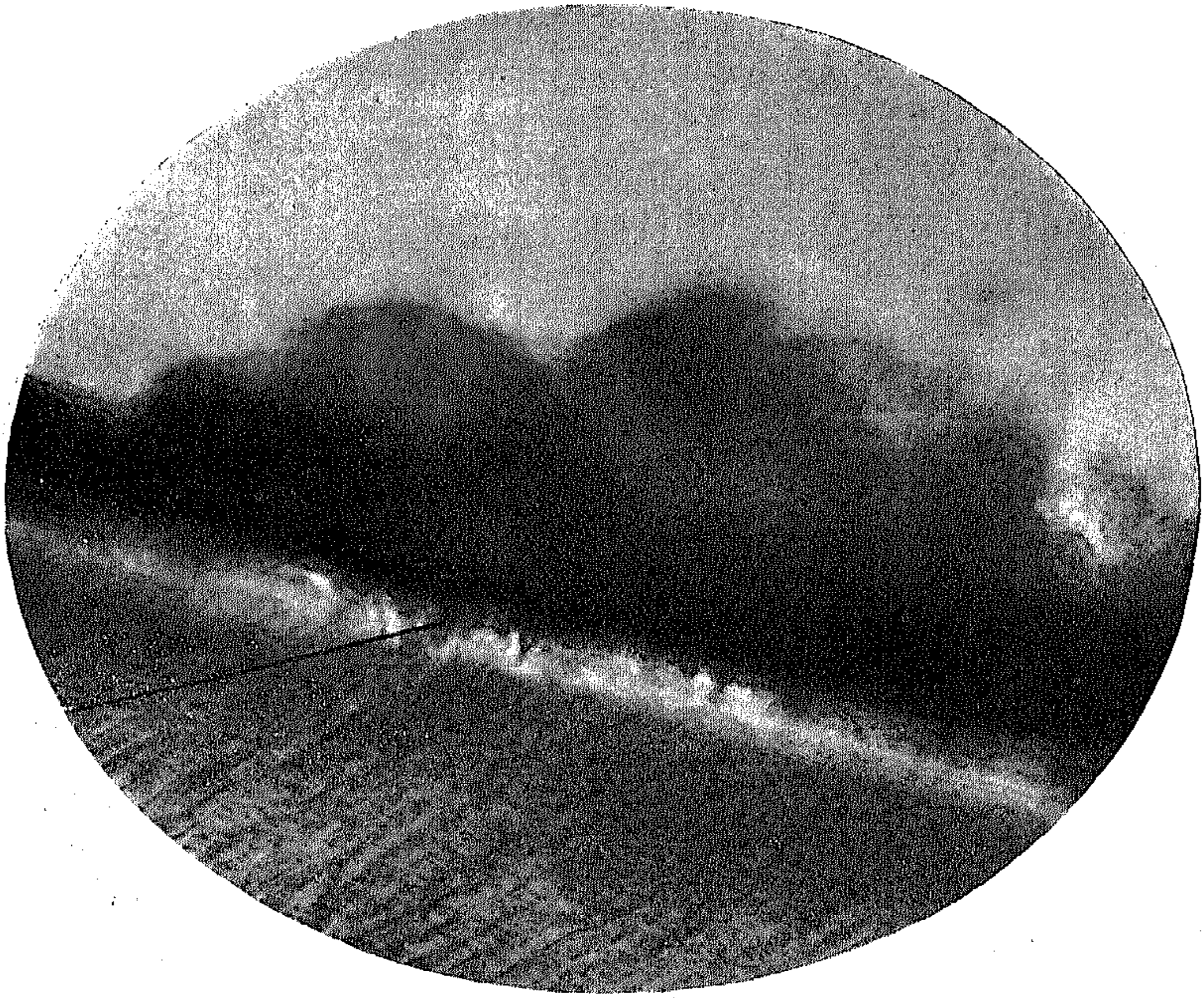


SECTION OF HUMAN ENAMEL SHOWING MICRO-ORGANISMS ATTACHED TO APPROXIMAL SURFACE OF BICUSPID. × 200.

a, b, shows commencement of caries by solution of cement-substance between the enamel-rods.

The appearances of enamel at the commencement of decay are very strikingly shown in Fig. 56, from a section of a lower bicuspid. This is a particularly interesting specimen from several points of view. It came from the mouth of a woman thirty-five years of age, who had suffered but little from caries, although the teeth had been poorly cared for. The patient returned to me after a year and a half with the teeth in a very bad condition. A marked change in systemic health was noted, and the traces of acid fermentation in the mouth were very evident. On both sides of the lower jaw the second bicuspid and first molar were decayed beyond the possibility of restoration. I removed the remains of these teeth preparatory to making a plate, and as the first bicuspid on one side stood outside of the arch, and at an angle which would have interfered with the fit of the proposed plate, I removed that also. Although somewhat stained, it appeared to be perfectly sound. I afterward ground a section of it, with the result which you see in the illustration shown. The tooth, which was without

FIG. 65.

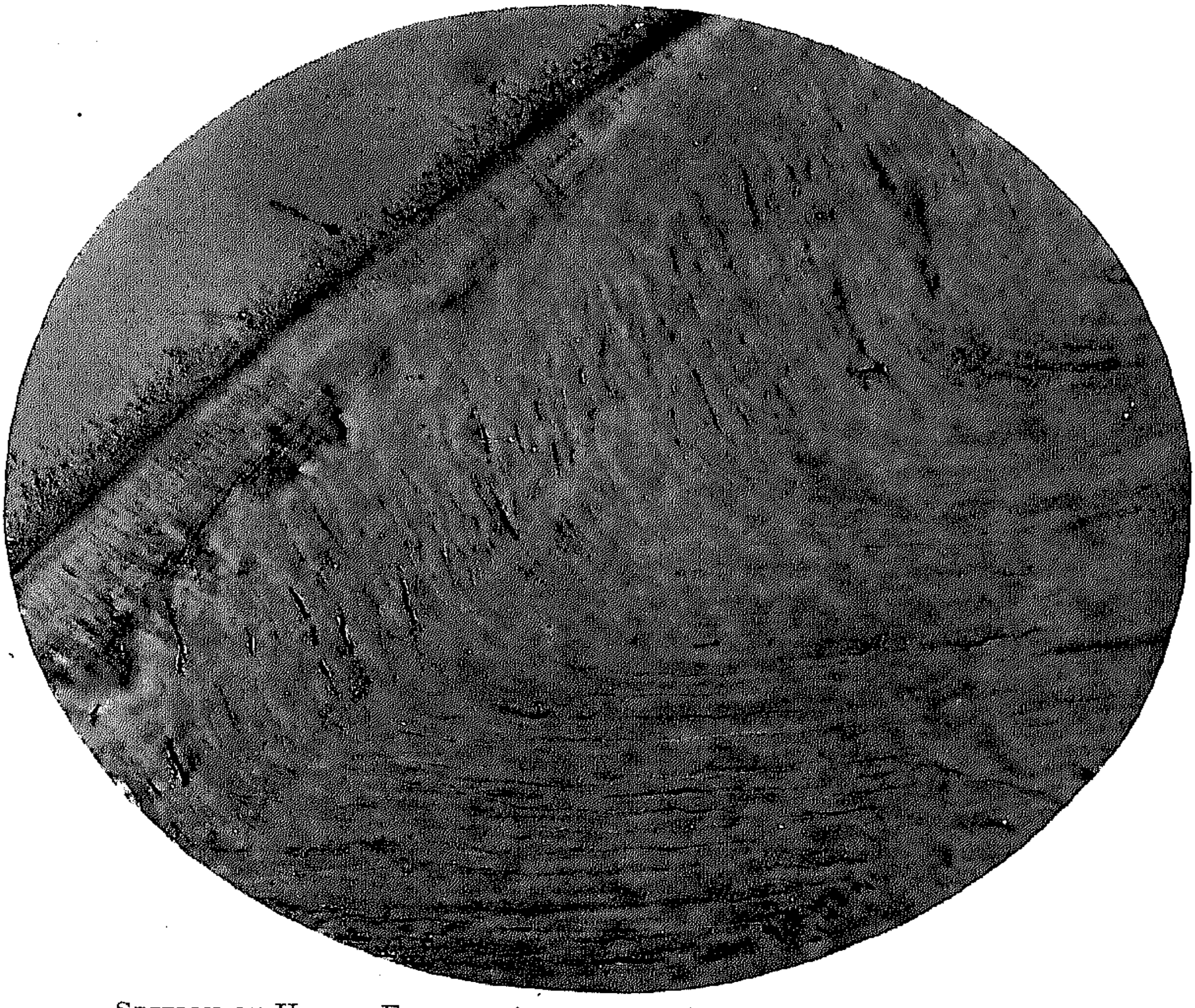


SECTION OF HUMAN ENAMEL. × 350.
Showing deeply-stained mass of micro-organisms attached to the surface, and further action of acid in dissolving the cement-substance and forming V-shaped spaces between the enamel-rods.

opposing teeth in the upper jaw, was literally covered with a thick growth of micro-organisms. The acid products of these fungi had softened the entire crown of the tooth in several places, penetrating both enamel and dentin, although there was not a trace of a cavity to be seen on the external surface.

Let us examine the spot on the approximal surface, shown at *a* in Fig. 56, under a higher magnifying power (see Fig. 57). A remarkable fact is revealed in this illustration. We observe that while there is no actual breaking down of tissue on the surface, yet the destructive agent, which has caused discoloration and penetrated the entire thickness of the enamel, has produced a cavity of considerable dimensions at the line of union of the dentin and enamel. Under still higher power (Fig. 58) we find that the cavity on the border of the dentin is partly filled with loose and decomposing particles of enamel. An acid, for nothing else could have produced this effect, has penetrated the enamel and accumu-

Fig. 66.

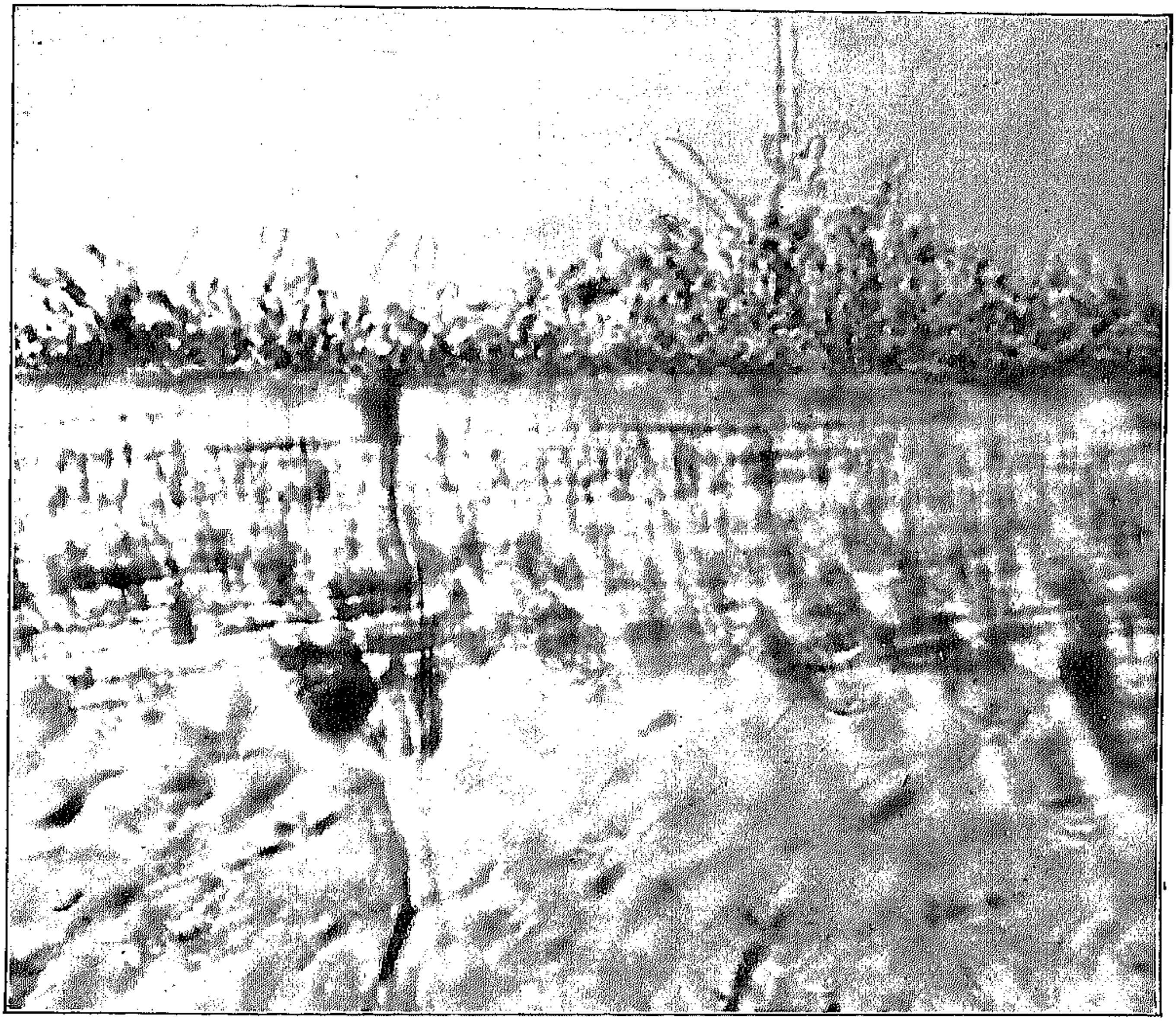


Section of Human Enamel, Approximal Surface of Cuspid. × 300.
Showing marked effect of acid excreted by micro-organisms attached to the surface.

lated in some congenitally defective spot, at the line of union of the tissues where such places are most frequently found, and has enlarged what was probably but a microscopic area at the beginning into a cavity of sufficient size to be seen by the unaided eye after grinding the section. If we examine the section in any part of the stained area shown at *a*, Fig. 56, we find the cement-substance which united the enamel-rods has been dissolved out until canals of considerable size have been formed between the rods (see Fig.

59). Down the canals thus formed the acid has penetrated to the cavity beneath. Experiments on sections of sound enamel out of the mouth show that effects substantially identical with those seen in the specimens just exhibited can be produced by the action of acids (see Fig. 60), the first action of the acids being to separate the rods, and, usually, also the globular bodies or sections of which the rods are composed, by solution of the cement-substance.

FIG. 67.



A PORTION OF THE PRECEDING ILLUSTRATION. × 800.

Shows fibrous substructure of enamel by solution of lime-salts near the surface of the tissue.

The condition of the tooth shown in Fig. 56 gives us a most complete explanation of what has been wrongfully interpreted as a retrograde metamorphosis of enamel. We see that the change which has been thus interpreted is entirely caused by an agent penetrating from without. The tissue thus softened by the action of an acid cuts much more easily than normal enamel, and so we have another illustration of the fact that observation is often correct, while the forced and arbitrary interpretation sometimes given of the cause of the phenomena observed is often radically wrong. In this connection I commend to your attention the editorial remarks in the December issue of the COSMOS on the practical value of scientific research. If the real cause of the softening of enamel so often observed had been known, thousands of patients would have been spared the annoyance and often the injury of being treated with phosphates and phosphatic foods in the belief that such treatment would improve and harden the enamel of their teeth.

Fig. 61 shows a mass of bacteria attached to Nasmyth's membrane on the approximal surface of a bicuspid tooth. At the ex-

FIG. 68.

SECTION OF HUMAN ENAMEL NEARLY DECALCIFIED BY RAPID "WHITE DECAY." THE FIBROUS SUBSTRUCTURE OF ENAMEL FINELY SHOWN. × 600.

treme left of the view the membrane is seen to be partly destroyed and slightly raised from the enamel, which, at this point, has already been attacked by the acid. The structure of the enamel on the surface is quite normal. In Fig. 62 the complete destruction of Nasmyth's membrane has been effected and the first attack made on the enamel, as shown by the fibrous appearance of the extreme edge of the tissue. The thick mass of micro-organisms is more easily raised from the surface of the enamel at this stage than at any other. Pressure upon the cover-glass in mounting the specimen will nearly always cause such a separation as is shown here. At the same time the mass of bacteria are strongly adherent to each other.

Fig. 63 is in every respect a typical specimen showing the action of bacteria in their attack upon perfectly formed enamel.

There is no depression, pit, groove, or imperfection of any sort at the point of attack, but everywhere along the surface the cement-substance between the enamel-rods is being dissolved away, and one sees the beginning of the formation of those V-shaped spaces which mark the first step in enamel decay. This is the usual method of attack on approximal surfaces where the tissue is generally perfect. In Fig. 64 the same appearances are seen, the V-shaped spaces on the surface being clearly shown, although the structure of the tissue is even finer than in the preceding specimen. If the bacteria are stained and the specimen examined under high power, the V-shaped spaces or fissures are more plainly seen (Fig. 65). The micro-organisms in this specimen have intentionally been left deeply saturated with the stain and the focus adjusted on the exact surface of the enamel, so as to show the bacteria entering the fissures which have been produced by the acid. These crevasses are rarely so marked after the surface layers of enamel have been destroyed. The surface layers, or what is sometimes called the cortical layer of enamel, seem generally to be much denser in structure than the deeper parts of the tissue, and this explains the difference in the action of the acid which is sometimes observed at this point.

Differences in the structure of enamel produce a great variety of carious appearances. In Fig. 66, for instance, the enamel is seen to be very porous in structure and everywhere permeated by canals which pass between the enamel-rods. Here one can plainly see just how far the acid has advanced, dissolving out the cement-substance to a considerable depth before the structure of the rods has commenced to break down at the surface. The action of the acid has also very clearly brought out the character of the fibrous substructure of the enamel, which is always more marked in the outer cortical layer than elsewhere (see Fig. 67). If any one still has doubts concerning the fibrous substructure of enamel, let him study Fig. 68, which is from a section of very rapid white decay of enamel. In this specimen the cement-substance is almost completely removed, and there remain the fibrous and globular products of the ameloblasts precisely as I have described these features in my previous papers on enamel formation.

(To be continued.)