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Micro-Organisms of the Human Mouth.

THE LOCAL AND GENERAL DISEASES WHICH ARE CAUSED BY THEM.

BY

WILLOUGHBY D. MILLER, D.D.S., M.D.,

Professor at the University of Berlin.

With One Hundred and Twenty-eight Illustrations, one Chromo-Lithographic and two Photo-Micrographic Plates.

PHILADELPHIA:

THE S. S. WHITE DENTAL MFG. CO.

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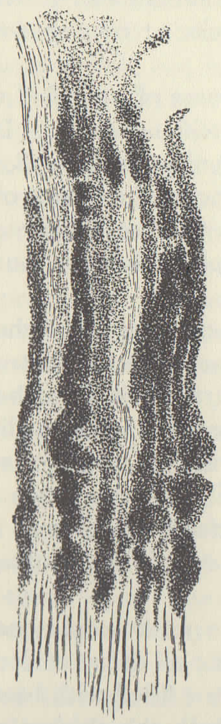
which artificial," and bases this declaration on the ground that "in every one that was artificial the micro-organisms followed the line of the tubules without striking into the consolidated intertubular substance," he makes a double mistake which I

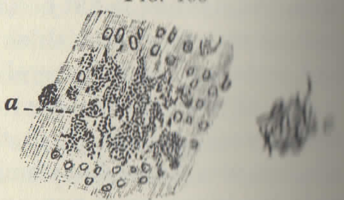
Fig. 99.



Artificial Decay.

Tubules infiltrated with cocci, distended and in parts running together through the liquefaction of the intertubular substance. Circa 400 : 1. Compare Fig. 77.

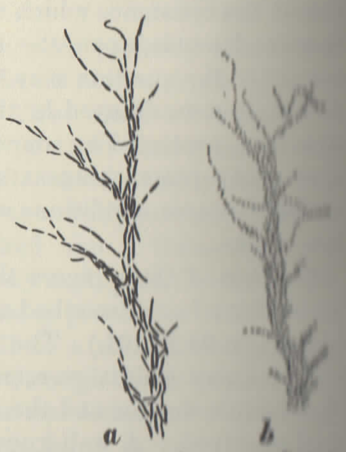
Fig. 100



Artificial Decay.

a, tubules distended and melted together; *b*, normal tubules; *c*, tubule under high power (1100 : 1). Cross-section.

Fig. 101.



Two Tubules from Artificial Decay.

a, filled with rods; *b*, with cocci. Only those branches lying in one plane are represented. 1100 : 1.

think he will correct himself when he shall have acquired a thorough knowledge of the appearances of natural and artificial decay under the microscope.

One does not require to examine a very large number of preparations in order to discover that both in artificial as well as in natural decay the micro-organisms in the deeper parts of the decaying tissue are confined strictly to the tubules, whereas those nearer the surface, although they do not *strike into* the basis-substance, yet they gradually liquefy it, and thus produce caverns or microscopic holes in it which they immediately fill up.

My experiments have been repeated and their results confirmed by Foerster. Since 1884 I myself have repeated the experiments a number of times, and have somewhat changed the conditions by adding meat to the mixture and changing it every second or third day. Not unfrequently the course of the experiment is interfered with by the appearance of yeast-fungi, particularly of Saccharomyces mycoderma, in the mixture. This fungus appears as a white, thick, dry, felty skin upon the surface of the mixture, and uses up the acid. In the course of a few days putrefaction sets in and the mixture shows an alkaline reaction, by which the course of the experiment is interfered with. If no such disturbance occurs, the pieces will be so far decalcified in a week that they may be easily taken up with a needle; after five weeks sections may be prepared, and by making sections each successive week one will be enabled to observe how the micro-organisms in the course of time penetrate deeper and deeper into the tissue and gradually bring about its destruction.

I do not look upon discoloration as an essential phenomenon of decay, and do not therefore trouble myself about the color of the dentine in artificial decay. It has appeared to me that where nitrogenous substances were present the discoloration appeared sooner than if only carbohydrates were used. A decalcified tooth placed in a mixture of saliva and meat will become discolored in a few days or weeks.

CARIES OF ANIMAL TEETH.

It is commonly believed that dental caries either does not occur at all in animals, or at best so seldom that the few cases which may have been observed are to be regarded as striking exceptions. And indeed we must grant that the teeth of animals, compared to those of modern civilized races, are relatively seldom attacked by caries. But if we compare the teeth of certain kinds of animals with those of uncivilized human races which subsist principally on meat, we arrive at quite different conclusions. The animals referred to are such as live on the same food as civilized human beings, especially dogs and other domesticated animals that feed on substances which form acids by fermentation.

All writers on this subject are, I believe, unanimous in the opinion that decay is exceedingly rare in the case of carnivora.

Bland Sutton, who has occupied himself with this study for many years, found only a small number of decayed teeth in carnivora, and these almost invariably in animals living in captivity for some length of time.

I have obtained information confirming these observations from the directors of various zoölogical institutes and veterinary colleges.

On the other hand, according to my experience, every considerable collection of dogs' skulls will be found to contain one or more decayed teeth, nor is decay of very rare occurrence in horses and apes.

In two hundred and ninety-five dogs' skulls, mostly of bull- and lapdogs, I found eighteen cases of decay; in six, two teeth were decayed; in each of the remaining twelve, one. In two other cases probably incipient decay (I could not decide with certainty whether the teeth were really decayed or not); these two are therefore not included in the above number. In all these cases it was invariably the first upper molar that was decayed, which is explained by the fact that this tooth possesses deep retaining-points for food-particles on the grinding-surface. The fourth bicuspid also frequently showed signs of decay, but no cavity. Decay occurs in these skulls in the proportion of 6 : 100, which signifies much higher percentage than has been found in Esquimaux and various Indian tribes. I succeeded in obtaining material from the dry, decayed tooth of a dog, which being soaked for a few hours in water, and then cut on the freezing microtome and stained with fuchsine, yielded very fair microscopic specimens. Through these specimens I was enabled to establish the interesting fact that decay of dog teeth is accompanied by exactly the same phenomena as that of human teeth

(Fig. 102). Here also, as far as my observations reach, micrococci are the chief destructive agents. In twenty wild dogs, forty foxes, and forty jackals I discovered no decay. Among forty-four apes I found one having a molar tooth with a large cavity extending to the pulp, and two molar teeth with small cavities on the grinding-surface. Of a small number of porcupines' skulls examined, one had a molar completely broken down by decay, nothing being left but the thin walls.

Fig. 102.

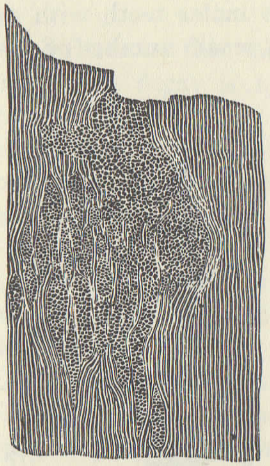
Group of Tubules from Dentine of the Decayed Tooth of a Dog. 400 : 1. In the side figure, piece of a tubule in the beginning of the infection. 1100 : 1.

In horses, decayed teeth are frequently found. In the pathological collection of the Berlin veterinary school there are two skulls in which nearly all the molars show pronounced decay on the grinding-surface. Other skulls also had decayed teeth. Out of about forty normal skulls in the collection of the agricultural school I found but one tooth which I could with certainty pronounce as decayed. But it is exceedingly difficult to recognize decay in old, dry teeth of horses unless it be already far advanced. Dr. Galbreath mentions three badly decayed teeth which he saw in the collection of Prof. Dr. Günther, of Hanover.

The microscopical examination of decayed dentine from the horse also showed the phenomena characteristic of human caries, invasions of bacteria, enlargement of the tubules, etc. (Fig. 103).

I have found the searching for decay in dry teeth of sheep skulls no easy matter. The many folds, islands, and spaces which are filled with remnants of food, and always intensely discolored, render it still more difficult to perceive small cavities here than in horses' teeth.*

FIG. 103.



DECAYED DENTINE FROM A HORSE'S TOOTH, showing the destruction of the tissue by bacteria. 800 : 1.

I have examined a few pig skulls and found but one small point of decay. Since pigs eat much fermentable food, we should expect decay more frequently, in spite of the alkalinity of their saliva, if the teeth were not so compact, and particularly if the animals were not slaughtered at so early an age (two to three years).

The conditions which explain the comparatively rare appearance of decay in animal teeth are, in my opinion:

1. The firm structure of animal teeth.
2. The nature of their food (but little fermentable).
3. The alkalinity of their saliva.
4. The comparatively short time during which the teeth are exposed to the causes that produce decay.

SPOTANEOUS HEALING OF DENTAL DECAY.

The process of decay, if not retarded by the proper treatment, usually results in the complete destruction of the crown. Cases, however, occur (comparatively seldom) which strangely deviate from the usual course, in that the destructive process ceases spontaneously, and the already softened dentine becomes hard again. This process is most frequently observed in the permanent first molars, but it also occurs in milk-teeth. Some years ago I examined the mouths of a boy and girl (twins, three years old)

*In more than one hundred skulls I could not establish with certainty the presence of any trace of decay. I was, on the other hand, astonished at the frequency of exostoses and destructive processes on the roots of sheep teeth.

whose teeth were in a very bad condition. All the front and several molar teeth were so much decayed that I entertained but little hope of saving them.

I made temporary fillings in a number of the teeth, and directed the little patients to be sent back again in two months. At the end of this time they punctually returned, but as the decay had apparently made no progress in the unfilled cavities, nothing further was done. All of these unfilled cavities, eight in the front teeth and three in the molars, healed completely, the dentine became hard and smooth, and no further loss of substance occurred.

The healed dentine retains the color of the carious dentine, is almost as hard as the normal, and according to the determinations of Dr. Cohn, of Berlin, contains a much greater percentage of lime than decayed dentine. Microscopic examinations of healed dentine have not, as far as I know, been made. In two cases of healed decay I prepared some sections, but was not able to note anything characteristic. The invasion of the bacteria in the cases examined had been superficial, a fusion of the basis-substance had not taken place, and the dilatation of the tubules was confined to the external layer. Results obtained from the examination of only two cases are, however, naturally not to be relied upon too implicitly.

Opinions concerning the cause of this healing vary. According to some authors, it is to be explained by a renewed deposit of lime-salts in the softened dentine. Such a deposit could of course occur only in places not yet invaded by bacteria. Others maintain that no vital process of any kind, as a redeposition of lime-salts, can take place in the completely developed dentine. They regard the healing as being due merely to the dehydration (drying) of the dentine. As is well known, the decayed dentine of extracted teeth becomes somewhat hard. Further experiments are necessary to determine which of these views is correct.

If we accept the dehydration theory, we shall find it very difficult, I am afraid, to explain how the dentine, continually bathed with liquid as it is, can at all dry out in the human mouth, particularly how it can dry out in one tooth and not in others which may be decayed in the same mouth. We shall, furthermore, in case the experiments of Cohn should be confirmed, be unable to account for the smooth, shining surface and the increased percentage of lime-salts in the repaired dentine. If we, on the other hand, accept the recalcification theory, we have to choose between two possibilities,—(1) the possibility of a recalcification of the dentine; more or less complete restoration of the lime-salts of the decayed dentine through the medium of the pulp (a virtual restitutio ad integrum), which would not be in accordance with the conception of Hoppe-Seyler (page 149); (2) the possibility that new dentine may be formed at the expense of the fibrils in the manner described under transparency of the dentine. Without pronouncing my adherence to the vitalistic theory, I think I may say that I am not quite satisfied with the dehydration theory. We have here another subject for experiment.

CHAPTER VIII

ETIOLOGY OF DENTAL DECAY.

Having acquainted ourselves with the physiological properties of the chemical and organic ferments occurring in the oral cavity, as well as with the nature of the fermentations excited by them, and having furthermore examined the chemical and microscopical changes of the dentine characteristic of decay, and shown the possibility of producing decay artificially, we now come to the question: What is the cause of dental decay?

Dental decay is a chemico-parasitical process consisting of two distinctly marked stages: decalcification, or softening of the tissue, and dissolution of the softened residue. In the case of enamel, however, the second stage is practically wanting, the decalcification of the enamel practically signifying its total destruction.

After having discussed the processes of fermentation in the mouth, it is not difficult to determine the source of the acids which effect the decalcification. They are derived chiefly from particles of amylaceous and saccharine substances which lodge in the retaining-centers and there undergo fermentation. The presence of an acid reaction in cavities of decay and in caries-centers may be easily determined by the simple test with blue litmus-paper. The test should not be made at the surface, but in the deeper layers, after the remains of food and outer layers of carious dentine have been removed. I examined two hundred and thirty cases in regard to this question, and found the reaction acid in two hundred and twenty-five, neutral in four, and alkaline in one case. The latter five cases may be explained by the predominance of albuminous substances (meat, gangrenous pulp-tissue, etc.) in the cavity at the time of examination.

Inasmuch as the fermentation of carbohydrates gives rise to the production chiefly of lactic acid, and since lactic acid even in dilute form speedily acts upon tooth-tissue (decalcifies it), there can be little doubt that the acid reaction and the decalcification of the dentine are produced in a great part by this acid. The accuracy of the supposition may be easily proved by the Ewald test. If we place a large piece of decayed dentine in a test tube containing the solution given on page 106, and allow the tube to stand in the dark for some time, a yellowish zone like a halo will be formed about the piece, indicating the presence of lactic acid with tolerable certainty, since we know that the other substances which give this test (page 107) are not formed except in very minute quantities.

The acids formed in the mouth by fermentation of starch are quite as injurious to the teeth as those formed from sugar. The assertion that starch is not injurious to the teeth rests upon no experimental basis. On the other hand, it has been irrefutably established by experiment that saliva containing starch at blood temperature shows an acid reaction as soon and develops as much acid in a given space of time as saliva containing sugar.

If we divide a quantity of saliva into a number of equal portions, and add to each an equal quantity of different carbohydrates (sugar, bread, potato, starch, etc.), we shall find that those containing bread and potato not only show an acid reaction sooner, but even develop more acid in a given time than the portions to which sugar has been added. Starch-paste and sugar, as far as my observations go, react about equally strong.

Some very interesting experiments were performed by Ellenberger and Hofmeister,[121] which show that under certain circumstances starch-paste, too, is more rapidly transformed into lactic acid than sugar. An alkalinized pancreas-extract containing grape-sugar kept at a specified temperature did not develop an acid reaction till after forty-eight hours or more, whereas on the addition of starch-paste an acid reaction appeared in twenty-four hours. "Sugar in statu nascendi seems to be transformed into lactic acid more quickly than in its ordinary state. In all experiments on digestion with starch-paste, lactic acid is rapidly developed."

In all cases the starch is first transformed into grape-sugar by the ptyaline of the saliva or of the pancreatic juice, and is then split into lactic acid by the lactic acid ferment of various bacteria. Now, it is well known that many chemical bodies possess other affinities at the moment of their formation than at other times. According to the experiments referred to, this appears to be the case with sugar. For other reasons, also, I consider starch and amylaceous substances more detrimental to the teeth than sugar, particularly as sugar, being readily soluble, is soon carried away or so diluted with the saliva as to be rendered harmless, whereas amylaceous matter adheres to the teeth for a greater length of time and consequently manifests a more continued action than sugar.

Hesse's[122] observations in respect to caries of bakers' teeth lend support to this opinion. He writes, "In the Dental Institute of this city [Leipzig] I have had the opportunity of seeing a great number of patients among the industrial and working classes, and have been particularly surprised at the bad condition of the teeth of our bakers. They are affected by caries to such a degree that I have been able in many cases, since my acquaintance with this phenomenon, to determine the calling of a patient by the condition of his teeth. There can be little doubt that we have here to do with a disease which stands in causal connection with the calling, and the theory of caries recently propounded by Miller gives a satisfactory explanation of it. A few confectioners' children are the only individuals I have seen who could bear comparison with bakers, although their teeth were not in quite so bad a condition. Probably the millers may be able to compete with the bakers, and it would be desirable to be enlightened on this point."

Busch, on the contrary, is of the opinion that "baker caries" is due rather to the inhalation of sugar-dust than to that of flour-dust.

Different sugars manifest but little difference in their capability of being split up into acids. Those kinds belonging to the grape-sugar group—grape-sugar (dextrose), fruit-sugar (levulose), lactose (galactose), and maltose—are directly fermentable and decompose according to the equation: $C_6H_{12}O_6 = 2C_3H_6O_3$. Cane-sugar (saccharose) and milk-sugar become fermentable only after hydratization.

$$\underset{\text{Cane-sugar.}}{C_{12}H_{22}O_{11}} + H_2O = \underset{\text{Dextrose.}}{C_6H_{12}O_6} + \underset{\text{Levulose.}}{C_6H_{12}O_6}. \quad C_6H_{12}O_6 = \underset{\text{Lactic acid.}}{2C_3H_6O_3}$$

There seems to be no considerable difference of time in respect to the beginning of the fermentation of the grape-sugar and cane-sugar groups: the one is apparently about as detrimental to the teeth as the other.

Fermentable albuminous substances mixed with saliva develop but small quantities of acid, which soon disappear. They are not injurious to the teeth, even though retained for some length of time; they may even retard the progress of decay by neutralizing the acid through their alkaline products. The most diverging opinions prevail in regard to the participation of different substances in fermentations arising in the mouth, none of which rest on solid foundations. Above all, the conception that albuminous substances (meat) putrefying in the mouth produce acids is totally erroneous.

The facts mentioned on pages 27 and 115 cannot leave us in doubt on this point. It seemed to me desirable, however, to refute the above views experimentally, and at the same time to establish the relative significance of different carbohydrates as acidifiers. For this purpose I made over two hundred experiments with human saliva, and also a few with the saliva of dogs and rabbits. 4.0 c.cm. of fresh saliva were mixed with 0.5 g. of the food to be tested, and the reaction as well as the quantity of free acid determined after the lapse of a certain time.

The results obtained are given in the following table. The "acid unit" signifies that quantity of acid which is necessary to neutralize 0.1 c.cm. of a 0.5 per cent. solution of caustic potash.

Material.	Duration of experiment.	Acid formed in acid units.
Bread (dry) . .	12 and 30 hours	22 and 72
Starch . . .	" " "	20 " 42
Cane-sugar . .	" " "	17 " 37
Grape-sugar . .	" " "	19 " 40
Potato (boiled) . .	" " "	24 " 75
Corn (in milk) . .	" " "	24 " 77

Material.	Duration of experiment.	Acid formed in acid units.
Bread (1.0 g.) . .	12 and 30 hours	35 and 110
Sugar (2.0 g.) . .	" " "	20 " 41
Rice . . .	" " "	25 " 72
Macaroni . . .	" " "	20 " 76
Meat . . .	" " "	0 " —3*
Meat (raw) . .	" " "	— " —5
Fish . . .	" " "	0 " —5
Eggs . . .	" " "	0 " —
Cheese . . .	" " "	0 " (?)
Spinach (in water) .	" " "	0 " 0
Potato (raw) . .	" " "	0 " 0
Salad (raw) . .	" " "	0 " 0
Fat . . .	" " "	— " (?)

In but one series of experiments with dog saliva I obtained the following figures (reaction strongly alkaline at the beginning of the test):

Material.	Duration of experiment.	Reaction.
Starch . .	4½, 12, 20, and 35 hours.	always alkaline.
Meat (cooked)	" " " " " "	" "
Meat (raw) .	" " " " " "	alkaline, putrid smell.
Sugar . .	" " " " " "	"
Bread . .	" " " " " "	acid after 20 hours.
Potato . .	" " " " " "	" " 12 "

For rabbits' saliva.

Material.	Duration of experiment.	Reaction.
Grass . . .	4½ to 12 hours.	alkaline.
Turnips . . .	4½ " 35 "	up to thirty

hours alkaline, then an acid reaction set in, but not so strong as when the turnips were crushed in water.

The fresh saliva of both animals showed a strong alkaline reaction.

The few experiments made for the purpose of comparing the acidifying power of raw and cooked food seem to indicate that

* The sign — denotes an alkaline reaction.

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raw vegetable food is less fermentable than cooked. Should further researches prove that this is indeed the case, the cooking of food would have to be reckoned among those customs of civilization which have a detrimental influence upon the teeth.

It is well enough known that acids, brought into the mouth as medicines or with the foods, may have a deleterious action on the teeth. An excess of sour fruit, grapes, lemons, etc., and the continued use of acids or acid compounds doubtless has a decalcifying action on the teeth, attacking first not the concealed but the exposed parts.

Schlenker[72] calls attention to certain substances which, coming into contact with the teeth, either as food or as medicine, are generally injurious, some to such an extent that their decalcifying action becomes visible to the naked eye in the short space of five minutes. I do not attribute too great an importance to the influence of such substances, nor do I underrate them, since a slight injury of the enamel or dentine caused by such agents may give rise to decay at points which otherwise would have escaped.

An acid reaction of the saliva is equally detrimental. This is said to occur in rheumatism, gout, gastro-enteritis, diabetes mellitus, dyspepsia, and various disorders of the alimentary tract, in fevers (typhus, intermittent fever, etc.), in diseases of the lungs, etc., and during pregnancy. According to some authors, the mucus also, under certain circumstances, has an acid reaction, and the attempt has been made thereby to explain pathological phenomena, particularly at the neck of the tooth (wedge-shaped defect, neck decay). Our knowledge of the properties of mucus is unfortunately too limited to determine accurately the part it plays in decay of the teeth. (See page 42.)

With less reason, it appears to me, Tomes, Black, and others ascribe a destructive (probably meaning a decalcifying) action on the neck of the tooth to the "acid secretion" of the irritated gums. No conclusive facts have been adduced for this supposition. On the other hand, it is well known that decay very seldom occurs in cases of pyorrhœa alveolaris, in which the gums are in a state of irritation for months together. Whenever decay does accompany inflamed gums, we invariably find

pockets or spaces which, by retaining food-particles, serve as centers of fermentation and consequent decay.

According to Coleman,[123] the acid reaction of decayed dentine is caused by the formation of an acid phosphate of lime, arising from the disintegration of the lime-salts.

Bridgman[124] explains the acidification by an electrolytic decomposition of the buccal juices.

The second stage of caries, the dissolution of the softened dentine, is caused by bacteria. We have seen that many mouth-bacteria have the faculty of dissolving coagulated albumen or albuminous substances, of peptonizing or converting them into a soluble modification. We have also seen that the basis-substance of dentine consists of an albuminous substance. The explanation of the second stage of decay is therefore very easy, the more so, since the liquefaction of the softened dentine by bacteria is directly detectable under the microscope and may be easily accomplished experimentally. The dissolution of dental cartilage (in fact, decay in general) has been designated as putrefaction, on the whole an ill-chosen term, inasmuch as the characteristics of putrefaction (alkaline reaction and bad odor) are entirely wanting in a cavity of real decay. The decaying dentine shows an acid reaction and emits a sour smell.* This stage of caries, therefore, is a digestive process. The dental cartilage is dissolved by the bacterium-ferment, as albumen by the pepsine of the gastric juice.

We must rid ourselves of the impression, which the application of the very unscientific and unprofessional name of bugs to bacteria has no doubt tended to spread, that the parasites of the human mouth make holes in the dentine by boring into it as a worm bores into wood or by gnawing at it as a dog gnaws at a bone. Bacteria have no apparatus for boring, nor do they have mouths or any provision for breaking off small portions of solid substances which they then swallow whole or take directly up at any point of their periphery after the manner of an amœba. They nourish themselves alone by substances in a state

* Of course the odor of a gangrenous pulp or of suppurating gums, etc., must not be confounded with that of the dentine.

of solution, and if we present them solid substances they themselves must liquefy them before they can make any use of them for their own nourishment.

Upon this power of bacteria to liquety substances of an albuminous nature depends the destruction of the softened dentine, —in other words, the second stage of dental decay.

The objection has been raised against the chemico-parasitical theory of caries, that the reaction of the saliva in any mouth is no criterion for the extent of decay in that mouth. When the reaction of the saliva is alkaline, decay has been found to be extensive; and, on the other hand, cases have been reported where an acid reaction of the saliva was not accompanied by a corresponding amount of decay. None but a very superficial investigator, however, would draw conclusions from a simple examination of saliva.

The rapidity with which the process of destruction of the teeth in any mouth advances is evidently directly proportional to the intensity of the fermentations going on in the retention-centers, and inversely proportional to the density of the tooth-substance. Now, both of these factors are virtually independent of the reaction which the saliva may show on escaping from the ducts. A prolonged strong acid reaction of the saliva would indeed render the fluids of the mouth less adapted to the development of bacteria, and in so far as the acid could penetrate the centers of fermentation tend to decrease the intensity of such fermentation. Such a decrease would, however, be compensated for by the action of the acid itself.

The case becomes very different when we turn our attention to the free surfaces of the teeth. A prolonged acid reaction of the saliva would of necessity manifest its disastrous influences upon these surfaces sooner or later, according as the teeth are soft or dense in structure. Consequently, if anyone can show me a case in which an acid condition of the saliva has persisted for some months (not one in which the saliva chanced to react acid just at the moment of examination, or one in which the acid reaction was caused by bad litmus-paper, or by handling the paper with sweaty fingers, etc.), I shall have no difficulty in pointing out places at which its action is plainly manifest.

The total absence of decay in a closed root-canal which has for years been harboring a putrid pulp and innumerable bacteria is a still less warrantable objection to the above-mentioned theory. It evinces an entire ignorance of the vital conditions and fermentative action of bacteria. For, in the first place, the bacteria in a closed root-canal either perish, or, what happens more rarely, become inactive as soon as the nutriment in the pulp is consumed,—*i.e.*, in a few days. In the second place, even though they could really vegetate for years in a root-canal, we should still have no reason to expect decay, because the carbohydrates, essential to the formation of acids, are wanting. The reaction of a putrid pulp is invariably alkaline.

Leber and Rottenstein[58] discovered after boring into two incisors, which had a peculiar blue color without exhibiting a trace of decay externally, that the entire interior of the teeth was brown, completely softened up to the enamel, and that even the root was hollow. Such very exceptional cases "must not be identified with common caries." They are of such rare occurrence that no satisfactory explanation of them has yet been offered, and every one who reads the report of them can only shrug his shoulders and wait for the day when he may have an opportunity to examine such a case personally, an opportunity which but rarely comes even once in a lifetime.

The view that during the disintegration of the pulp the acid necessary for the softening of the dentine was formed, is untenable, first, because the reaction of putrid pulps is always alkaline; secondly, because even in case an acid reaction should take place, under peculiar circumstances, all bacteria of the pulp would be destroyed long before even a fraction of the quantity of acid requisite to decalcification would be formed. We cannot ascribe this occurrence to a process of nitrification, such as occurs in the soil, since this demands free access of air.

In support of the inflammation theory, a difference has been assumed between decay of living and dead teeth. It has been asserted that the softened layer of dentine is much thinner, dryer, and blacker in dead than in living teeth. Every practitioner has surely seen phenomena which seem to agree with this assertion, but a satisfactory explanation may be found without much trouble. The alkaline products of the putrefying pulp and of the inflamed suppurating or disintegrating gums neutralize the acids formed in the dental cavity by fermentation. The process of decalcification ceases, partially at least, whereas the dissolution of the already softened dentine proceeds. The decalcified layer of dentine must gradually become thinner under such circumstances. If a just extracted carious tooth be kept in a putrefying albuminous solution for some length of time, the softening of the dentine completely ceases, while the dentine which has already been softened gradually disappears.

THE MICRO-ORGANISMS OF DENTAL DECAY.

Our knowledge of the micro-organisms most directly concerned in the destruction of the substance of the tooth is as yet very deficient. We have been able to establish the fact that all micro-organisms of the human mouth which possess the power of exciting an acid fermentation of foods may and do take part in producing the first stage of caries; also, that all possessing a peptonizing or digestive action upon albuminous substances may take part in the second stage; and, finally, that those possessing both properties at the same time may take part in the production of both stages. But whether there is any one bacterium which may *always* be found in decayed dentine, and which might therefore be entitled to the name of *the* bacterium of tooth-decay, or whether there are various kinds which occur with considerable constancy, we are not able to say.

During my experiments upon the bacteria of decay in the year 1883, I isolated four different kinds of bacteria from decaying dentine. These I described in the *Independent Practitioner* for July, 1884.

I have frequently met with them in more recent investigations, and they have also been observed by others. I do not consider the experiments I then made sufficiently extensive or conclusive to be incorporated here, and experiments now in progress, with new methods and larger material, are not yet concluded, it being necessary to examine at least fifty to one hundred different teeth in order to arrive at satisfactory results.

The researches recently made by Vignal and Galippe,[illegible] and

reported in *L'Odontologie*, although not yet concluded, appear to be deserving of more notice.

The investigators named have examined eighteen decayed teeth, in all which they found four different kinds of bacteria; a fifth kind they met with eight times, and a sixth five times.

1. The first kind met with is a short, thick bacillus, not forming chains. It has a length of 1.5μ, and is almost as thick as it is long. In puncture-cultures, in gelatine, it grows tolerably rapidly, forming a white trail, and begins to liquefy the gelatine at the end of the third or fourth day, turning it white and opaque. In plate-cultures it forms small, slightly prominent colonies, which having attained a diameter of two to three millimeters spread out in the liquefied gelatine.

2. The second kind is a bacillus 3.0μ long and about one-half as thick, slightly constricted in the middle. Its cultures are similar to those of the preceding, except that its colonies spread out more upon the surface of the gelatine before liquefying it.

3. The third kind is a bacillus quite similar to the preceding, showing, however, no constriction. It is square at the ends, and forms quite long chains, particularly in liquid media. It does not liquefy the gelatine, but slightly softens it.

4. The fourth kind is a very small, thin bacillus, almost as thick as long, so that it might at first be mistaken for a coccus. It forms a white trail in the gelatine, which it speedily turns yellow and then liquefies.

5. The fifth kind, found but eight times, is a bacillus with rounded ends, which forms at first a white trail in the gelatine and then liquefies and clouds it.

6. The sixth micro-organism, found but five times, is a very large coccus. It was found only in advanced stages of decay, where the canaliculi were already considerably dilated, it being too large to enter the sound tubuli.

It forms trails in the gelatine, which it does not liquefy, and to which it lends a whitish aspect.

In a memoir, soon to be published, Galippe and Vignal promise to present in detail the characters of the cultures above mentioned.

PREDISPOSING CAUSES OF DENTAL CARIES.

In contradistinction to the exciting causes of caries, we characterize as *predisposing* such conditions of individual or of all teeth which divest them of their normal power of resisting exciting causes, or by which they offer them especial points of attack.

Predisposing conditions are only found in the teeth themselves, in their development, position, etc., while, on the other hand, all external agencies are to be considered as exciting causes. It is therefore not logical to regard gout, *e.g.*, as a predisposing cause, because it is accompanied by an acid reaction of the saliva. The action of an acid on the teeth will always be the same, whether it is secreted by the mucus or salivary glands, or formed in the mouth by fermentation, or introduced from without; it is invariably an exciting, not a predisposing cause.

1. The structure of the teeth plays the most important part as a predisposing cause of dental caries. Poorly developed, soft, porous teeth, with many large interglobular spaces, are highly predisposed to caries. As a lump of table-salt dissolves more rapidly in water, on account of its porosity, than an equally large piece of rock-salt, porous dentine is more rapidly decalcified than well-developed, firm dentine, because the acid may the more readily penetrate the tissue, and because less acid is required to decalcify a porous than a hard tooth. It may easily be proved by experiment that poorly developed dentine is much more rapidly attacked by acids than sound dentine. (See page 196.) Not only does the decalcification, but also the destruction of the cartilage, advance more rapidly in the former case, because the micro-organisms, in many cases at least, enter the interglobular spaces and more readily pervade and destroy the entire softened tissue.

2. As a second predisposing factor I designate abnormally deep fissures or blind holes (foramina cœca) in molars and superior lateral incisors, especially in cases where the enamel also is poorly developed. By their continual retention of food-particles, such points directly induce caries, and offer but little resistance to it in consequence of the absence of an intact protecting cover of enamel.

3. In the third place, fissures or cracks in the enamel are regarded as a predisposing cause. I have not, however, been able to convince myself that decay frequently starts from these enamel-cracks, often found in senile teeth. They are usually too narrow to permit the entrance of food-particles, and consequently do not serve as points of retention.

4. In the fourth place, teeth are predisposed to decay by a crowded, irregular position. An instructive example is furnished in cases where the first bicuspid stands inside of the arch, so as to form a triangle with the second bicuspid and the cuspid; or the second bicuspid forms a triangle with the first bicuspid and first molar. It is impossible to keep the space between these three teeth clean, and fermentation and acid formation continually occur there and attack the teeth. Not only in such cases, but wherever a crowded position of the teeth favors the retention of food-particles, or renders their removal difficult, a predisposition to caries prevails. The form of a tooth is not without influence; teeth with convex approximal surfaces touching each other at one point only (Fig. 104) are, *cæteris paribus*, less subject

Fig. 104. Fig. 105.

to caries than teeth with flat or slightly concave surfaces (Fig. 105), because the latter cannot be kept so clean, either spontaneously (by the tongue, etc.) or with the brush.

5. A recession or loosening of the gums from the neck of the tooth not only lays bare the dentine, but also permits the entrance of food-particles between the necks of the teeth or into the pockets formed by the loosening of the gums, by which means a further predisposing cause for caries is furnished.

6. Many consider pregnancy as a predisposing cause. It is not to be denied that during pregnancy women are particularly subject to caries. The reason for this is, however, probably to be sought in the fact that the patients generally neglect the care of the mouth during that time, and that the buccal secretions

assume an acid reaction; these are both exciting causes of decay. Pregnancy itself can only be regarded as a predisposing cause in so far as it effects a loosening of the gums or a change in the structure of the teeth by a withdrawal of the lime-salts to build up the fœtal skeleton. Whether such an extraction takes place has not been definitely ascertained.

7. Many believe that a predisposition to caries may be inherited. It cannot be denied that badly developed, irregular teeth may be and are inherited, and in so far inheritance may be considered as a predisposing cause of caries.

8. Wedl, Tomes, and others mention as predisposing causes various general diseases, as rheumatism, gout, diabetes, gastro-enteritis, dyspepsia, cancer of the stomach, scrofula, rachitis, and tuberculosis. These diseases may indeed furnish the exciting causes of caries by imparting an acid reaction to the buccal juices, but how they can predispose the teeth themselves to caries is not readily apparent, unless they render them more easy of access to the exciting causes by concomitant gum-diseases as described under 5.

I doubt whether climatic or geological conditions have much to do with the origin of caries. Esquimaux, Lapps, Icelanders, Arabs in Nubia, Patagonians, etc., have the best teeth in spite of unfavorable climatic conditions.

INFLUENCE OF CIVILIZATION ON DECAY.

That decay of the teeth is not a disease peculiar to civilization is proved by the manifold observations which have been made on the skulls of ancient and modern uncivilized races in Europe and America. A visit to any anatomical or anthropological museum and an examination of a large number of race-skulls will convince every one of the correctness of this assertion. Such examinations have been made by Broca, Magitot,[126] Mummery,[127] Barrett,[128] myself,[129] and many others, and invariably led to the same conclusion, that decay has occurred in all races, civilized as well as uncivilized, and at all times.

Races subsisting solely on meat (Greenlanders, etc.) come near forming an exception to the rule, yet they appear to be not absolutely exempt from decay. (See page 221.)

That the frequency of decay is greater in civilized races than among savages has also been established by numerous observations. Mummery's interesting communications are especially worthy of mention. He found decay among the old Britons of the dolichocephalous type in 2.94 per cent., among the brachycephalous Britons in 21.87 per cent., among the Anglo-Saxons in 15.78 per cent., among the Romano-Britons in 28.67 per cent., and among the ancient Egyptians in 41.66 per cent.

There is no doubt that a deterioration of the teeth accompanies the progress of civilization. The reasons for this are many. The mode of life of most uncivilized races not only conditions a sound, well-developed body, but the osseous system, of course including the teeth, shows the same vigorous development, and above all a compact structure. An individual whose youth is spent in the open air, unrestricted in his bodily freedom, is likely to possess a body better developed in all its parts than one who has been brought up in a modern school-room.

The quality of the food also exerts an influence on the teeth not to be underrated. They form no exception to the rule that an unused member will be less perfectly developed than one constantly used.

The pressure brought to bear upon the teeth by mastication causes a more lively circulation in the periosteum and in the pulp, thereby inducing an increased deposit of lime-salts or a more complete calcification. Practical experience also teaches that children brought up on soft food (broths, paps, etc.) generally have bad teeth. If a race of human beings or of animals were to make no use of their teeth for several generations, we should expect to find a gradual deterioration of the dental structure. It is, to say the least, highly probable that the soft quality of many of our foods, as compared to those of uncivilized races, conditions a soft, porous dental substance, as well as an imperfect development of the jaw-bone, and a concomitant crowded position of the teeth.

Then again, the chemical composition of the food is of great influence upon the origin and extension of caries. Whoever grants the truth of our proposition,—no caries without acid,—and recognizes the fermentative processes in the mouth as the chief source of the decalcifying acids, and has verified our table (pages 208, 209), will hardly deny the correctness of this statement.

A person living on such foods only as undergo no acid fermentation in the mouth (meat, raw vegetables, roots, etc.) will, I am convinced, be but comparatively little afflicted with caries. If this supposition were well founded, a comparison of the frequency of caries among races subsisting on meat alone with that of races who consume vegetable or mixed foods would yield higher figures for the latter. Caries should also then be more frequent in phytophagous animals than in carnivora.

That such investigations are connected with enormous difficulties is apparent. It is extremely difficult or altogether impossible to eliminate other simultaneously present, especially predisposing causes. In the second place, the statements of certain authors concerning the food of savage tribes do not always agree, and furthermore suitable material for these examinations is extremely scarce in most anatomical collections.

Very interesting and valuable figures have been gathered by Mummery, which are meant to establish the relation of caries to the healthy or unhealthy manner of life of a given race.

These figures, with a few changes which concern the nourishment of the races specified, and with the addition of those which I have deduced from various anatomical and anthropological collections, are presented in the following table:

Ancient Races.	No. of Skulls.	Caries.	Percentage of Caries.	Food.
Ancient Britons (dolichocephalous.)	68	2	2.94	Meat (beef, wild boar).
Ancient Britons (brachycephalous.)	32	7	21.87	Mixed food (meat, fish, oats, wheat, beans, roots, etc.).
Ancient Britons (exploration of Greenwell.)	59	24	40.68	"
Ancient Britons (mixed.)	44	9	20.45	"
Romano-Britons	143	41	28 67	"
Anglo-Saxons	76	12	15.78	"
Ancient Egyptians	36	15	41.66	"

Modern Races.	No. of Skulls.	Caries.	Percentage of Caries.	Food.
Esquimaux	81	2	2.46	Meat and fish.
North Americans (coasters.)	63	2	3.17	Meat and fish, probably not quite exclusively.
North Americans (interior.)	22	2	9.09	Mostly meat, some vegetables.
South Americans	26	7	27.00	Principally meat.
Feejee Islanders	38	2	5.26	Human flesh and mixed food.
Polynesians	79	8	10.12	Mixed food.
Sandwich Islanders	21	3	14.28	" "
New Zealanders	66	2	3.30	Human flesh, pork, fish, roots.
Australians	132	27	20.45	Mixed food.
Tasmanians	33	9	27.27	" "
Chinese	50	21	40.20	" " mostly vegetable
East Indians (north)	152	9	5.92	" "
East Indians (south)	71	10	14.84	" "
Africans (east)	32	8	25.00	" "
Kaffirs	49	7	14.28	" "
Africans (west)	236	66	27.96	" "
Lapps	22	1 (?)	4.54 (?)	Meat or fish, milk, cheese.

The Gauchos, a cattle-breeding tribe, inhabiting the pampas of La Plata, and subsisting on meat, are said to be free from caries, while a related tribe in Chili, that subsists on bread, beans, meat, etc., showed 19.3 per cent. of caries. Again, those Gauchos who live in cities, and who eat mixed food and much sugar, also suffer much from decay of the teeth.

A hasty examination of several skulls led Black[130] to the supposition that those races which consume much sour fruit are less afflicted with caries than those living on meat and grain. But when we remember how the teeth are destroyed by a grape cure, we can only regard the result of Black's investigation as accidental, particularly as it was but a "hasty" one.

In one point, however, all examinations coincide. All authors call attention to the fact that the Esquimaux, certain meat-eating tribes of North American Indians, Icelanders, and, as far as I have observed, Lapps also, are almost entirely exempt from caries.

The immunity of these races cannot, it seems to me, be explained by the favorable hygienic mode of life, climatic influences, etc., alone. They often suffer from famines; various diseases are frequent, especially among the Lapps, and the latter, as well as the Esquimaux, are becoming extinct. That the number of inhabitants of Iceland has remained stationary for the last few centuries is said to be due to "volcanic eruptions, frequent epidemics, unhealthy mode of life, famines, etc."

I think therefore every one will agree with me that the conditions prevailing in the countries named are not to be regarded as conducive to a perfect development of the human body.

Those factors which contribute to restrict the occurrence of decay of the teeth are, in my opinion, (1) a mode of life favorable to the development of the whole body, (2) the use of food which is sufficiently hard to afford the teeth the exercise necessary for their vigorous development, (3) the use of food which does not undergo an acid fermentation in the mouth.

SUGAR

CHAPTER IX.

PROPHYLAXIS OF DENTAL DECAY.

To every one at all acquainted with the nature of that condition of the teeth denominated as decay, caries, etc., and with the causes by which it is produced, it must be apparent that there are four ways by which we may counteract or limit the ravages of this disease. We may endeavor (1) by hygienic measures to secure the best possible development of the teeth; (2) by repeated, thorough, systematic cleansing of the oral cavity and the teeth, to so far reduce the amount of fermentable substances as to materially diminish the production of acid, as well as to rob the bacteria of the organic matter necessary to their rapid development; (3) by prohibiting or limiting the consumption of such foods or luxuries which readily undergo acid fermentation to remove the chief source of the ferment-products injurious to the teeth; (4) by the proper and intelligent use of antiseptics to destroy the bacteria, or at least to limit their number and activity.

That a great influence is exerted upon the process of fermentation in the human mouth by the mechanical cleansing mentioned under 2 may be easily proved by the following experiment: Take 10.0 c.cm. saliva from the mouth in the morning before cleansing it, add 0.5 gr. starch, and place the mixture in the incubator. Then cleanse the mouth and teeth most thoroughly with the brush, toothpick, floss silk, etc., after which take 10.0 c.cm. again (easily obtained by chewing a quill toothpick or in the manner described on page 40), add 0.5 gr. starch as before, and place also in the incubator. The first mixture not only shows signs of fermentation sooner than the second, but also forms much more acid in a given time. That different kinds of foods and luxuries play vastly different rôles in the fermentations of the human mouth must be apparent to every one from the table given on pages 208, 209.

The substances which give rise to fermentation in the mouth accompanied by the development of acid, belong almost without exception to the group of the carbohydrates. The general opinion that putrefying meat gives rise to products which attack the teeth is, I repeat it, entirely unfounded and erroneous. The products of a putrefying mixture of saliva and meat (whether cooked or raw) are always alkaline, and when meat has remained for some time between the teeth it may even act as a preventive to decay in so far as it tends to neutralize the acids produced by the fermentations of carbohydrates. The latter, however, are, as a rule, unless the albuminous substances preponderate to a great degree, more than sufficient to satisfy the basic products of the albuminous fermentation (putrefaction), so that in case of mixed diet the reaction will still be acid, not so strongly, however, as in purely amylaceous diet.

Most authors give sugar the chief place among those foods which exert an injurious action upon the teeth—again a conception which is not quite right. It is true that the constant breathing in of sugar-dust exerts a very destructive effect upon the front teeth in particular, known as sugar-decay (Zuckercaries). In general, however, the chief rôle in the production of decay is performed by bread, potatoes, etc., not only because they produce more acid, but because they, on account of their insolubility, may remain for a long time sticking to or between the teeth, whereas the readily soluble sugar is soon diluted or carried away. In my opinion, sugar can equal bread in its destructive action upon the teeth only when it is consumed as an ingredient of sticky, insoluble substances.

Naturally, we cannot think of making the attempt to banish the carbohydrates from the list of the foods and luxuries of civilized races; but we may accomplish a great deal for the teeth if we prevent the constant and unnecessary consumption of sweets, etc., indulged in by many young and not a few adult persons.

The Use of Antiseptics in the Prophylactic Treatment of Decay.

When at the beginning of the present decade, through the most exact methods of bacteriological investigation now in use, the true (parasitic) cause of one disease after another was brought to light, we had many reasons to hope that the helpless position of medicine in the presence of the severest infectious diseases was soon to be changed. As yet, however, our expectations have not been realized. With the exception of the still somewhat doubtful triumphs of Pasteur over anthrax and hydrophobia, very little advantage whatever has resulted to therapeutics from the eminent bacteriological discoveries of the last ten years. Consumption, cholera, typhus, diphtheria, syphilis, have not become less terrible through the discovery of the specific micro-organisms of these disorders.

Diseases which come under the treatment of the dentist form no exception to this statement. The fact that decay of the teeth is of parasitic origin having been once established, the thought suggests itself that we ought to be able by means of properly chosen antiseptic materials not only to arrest decay, but to prevent its appearance. This is, indeed, the avowed object of the very many antiseptic mouth-washes now in the market. As a matter of fact, however, there is no evidence that anything whatever has as yet been accomplished in the prophylactic treatment of the teeth through the use of antiseptic mouth-washes, and it is evident that anyone who would discover some means by which the often fatal ravages caused by decay of the teeth might be held in check would thereby confer a great boon on humanity.

It would, however, be going too far if we were to adopt the views of those who have expressed the opinion that by proper care of the teeth and constant use of antiseptic washes from childhood on, decay would be entirely banished from the human mouth.

This view is too optimistic for various reasons: chiefly because there are places in every denture which will remain completely untouched even by the most thorough application of the antiseptic, or the antiseptic will reach them in so diluted a condition that it possesses little or no action. If a very thorough mechanical cleansing has not preceded the antiseptic, its action upon the centers of decay will be equal to little more than zero.

A great difficulty lies further, in the fact that nearly all materials which possess antiseptic action are either contraindicated altogether in the mouth, or that they may be used only in very dilute solutions, either because they are injurious to the general health, or locally to the mucous membrane or to the teeth themselves. Finally, many otherwise useful antiseptics are excluded because of their bad taste and smell.

For these reasons the preparation of a mouth-wash which possesses an antiseptic action of any importance is accompanied by the greatest difficulties.

Determinations of the antiseptic power of different materials have been made in great number. Some of them which refer especially to those materials which are made use of in the human mouth may find place here.

Koch[131] found for anthrax bacilli the following numbers:

	Evident retardation of the development was produced by a concentration of	Complete prevention of the development
Sublimate	1 : 1000000	1 : 300000
Thymol	1 : 80000	——
Oil of turpentine	1 : 75000	——
Oil of peppermint	1 : 33000	——
Chromic acid	1 : 10000	1 : 5000
Oil of cloves	1 : 5000	——
Iodine	1 : 5000	——
Salicylic acid	1 : 3300	1 : 1500
Oil of eucalyptus	1 : 2500	——
Hydrochloric acid	1 : 2500	1 : 1700
Camphor	1 : 2500	——
Benzoic acid	1 : 2000	——
Permanganate of potash	1 : 1400	——
Carbolic acid	1 : 1250	1 : 850
Boric acid	1 : 1250	1 : 800
Chinin	1 : 830	1 : 625
Benzoate of sodium	1 : 200	——
Alcohol	1 : 100	1 : 25
Table-salt	1 : 64	——

According to Miquel, the development of bacteria in bouillon is prevented by the following antiseptics in the given concentration:

Mercurous oxide	1 : 40000	Carbolic acid	1 : 318
Peroxide of hydrogen	1 : 20000	Permanganate of potash	1 : 286
Bichloride of mercury	1 : 14300	Arsenious acid	1 : 270
Nitrate of silver	1 : 12500	Boric acid	1 : 180
Iodine	1 : 4000	Borax	1 : 14
Salicylic acid	1 : 1000	Alcohol	1 : 10.5
Mineral acids	1 : 500 to 1 : 333		

In the *Deutsche medicinische Wochenschrift* for 1884 I gave in the form of a table the results of a series of experiments which I undertook for the purpose of determining the action of a number of antiseptics upon the bacteria of the human mouth. This table, to which a number of materials have recently been added, follows here:

Antiseptics.	Development of Bacteria prevented by
Bichloride of mercury	1 : 100000
Nitrate of silver	1 : 50000
Peroxide of hydrogen	1 : 8000
Iodine	1 : 6000
Iodoform	1 : 5000
Naphthaline	1 : 4000
Salicylic acid	1 : 2000
Benzoic acid	1 : 1500
Permanganate of potash	1 : 1000
Oil of eucalyptus	1 : 600
Carbolic acid	1 : 500
Hydrochloric acid	1 : 500
Biborate of sodium	1 : 350
Arsenious acid	1 : 250
Chloride of zinc	1 : 250
Lactic acid	1 : 125
Carbonate of sodium	1 : 100
Listerine	1 : 20
Absolute alcohol	1 : 10
Chlorate of potash	1 : 8

Ag N I

It is evident that it would not do to tax the value of these materials for therapeutic purposes exactly according to the above numbers. Whoever, for example, would consider bichloride of mercury, particularly for dental purposes, two hundred times as active as carbolic acid would make a great mistake, since the former can as a rule be applied only in dilute solutions, whereas the latter may usually be made use of in concentrated form.

In connection with the antiseptic materials used in the human mouth, the question of their adaptability demands particular consideration; and in regard to this point I have examined a number of the materials used in the treatment of the human mouth in the same form and concentration as they may be made use of in the form of a mouth-wash. Usually in rinsing the mouth the solution remains from a few seconds to at most a minute in connection with the mucous membrane and the teeth; and we need accordingly for the purpose of sterilizing the oral cavity a material which in the adapted concentration is able to devitalize bacteria inside of a minute. How far this is accomplished by the means at our command may be seen from the following table:

Antiseptic.	Concentration.	Time necessary for devitalization.
*Salicylic acid	1 : 100	¼ minute
*Benzoic acid	1 : 100	¼ "
Listerine	——	¼ to ½ minute.
Salicylic acid	1 : 200	½ "
Bichloride of mercury	1 : 2500	½ to ¾ "
Benzoic acid	1 : 200	1 to 2 minutes
Borobenzoic acid	1 : 175	1 to 2 "
Thymol	1 : 1500	2 to 4 "
Bichloride of mercury	1 : 5000	2 to 5 "
Peroxide of hydrogen	10 per cent.	10 to 15 "
Carbolic acid	1 : 100	10 to 15 "
Oil of peppermint in agreeable strength	——	5 to 10 "
Permanganate of potash	1 : 4000	more than 15 minutes
Boric acid	1 : 50	" " 15 "
Oil of wintergreen	——	" " 15 "
Tincture of cinchona	1 : 18	" " 15 "
Lime-water	——	no action.

The above experiments were made in the following manner:

A determined quantity of a pure culture of a ferment bacterium of the mouth is brought into 0.5 c.cm. of the antiseptic to be tested, and then in determined intervals single drops of this mixture are brought into test tubes containing 5 c.cm. of a nutritive solution. If a development of bacteria does not take place in any tube or tubes, it may be taken as an indication that the bacteria were devitalized in the corresponding time.

* Salicylic and benzoic acids may be applied in this concentration only on the brush.

Control experiments were naturally made at the same time. A number of tests which I made with a coccus found in a case of mycosis tonsillaris benigna led to the same result.

It appears from the above experiments that only few of these substances are serviceable for the purpose of cleansing the mouth. The bichloride of mercury is the most active, not only because it has the highest antiseptic power, but because its action continues for a longer time. Even after the solution has been removed from the mouth, traces remaining retain their antiseptic action, even when they have been diluted from one to two hundred times by the fluids of the mouth. None of the other materials possess this property in so high a degree. Furthermore, sublimate appears to penetrate particles of food, deposits, etc., more rapidly than the other materials given. I have satisfied myself by many experiments that it is possible, after a complete mechanical cleansing of the mouth, to obtain by means of sublimate (1–2500) an almost perfect sterilization of the mouth. Unfortunately, the application of the bichloride of mercury is limited, on account of its very poisonous properties.

As for salicylic acid, many are of the opinion that it attacks the teeth (decalcifies them), and that it consequently should never be used in the mouth. On the other hand, others deny this action. I myself have seen it used for years without any evil consequences, and do not fear to use it now and then in the strength of 1–200 or 1–300.

In all diseases of the human mouth in which antiseptics are indicated, particularly in acute infectious diseases, salicylic acid may be used for a short time without any danger to the teeth. For continual use perhaps the milder, though somewhat weaker, benzoic acid in the concentration of 1–200 is preferable, unless it should turn out that this also may have an injurious effect upon the teeth.

Listerine has proved to be a very useful and active antiseptic. This is a preparation of Lambert & Co., in St. Louis, consisting of oil of eucalyptus, borobenzoic acid, wintergreen oil, etc.; it owes its antiseptic property probably more to the borobenzoic acid than to the oil of eucalyptus. It is to be applied on the brush in cleansing the teeth, or slightly diluted as a mouth-wash.

For cleansing root-canals, cavities, etc., the more powerful antiseptics are of course preferable.

Wintergreen oil and similar aromatic substances, which usually form an important constituent of mouth-washes, have as far as I have examined them, in an adaptable concentration, very little antiseptic action, unless the oil of peppermint is an exception. This possesses considerable antiseptic action, and is consequently as a constituent of mouth-washes to be preferred to the other ethereal oils. According to Black,[132] however, oil of cassia, oil of cinnamon, and oil of cloves have a much higher antiseptic action than the oil of peppermint. The results obtained by Black, in so far as they refer to the oil of cloves and oil of peppermint, are in direct contradiction to those obtained by Koch, who found that the oil of peppermint has an action nearly seven times as strong as that of the oil of cloves. This difference is no doubt to be accounted for in the difference of the bacteria experimented upon.

If we compare the two tables last given, we find some apparent contradictions. For example, listerine, which is, according to one table, forty times weaker than a 10 per cent. solution of the peroxide of hydrogen, devitalizes bacteria much more quickly than the latter. I am able to explain this remarkable difference only on the supposition that the rapidity with which an antiseptic acts need by no means be proportional to its strength. We must furthermore distinguish clearly between those substances which only *prevent development*, as indicated in the first three tables, and those which devitalize, as indicated in the last table. It is possible that an agent may prevent the development of bacteria in very dilute solutions, and yet not devitalize them even in more concentrated condition.

In the third place, it may be readily conceived that a highly diffusible substance may penetrate the cell-membrane more quickly and therefore act more rapidly than a less diffusible one, even though the latter may retard or prevent development in a much more dilute condition.

Recently I have tested salol, aseptine, and the acetate of aluminium in a similar manner. Salol is a very agreeable antiseptic, but in my experiments it showed very little action.

Aseptine compared with thymol, sublimate, carbolic acid, etc., is a very weak antiseptic, but it has the advantage that it may be applied in concentrated solutions. Acetate of aluminium is an old medicament still adhered to by many physicians; it combines considerable antiseptic power with a strong astringent action. The strongest solution which may be used in the human mouth had in some cases a marked action, but on the whole not strong enough to encourage me in its use.

I finally made a series of experiments with various mixtures, my aim being to combine a number of antiseptics in such a manner as to produce the greatest possible antiseptic action with the least possible action upon the mucous membrane and the teeth, etc.

My experiments were made on the following mixtures:

(1)	Water	50.00		
	Alcohol	5.00		
	Tinct. eucalypt.	0.75		
	Benzoic acid	0.15		
	Thymol	0.0125		
(2)	Listerine	25.5		
	Water	25.0		
(3)	Aseptin	25.00		
	Water	25.00		
	Alcohol	5.00		
	Tinct. eucalypt.	0.75		
	Benzoic acid	0.15		
	Thymol	0.0125		
(4)	Water	50.00		
	Alcohol	5.00		
	Tinct. eucalypt.	0.75		
	Benzoic acid	0.15		
	Thymol	0.0125		
	Bichloride of mercury	0.025		
(5)	Water	25.00		
	Aseptin	25.00		
	Salol	5.00		
	Alcohol	5.00		
	Acetate of aluminium	1.50		
	Benzoic acid	0.15		
	Thymol	0.0125		
	Tinct. eucalypt.	0.75		

These mixtures are not mouth-washes, but they might serve as bases for mouth-washes, as indicated below.

The alcohol was added only as a solvent, not because of its antiseptic powers.

As a mouth-wash, we need above all a solution which acts *quickly*, and which does not simply prevent the development of micro-organisms while it is acting, but which devitalizes them.

There are agents which, even in very dilute form, if applied constantly have a powerful antiseptic action, inasmuch as they prevent the development of such micro-organisms as may be present without, however, devitalizing them; such agents are of no more value as antiseptics in the treatment of the oral cavity than an equal amount of distilled water. It is seldom that any one in rinsing his mouth will retain the wash longer than one minute, and an antiseptic mouth-wash, to be efficient, should be able to devitalize the micro-organisms with which it comes in contact within this short time.

Solution No. 4 accomplishes this for nearly, if not for all, micro-organisms in the vegetative form. A solution which devitalizes spores in one minute is out of the question, and, in fact, is not at all necessary, since the conditions which lead to the formation of spores do not exist in the mouth, where we find almost exclusively the vegetative forms.

This solution (No. 4) has a decided action in one-fourth to one-half of a minute; in one minute the sterilization is nearly or quite complete.

Next to this came the solutions Nos. 5, 3, and 1, in close order; the addition of aseptin and acetate of aluminium, both of which, but particularly the former, are antiseptics of considerable strength, did not produce the hoped-for increase in the action of the solution. The addition of salol had, as I anticipated, no effect whatever. These solutions produced a decided diminution in the number of colonies in half a minute; a complete sterilization usually required two minutes, sometimes even longer.

Nearly as strong as these solutions was a 50 per cent. solution of listerine, which also has the advantage of a very agreeable taste and odor.

Now, it very often happens that the centers of decay about the teeth are filled with particles of food, and we do not in such cases have liquids to sterilize, but solid substances impregnated with micro-organisms; what effect can we produce upon these by the action of the solutions given above?

To determine this question, a second series of experiments was made in the following manner:

Small porous bodies (bread, meat, paper, etc.), of as nearly the same size as possible, were saturated with bouillon containing certain micro-organisms, or with stale saliva, then subjected to the action of the antiseptic solutions during a specified length

of time, after which they were brought into culture-gelatine and the number of colonies which developed determined. The stronger the antiseptic and the longer the time of exposure, the less will be the number of colonies which develop in the culture tube. As control, the experiment was repeated, using sterilized water instead of an antiseptic solution.

To avoid transferring too much of the antiseptic to the culture tube, each piece was placed for an instant on sterilized blotting-paper, to remove the excess of liquid. I give the results of one of these experiments below. In this solution No. 4 was made use of, and *small* pieces of bread charged with bacteria subjected to the action of the solution 20, 35, 55, 70, 90, and 120 seconds respectively. The control tube developed 4500 colonies:

Tube 1	(20	seconds	action)	developed	420 colonies.
" 2	(35	"	")	"	46 "
" 3	(55	"	")	"	250 "
" 4	(70	"	")	"	13 "
" 5	(90	"	")	"	1 colony.
" 6	(120	"	")	remained sterile.	

It may appear strange that tube 3 should develop more colonies than tube 2, but such irregularities often occur, owing to the fact that it is not possible to obtain pieces of bread or meat of *exactly* the same size and consistency. The result of the experiment is, however, very clear. When large compact pieces were used (as large as a pea, for example), such as may sometimes be found in cavities of decay, it required as much as ten to fifteen minutes to effect a complete sterilization. The lesson is plain. Even such a powerful wash as the one under consideration will accomplish but little in sterilizing the human mouth when the centers of decay are stuffed full of food. This is also the reason why excessive smoking, notwithstanding the fact that tobacco-smoke is a powerful antiseptic, does not insure the teeth against decay; the smoke passes over the surface, but does not penetrate to the point of action. It follows that the use of the mouth-wash should always be preceded by the thorough use of the brush or toothpick, removing at least all larger particles of food and opening the spaces between the teeth, so that the wash may penetrate to the vulnerable point. If this is conscientiously done, I think that we have in solution No. 4, and, in a less degree, in the other solutions specified, a powerful means of preventing the excessive ravages of decay. The solutions 1 and 4 may be made use of in the following form:

No. 1.	Thymol	0.25 grams.
	Benzoic acid	3.00 "
	Tincture of eucalyptus . . .	15.00 "
	Alcohol	100.00 "
	Oil of wintergreen	25 drops
	(or oil of peppermint	20 ")

In use, enough of this mixture is added to a mouthful of water to produce a decided cloudiness.

The wash, no doubt, may be rendered softer and more palatable by the addition of glycerine, tincture of catechu, or something of the kind. Perhaps some one who is interested in mouth-washes will kindly undertake the task.

No. 4 is prepared in the same way, with the addition of 0.8 bichloride of mercury:

Acid. thymic.	0.25
Acid. benzoic.	3.00
Hydrarg. bichlorid.	0.80
Tinct. eucalypt.	15.00
Alcohol absolut.	100.00
Ol. gaultheriæ	gtt. xxv.

One naturally hesitates to prescribe a mouth-wash which contains bichloride of mercury, but I think a more thorough consideration of the question will show that it is not so reprehensible an act as may at first appear.

The strength in which the bichloride is used in the mouth is about $\frac{1}{2000}$. Let us suppose that the patient swallows of the solution two grams daily (as a matter of fact, one need not swallow any at all); it would require one hundred days to have swallowed 0.1 gram of the salt, which is the maximum dose for one day. In this matter, however, reasoning is of little value; nowhere is the saying in medicine, experience is of greater value than reasoning, truer than in questions dealing with the physiological action of the salts of mercury. I, myself, have made extensive use of the above formula without a trace of any physiological or toxicological action, and if a sufficient number of members of the profession would make a trial of this solution upon themselves, and report the results, a great deal would be done toward solving the question of the advisability of recommending the wash in practice.

The taste of the bichloride is exceedingly disagreeable, even in dilute solutions; it may to a certain extent be disguised by the use of rose-water in place of aqua destillata as a solvent, as suggested by Allan.

Unfortunately, our pharmacopœia is not yet so rich that the physician or dentist can restrict himself to the use of good-tasting medicaments.

I have been informed by some who have used the bichloride as a mouth-wash that whereas it has most excellent effect in all suppurative diseases of the gums, it discolors the teeth. This of course would be a serious disadvantage if it should prove to be true. All the discoloration I have ever observed could be readily removed with brush and powder.

On the whole, however, the fear of a possible toxic effect from the bichloride, which, in consideration of the fact that certain individuals are extremely sensitive to the action of this drug, we shall scarcely be able to escape from, will probably prevent its ever being extensively introduced except for occasional use in acute infectious and putrid conditions of the mouth. I personally have never prescribed it for prolonged use, except for a few friends who were in a position to control its action. From such the only complaint I have heard has been of its bad taste.

Witzel is enthusiastic in his praise of sublimate in the treatment of putrid and septic conditions of the mouth. "A few drops of a 2 per cent. ethereal solution of sublimate in a glass of water suffice to remove for a short time the most offensive smell from the mouth." "Syringing the alveoli with sublimate 1-1000 followed by the injection of six to eight drops of a 2 per cent. solution into the septic parts . . . . as most sovereign medicament in case of septic alveolitis." In septic wounds following extractions, syringing with sublimate 1–1000 twice a day was continued for eight days with most beneficial results, etc.

In the last few years a large number of different materials have been recommended as disinfectants for the mouth. The most of them, however, have been as yet too little tested to enable us to give an estimation of their value.

Von Kaczorowski[133] recommends iodine-chloride of sodium solution (Natrium chloratum 1 per cent., Tr. Iodi 0.5 per cent.), one-half to a whole teaspoonful every quarter to half hour.

Truman praises hydronaphthol, which he finds as efficient as it is harmless.

Black[132] recommends a mixture of carbolic acid 1, oil of wintergreen 2, oil of sassafras 3. Others recommend iodol, sozoiodol, betanaphthol, sanitas oil, etc.

Witzel[134] recommends his so-called 20 per cent. solution of sublimate, for root-treatments, which, however, is said to discolor the teeth. Personally I use a 1 to 5 per cent. solution for the same purpose, and a $\frac{1}{2}$ to 1 per cent. solution for syringing abscesses or suppurating wounds after extraction, and for the latter purposes in particular find it decidedly superior to either 2 per cent. carbolic acid or 5 per cent. peroxide of hydrogen.

Busch[135] has obtained most beneficial results from the use of peroxide of hydrogen, particularly in putrid and septic conditions of the gums, and is of the opinion that no other antiseptic at present in use is to be compared with this. He adds a sufficient quantity of the so-called 10 per cent. solution to water to produce about a 2 to 3 per cent. solution for rinsing the mouth.

Harlan has also enriched the dental materia medica with a considerable number of new antiseptics.

I lay no particular value on tooth-powder as a means of cleaning the teeth. It is true that the external surfaces, particularly of the front teeth, may be kept whiter by the use of tooth-powder, but the centers of decay are more liable to become stopped up than to be cleansed by tooth-powder, particularly when they contain insoluble constituents.

Somewhat more recommendable I find the tooth-soaps, in so

far as they dissolve fatty substances without attacking the teeth, and, furthermore, possibly make the penetration of the bristles of the tooth-brush into the center of decay somewhat more easy. They should be made of neutral soap, and have a neutral or slight alkaline reaction. Under all conditions, however, the chief thing is the thorough mechanical cleansing of the teeth.

THE ANTISEPTIC ACTION OF FILLING-MATERIALS.

It will scarcely be questioned by anyone acquainted with the nature of those diseases of the teeth which we treat by filling, that in a great many cases, if not in all, the probability of success would be greatly heightened if the filling-material could be made to exert a permanent antiseptic action upon the walls and margin of the cavity. This is more particularly true of all cases where, for some reason or other, carious dentine is left in the cavity at the time of filling; and such cases constantly occur in every dental practice. There are, I hope, very few practitioners in dentistry who place so high an estimate upon their own skill and thoroughness, or so far overlook the imperfection in the structure of the dentine, as to imagine that they excavate every cavity perfectly. Many even *prefer* leaving a thin layer of softened dentine in the cavity to removing it, if the pulp would thereby be exposed. Others, no doubt, for very humane reasons, sometimes excavate less thoroughly than they otherwise would do, in order to spare their patient the excessive pain accompanying the operation, or because the patient cannot or will not bear the pain. Most of us, for the sake of our backs, toward the end of a hard day's work, now and then decide that a difficult cavity is ready to fill when a careful examination of it might still reveal soft points. It is not necessary, however, to enumerate other cases in which the preparation of the cavity is not quite faultless; most readers will no doubt be able to suggest many more.

Now, it may appear remarkable that, while so much attention has of late years been bestowed upon the antiseptic treatment of root-canals and the employment of antiseptic materials for filling them, very little attention has been given to the subject of the antiseptic materials for filling cavities of decay; iodoform cement being, as far as I know, the only material which was introduced with this object in view. That it does not accomplish its object will, I think, be apparent from the experiments recorded below.

Methods.—I.

Various methods may be employed for determining the antiseptic action of filling-materials. The two which I have made use of are exceedingly simple, and at the same time very instructive. In applying the first of these methods we proceed as follows: A tube of ordinary nutritive gelatine is infected with a bacterium from the oral cavity, which grows rapidly at room temperature without liquefying the gelatine. The gelatine is then melted, slightly shaken, so as to distribute the fungi equally throughout the solution, and poured upon a horizontal sterilized glass plate, upon which we drop pieces of the filling-material or other substances whose antiseptic action we wish to determine. As soon as the gelatine becomes stiff we place the plate in a damp chamber. A plate prepared in this way, without the addition of any material having an antiseptic action, will become cloudy and opaque in the course of twenty-four to forty-eight hours, through the development of innumerable colonies of bacteria. If, however, the pieces of filling-materials which we have dropped upon the plate possess an antiseptic action, the development of the fungi in their neighborhood will be retarded or altogether prevented, and each piece will appear surrounded by an area of transparent gelatine whose size will depend upon the activity of the antiseptic employed. Most of the filling-materials in use were tested by this method in respect to the antiseptic action, with the result that the only one which possesses such action and retains it for an indefinite time after it has been inserted is copper amalgam.* Not only freshly-mixed fillings, but pieces of old, half-worn-out fillings, taken from teeth extracted in the polyclinic of the Dental Institute, and even pieces of *dentine* from teeth which had been filled with copper amalgam, in-

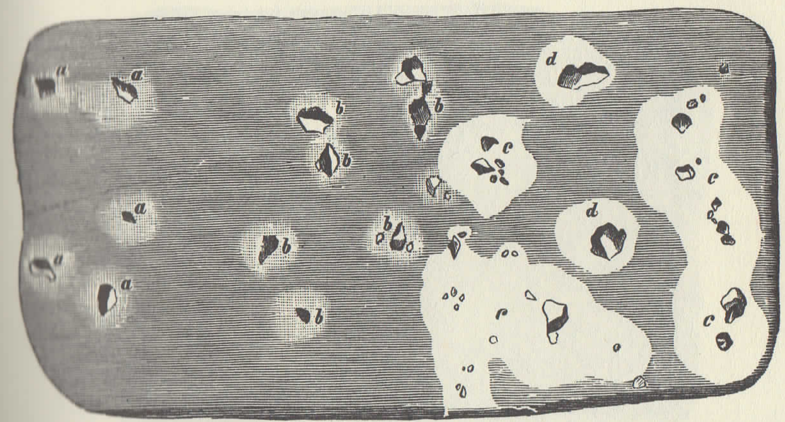
* Regarding an unexpected antiseptic action of certain preparations of gold which might appear to furnish an exception to this rule, see the experiments described below.

variably manifested a retarding or preventing action upon the growth of bacteria. (Fig. 106.)

These results accord exactly with those which I obtained by entirely different methods in 1884 (*Independent Practitioner*, June), and which have been called in question by Bogue and others.

Of course it must not be inferred from these remarks that a little piece of copper amalgam dropped into a liter of bouillon will keep it from spoiling. Nor would an experiment of this nature be a just test of the antiseptic action of a material used in filling.

Fig. 106.

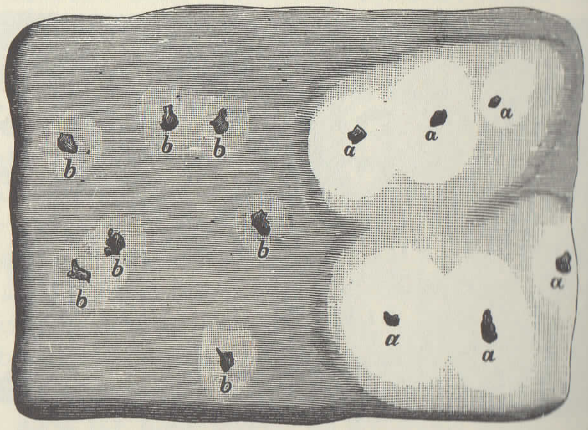


An inoculated gelatine plate containing: *a*, pieces of oxyphosphate cement one day old; *b*, pieces of gold amalgam one day old; *c*, pieces of an old copper amalgam filling, age unknown; *d*, pieces of stained dentine from a tooth which had been filled many years previously with copper amalgam.

If the filling prevents the progress of decay in softened dentine under it or in immediate contact with it, and if it retards the progress of fermentation in fine spaces (leakages) between it and the marginal wall, then it is doing a great deal toward preventing the recurrence of caries, which another filling not possessing antiseptic properties would not do.

That so much is accomplished by copper amalgam, I am, I believe, justified in concluding from the experiments enumerated above, and more particularly from those made under the second method and described below. It is a view, moreover, pretty generally accepted by all operators who have had opportunity of observing the action of copper amalgam fillings, that they do possess a preserving action upon tooth-substance. I, along with most others, formerly accounted for this action upon the supposition that copper amalgam does not shrink while setting. I meet almost daily with amalgam fillings, not containing copper, which admit of the point of an excavator being inserted between the filling and the margin of the cavity, whereas copper amalgam fillings appear to hug the walls of the cavity perfectly.

Fig. 107.



An inoculated gelatine plate containing pieces of freshly-mixed cement. *a*, oxychloride; *b*, oxyphosphate. A very marked hindrance in the development of the bacteria is noted around the pieces of oxychloride: around the pieces of oxyphosphate it is scarcely perceptible. Plate twenty-four hours old.

Elliott,* however, found by a very extended series of experiments that copper amalgams do contract, and some of them to a surprising degree. Elliott's results are corroborated by the evidence of J. Boyd Wallis,† who claims that the slight contraction is a distinct advantage in the case of soft and sensitive teeth, because of the more speedy formation of the oxide or sulphide, which, being absorbed by the surrounding dentine, protects it from further progress of decay. "Pulps dying under copper amalgam

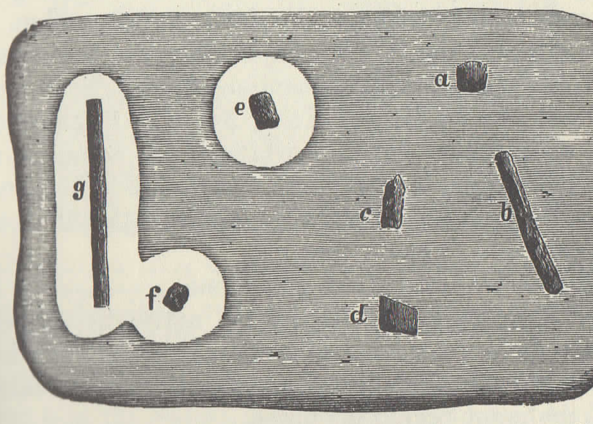
* Transactions of the Odontological Society of Great Britain, December, 1888.
† *Dental Record*, February, 1889.

fillings do not so readily decompose, owing to their becoming charged with antiseptic cupric salts."

Other materials experimented with by the first method were gold amalgam, oxychloride of zinc (agate cement), oxyphosphate of zinc (Caulk's cement), gutta-percha, gold, tin, and tin-gold.

Gold amalgam, freshly mixed, caused a slight retardation in the development of bacteria; old pieces had no effect. Oxychloride of zinc, fresh, had a very marked action. (See Fig. 107.) Pieces which had lain twenty-four hours in saliva and bread lost their antiseptic power. Oxyphosphate of zinc, fresh, had a slight, inconstant action (Fig. 107), sometimes none at all. After twenty-four hours' exposure in a mixture of saliva and bread, it showed no action whatever; gutta-percha and tin proved completely inactive.

Fig. 108.



Inoculated gelatine plate containing Pack's pellets and Abbey's foil No. 4, folded to make strips of No. 32. *a*, *b*, *c*, *d*, annealed; *e*, *f*, *g*, unannealed. The latter have retarded the growth of the bacteria in their neighborhood, as is shown by the gelatine remaining clear. Plate twenty-four hours old.

The results obtained with gold were very peculiar and perplexing. Some preparations of gold manifest a decided restraining effect upon the development of bacteria, so that if a pellet is dropped upon the plate it will after twenty-four to forty-eight hours appear surrounded by a perfectly round circle of transparent gelatine, separated from the clouded gelatine by a sharp border. Within this zone the bacteria develop very slowly, so that the cloudiness appears much later than on other parts of the plate. The antiseptic action of Pack's pellets was particularly marked. Plugs of the unannealed pellets made in holes bored in wood showed considerable action, even after they had lain for forty-eight to seventy-two hours in a mixture of saliva and bread. Also Abbey's soft foil and quarter-century foil showed similar action, but in a somewhat less degree. Other preparations showed varied effects; some were almost or quite indifferent. *The antiseptic action was completely destroyed by annealing the gold beforehand* (Fig. 108). Some preparations of sponge gold and platinum gold acted in a similar manner, and even old gold fillings now and then showed considerable antiseptic action.

I shall not attempt to give any explanation for these facts now. Different explanations suggest themselves, none, however, with which I have been quite satisfied. Nor will I at present endeavor to answer the question whether the action is strong enough to be entitled to any consideration as a saving property of unannealed gold. I am inclined to think that it would be rather venturesome to assert that it is.

Tin-gold was less active than gold alone.

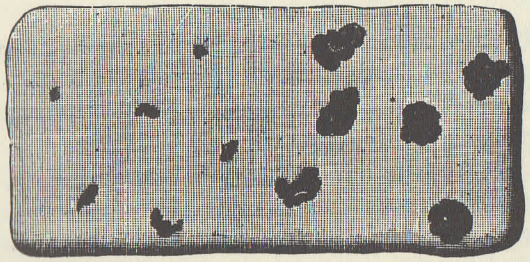
I applied this method of testing the antiseptic property of filling-materials to a few other substances; among them to iodoform, which did not have the slightest action in checking the growth of the micro-organisms tested.

II.

In order to make a direct test of the action of fillings upon carious dentine or upon the micro-organisms contained in it, we proceed as follows: A number of freshly-extracted teeth which are extensively decayed, not, however, so as to expose the pulp, are cleansed of the remains of food, and only partially excavated, so as to leave a thick layer of carious dentine in each cavity.

The cavities are then filled with various substances whose antiseptic action we wish to test, and the teeth placed in a mixture of saliva and bread and kept for three days at a temperature of 30° C. to 40° C. At the end of this time they are taken out, washed in pure water, placed for a moment in sublimate 1–1000, then in a larger quantity of sterilized water to remove the sublimate, after which they are dried with sterilized bibulous paper. We then take the teeth by the root or roots, rest the side of the crown upon a small anvil, and strike a sharp blow upon it with a hammer. The filling flies out, exposing the untouched surface of carious dentine. We now with a sterilized spoon-shaped excavator remove a small piece of the carious dentine and place it upon a previously prepared plate of sterile nutritive agar-agar. The plate is then put away in a moist chamber at or near the temperature of the human body. If now the bacteria in the carious dentine have been killed by the action of the filling-material, or if the dentine has been so acted upon by the material as itself to become antiseptic, no growth will develop around it; otherwise we will find in the course of forty-eight to sixty hours that the piece of dentine becomes surrounded by a growth of varying extent.

Fig. 109.



A STERILE AGAR-AGAR PLATE, containing in the left half pieces of dentine from a cavity which had been filled with copper amalgam, in the right half pieces from a cavity which had been filled with gold amalgam. The former have remained sterile, whereas an extensive growth of bacteria has taken place around the latter. Plate three days old.

In examining the plates, a low power of the microscope should be used in cases where a growth is not visible to the naked eye. Furthermore, a slight cloudiness or precipitate which sometimes forms around pieces impregnated with copper salts must not be mistaken for micro-organisms; and lastly, a development of bud-fungi (yeast-fungi, Saccharomycetes), or mould-fungi (Hyphomycetes), which is very frequently observed, must not be mistaken for bacteria (Schizomycetes).

The following materials were examined by this method:

1. Copper amalgam (Lippoldt's). Fifteen teeth were treated as described, and the carious dentine examined by culture. In not a single case did a development of bacteria take place. They had either been devitalized or the dentine itself had become antiseptic. In two cases bud-fungi developed; in one case mould-fungi.

2. Gold amalgam, ten teeth. In all cases a development of bacteria took place around the dentine, to say nothing of bud- and mould-fungi (Fig. 109).

3. Oxyphosphate, eight teeth. Result same as with gold amalgam.

4. Oxychloride of zinc, eight teeth. In seven cases a growth of bacteria formed, though very much retarded when compared with the oxyphosphate or gold amalgam. In one case the piece remained sterile.

5. Iodoform powder mixed with phosphate cement, one tooth. Development of bacteria unchecked. In another case the floor of the cavity was covered with powdered iodoform and oxyphosphate filled over. Pieces of dentine taken from the cavity after three days and transferred to the culture plate were soon surrounded by a growth of bacteria and bud-fungi.

6. Powdered sulphate of copper incorporated with cement or with gutta-percha, or simply strewn upon the bottom of the cavity before filling, nine teeth. No trace of bacterial growth appeared in any case.

From these results we are forced to the conclusion that copper amalgam fillings exert a marked antibacterial influence upon the walls of the cavities containing them, that oxychloride cements have an appreciable though markedly less effect, and that oxyphosphate and gold amalgam are wanting in any such action. We learn, furthermore, that by incorporating certain antiseptics into the mass of the filling or covering the bottom of the cavity before inserting the filling we may produce an effect analogous to that of copper amalgam.

Can any application of these results be made in practice? I think so, though I am certainly not in favor of being over-hasty in drawing conclusions.

Personally, I have always had much faith in the preservative properties of copper amalgam fillings, because I have had abundant opportunity to observe the splendid results obtained by its use even when very little care was taken in its insertion. The experiments which I have made have naturally served to strengthen my confidence in this material, in consequence of which I have been using it to some extent in my practice. At the cervical margin I often put a layer of copper amalgam, and then fill the rest of the cavity with some other material. In cases of complicated caries extending under the gum and very near the pulp, where phosphate fillings are utterly unreliable, and even combined with gutta-percha often very unsatisfactory, and where it is not considered wise to risk a permanent filling at once, I protect the neck of the tooth by copper amalgam, allowing a very thin layer to extend over the floor of the cavity in order to thoroughly sterilize the dentine and keep it sterile. I then fill the remaining part of the cavity with cement or gutta-percha, with the intention, in case all goes well, of replacing it in some months by a permanent material.

I am inclined to believe that the use of antiseptic materials may be accompanied by excellent results also for capping exposed pulps, particularly when they are not in a healthy condition, or contain germs of infection, as well as for covering the floor of the cavity in all cases where the pulp is protected by but a thin layer of dentine, which is very often more or less softened, or even infected with bacteria. For this purpose sulphate of copper, incorporated with gutta-percha or with some soft cement like oxysulphate, would, I am convinced, go far to effectually sterilize the thin layer of dentine covering the pulp, and thereby to prevent not only the decomposition of such softened dentine as may have been left over the pulp, but also the infection of the latter, which is very often the cause of pulp-troubles arising under fillings.

The sulphate of copper, however, seriously stains dead teeth in the course of three days, and would probably act with equal rapidity upon living teeth, so that its use would be on that account very much restricted, if not altogether contraindicated. Dr. Cunningham, of Cambridge, informs me, however, that he has been using the sulphate of copper in this manner for some time, without any discoloration resulting.

Various substances suggest themselves, which, being incorporated with cement or gutta-percha, might do good service as antiseptic dressings over diseased pulps or over softened dentine; first of all, naturally, the bichloride of mercury. Which of the many available antiseptics, however, is best adapted to the purpose must be determined by further experiments in the laboratory and in practice.

The practice of treating exposed pulps, whether healthy or diseased, to a bath of concentrated carbolic acid has been sharply criticised by various writers. There are nevertheless many practitioners in high standing who treat all exposures of the pulp in this manner, and claim to obtain better results than by any other method. I will not venture to say that this may not be so, because the ill effects of so severely cauterizing the pulp-tissue may be balanced by the good effects of thorough antiseptic treatment. If we, however, could attain the same object by the use of less irritating agents, our probability of success would be much greater.

Further experiments relating to this subject are now in progress, and will be reported in due time.

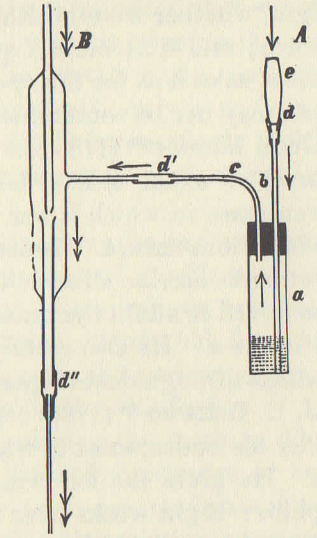
THE ACTION OF TOBACCO UPON THE TEETH.

Five grammes of old Virginia plug were boiled fifteen minutes in 50 c.cm. of water, the loss by evaporation being constantly replaced; the decoction was then filtered, and a portion added to an equal volume of saliva with sugar. This produced a mixture scarcely stronger than that which many veteran chewers carry around in their mouths all day, and in it the bacteria led only a miserable existence.

Much more remarkable, however, was the action of tobacco-smoke upon the micro-organisms of the mouth; the smoke from the first third or last quarter of a Colorado Claro cigar being found amply sufficient to sterilize 10 c.cm. of a beef-extract-sugar solution, previously richly infected with bacteria from decayed dentine.

The apparatus used for this experiment (Fig. 110) explains itself. A current of water passing through the part B in the direction of the ↘ produces a current of air through the part A, in the direction of the ↘, which draws the smoke from a lighted cigar through the solution. The rate at which the cigar smokes may be regulated at will by the cock of the hydrant. The results of my experiments, which I[136] published in 1884, have been completely confirmed by an extended series of experiments by Tassinari.[137]

Fig. 110.



a, glass cylinder with infected solution; *b*, *c*, glass tubes; *d*, *d'*, *d''*, rubber tubing; *e*, cigar (Colorado Claro); *B*, water air-pump; *A*, current of water passing through *B* in the direction of the double arrow produces a partial vacuum in the bulb, and consequently a current of air in the direction of the arrow or through the cigar, which if lighted will smoke at a rate determined by the pressure under which the water is flowing.

In consideration of the strong antiseptic power of tobacco-smoke, we might be inclined to infer that tobacco-smokers should never suffer from decay of the teeth; it is evident, however, that there are many points in the dental arch, particularly when the teeth are not kept scrupulously clean, to which the smoke never penetrates.

THE STERILIZATION OF TEETH FOR THE PURPOSE OF IMPLANTATION.

It is well known that operations designated as replantation, in which a diseased tooth is extracted, cleansed, and returned to its alveolus again, and transplantation, in which a tooth taken from one individual is planted into the alveolus of another, which has been emptied by extraction, have now and then been performed by individual dentists for two and a half centuries.* Since some few years, a similar but more serious operation is being

* Dupont, Remède contre le mal des dents, 1633, recommended for toothache the extraction and replantation of the tooth.

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PART I.

General Bacteriological Studies,

with

SPECIAL REFERENCE TO THE BACTERIA OF THE HUMAN MOUTH.