MICROSCOPY OF THE DENTAL TISSUES.*

BY J. H. McQUILLEN, M.D., D.D.S.,

PROFESSOR OF ANATOMY, PHYSIOLOGY, AND HYGIENE IN THE PHILADELPHIA DENTAL COLLEGE.

An Address before the Connecticut State Dental Association, October 4th, 1865

Gentlemen:—When accepting the invitation to deliver an address before your body, I concluded to make the MICROSCOPY OF THE DENTAL TISSUES the theme for consideration, under the impression that it would prove alike interesting, instructive, and a prolific source of investigation to all. And although many writers and observers are disposed to regard the subject as one that has been so thoroughly examined that it is impossible to throw additional light upon it by continued research, yet all accurate observers and thinkers must admit that there still remains "ample scope and verge enough" to whet the appetite of the earnest inquirer in this direction. The celebrated JOHN HUNTER, in preparing his work on the NATURAL HISTORY OF THE HUMAN TEETH, no doubt supposed that he had exhausted the subject; and yet who to-day would agree with him in the assertion that "a tooth is composed of *two substances*, enamel and bone;" or be satisfied with the description which he gives of the different tissues which enter into the formation of the dental organs? I do not wish to be understood as underrating his valuable contributions to our specialty; but, on the contrary, appreciating them most highly, and fully recognizing the impulse they gave toward raising our calling from a mere handicraft to the position of a liberal profession, I yet cannot refrain from expressing the opinion, that had he availed himself of the aid of the microscope (that wonderful instrument which has revealed during the past half a century so much of the minute structure of organic bodies that is hidden from the naked eye), his work, in place of being laid on the shelf as a curious and truly wonderful production as far as it goes, would still be used as a valuable text-book. It may be said that microscopic research in his day was not prosecuted with the same vigor that it has been during the past fifty years; while this is true, the fact

---

* In the illustrations accompanying this address, from TOMES, LEIDY, and KÖLLIKER, the plan in GRAY'S ANATOMY, of placing the names of different parts on or near them, has been adopted, in place of the usual numbers and foot-notes.

must not be lost sight of, that ANTON VAN LEEUWENHOEK, as early as the period between 1632–1723, with the assistance of magnifying glasses, powerful though of very simple form, discovered and described the dentinal tubuli. Yet, notwithstanding the valuable assistance that was here afforded to him by the labors of another, Hunter, evidently owing to a want of familiarity with all the literature of the subject, contenting himself with the description of the gross anatomy of the jaws and teeth, permitted the opportunity to pass by for a thorough account of the minute structure of the organs, and thus left the field entirely open for the valuable efforts of RETZIUS, OWEN, NASMYTH, TOMES, and KÖLLIKER, whose contributions in this field will ever be regarded as inestimable additions to the domain of science. Let the remembrance of the fact just referred to be to each and all of us a constant incentive to exertion, not only to become *observers*, but also familiar with the *entire* literature of a subject, and thus avoid falling into the error of supposing that having made some advance in any given direction, we have therefore mastered and exhausted the theme.

The subject is not merely interesting and important to us as professional men, but to the naturalist, who, in the classification of animated nature from the days of CUVIER, has made the *general* form of the teeth one of the most important guides in determining what position should be assigned to different animals in the Zoological series, a thorough knowledge of this subject is equally indispensable in ascertaining the nature, affinities, and position of extinct species, of whose organization, on account of the greater durability of the dental tissues, they are frequently all that remains in the geological strata. Possessing such knowledge, the paleontologist, with the aid of the microscope, has been able to decide questions which were not only attractive from the scientific interest attached to them, but also vastly important on account of large pecuniary interests involved in their solution.*

---

* In confirmation of the above, the following is appended: "It was in regard to *Teeth* that the possibility of such determinations was first made clear by the laborious researches of Prof. Owen; and the following may be given as examples of their value: A rocky formation extends over many parts of Russia, whose mineral characters might justify its being likened either to the *Old* or to the *New* Red Sandstone of this country, and whose position relatively to other strata is such, that there is great difficulty in obtaining evidence from the usual sources as to its place in the series. Hence, the only hope of settling this question (which was one of great practical importance, since, if the formation were *new* red, Coal might be expected to underlie it, whilst if *old* red, no reasonable hope of coal could be entertained) lay in the determination of the Organic remains which this stratum might yield; but unfortunately these were few and fragmentary, consisting chiefly of teeth, which are seldom perfectly preserved. From the gigantic size of these teeth, together

In inviting your attention to the Microscopy of the Dental Tissues, I do not propose to offer to you any discoveries of my own, but rather to describe in a plain, and, I trust, comprehensive manner, the characteristic peculiarities of the tissues which enter into the composition of the dental organs. In doing this, however, I shall present that which I have *seen* myself and *shown* to you, for as you are well aware a large number of valuable sections of the teeth of man and animals and also of bone were exhibited to you under the microscope last evening; these, in connection with the drawings which are suspended in the room, will, I trust, enable me to make the subject more clear and intelligible to you than could have been the case without them. The limited period which is afforded me only admits, I regret to say, of a hasty survey of the subject; yet I trust the time, however, will not be misspent, but may be the means of inducing you, as already remarked, to examine the subject yourself with the aid of good instruments, and thus *confirm* or *correct* the statements of other observers. In this connection, let me say, it is not absolutely necessary that you should invest a large sum of money in the purchase of a microscope, for with from sixty to one hundred and twenty-five dollars an instrument can be procured adapted to all practical purposes; and with such as these some of the most important and valuable discoveries have been made. Every Dental Society should have a microscope.

With these preliminary remarks, the teeth may be defined as small, hard, white bodies found implanted in the alveolar processes of the superior and inferior maxillary bones in man and the mammalia generally; while in other portions of the animal kingdom supplied with these organs they occupy various positions in the alimentary canal, extending in some instances from the mouth to the pylorus. In man, as you are well aware, the number of permanent teeth is thirty-two, but the *typical* number of the *vertebrata* is forty-four, and in the series it varies from a single tooth to as high as one hundred and forty. Varying thus in number and position they also differ in shape, size, and microscopical structure,

---

with their form, it was at first inferred that they belonged to Saurian Reptiles, in which case the sandstone must have been considered as New Red; but microscopic examination of their intimate structure unmistakably proved them to belong to a genus of Fishes (*Dendrodus*), which is exclusively Palæozoic, and thus decided that the formation must be Old Red. So, again, the microscopic examination of certain fragments of teeth found in a Sandstone of Warwickshire, disclosed a most remarkable type of tooth-structure, which was also ascertained to exist in certain teeth that had been discovered in the 'keuper-sandstein' of Wirtemberg; and the identity or close resemblance of the animals to which these teeth belonged having been thus established, it became almost certain that the Warwickshire and Wirtemberg sandstones were equivalent formations, a point of much geological importance." —*Carpenter on the Microscope*, page 641.

and in the relations which the different tissues that enter into their composition bear to each other, but having reference under all circumstances, however, to the *habits* and *food* of the animal; for the teeth, as the primary agents in the assimilation of the food, serve to prepare it by mastication for the important changes which it undergoes in the rest of the nutritive system.

Although presenting a variety of shapes, the general form of the teeth is either conical, wedge-like, or a combination of both. As the time allotted does not permit me to describe the shape of the different classes of teeth, I will merely state that the body of each tooth is divisible into three sections: one part projecting above the mucous membrane or gum, the *crown;* another portion received or implanted in the alveolar socket or *alveolus*, the *root;* and a line of demarkation, not always strongly marked, between these two, the *neck*.

If a recent human tooth, an incisor for instance, is divided longitudinally, a chamber called the pulp cavity, corresponding with the shape of the tooth and occupied by a soft and highly vascular substance, the dental pulp, richly supplied with vessels and nerves that have entered a foramen at the end of the root, will be brought into view. In addition to this, the exterior of the root will be found invested by a soft fibrous structure, the periodental membrane. These constitute the soft tissues of the tooth. On examining the solid portion of the tooth with respect to its component tissues, it will present at least *three* distinct structures: viz., 1, a yellowish-white substance constituting the greater portion of the body of the tooth, the DENTINE; 2, a hard, vitreous, translucent substance investing the crown, the ENAMEL; 3, a cortical structure generally disposed in a thin layer around the root, the CEMENTUM. In addition to these a fourth substance is not unfrequently observable intermediate between dentine and bone, the OSTEO-DENTINE of OWEN, or the SECONDARY DENTINE of TOMES.

FIG. 1.

As a primary object in this address is to induce you to become observers, it is advisable at this point to describe how microscopical sections of hard structures like bone and the dental tissues are made; for the errors into which investigators have frequently fallen have been due either to the employment of defective instruments, or the imperfect man-

ner in which the preparations under examination have been made. The necessary appliances for the accomplishment of this purpose are, a fine watch-spring saw, files, and water of ayr-stones; or, what is still better for the purpose, as it will effect the work much more rapidly, a lathe, to which can be adjusted a disk of soft iron like that used by the lapidary, charged at its end with diamond dust, corundum wheels, and Arkansas stones, for the purpose of making and polishing sections of the substance to be examined. In addition, oblong slips of plate-glass that should be clear, free from veins and bubbles (on which the preparations are to be placed, and very thin glass for covering them, which can be obtained from opticians), of a standard form and size, agreed upon by microscopists, along with Canada balsam and a spirit-lamp, are required.

The first thing to be done in the preparation of a specimen, is to obtain a longitudinal or transverse section as thin as it can be safely cut with the saw or circular disk. This section is then attached to a slip of well-annealed glass with Canada balsam, and filed or ground down until it becomes translucent, care being taken to have the pressure applied with such equality that the thickness of the section shall be the same in its entire structure. By occasionally examining it under the microscope during this process, any inequalities that may be present can be detected. Having obtained a perfectly smooth and polished surface, by gently warming the glass, the section can be detached, and, with the finished surface turned downward, may be transferred to the permanent glass slide, to which it is to be united by Canada balsam. The upper surface of the section is then treated in the same manner as the opposite surface was, until a perfect microscopical section is obtained, when it should be covered with the thin glass, and the latter secured in position by a black cement surrounding its edge. In using the balsam, great care should be exercised to prevent the formation of air-bubbles, as these injure the appearance of the specimen, and the true character of the structure cannot be made out with any satisfaction. This can be best effected by placing a drop of balsam on the glass slide, and then, holding the latter over the flame of the spirit-lamp, when this becomes sufficiently warm, the object can be brought in contact with the balsam, and pressed evenly and gently against the glass. In placing the thin glass cover in position, it should first be warmed on the under surface before it is laid over the specimen: if this does not suffice to attach it, the under surface of the slide can be warmed so as to soften the balsam. Care should be exercised, however, not to apply too high a heat in this operation, as it may cause the specimen to curl up, and destroy its usefulness for microscopical examination.

An easier method of obtaining sections than that described above, is

to place a tooth in the lathe and make shavings of it with a thin, sharp, and well-tempered chisel, or to put a tooth, that has been slightly softened by acid, in a vice, and then take off thin slices with a sharp razor.

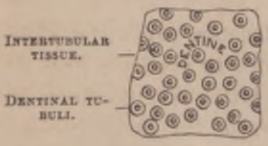
Those who may not feel inclined to incur the time and trouble incident to the preparation and mounting of specimens, can procure good ones at a trifling cost from prominent opticians in our large cities. Those, however, who purpose to carry out a line of investigation for themselves, cannot depend entirely upon such sources, but must frequently rely on their own efforts in the preparation of specimens, and hence the importance of knowing how to make them.

Having secured a longitudinal section of a human tooth, it is found to be made up of three distinct structures, of which the first is a substance, now to be described, named, by PROF. OWEN,

DENTINE.—This tissue, which was formerly called *ivory* or *tooth substance*, constituting the greater part of the crown and root of a tooth, giving to it its general form, and inclosing the pulp cavity, is in a perfect human tooth never exposed at any point, but is perfectly protected from the influence of external agents by the dense and impermeable enamel covering the crown and extending by a thin layer to the neck; where this ceases, the cementum commences to invest the root. The satiny aspect which a section of dentine presents to the naked eye gives it the appearance of a perfectly compact solid structure, but under the microscope it is found to consist of a multitude of fine canals, the DENTINAL TUBULI, and a connective matrix or intervening substance, the INTERTUBULAR TISSUE.

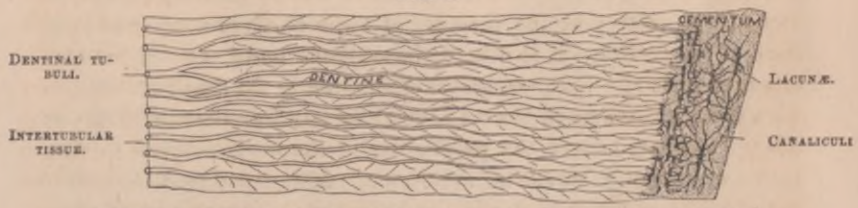
The DENTINAL TUBULI are generally described by microscopists as having distinct parietes or walls, formed of harder material than the *intertubular tissue*, whose thickness is much less than the diameter of the tubuli, which, in the largest, according to TOMES, is about $\frac{1}{10000}$ of an inch. It is difficult to distinguish these walls in longitudinal sections, but in *transverse* sections what appears to be a narrow ring is readily observable surrounding each tubule. Whether this is an optical illusion induced by the wavy character of the *secondary curvatures* of the tubuli, is a matter of question with many. Be this as it may, there can be no doubt entertained by any one at the present time relative to the fallacy of the opinion advanced by NASMYTH, that the *tubuli* are not canals but *solid fibres*, with brick-shaped cells built around them. How this distinguished and laborious observer could have been led into such an error is difficult to conceive, as the tubular character is readily demonstrable by the passage of colored fluids and minute bubbles of air along them.

FIG. 2.



The TUBULI originate by open mouths on the walls of the pulp cavity, and proceed in a slightly wavy and radiated manner through every portion of the dentine to its periphery, where they generally terminate, although in some instances extending beyond and penetrating the enamel or the cementum, in the latter of which they communicate with the *lacunæ* through the *canaliculi*. Toward the masticating surface of the crown, where the occlusion of an antagonizing tooth has to be received, they are vertical, or nearly so, and horizontal where the pressure of contiguous teeth has to be resisted; by this arrangement a certain amount of elasticity is gained, and the shock of occlusion and pressure is more generally distributed over the entire structure. The wavy character of the tubuli above referred to consists of two or three large or *primary curvatures*, and a number of smaller or *secondary curvatures*, which follow closely upon each other, and are estimated by RETZIUS as numerous as two hundred in a single line.

FIG. 3.



VERTICAL SECTION OF THE ROOT OF A CANINE TOOTH. (AFTER LEIDY.)

Starting from the pulp cavity in close proximity to each other, the divergence of adjacent tubuli is so slightly apparent, that they seem to run parallel with each other. In following them out, however, toward the periphery of the dentine, the divergence in the *crown* is readily observable on account of the increased distance between them and the ultimate dichotomous division, without at first much diminution in the caliber of the tubes. These branchings increase in number and decrease in size the nearer they approach the periphery of the dentine, and they either anastomose with each other, pass into the enamel or cementum, terminate abruptly, or in very minute cells. In addition to the large branches just referred to, innumerable fine branches are given off from the sides of the tubuli, which penetrate the intertubular tissue and anastomose with each other. In this way the most perfect arrangement for the passage of that nutrient fluid, the *liquor sanguinis*, to every portion of the tissue, is effected.

Up to within the past few years the dentinal tubuli have been invariably regarded by histologists as conduits for conveying to the *tubular* and *inter-tubular* tissues materials inservient to repair the constant molecular disintegration or waste which takes place in dentine as in all other living

organic structures. Of late, however, Mr. Tomes has discovered under the microscope a number of fibrils projecting from the dentinal tubuli, which he is disposed to regard as continuations of the nerve fibres of the dental pulp, and in confirmation of this discovery, Dr. Lionel S. Beale, in his work on "The Structure of the Simple Tissues," says that he has been able to verify this statement, and, furthermore, that they are not "conduits for nutrient fluids which transude through the walls of the vessels, and are supposed to pass along the tubes to the outer part of the tooth." Last evening, among other microscopical specimens, I showed you a section of dentine presented to me by Dr. Allport, of Chicago, in which these *fibrils* were readily seen projecting from the dentinal tubuli. Now it is a matter of question with me, whether the fibrils exist as "a soft, solid substance" in the *living* tooth, or are formed *after* its extraction.

You are well aware that when blood is drawn from an artery or vein into a basin, or any other vessel, it *coagulates* or separates into two portions, the *crassamentum* or *clot*, and the *serum* or watery part. I think it is reasonable to infer that the presence of these fibrils in a microscopical section of a recent tooth is due to the *coagulation* of the organic elements present in the liquor sanguinis circulating in the dentinal tubuli.

In a series of lectures on the "Anatomy of the Elementary Tissues of Man," delivered since the publication of the work referred to, Dr. Beale asserts that "there is no evidence of addition and removal of material going on in the enamel and dentine after the completion of their formation, and it is probable that the matter upon which the hardness of these tissues depends is not removed at all after its deposition." Notwithstanding this decided assertion, with the exception of enamel after it is fully formed, and the consolidated dentine of very old persons, the universally received opinion that there is a constant change taking place in *all* the tissues during the life of a being, is beyond a question of doubt correct. It is only necessary to refer to the absorption of the roots of the deciduous teeth (a retrograde metamorphosis by which the dentine and cementum are removed cell by cell, as in their original construction they were formed cell by cell), to disprove the assertion of Dr. Beale. The evidence of molecular change in the dentine and cementum is by no means, however, confined to the deciduous teeth; for frequent and well-marked instances are brought to the notice of the dental practitioner in which teeth, originally soft in their structure and cutting readily under the instrument, become, in course of time, hard and compact, while on the other hand, teeth which are quite hard become very soft and chalky. That this change of structure is due to constitutional influences, and is brought about by molecular change in the part affected, is more than a reasonable supposition, for it bears upon its face an air of positive certainty.

Much more might be said in confirmation of this, but I refrain from doing so at this time, and now direct your attention to what are called the CONTOUR LINES of OWEN. You will observe them in this drawing, running in an arched manner, somewhat parallel to each other, and nearly at right angles with the dentinal tubuli, in that portion of the dentine which constitutes the greater part of the crown of the tooth; although thus represented in this instance, they are by no means confined to this part of the tooth, but may be found in the dentine of the root. The appearance of these markings, arched or contour lines, is attributable to the *primary curvatures* of the dentinal tubuli and the formation of the dentine in striæ or laminæ, as with the rings observable in the trunk of a tree. These markings are not always presented in a decided manner in human dentine, but they constitute quite a marked and frequently beautiful feature in the teeth of some of the lower animals. In addition to the peculiarities just referred to, which are in every sense a normal condition, certain cavities or spaces, to which the term INTER-GLOBULAR SPACES has been applied, are also observable. These spaces, which are most numerous in the vicinity of the enamel, although they occur in other portions of the dentine, are said by KÖLLIKER not to be filled with fluid during life, but by a "soft substance, resembling tooth cartilage." This dries up in microscopical sections, and cavities are formed, which give the appearance denominated inter-globular spaces. Although this cannot always be regarded as an abnormal condition, still in defective

FIG. 4.

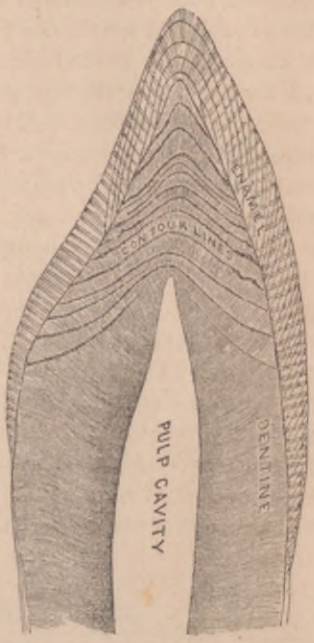
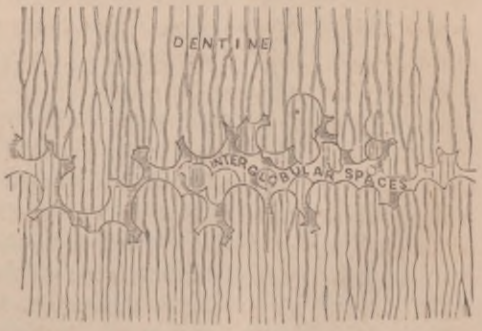


FIG. 5.



teeth these cavities are larger and much more numerous than in perfect teeth.

INTER-TUBULAR TISSUE.—This was spoken of in the preceding part of the address as a connective matrix between the dentinal tubuli. It contains the greater part of the earthy constituents of dentine, and under a high power of the microscope presents a granular appearance. The formation of the contour markings and the inter-globular spaces of course involves the inter-tubular tissue as well as the dentinal tubuli.

According to VON BIBRA, the chemical proportions of dentine in man are—

Organic Substance, 28·01.
Inorganic Substance, 71·99.

ENAMEL.—This substance, which is the hardest of all organic structures, covers and protects the dentine to the neck of the tooth, being thicker at the grinding surface, and gradually tapering to a thin edge at the neck. A calcified structural substance, called NASMYTH'S MEMBRANE, is found covering the enamel for a short time after the eruption of a tooth, but is eventually worn away. The enamel is translucent rather than white, and although extremely hard is frequently worn away by protracted use. It is composed of solid hexagonal fibres or prisms, about $\frac{1}{3500}$ of an inch in diameter, arranged in close proximity to each other, and fitting at their inner extremities into hexagonal depressions upon the coronal surface of the dentine. As you observe in this drawing, the fibres marked at short intervals by dark transverse lines, run in a gently waving manner parallel to each other. They are nearly vertical when passing toward the grinding surface of the tooth, and horizontal on the sides. To compensate for the increased extent of surface at the periphery of the enamel, the diameter of the outer ends of the fibres is somewhat larger than the inner, and still further to secure a perfect structure, short enamel fibres are interposed in what would otherwise be vacant spaces. In young teeth, TOMES states that canals exist in the enamel prisms. In addition to this, fissures frequently occur in the enamel, particularly in the depressions or crevices between the cusps of the bicuspids and molars, and extend down to the dentine. When existing, these fissures constitute a decided predisposing cause of

FIG. 6.

decay in the teeth. The dentinal canals sometimes extend into the enamel, and terminate in somewhat expanded cavities.

Concentric ridges or furrows may be readily distinguished, and frequently even without the aid of a magnifying glass, upon the external surface of the enamel, particularly in deciduous teeth. Their presence is to be accounted for on the same principle as the contour lines of dentine.

When subjected to the action of dilute acids, the enamel is almost entirely dissolved, and scarcely a trace of animal matter is discernible. According to VON BIBRA, the chemical composition of enamel is—

Organic Substances, 3·5.
Inorganic Substances, 96·5.

CEMENTUM.—This substance, which invests the roots of human teeth from the termination of the enamel to the apex of the root, where it is usually very thick, approximates to bone, not only in microscopical structure, but also in chemical composition. The *Haversian* canals, peculiar to bone, are rarely seen in cementum, except in hypertrophied conditions of the structure, but LACUNÆ and CANALICULI are always present (though sparingly), and well marked, as in the drawing (see Fig. 3, page 7), and resemble in every particular the lacunæ and canaliculi of bone. They are placed lengthwise around the fang, those in proximity to the dentine joining with the terminal branches of the dentinal tubuli, while those upon the external surface radiate toward the periodontal membrane. By this arrangement, even after the extirpation of the dental pulp, the vitality not only of the cementum but also of the dentine of the root is maintained. As age advances, or from exciting causes in adult life, the cementum frequently becomes hypertrophied, and constitutes what is called *exostosis* of the roots. The chemical composition of human *cementum*, according to VON BIBRA, is—

Organic Substances, 29·42.
Inorganic Substances, 70·58.

OSTEO-DENTINE of OWEN, or the SECONDARY DENTINE OF TOMES.—This structure is frequently found in the pulp cavities of human teeth, either coalescing with the previously formed dentine, or as separate and distinct nodules; and in some instances the pulp cavity is occupied by an entirely calcified pulp, which has no connection with the walls of the cavity, and with proper management can be removed entire from its position. Under the microscope, this substance presents the *lacunæ* and *canaliculi* of bone and cementum, and in some rare instances the *Haversian canals* are also observable.

The different microscopical structures which have engaged our atten-

tion as presented in the human teeth are arranged upon a different plan in many of the lower animals. We have found, for instance, in making a *vertical* section of a human tooth, that the dentine of the crown is covered entirely by enamel, while that of the root is invested by the cementum, and this is true of the Quadrumana, and nearly all the Carnivora; but in the Herbivora, the Pachydermata, Ruminantia, Rodentia, etc., on making a *transverse* section of the crown of their teeth, the enamel, cementum, and dentine are found upon the same plane. By this arrangement an admirable provision is made for the thorough comminution of the food upon which such animals subsist. Consisting as it does of grass, hay, or grain, considerable trituration or grinding is necessary, and owing to the presence of large quantities of silica, which is extremely hard, the teeth wear away rapidly, and on account of the different degrees of density of the various tissues, do so in an unequal manner; the cementum being the softest, wears most rapidly, the dentine next, and enamel the slowest of all. In this way an uneven and roughened exterior is presented by the masticating surface of the molars, like that in the opposing surfaces of the upper and nether stones in a grist-mill.

Much more could be said in connection with this interesting subject, for it has only been touched upon by me in the most general and elementary manner, but I will not trespass further upon your patience, as a considerable portion of your time has already been occupied.