Three memoirs on the developement and structure of the teeth and epithelium, read at the ninth annual meeting of the British Association for the Encouragement of Science, held at Birmingham in August, 1839 / by Alexander Nasmyth.

THREE MEMOIRS

ON THE

DEVELOPEMENT AND STRUCTURE

OF THE

TEETH AND EPITHELIUM,

READ AT THE NINTH ANNUAL MEETING OF THE BRITISH ASSOCIATION FOR THE ENCOURAGEMENT OF SCIENCE, HELD AT BIRMINGHAM,

IN AUGUST, 1839;

WITH DIAGRAMS

EXHIBITED IN ILLUSTRATION OF THEM.

BY ALEXANDER NASMYTH, F.L.S., F.G.S.

MEMBER OF THE ROYAL COLLEGE OF SURGEONS, &c.

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INTRODUCTION.

In the early part of 1839, having the highest idea of the independence and utility of the British Association for the encouragement of science, and the fullest confidence in its protection and fostering care, I prepared three communications for its ninth meeting held at Birmingham, sparing no exertion to render them worthy of the occasion; and I have since been gratified to find that they have been regarded by many eminent physiologists as important contributions to science, and have been recognized as throwing new light on the organization of animal tissues. As it has been, and I find from a recent publication, still is, industriously attempted to disseminate the most ridiculous errors and misrepresentations with respect to the nature of the theory of the formation of ivory embodied in these communications, and as many inquiries have been made for an authentic account of them, I think it best to publish the original materials of my communications as they were delivered at Birmingham; and I accordingly now proceed to lay before the public my papers as they were there read, my diagrams as they were there demonstrated, and the necessary remarks descriptive of the diagrams,—these remarks being printed within brackets at those parts of the papers where the diagrams were referred to.*

I must premise, however, that the following papers were not written with a view to publication: though most of the facts which they contain are the results of long in-

* The foot-notes in the following papers are, as will at once be seen, observations which have been rendered necessary by the misrepresentations above mentioned.

vestigation, and of frequently repeated observations; the papers were, nevertheless, hastily drawn up for the meeting at Birmingham, with a full confidence in the generous encouragement of the body, under whose protection I sought to introduce them to the world. They are accordingly somewhat defective in style and arrangement, but the liberal and ingenuous reader, I have no doubt, will look over such defects, and also minor inaccuracies, in consideration of the nature of their origin, of the evidently uniform tenor of the whole, and of the spirit of candour in which, notwithstanding all disadvantages, they are laid before the public. I need scarcely observe that the papers and the diagrams, taken severally, form but sections of the entire communication; and that each section, having been prepared to accompany the other, gives necessarily but an incomplete idea of the whole: the diagrams are essential for the full comprehension of the papers, and the latter necessarily contain many passages embodying a description of the diagrams.

As Mr. Phillips, the editorial secretary of the Association, has informed me that 'I was at full liberty to publish elsewhere,' (that is to say, besides in the Transactions of the Association,) 'and at any time, the whole papers illustrated as I please,' and as the Council itself has since distinctly confirmed the statement that the papers have always been and still are my private property, the step which I at present take will not of course in the slightest degree affect the due publication of my own condensed report of these researches in the Transactions of the British Association—a report which was furnished at the request of the editorial secretary to the Association, was regularly approved and accepted by him, and is thus, though it has not yet been delivered to them, the indefeasible property of the body of Associates.

In consequence of the above-mentioned information conveyed to me by Professor Phillips, I proceeded long ago to

make use of my original manuscripts in the prosecution of my researches, and prepared them for incorporation with the forthcoming second part of my work on Odontology, but my professional avocations have retarded its publication, which the proceedings of the Council of the British Association with regard to my communications have also impeded; and indeed the retrograde movements of the Council in reference to the publication of a report of them, leave me at length no other alternative than to adopt the present course.

No one can regret more than myself the necessity I am under of complaining of the conduct of the Council towards me in this matter; nor am I in the least disposed to indulge in acrimonious feelings against the enlightened members of that body, because I am confident that they had been improperly informed as to the circumstances of the case, when they first committed themselves to the line of conduct in which they have since thought it proper to persevere.

Then, again, I am confident that had the official mechanism of the Association been in somewhat more perfect order, had the provinces of its respective functionaries been more distinctly marked out, and the communications of its officers with each other been more easy and frequent, the irregularities of which I have to complain would not have arisen. As it is, it appears to me that these irregularities have arisen *from two steps taken in the first instance by the editorial secretary*, and from the Council itself having been induced for some reason to persevere in the course thus commenced.

The first of these irregularities was that mentioned above, of the editorial secretary, who, after having accepted the condensed report of my communications, which was drawn up at his request, abbreviated at his suggestion, after he had carefully examined it, corrected under his superintendence, and of which I afterwards received a hundred separate

perfect copies, without any restriction as to the use I might make of them; nevertheless, without the authority of any law, custom, or precedent, subsequently withheld it from publication, merely because the accuracy of a paragraph of this report, which extended to eight pages and comprised a great variety of topics, was made the subject of groundless comments by a member of the Council, he (Mr. Phillips) stating at the same time that he expressed no opinion as to the merits of those comments, though he was the very person whose office imposed upon him the obligation of doing so, were interference justifiable.

In order to prevent him from thus abdicating his office in favour (or for the "protection," to use his own phrase) of an interested party, who, by inducing him to take this step, removed the question from the jurisdiction of the officer specially appointed to decide on such matters, to a tribunal of which he, the interested party, was a member, and where accordingly he would sit as judge in his own case, *I immediately offered*, (although entirely released by Professor Phillips' own deliberate official acts just mentioned from any such obligation) *at great inconvenience to myself, to carry to his residence at York, for his further satisfaction, the whole of the original materials of my communications exactly as delivered at Birmingham;* and I may here state, that I have always been willing, and indeed desirous, to exhibit my communications, in an entire state, to any one who might wish to examine them.

The *next irregularity* of which I have to complain is, that both Professor Phillips and the Council, which immediately afterwards took the matter into its own hands, *not only did not accept this offer, but never even alluded to it*, and that the Council instantly proceeded, as if the offer had never been made, and without even exhibiting any charge, to instruct a committee to search for evidence on the accuracy of my own condensed report, *not in the original documents which I had instantly and spontaneously*

offered to exhibit, but in unauthenticated reports of third parties in the weekly journals. Such a singular step evidently shows that the Council must have had at that time very erroneous or imperfect impressions on this matter; and it is quite impossible to credit that, had the Council been left to itself to form a deliberate judgment, it could have ever decided on totally disregarding my offer, and on committing itself at once to such an irrelevant course. The Council having been once induced to involve itself in an anomalous line of conduct, of which the direct tendency was to attempt to remove the question under consideration from its only natural sphere, and to place it upon altogether irrelevant grounds, no one can be surprised to find, that a series of objectionable and inconsistent proceedings has flown out of these first measures; in complaining of which, as I am forced to do, my principal feeling is one of regret that the Council, which I am well aware cannot have been actuated by inimical feelings towards me, should, from some unfortunate causes, have permitted itself to be led into such a devious and unsatisfactory course.

I am hence, in proceeding to enumerate these proceedings, only influenced by a sense of duty, and have no wish to reproach the Council, which I am convinced has still the intention of doing justice to the Associates by restoring to them my report, which the acts of Professor Phillips have rendered their property, and of re-instating me in the enjoyment of my inalienable rights.

In the first place, I think it very strange that though the authentic condensed report of my three communications has been withheld from publication, and an inquiry has been instituted with respect to it, no charge has, even to the present day, been exhibited against it, and no distinct object of inquiry recognized. Then, again, it has caused me no little surprise that the Council, though in the first place it spontaneously undertook an irregular inquiry, has

since declared itself " incompetent " to prosecute it, owing to what it denominates " the delicate physiological considerations " which it involves. The Committee delegated to undertake the inquiry, and mentioned above as having been so singularly instructed by the Council, *not only never availed itself of my offer to re-exhibit all my original documents*, but had recourse, in the anomalous investigation which it was appointed to carry on, to such evidence, in lieu of these original documents in their entire state, that it confounded, in its report to the Council, one subject of my investigations, viz. the formation of ivory, with " dentition," or the protrusion of the tooth through the gum, a topic never even hinted at in any of the three communications.

Consistently with the impression which led to the declining of my offer above mentioned, both Council and Committee have persevered in neglecting even to acknowledge a mass of direct and positive evidence which, in my desire to assist them in obtaining a *complete* view of the case, I have been, in the course of our correspondence, at the trouble to submit to them. Several attempts have been made definitively to suppress the publication of my report; that is to say, to destroy what had been, by the deliberate, official acts of the Editorial Secretary, rendered the indefeasible property of the Associates, because the inquiry, it has been alleged, could not be prosecuted to any definite result on the partial and limited grounds on which, in despite of my offer, it had been attempted to base it; though, according to ordinary principles of justice, such an abrupt termination of the inquiry, without the proof of any allegation whatever against my report, ought instantly and indisputably to ensure its publication. Finally, both Council and Committee, after insisting, *exclusively*, in the first place, on the unauthenticated reports of my papers published in the weekly journals, have, in the second place, confined

themselves, in their pursuit of evidence, to intimating a request that certain *portions* only, specified by them, of my original communications, should be delivered up to them, though, as I have stated before, my communications at Birmingham were threefold, consisting of papers, diagrams, and observations descriptive of the latter; though for these communications to be properly judged of, it is evidently necessary not only that all the materials should be present, but that each of them should be considered in its proper place; though I had previously voluntarily offered to submit the whole of my communications as evidence, without any reserve whatever, and though *the only portions required were manuscripts, to which*, as I have stated above, and *as the Council and Committee have known from the very first, additions have been made, rendering them unfit to leave my custody.*

Surprised at the continued neglect of my offer above mentioned, both by the Council and Committee, as also at the plea of incompetency to judge the matter set forth by the former, and at the singular misconception already alluded to in the report of the latter, I at length, in my earnest desire to afford the fullest satisfaction, and to place the whole matter on an unexceptionable and natural footing, offered to refer the question, whatever its precise nature may be, and *to submit the whole of my original documents to the President and Council of the Royal College of Surgeons*, the only constituted body of anatomists in this country, and therefore the best tribunal for the decision of any physiological point; but, strange to say, *this proposition, like my original offer to Professor Phillips, has been passed over in utter silence.*

Such have been the proceedings by which this unfortunate transaction between the Council and myself has been characterized; and I feel that it is impossible for any one to consider them, without coming instantly to the conclusion, that an explanation of the irregular course

which the Council has been induced to adopt, can alone be found in some singular misrepresentation: at all events, it must be perfectly evident to every impartial mind, that had the matter been allowed to take its natural course, that is to say, had the editorial secretary or the Council fortunately consented to avail themselves of my original offer to submit the entire evidence on the subject, instead of the Council referring, in the first place, exclusively, to unauthenticated reports, and, in the second place, exclusively confining itself to requiring as evidence isolated portions of the original manuscripts, selected at its own discretion, for the behoof of an inquiry, the object of which was never distinctly specified—I say, *had the Council or Committee availed itself of my original offer*, I think that not one of the strange irregularities which I have been compelled, with pain, to enumerate, could have arisen, and that even if my proposal to submit this question, involving "delicate physiological considerations" to the Council of the College of Surgeons for its decision had been acceded to, the whole matter would have been easily, speedily, and satisfactorily settled.

I may here state, however, that in fact all inquiry on the subject, leaving out of the question its evident irregularity, was quite superfluous, for the accuracy of my own condensed report had been, some time before the Council entertained the question, satisfactorily vindicated in the Lancet, Medical Gazette, and Dublin Medical Press, by a reference exclusively to the unauthenticated reports of my communications published in the Literary Gazette and Athenæum. In the Lancet for 1839-40, vol. ii. p. 644, the editor states,—"Mr. Nasmyth has demonstrated "in the clearest manner that he was acquainted with, "and had published, an account of the organised nature "of the teeth long before the month of December, 1839; "and, furthermore, that he considered the teeth to be "developed 'by a transition of the pulp cells (*at*, not *on*

" the external surface) into the cells of the ivory.'" . . . .
" The essence of the theory evidently is a *transition of*
" *pulp cells into ivory cells;* and this essential element
" is developed in the papers of Mr. Nasmyth, which
" were published fourteen weeks before the presentation
" of Mr. Owen's memoir to the Academy of Sciences."

In the Medical Gazette for 1839-40, vol. ii. p. 593, is the following passage. " He (Mr. Owen) will never suc-
" ceed in convincing a single rational being that Mr. Nas-
" myth, in the papers from which we have quoted above,
" (viz. the reports in the Literary Gazette and Athenæum,)
" teaches the old doctrine of secretion or exudation of the
" ivory from the bulb, in contradistinction to Mr. Owen's
" pretended 'nouvelle théorie' that the ivory is formed
" by the transition of the pulp to an ossified state."

The Dublin Medical Press says, in its No. for August 19, 1840, p. 121,—" We have now given the substance of
" Mr. Nasmyth's researches and discoveries, as related in
" the report of his papers published in the Literary Ga-
" zette of Sept. 21, 1839, and in the Athenæum of Sept.
" 14, 1839. The most careless reader cannot cast his eyes
" over these reports without perceiving at once that they
" attempt to establish the vesicularity or cellularity of the
" pulp, and its conversion into the cells and fibres of the
" ivory by the deposition of osseous matter."

As a specific and direct confirmation of the above public testimonies to the consistency of my opinions, it was with great pleasure that I was able to submit to the Council the following documents, which contain an account of the nature of my communications drawn up by three eminent physiologists, who saw them *before* I took them to Birmingham, and consequently before there could be any motive for misrepresentation; but I am sorry to say that even the receipt of them, as was the case with the other gratuitous aids to inquiry which I have afforded, has never been acknowledged:

6, *Holles Street, March* 17, 1841.

My Dear Sir,

As you have asked me to state my recollections of a visit to your house for the purpose of seeing your diagrams, and hearing your demonstration of them prior to your visit to Birmingham in 1839, I can have no hesitation in complying with your wish.

On the afternoon of the day immediately prior to your starting for Birmingham, where you were engaged to read some papers at a Meeting of the British Association, on the minute structure of the teeth, I availed myself of your invitation, and met several gentlemen, amongst whom I well remember to have seen the late Sir A. Cooper, Mr. Liston, Mr. Burrowes, Mr. Gulliver, the Rev. Mr. Daniell, and one or two others. On the floor of your room were laid a great many very beautiful diagrams on various subjects connected with the developement of ivory, enamel, the pulp of the tooth, &c., as well as some on the microscopic characters of epithelium. You explained your views of these drawings, and read various extracts from the papers you were about to communicate to the Association, and this meeting I considered as a private view to your friends, none of whom I believe were able to be present at the Association.

I distinctly remember being struck with one particular diagram, which I then considered as demonstrative of the views you then expressed as to the conversion of the cells of the reticulations of the pulp into the cells of the ivory. In answer to several questions of Sir A. Cooper, who told us he had many years before attentively studied this subject with Mr. Fox, you controverted his opinions as to the formation of the ivory being simply an ossific secretion from a vascular pulp, and showed him the correspondence in figure and size between the cells of the ivory and those of the reticulations observed on the surface of the pulp. I recollect, also, most distinctly observ-

ing, in the particular diagram alluded to, that there were several leaf-like processes, which I could not help comparing, in my own mind, with some of the fan-like coral-lines, which were coloured partly blue and partly yellow: you observed that the artist had in all the diagrams preserved the same colour for similar structures; thus, in all, the yellow represented the ivory, and the blue the pulp. Upon being struck with the exact resemblance between the yellow and blue portions of this drawing, we were informed that in the lighter parts (yellowish) the pulp cells were in a transition stage of change into ivory; and in those more deeply tinted yellow, that change had been completed; and that the original curiously-arranged pulp cells had been converted into bone. There were several other diagrams more or less demonstrative of this fact, but I well remember to have considered, at that time, that this particular diagram distinctly demonstrated the facts you then tried to impress upon us, because of its representing in one view the successive changes from original pulp cells into the complete ivory of the tooth. My memory does not serve me as to whether the drawing was made from the human or some animal's tooth, but I satisfied myself of the correctness of the artist as to the arrangement of the cells and the reticulations, by an examination of a preparation which was placed under the microscope in another part of the room, which I examined immediately after Sir Astley Cooper, who expressed himself satisfied of the fidelity of your artist.

Yours faithfully,

(Signed) JOHN DALRYMPLE.

A Nasmyth, Esq.

I have read Mr. Dalrymple's statement, and am able to confirm it in every particular; indeed, my recollection

of the transactions in question coincides precisely with Mr. Dalrymple's narration.

(Signed) GEORGE GULLIVER.

Hyde Park Barracks, March 17, 1841.

I recollect perfectly the meeting at Mr. Nasmyth's house above referred to, and I have the same impression of what then passed as Mr. Dalrymple and Mr. Gulliver have expressed.

(Signed) ROB. LISTON.

5, *Clifford Street, March* 17, 1841.

In addition to all these distinct and unimpeachable public and private testimonies regarding the nature of my researches, I have still another witness to call, and his evidence cannot, like the above, be passed over in silence by the Council, for he is no other than *its own editorial secretary, Professor Phillips*, who himself drew up a report of my communications, (the proof of which was sent to me under cover of a note from him, and is still in my possession.) This report, with which I had nothing whatever to do, except that, on the very morning I first received it, having never heard of it before, I protested, by letter to Professor Phillips, against its insertion in the Transactions, on account of its brevity and inadequacy, was still accurate as far as it went, and contained *the very passages embodying that particular theory of the formation of ivory, on account of the presence of which, in my own condensed report, Professor Phillips*, that is to say, so far as I am able to understand his motives, *withheld the latter from publication in the Transactions of the Association*. As the Council, in the course of this transaction, has sanctioned an irregular and unprecedented act of the editorial secretary, (viz. in withdrawing from publication an officially accepted report,) in favour of

another party, it will not, of course, refuse to recognise one of his ordinary proceedings, which happens unintentionally, and therefore the more unimpeachably, to establish the accuracy of my own report. Professor Phillips's notice of my communications is as follows, and the statements above alluded to I have printed in Italics.

"*On the Structure of Fossil Teeth.* *By* Alexander "Nasmyth, *Esq. F.G.S.*

"During the author's microscopic researches in the "structure of the teeth, he was led to *the discovery of the* "*organized nature of the interfibrous substance of the* "*proper dental substance, which Purkinje, Fränkel,* "*Retzius, Müller, and others, have regarded as structure-*"*less, and which he is disposed to believe is so cha-*"*racteristic in different animals as to be capable of* "*affording valuable aid in the classification of the animal* "*kingdom.* This structure he first observed in a section "of a fossil tooth of a rhinoceros, by the aid of a mag-"nifying power of one-tenth of an inch focal distance, "with an acromatic condenser of the light. *The section* "*presented the appearance of cells or compartments, their* "*form varying in different animals.* The structure also "of the fibres presented an interrupted or baccated ap-"pearance, the divisions differing in size and relative "position in various series of animals. The laminated "concentric structure of the tusk of the mammoth, the "strength of ivory, when cut parallel to the axis of the "tusk, and its weakness if cut at right angles, are urged "in corroboration of this peculiar structure. The struc-"ture of the enamel, as seen in a section parallel to the "axis of a tooth, exhibits compartments of a semicircular "form, the convexity of the semicircle directed upwards "towards the free external part of the tooth. From recent "analysis by Dr. Thomson, the proportion of animal

" matter proper to the enamel appears to have been much " underrated. *The pulp is observed to be cellular* " *throughout its internal structure, and this structure is* " *essentially concerned in the developement of the ivory,* " *which is neither more nor less than the ossified pulp.* " There exists a great analogy between the internal or " productive surface of the capsule and the external or " productive surface of the pulp. The membranous in- " vestment of the enamel in human teeth (lately discovered " by the author) displays a similar arrangement. The " *crusta petrosa* is provided with a membranous invest- " ment. The whole of this paper was illustrated by " numerous interesting diagrams.

" The subject of the developement of the ivory was " treated by Mr. Nasmyth in a separate paper read before " the Medical Section."

I now with confidence leave the reader to form his own judgment of the consistency of my opinions from the following documents, the original materials of my communications at Birmingham, and after an examination of the whole, he will learn with surprise, I think, that the only plea, so far as I can guess, for withholding my own condensed report from publication in the Transactions of the Association, has been, that it contains the theory of the formation of ivory by ossific transition instead of by " exudation," which latter theory it has been ridiculously attempted to show that I supported at Birmingham; and I think it must be evident that the Council, in indirectly favouring this attempt, by neglecting my original offer to afford full satisfaction in the only possible manner, as well as by totally disregarding all the unexceptionable evidence quoted above, has shown that it has been unconsciously biassed in its proceedings; but I have no doubt that it will yet restore me to my rights, and deliver to the associates my authentic report, which is their indefeasible property.

THREE MEMOIRS.

*** The subjoined extracts from the correspondence of Professor Phillips, the Editorial Secretary of the British Association for the Encouragement of Science, contain the instructions in strict conformity with which I drew up a report of the following communications for insertion in the Transactions of the Association. The passages to which I wish more particularly to call attention, I have placed in Italics.

On the 10th of Febuary, 1840, I received from the Editorial Secretary the following note:—

"Professor Phillips begs to inform Mr. Nasmyth, that the arrangements for printing the volume of the British Association require the very earliest possible transmission of abstracts of Memoirs read, to Professor Phillips. There can only be an *abstract* of Mr. Nasmyth's paper, *not requiring plates,* but *Mr. N. is at full liberty to publish elsewhere, and at any time, the whole paper illustrated as he pleases.* Professor Phillips encloses the MS. as read in the Geological Section, for Mr. Nasmyth's guidance in making his abstract.

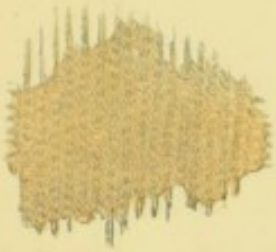
"*There will be, of course, only one abstract,* though the subject of the paper was treated in two sections."

In a subsequent letter, dated Launceston, Cornwall, April 4, 1840, written after I had transmitted to him my own report, he informed me, that this report "is to appear in the Proceedings of the Medical Section. On looking carefully over it," he continues, "there seem to be a few parts capable of abbreviation; and as *our rule of publication requires very close condensation of the communications to the sections,* I return you the MS. with pencil-marks, proposing to you the omission of these few passages, *to save space.* They do not affect the substance of the Memoir."

Structure of the Teeth.

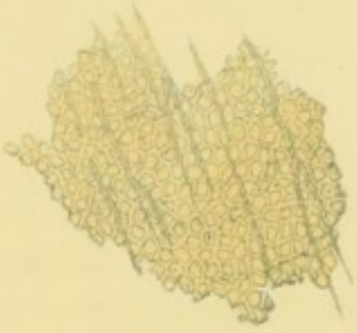
Fossil Ivory.

No. 8.



Megalichthys.

No. 10.



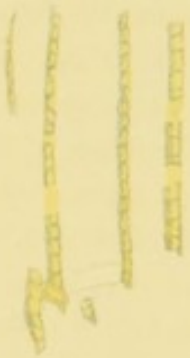
Lamna.

Ivory Fibres.

No. 3.

Loris.

No. 4.



Orang Outang.

No. 5.

Mandril.

No. 6.

Cynocephalus.

Structure of the Teeth.

Ivory deprived of Earth.

No. 1.

No. 2.

No. 3.

Human.

No. 4.

Elephant.

Structure of the Pulp.

Pulp, No. 1.

Vesicles.

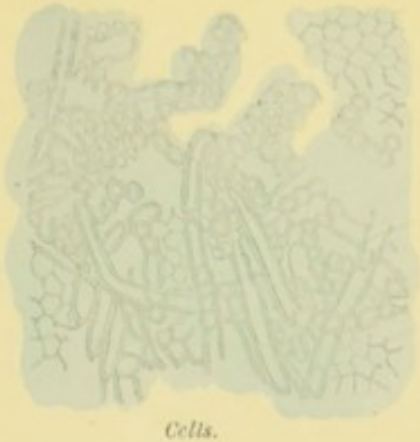
Pulp, No. 2.

Vesicles.

Structure of the Teeth.

Structure of the Pulp.

Pulp, No. 3.



Cells.

Pulp, No. 4.

Cells.

Pulp, No. 5.

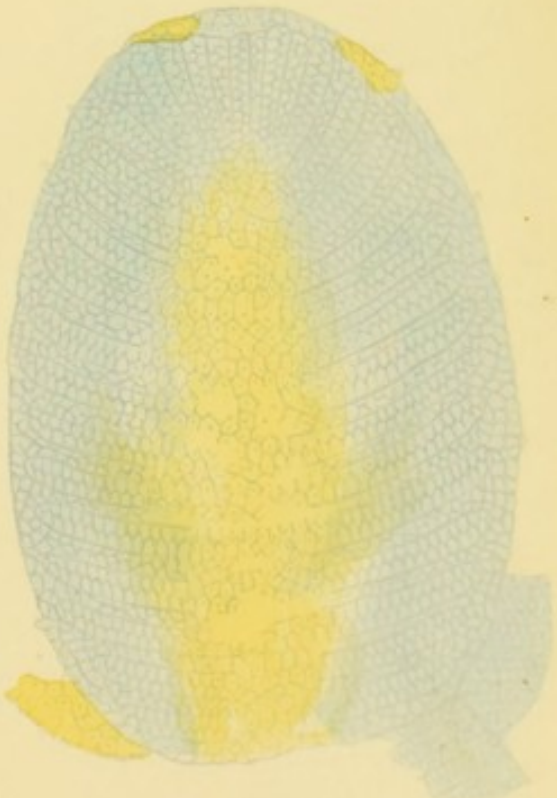
Human. Vascularity.

Structure of the Pulp, and Developement of Ivory.

Pulp, No. 6 A.

Reticulation.

Pulp, No. 6 B.



Reticulation.

Structure of the Teeth.

Structure of the Pulp, and Developement of Ivory.

Pulp, No. 8.

General View.

Pulp, No. 9.

Ossification, or Developement of Ivory.

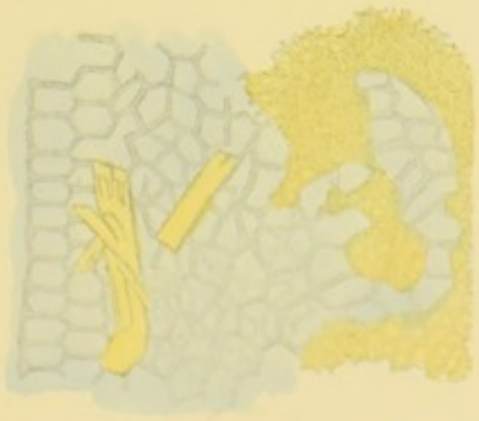
Pulp, No. 10.

Ossification, or Developement of Ivory.

Pulp, No. 16.

Ossification, or Developement of Ivory.

Pulp, No. 11.



Ossification, or Developement of Ivory.

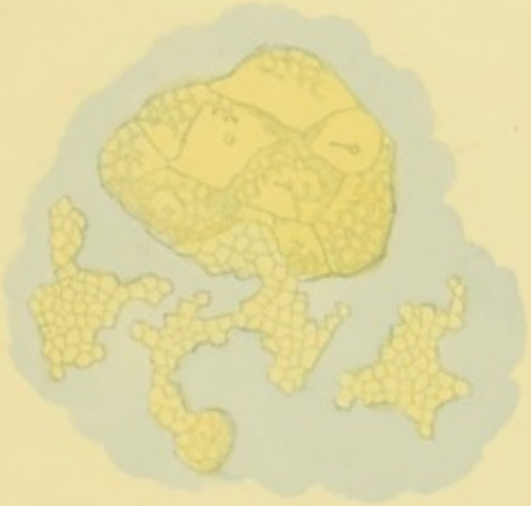
Pulp, No. 12.

Ossification, or Developement of Ivory.

Structure of the Teeth.

Structure of the Pulp, and Developement of Ivory.

Pulp, No. 13.



Ossification, or Developement of Ivory.

Pulp, No. 14.

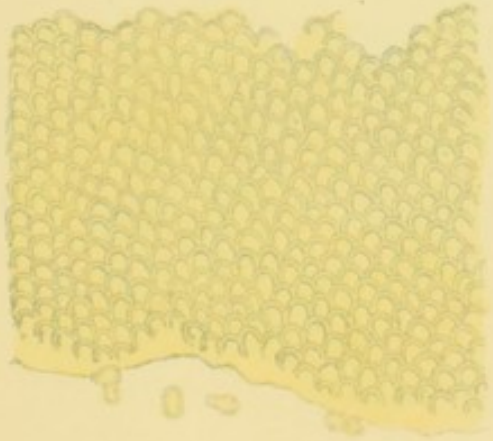
Ossification, or Developement of Ivory.

No. 15.

Human Fibres of Ivory in connexion with Pulp.

Structure of the Enamel.

No. 1.

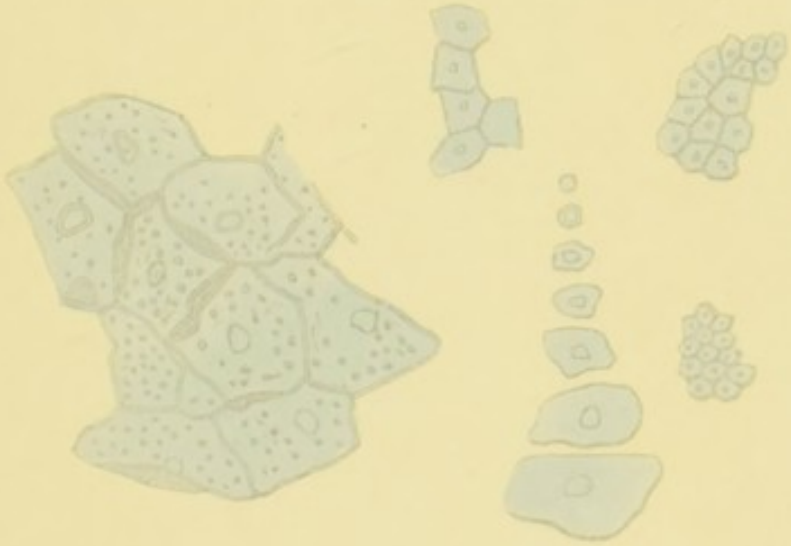


Human, parallel with Surface.

No. 2.

Human, Vertical.

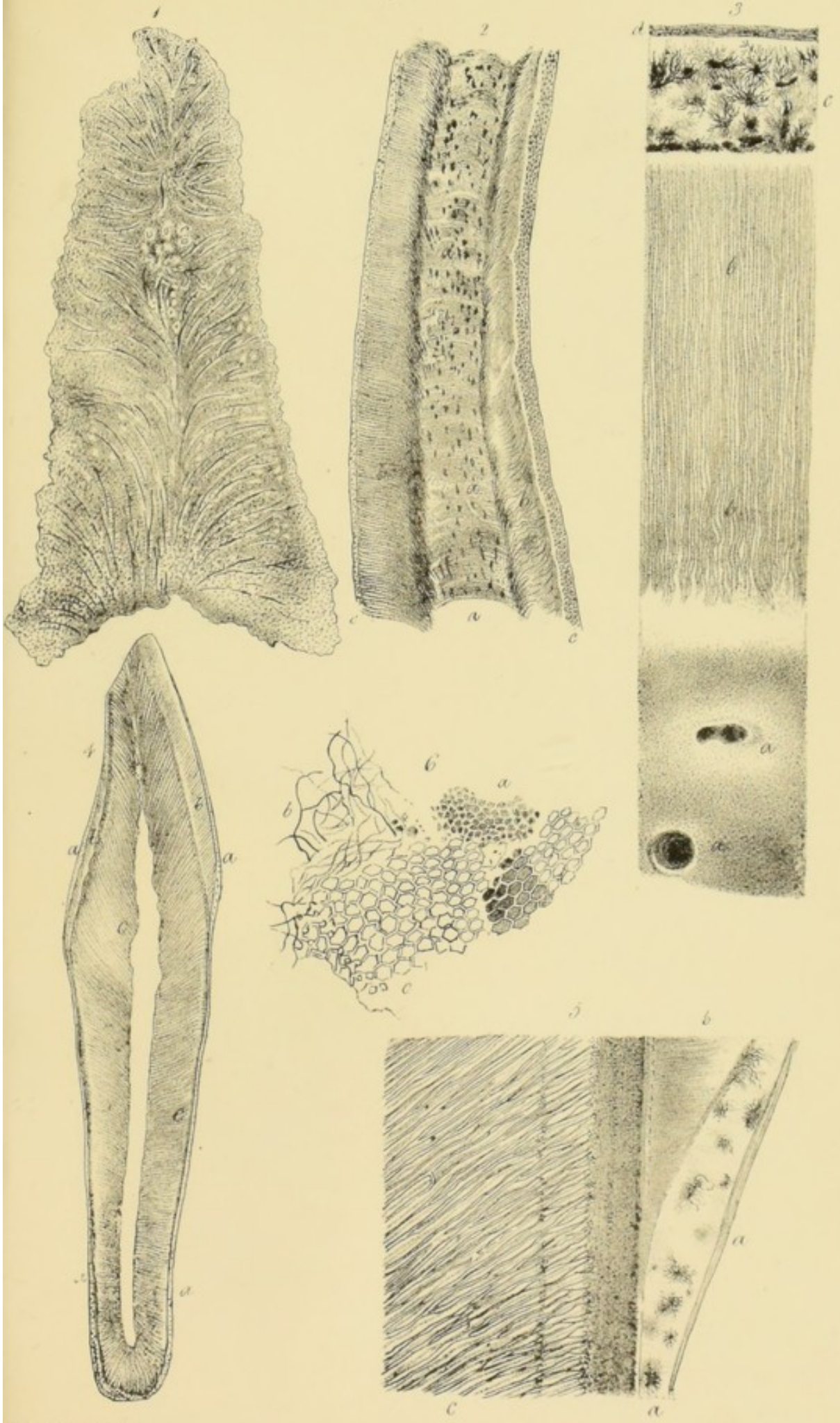
No. 2.



No. 3.

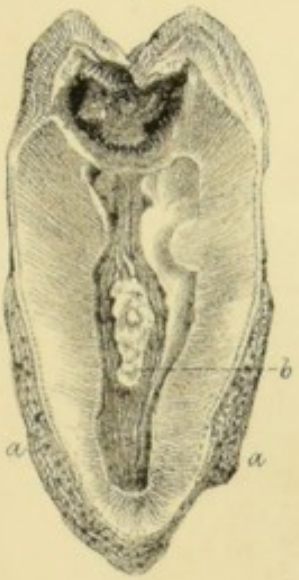
Structure of the Teeth.

Pl. C. 11.



Structure of the Teeth

1



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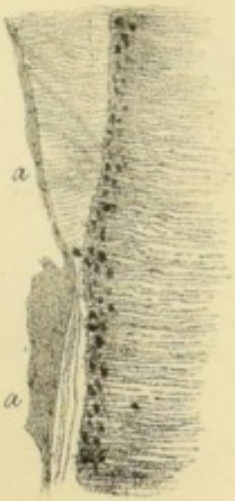

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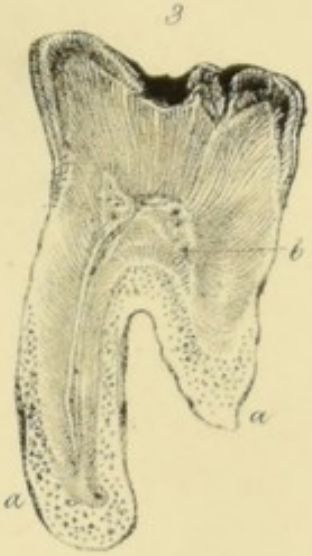

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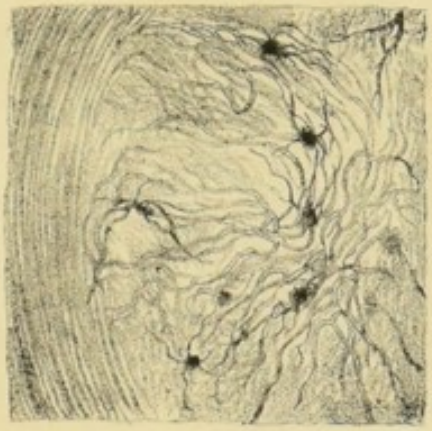

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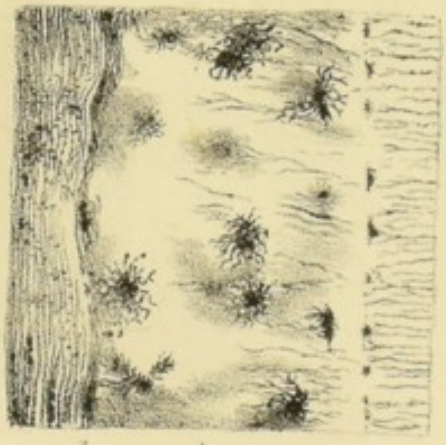

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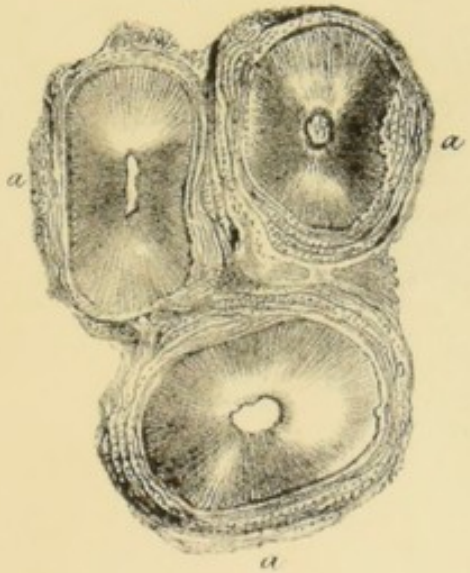

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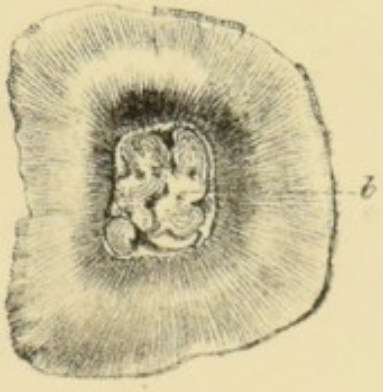


Holmes del. G. Scharf lithog.

Fig. 5.

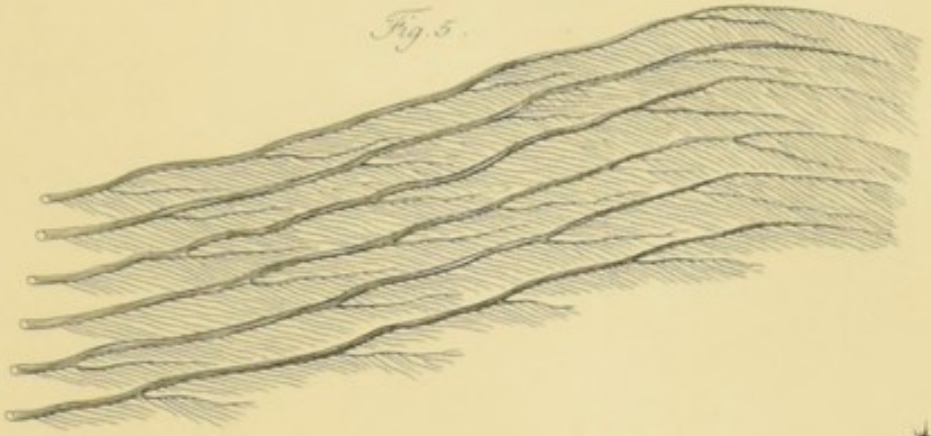


Fig. 6.

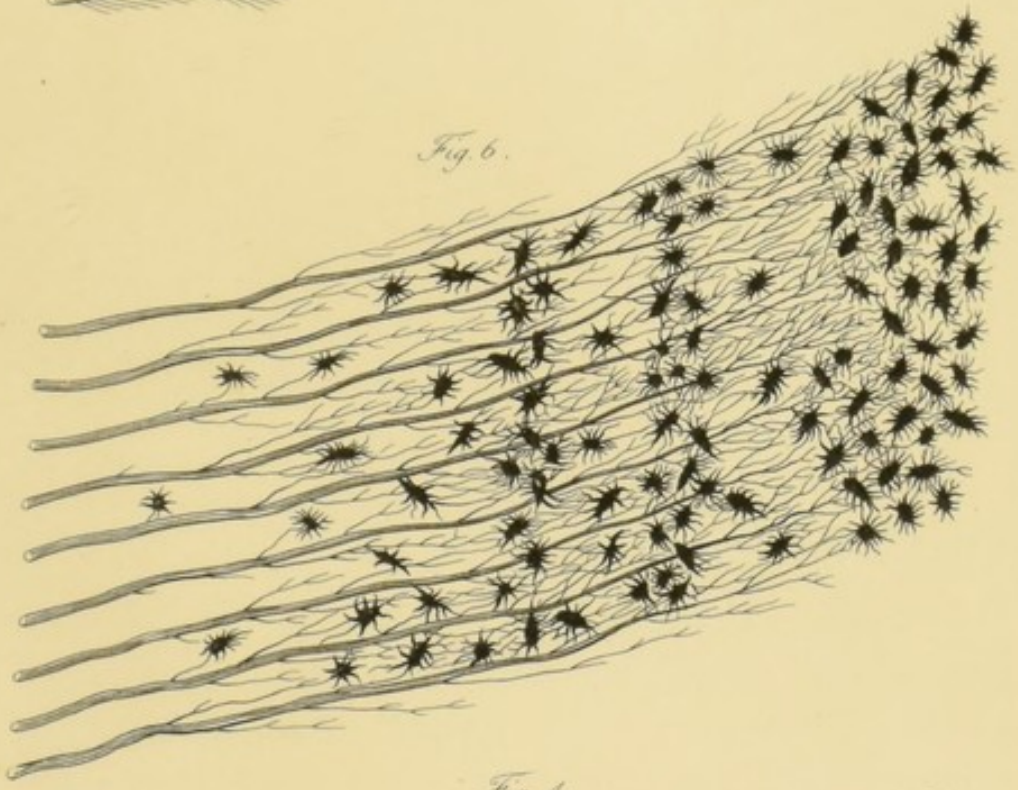
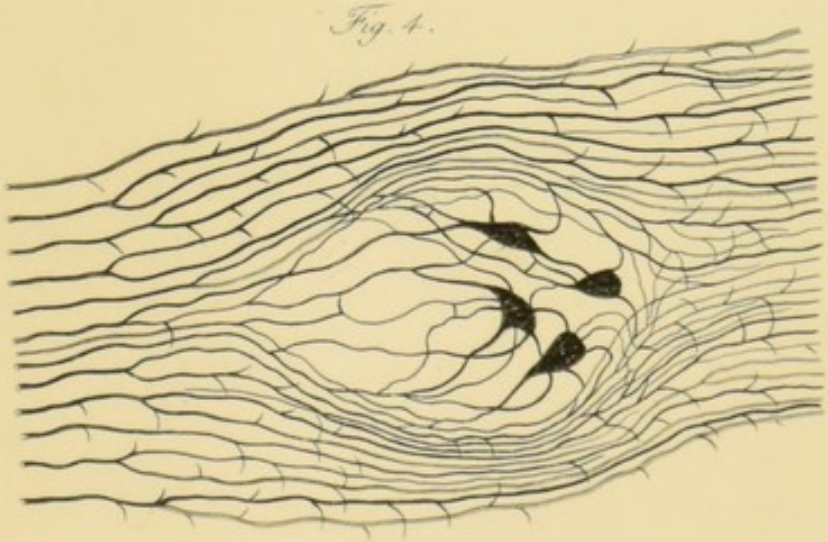


Fig. 4.



London, John Churchill, Princes Street, Soho.

MEMOIR No. I.

Investigations into the Structure of Fossil Teeth, &c. presented to the Geological Section of the British Association for the Encouragement of Science, at the Meeting held at Birmingham in August, 1839. By Alexander Nasmyth, Member of the Royal College of Surgeons, London, &c. &c.

The modern science of Geology may be considered the most comprehensive of all the branches into which human knowledge resolves itself. No progress can be made in any department of physical philosophy, which does not throw light upon its vast and wondrous domain, and exalt the brilliancy of its truths. Though it exacts a knowledge of the perishable portions of the animal frame, it is obvious that its advance chiefly depends on accessions of information respecting permanent animal relics which remain embedded in the crust of our globe, unaffected by the powerful chemical agents contained in the laboratory of nature. The skeleton,

scales, and teeth of animals being the only parts which are found in a fossil state, it is evidently of paramount importance that the general character and internal structure of these should be clearly understood. Their external forms have already been well established, and the combined labours of eminent naturalists have left little to be desired in this department of science;—but natural revolutions, slowly but surely taking place, during the long march of time, whose steps the geologist is summoned to trace back to a period incalculably remote, have occasionally so mutilated these otherwise permanent remains of animals, that they retain none of the characteristic peculiarities of the species to which they belong. Here micrography comes to our aid; and its able application to odontology by Retzius and others, so ably described to you last year by Professor Owen, has opened a new field of inquiry, which already promises the most brilliant results. Presuming that any additional researches in this direction cannot but be of interest to the members of this section of the Association, I hasten to lay before you a succinct account of my recent researches on the microscopic structure of the teeth. In endeavouring to form a classification of the animal kingdom, having for its basis the peculiar disposition and arrangement of the internal organization of the teeth, I was led to the discovery of a structure, which has hitherto not been noticed. Purkinje and Fränkel state that "the proper dental substance consists of a uniform structureless sub-

stance, and of fibres passing through it." The writings on the subject by Retzius, Müller, and others, leave us to conclude that the interfibrous substance does not present any traces of peculiar conformation :—but I am disposed to believe that it is not only organized, but so differently and characteristically so in different animals, as to be capable of affording valuable aid to the naturalist in classifying the animal kingdom.*

[In illustration of this subject, I beg to refer to the drawings, showing the characteristic varieties of this conformation [two of which, marked Fossil Ivory, No. 8 and 10, are engraved in Pl. C. 5, at the end of the present papers]. The beautiful characteristic varieties of this cellular conformation in different classes of animals, show the delicate nature of the process of transition by which it is produced.]

* It has been absurdly attempted to show that, in my papers delivered at Birmingham, I supported the old theory of the formation of ivory by "excretion," or "exudation," from the pulp. Neither of those words, however, occurs at all in my papers; and the corresponding ideas were equally absent from my mind. Moreover, the slightest reflection will convince even a tyro in anatomy, that the above simple announcement of a characteristic and in every case beautiful cellular organization of the interfibrous substance of ivory, is diametrically opposed to such a theory. How could this organization be the result of a process of exudation or excretion? In short, to speak of the excretion or exudation of ossified cells, is a ridiculous absurdity. When, on first entering upon my researches into the structure and formation of ivory, I discovered, by an examination of extremely thin sections of the latter, the cellular arrangement of its inter-

My attention was first drawn to the structure of the interfibrous substance on examining a delicate section of the fossil tooth of a rhinoceros, by the aid of a very high magnifying power; and I must here remark, that those who repeat these investiga-

fibrous substance, I was compelled to conclude that this could only be produced by a process of transition which I then proceeded to trace. The results of my further inquiries will be given in the course of this memoir, but at greater length in the next. In connection with this subject may be examined Pl. A. 3, Fig 6, at the end of the appended series of plates: it is copied from Retzius, and shows in a tooth, which he says is that of the adult horse, the corpuscles, or cells, as he calls them, in which, and on which, according to him, the dental tubes terminate. These corpuscles or cells are the dark spots with lines radiating from them, in a manner similar to the corpuscles of true bone. They are only to be found, he states, towards the periphery of the tooth. It will be seen at once that they are altogether distinct from the interfibrous cells which I have described, though one writer on Odontography has, from unaccountable ignorance of the subject, or from some other cause, confounded them with each other; and has accused me of announcing, as my own discovery, that which had been previously published by the distinguished Swedish anatomist. Neither in connexion with this plate, nor in any other part of his work, does Retzius ascribe any structure to the proper interfibrous substance: he only alludes to the corpuscles above mentioned, which he says are extremely minute, and scarcely demonstrable *in human teeth*, and to what he terms the ramifications of the tubes, as occupying a portion of the interfibrous spaces. How the corpuscles of Retzius can have been mistaken for the cells of the interfibrous substance which I have described, I think any one who compares the former, as delineated in Pl. A. 3, Figs. 4 and 6, at the end of the series appended, with the latter as represented in Figs 8 and 10 of Pl. C. 5, will be at a loss to imagine.

tions, the results of which I am about to detail, will find it necessary to make use of a magnifying power of one tenth of an inch focal distance, and of the most perfect kind, with an achromatic condenser of the light. The instrument with which I have conducted my researches, and upon the accuracy of which I place the greatest reliance, is that of Mr. Powell.*

In the section of the tooth of the rhinoceros to which I have just alluded, will be observed an appearance of cells or compartments. This I at first imagined might arise from fractures of the material, but on examining other sections of fossil teeth, examples of which are now exhibited, and at the same time seeking whether this cellular appearance could be observed in recent teeth, I was enabled to demonstrate that in every case this peculiar appearance was that of real structure.

The examples of this appearance in the ivory, both of fossil and recent teeth, which I now place

* All the anatomical observations detailed in these memoirs were frequently repeated, were verified by the eyes of others, and the preparations were faithfully copied by my talented artist. It may require some practice, and a certain degree of proficiency in manipulation, to produce and examine such preparations of the pulp and ivory in the human subject; and some persons may perhaps be found, who, having been unsuccessful in making them, at once deny that it is possible for others to be more expert or fortunate; but the fallacy of this will soon be evident to all persons of tact and perseverance who devote themselves to the subject.

before you, are brought forward merely with a view to establish the general principle, that the organization of the dental bone is cellular, and they have been selected more from convenience at the moment, and as demonstrating the variety of cellular conformation existing in the teeth throughout the wide range of the animal kingdom, than with any intention of establishing at once a complete and systematic view of the subject.

I have also made researches into the structure and composition of the fibres of different teeth, and have generally found that these present an interrupted or baccated appearance, as if they were made up of different compartments,—an obvious concomitant of the cellular structure of the interfibrous material. The size and relative position of these portions or divisions of a fibre differ in various series of animals. In the human subject, for instance, each compartment of the fibre is of an oval shape, and its long small extremity is in apposition to the one next adjoining. The long axis of the oval corresponds with the course of the fibre. In some species of the monkey tribe the fibre appears to be composed of two rows of compartments parallel to each other. In the orang utan the fibre is composed of rhomboidal divisions, and in the baboon they are oval like those of the human subject, and the surfaces of the long axes are in apposition. In fact, each class of animals seems to have a distinct characteristic appearance, but all are similar in respect to the general baccated

appearance. A few examples of this structural arrangement are seen [at Pl. C. 6,] in the diagrams marked "Ivory deprived of earth," Nos. 1 to 4, showing its appearance after the earthy matter has been removed.

Among the gigantic remains which are brought under the consideration of the geologist, there is one which to me is particularly interesting—I allude to the tusk of the mammoth. As found in our museums, it will be observed to present a laminated, concentric structure, being apparently composed of layers gradually increasing in size from the centre to the circumference. These layers in numerous instances are separated from each other by considerable spaces. The experiments of Hunter on animals fed on madder also lead to the conclusion that the structure of the teeth is actually laminated; and the workshop of the mechanic, called by Professor Leslie the School for Philosophers, furnishes numerous facts in support of the same position: for instance, the circumstance that ivory is found to possess considerable strength if cut parallel to the long axis of the tooth, and that it is weak if cut at right angles. If we suppose that ivory consists only of fibres surrounded by a structureless material, passing from the centre to the circumference, we must conclude that at right angles to their course it would be most difficult of fracture; but the contrary is the fact, as is exemplified by the natural separation of the lamellæ of the tusk of the mammoth in a direction

contrary to the course of these fibres, as well as by the mode adopted by ivory cutters of making sections corresponding to the vertical, and not to the transverse diameter of the tooth. Many other facts might be here adduced, as well as phenomena accompanying the decay of these organs, were this necessary or relevant to the business of this section. All systems of dental structure which have hitherto been propounded have failed, I think, to explain facts of daily occurrence, but they may be accounted for, I venture to assert, by the cellular organization of the interfibrous substance which has been improperly termed structureless, and by the peculiar baccated arrangement of the fibres.

According to the views of Retzius, Purkinje, and the recent investigators of the structure of the teeth by the aid of the miscroscope, the enamel consists of fibres running in a direction from the centre to the circumference of the tooth. Both Retzius and Purkinje have given delineations of the course of these fibres. On making a section of the enamel, in a direction parallel to the transverse diameter of the tooth, the appearance as described by these writers is observed, and they are said to be seen to terminate in an hexagonal form beneath the investing crusta petrosa. If, however, a different section of the enamel of the human tooth be made; for instance, one near the surface, parallel to the vertical direction or long axis of the tooth, an appearance presents itself which has induced me to take a different view of the nature of the struc-

ture of the enamel. The appearance to which I now allude is represented at [Plate C. 9,] figure marked Structure of the enamel, No. 1. It will there be found that the section of the enamel presents compartments or divisions, but of a different character from those I have already spoken of as existing in the interfibrous substance of the ivory. Each compartment of the enamel is of a semicircular form, and the convexity of the semicircle or arch looks upwards towards the free external portion of the tooth. The vertical section, [Plate C. 9,] enamel No. 2, gives the appearance of these cells as seen in that direction.

In the sections both of enamel and ivory, there will be always observed near the margins isolated cells, which admit of their form and appearance being carefully studied.

All the analyses hitherto made of the chemical composition of the enamel lead to the conclusion that the structure contains only a very small portion of animal matter. But when I detected the cells or compartments just mentioned, I could not but infer that each of these had for its basis and support a frame-work of animal tissue; and I immediately requested my friend Dr. Thomson of Glasgow to favour me with a complete analysis of the teeth, and their different component structures, in their various states of health and disease. The results of this analysis, so far as it has been proceeded with, are highly interesting; I present them to you in a tabular form, and you will observe how

fully accordant they are with the position that the enamel is provided with an animal basis—a view my microscopic investigations had already corroborated by various appearances.*

Having thus uniformly found appearances denoting cells or compartments in all these states and stages, I became doubly eager to investigate the structure of the pulp, with a view to discover the nature of the process by which this cellular structure is produced, and the source from which it is derived. I might now enter upon a description of the organization of the pulp, and its relation to the process in question; but as this is a subject of purely anatomical detail, I consider that it falls more particularly under the cognizance of the medical section of the association. Suffice it here to state, that the pulp is cellular throughout its entire structure, as may be seen from the series of diagrams placed before you, marked Structure of the Pulp, and Developement of Ivory, Nos. 1 to 16, (and contained in Plates C. 6, C. 7, C. 8, & C. 9.)†

I at first experienced great difficulty in submitting to minute examination the surface of the pulp; that is to say, that portion of it where its transition into ivory takes place; but I at length

* To this table considerable additions have since been made, which are not yet completed; and I therefore, in justice to its eminent author, withhold it, until I am enabled to publish it in a perfect state.

† To avoid repetition, I beg to refer to the next Memoir, p. 27, for a description of these diagrams.

succeeded in obtaining a clear view of it, and found it to present the beautifully interesting reticulated cellular appearance which is represented in the series of drawings marked Pulp, Nos. 6 to 16, [Pl. C. 7, 8, and 9,] where the cells of the pulp in a state of transition are coloured blue, and those ossified are coloured yellow.

Having ascertained that this reticular conformation was constant in all the pulps which I examined, I proceeded to study it with confidence, and soon found that it was essentially concerned in the process of the developement of the ivory, and in the production of the fibres of the latter, as well as of the interfibrous substance. Of this part of my subject I intend to treat more at length before the medical section, but some idea of the different stages of the formation of dental bone may be gained from an examination of the series of diagrams above alluded to, showing the transition of the cells of this reticular surface into the cells of the ivory.

Conceiving that there existed a great analogy in the productions of the capsule and the pulp, I searched for the appearances displayed by the internal or productive surface of that membrane, and found them analogous to the external or productive surface of the pulp, as shown in the drawing, [Pl. C. 11,] No. 6.

The membranous investment which I lately discovered as investing the enamel of the teeth of man and other simple teeth, displays a similar arrangement.

Thus, there is a remarkable uniformity in the structure of the formative tissues of the tooth, and of the dental substance itself; for not only is the interfibrous material cellular, but the surface of the pulp, which is the organ for the production of the ivory, and the internal or productive surface of the capsule, also uniformly present a reticulated or cellular appearance.

My researches have, I venture to hope, also established a new and beautiful instance of the harmony of the laws of nature in demonstrating the fact of the uniformity of the products of the capsule; for not only is the enamel uniformly provided with an external covering, but there is also a membranous investment of the crusta petrosa itself. I think, also, that we must be compelled to allow the uniform presence of a fourth tooth-bone substance, the existence of which is more constant in all animals, either normally or anormally, than any of the other three hitherto recognized textures. But as all these subjects belong properly to the province of the medical section of the Association, I think it unnecessary to allude to them more fully here.

MEMOIR No. II.

Investigations into the Developement and Organization of the Dental Tissues, &c., presented to the Medical Section of the British Association for the Encouragement of Science, at its Meeting held at Birmingham, in August, 1839. By Alexander Nasmyth, M.R.C.S., &c. &c.

At the last meeting of this Association, the subject of the structure of the teeth was entered into by Professor Owen, who detailed before this section more especially the investigations which have of late years been conducted in this branch of science. I must confess that I felt dissatisfied with some of the results of these investigations, contained in the writings of Retzius, Purkinje, and Müller; and at the time that paper was read, I was endeavouring to arrive at a confident conclusion on the subject, by prosecuting a series of researches which I had commenced several years before, and which I have pursued uninterruptedly to the present time.

I will in the first place briefly place before you the conclusions to which I have arrived on the fol-

lowing subjects: 1st. on the Covering of the Enamel: 2ndly, I will communicate my own views on the Structure of Teeth; and 3rdly, I will treat succinctly of the Structure of the Pulp, and its relation to the developement of the ivory.

The researches of Retzius and Purkinje, so faithfully detailed to you last year, have established that there enters into the composition of the simple and compound teeth of man and mammalia generally, not only ivory and enamel, but a third substance, the crusta petrosa, which had been noticed previously on the free surface of the compound teeth of graminivorous animals. The crusta petrosa, as existing on simple teeth, was described to you, after Retzius, Purkinje, and Fränkel, as a layer external to the ivory of the fang, but as not present on these simple teeth as a covering to the enamel. I should here mention, however, that Purkinje and Fränkel state, that they had once noticed it coating partially the enamel on the tooth of an old man. My researches, however, have led me to the conviction, that the enamel itself possesses in all instances a distinct envelope or coating. On the incisor of the calf and several other simple teeth, I have also distinctly traced in this layer of crusta petrosa, superimposed on the enamel, the corpuscles of Purkinje, analogous to those found in bone. I possess preparations of teeth of the human subject, and simple teeth of the herbivora and carnivora, showing this structure in a clear and unequivocal form. The details of its discovery and of its anato-

mical description may be found, by those who feel anxious to inquire further into the subject, in a paper of mine in the forthcoming volume of the Transactions of the Med. and Chir. Society, accompanied by drawings. *

At present, in order not to make inordinate demands on your limited time, I hasten to the next branch of my subject. In a paper which I have had the honour of submitting to the notice of the geological section of the Association, I have treated of the structure of the substance which in the dental ivory occupies the space between the fibres. I have proved, by a careful examination both of fossil and recent teeth, that the interfibrous substance is not structureless, but that it presents a character so remarkably well defined as to furnish a most important and interesting accession to the odontographic basis for a classification of the animal kingdom.

I have selected specimens of these appearances, (seen in the diagrams, marked Recent and Fossil Ivory, two of which I have given at [Pl. C. 5,] Nos. 8 and 10,) not with any reference to the individual peculiarity of their arrangement, but merely because the drawings of them are in a more convenient and advanced state.

I have also made researches into the structure and composition of the fibres of different teeth. I have generally found that these present an in-

* Here were exhibited and described the drawings contained in Pl. C. 11 and 12 of the appended series.

terrupted or baccated appearance, as if they were made up of different compartments. The size and relative positions of these portions or divisions of a fibre differ in various series of animals. In the human subject, for instance, each compartment of the fibre is of an oval shape, and its long, small extremity is in apposition to the one next adjoining. The long axis of the oval corresponds with the course of the fibre. In some species of the monkey tribe the fibre appears to be composed of two rows of compartments parallel to each other, and a trace of the same appearance is evident even in some of the principal ramifications of the fibres. In the orang utan the fibre is composed of rhomboidal divisions, and in the baboon they are oval like those of the human subject, and the surfaces of the long axis are in apposition. Some of the appearances are seen in the diagrams [Pl. C. 5,] marked ivory fibres, Nos. 3 to 6, where the appearances of the fibres of the orang utan, loris, mandril, and cynocephalus, are shown.

When teeth are submitted to the action of acid, for a period long enough to allow the earthy matter to be all taken up, I find that the animal residue consists of solid fibres, and if the decomposition be allowed to continue, these fibres present a peculiar baccated appearance. The drawings marked, *Ivory deprived of Earth*, [Pl. C. 6,] Nos. 1 to 4, show these appearances.

[No. 1 shows the appearance of the ivory when the earthy matter has been almost entirely re-

moved by acid, but where the cells still retain their position, general appearance, and connexion with each other.

Diagram No. 2, represents a more advanced stage of decomposition, where there seem to be attached to each fibre minute lateral filaments, which I presume to be the remaining portions of the emptied cells.

Diagrams No. 3, and No. 4, depict the appearances presented when decomposition has so far advanced as to have rendered the fibre interrupted or baccated. No. 3, represents the fibre of a human tooth, and No. 4, that of the elephant in this state.

It may be useful to compare these cells in No. 1, after they have been deprived of their earthy contents, with their state previous to the reception of the earthy matter as delineated in pulp No. 6, A. &c. [Pl. C. 7 and 8.] In the reticulations they are collapsed, lying one above another, but after having been deprived of earth, they will be observed to be rigid, and to retain the erect distended form which they acquired by the deposition within them of ossific matter.*]

* To indicate the true theory of the formation of ivory, nothing more is required than the display of these appearances. No "excreted" or "exuded" substance can possibly present an animal tissue arranged in regular connected cells. It is quite evident that these cells, whilst receiving a supply of earthy matter during the process of transition, must remain in connection with, and indeed continue to form part of, the pulp. It would be absurd to suppose that a regularly cellular structure can be "excreted;"

The general appearance of the fibres thus treated is exactly similar to that of the fibres of cellular tissue generally, and the diameter of each corresponds exactly to the diameter of the calibre of the tube, which, according to Retzius, is pervious, although at the same time he says that it is always more or less filled with earthy matter. In fact, the tubes have been said to be principally visible by means of their contents, the reason of which appears to me obviously to be, that these contents are the only part of them which actually exist.

In order to separate the animal matter from the osseous substance of the tooth, I submitted thin slices of many different kinds of dental bone to the action of a solution of caustic potash, for a period sufficient to dissolve and remove the organic tissue; but the brittle nature of the residue, the difficulty of washing it without breaking down its structure, and the great opacity of the sections which had been thus treated, deprived this experiment of any striking results illustrative of the internal organization of teeth: but the appearances presented in its progress were all such as to favour the conclusion that the structure of the ivory is essentially cellular.

but it would be still more ludicrous to maintain, that after such cells have been excreted, that is to say, after all connexion between them and the pulp has ceased, they still possess the power or means of deriving from the blood the materials requisite for their transition into ivory, and of carrying on that process in their isolated state.

Having convinced myself of the existence of the peculiar cellular structure of the tooth, I entered with great interest on an examination of the organ by which it is produced, viz. the pulp.

On examining the internal structure of the pulp generally, the number of minute cells presenting themselves in a vesicular form is very remarkable ; they seem to constitute indeed the principal portion of its bulk. These vesicles vary in size from the smallest perceptible microscopic appearance, probably the ten-thousandth part of an inch in diameter, to one-eighth of an inch, and are evidently disposed in different layers throughout the body of the pulp. They are of various shapes, as is shown at [Pl. C. 6], Pulp Nos. 1 and 2.

[No comparison can properly be instituted between these vesicles and the cells of the ivory, for it is only at the surface of the pulp that these vesicles are prepared by some peculiar change in their form and arrangement for the reception of earthy matter.]

When thin layers of macerated pulp are examined, they present an irregular reticular appearance, and are found to be interspersed with granules. The parenchyma is traversed by vessels of which the direction is generally vertical, as seen in [Pl. C. 7], Pulp No. 5. Pulp Nos. 3 and 4, [Pl. C. 7], show the appearance of these cells in sections of the pulp which have been thus macerated.

I have frequently been struck with the rapidity

with which the pulp diminishes in volume, and with the extent of this diminution. Sometimes, indeed, it would appear in a short space of time to be almost annihilated, and this seems to take place more decidedly when the tooth has been in a healthy state, and more frequently in adult than in temporary teeth. This shrinking, or almost total disappearance, may, I think, be accounted for by a peculiar collapse or change in the congeries of cells of which we find the pulp to be made up. The use of this peculiar arrangement, and the purpose which it serves in the economy of the part, will furnish curious subjects for future inquiry. A subject also highly worthy of investigation is the nature of the contents of these cells. They must evidently be filled either with air or fluid, but they are so extremely minute that I have not yet been able to ascertain which.

After repeated and careful investigation, I have convinced myself that they constantly exist on the surface of the pulp which is in apposition to the ivory, and which is essentially concerned in its developement.

[By comparing, however, the diagram, Pulp No. 4, with Pulp No. 6 B, it will be seen that these vesicles are present on the surface of the pulp in a modified, more regular, and more distinctly cellular form than in its interior: and with this additional difference, that throughout the substance of the pulp they present ill-defined layers, whereas, at its surface, they are arranged in reticular leaflets, to be hereafter described.]

Much diversity of opinion has always existed respecting the connexion of the pulp with the ivory of the tooth; and as to whether the ivory be simply a product of the pulp, or a transformation of its substance. Although this is by far the most interesting point in dental physiology, and involves the grand question of the manner in which the tooth is formed, as well as that of its arrangement and conformation, it is notwithstanding less understood, has been less studied, and is consequently more obscure, than any other part of the subject. The vague style in which authors discuss, or rather dismiss this topic, shows how little has been really done to elucidate it. I must confess that I devoted myself to its examination for a long time before I was fortunate enough to obtain any light wherewith to guide my steps to the discovery of its true bearings, nor am I yet certain to what extent this knowledge of the structure of the transition surface of the pulp will be found to facilitate our comprehension of the whole complicated process by which the ivory is developed.*

* Although, from an examination of the diagrams, Pulp No. 6 A. and No. 6 B., Pl. C. 7, of all the diagrams in Pl. C. 8, and of the first three in Pl. C. 9, it is distinctly demonstrated that the interfibrous substance of the ivory is formed by the deposition of osseous matter in the cells of the reticular surface of the pulp, I cannot boast of being able fully to unveil that interesting process. The cells for the reception of the earthy matter are displayed, but—how is this matter arranged in those cells? How is it, in the first place, derived from the blood and ntroduced into them? What are the causes of the characteristic varieties of the interfibrous cellular substance in different

The formative surface of the pulp displays a regular cellular arrangement, which I have denominated reticular, and which may be described as resembling a series of skeletons of desiccated leaves. (See [Pl. C. 7], Pulp No. 6 A. and B.) It is not easy to obtain a preparation where the appearance is so perfect as to allow of a clear sketch of the consecutive parts of it being taken. The drawing I now present to your notice is the most perfect I have been able to obtain, and is from the tooth of a calf. The compartments of the reticulation are seen to be oval, and overlap one another. On insulating one of these compartments or leaves, (see [Pl. C. 7], Pulp No. 6, B,) we find that its structure is curious and regular. These beautiful reticulations have peculiar diversities in different animals. I first observed them in the human pulp, and soon found them in all other animals which I had an opportunity of examining, varying, as I have said, in size and arrangement in different cases. I next extended my observations to the capsule, and to the capsular investment of the enamel, and found in

classes of animals? What is the precise degree of importance of the reticular cellular organization observed on the surface of the pulp with regard to the process of transition, besides the fact that it presents cells into which the earth is deposited? Do these reticular cells form a system containing circulating fluids, from which the osseous material of the tooth is eliminated? How are these cells connected together, both in their transition state and in the pulp, as well as when they have passed into the state of ivory? These, and many other similar questions, remain to be solved before our comprehension of the process of the formation of ivory can be said to be complete.

these the same reticular disposition, though with characteristic variations, as seen in diagrams marked "Capsule" and "Enamel Investment." [One of these is seen at Pl. C. 11, No. 6.]

These leaves of reticulation are surrounded by a well-defined scolloped border, from which occasionally processes are observed to project at regular intervals, (as may be seen at [Pl. C. 7] Pulp, No. 6 B.)

Having thus demonstrated the cellular texture of the pulp, throughout its entire extent, I next proceeded to inquire how its transition into ivory is effected. The researches which I have made on this point are as yet imperfect, and I approach the subject with diffidence, knowing the deceptive results to which novel experiments are liable; and well aware of the necessity of long study and deliberation, before judgment be positively given on a point hitherto undecided.

How does the fibre of the tooth originate? and how is the interfibrous substance, which must form the main bulk of the tooth, deposited? I will state how far my own observations allow me to answer these difficult questions. If I cannot at once satisfy the querist entirely on this subject, which has been seldom even approached, much less frankly entered upon, I may at least hope, by a few facts which I think my investigations have placed beyond doubt, to pave the way for a satisfactory explanation of the formation of dental bone.

On the surface of the pulp are found innumerable

detached cells, with central points. Generally, these cells form a regular and complete coating, studded with points, which are placed at intervals, corresponding in extent to those between the fibres. [Pl. C. 8], Pulp, Nos. 10, 16, 12, and [Pl. C. 9] Nos. 13 and 14, show the appearances of these ossified cells.

These points are rendered visible from the greater opacity of the intermediate material, and will be seen to reflect or absorb the light, according to the difference in the focal distance. A comparison between the superincumbent perfect ivory, and the formative surface of the pulp beneath, is always easy, because portions of the former, at an early stage at any rate, remain adherent to the latter, and fragments of the dental bone are found strewn over it, more especially in human teeth, as seen in the drawings alluded to above.*

* It is almost unnecessary to state that it is impossible to obtain a clear view of the surface of the pulp after the process of the formation of ivory has commenced, without breaking away, or forcibly separating in some manner, the superincumbent crust of ivory from the pulp beneath; and in this disruption the ivory is always somewhat shattered, and the surface of the pulp is found with separate cells and cellular fragments of all shapes, and in every stage of transition, strewn over it. In the diagrams marked Pulp No. 10, Pulp No. 16, Pulp No. 11, and Pulp No. 12 and No. 13, are seen fragments of this kind, coloured yellow. In No. 14, on the other hand, which is of a very young tooth, the pulp is shown at the period of the formation of the first layers of ivory; no disruption, consequently, was necessary in order to exhibit it, and hence the pulp is seen with its two superior layers in successive stages of transition into ivory. The fragments above alluded to can

The cellular conformation of these fragments is always evident, and in size and appearance they never be too minute for the purposes of study. Indeed, there is no more satisfactory and interesting method of examining all hard organized bodies, than by pounding them in a mortar: fragments thus produced present themselves under an infinite variety of aspects, and display, in the most various and complete manner, the structure of these tissues. Such particles will never be too small for observation in the focus of the instruments of the present day. With respect to the preparation of anatomical specimens like the above-mentioned, where the formative surface of the pulp is shown by the removal of the ivory, I may observe that considerable patience and perseverance, and an abundant supply of subjects of investigation, are indispensable before they can be properly made; and that even great proficiency and experience will not always insure success, which necessarily depends, to a certain extent, on fortuitous circumstances, such as the nature and state of the subject, the direction and degree of the fracture, &c. It sometimes happens that out of a great number of fresh-drawn teeth, not one available preparation of this kind can be made. The pulp and the ivory being in positive union, the separation at the proper point seldom occurs. When, however, the industry of the inquirer is at length rewarded by a successful preparation, he will be gratified by a view of phenomena of the highest general physiological interest, the importance and full bearings of which could only be glanced at in the present memoir.

It has been asserted that no preparations can be made from mammalia showing the transition of the pulp into ivory. Such a statement can only have originated in inexperience or in ill success, arising from causes hinted at above; but the number of such preparations of the most satisfactory kind which are in my possession, and which I am always glad to exhibit to any person who may feel a wish to see them, precludes the necessity for my wasting any of my own or my reader's time, by refuting such an inconsiderate and groundless assertion.

are perfectly accordant with the cells of the pulp. (See [Pl. C. 8] Pulp, 9 to 16, where the yellow colour shows the ossified cells or ivory.)

At an early stage of dental developement, the reticulated or cellular appearance of the pulp is particularly beautiful. When merely a thin layer of ossific matter has been deposited on its surface,* it may with great facility be drawn out entire,

* I am ready to allow that there is a certain degree of vagueness in this phrase, which, had the paper been intended for publication, I should have rendered more definite and precise. It contains, however, not the slightest contradiction or incongruity; and it is only the most unfair and malevolent criticism which could avail itself of passages of this kind, written as they were for oral delivery, with the accompaniment of illustrative diagrams, and not for the press, to impugn the general tenor of my communications, written and graphic. "The fact is," as I have elsewhere observed, "that when the "external layer of the pulp becomes ossified, it can no longer be "regarded as pulp. It is then spoken of as a layer of ivory in "apposition to and connexion with the surface of the pulp be- "neath. Thus the deposition of ossific matter on the surface of "the pulp, simply means its deposition in the cells of the reticular "formative surface, which is undergoing the process of dentifica- "tion. That the idea of exudation could not even have been "floating before my mind, is proved by a subsequent passage, "where I state *that the manner in which the osseous matter is "deposited in the cells of the interfibrous substance I had not been "able to discover;*" the concluding portion of even the above paragraph proves the same: but it is useless to waste more time in demonstrating the monstrous absurdity of the assertion that my two papers on the structure of the teeth, and the diagrams exhibited in illustration of them, were in support of the theory of excretion or exudation!

together with the former, laid on a glass, compressed a little, and then examined with the high powers of the microscope. The different layers of cells will be seen, and the transition into ivory may be observed, (as shown in [Pl. C. 9] Pulp No. 14, where the different gradations of ossification are marked by the shade of colour.)

[The diagram marked Pulp, No. 6 A. [at plate C. 7] represents the general arrangement of the reticular leaflets of the surface of the pulp. In No. 6 B. is seen a beautifully-organized single leaflet of this reticular surface, in the pre-existing cells of which the earthy matter is in course of deposition, and the process of ossification is seen to be gradually extending from its centre towards its circumference. No. 8 [plate C. 8] shows the blood-vessels coursing beneath the reticular formative surface. This drawing is an exact copy of the preparation, in which, as is seen, the blood-vessels have been ruptured in two places, in separating the ivory from the pulp, owing to the close connexion between the reticular surface and the ivory already formed. Pulp No. 9, with the title, *Ossification, or Developement of Ivory*, and the following drawings, [see Plates C. 8 and 9,] are a selection from the interesting preparations which I have made for the purpose of elucidating the process of the formation of ivory. They display under various aspects the different appearances, some constant, the others incidental, which present themselves on the removal of the superincumbent ivory

from the surface of the pulp beneath. The portions coloured blue are cells of the pulp as yet unossified, and the parts coloured yellow are either entire layers of ossified pulp-cells, or fragments of ivory which have remained adherent to the pulp, or extravasated fluid, containing probably osseous matter, (See [Pl. C. 8.] Nos. 11 and 12.) The whole appearances denote the existence of a peculiar system of cells external to the peripheral ramifications of the blood-vessels, the functions of which are highly interesting, and the study of which will ultimately lead, I think, to the unveiling of many vital processes connected with the growth of animal tissues, which are at present shrouded in obscurity, besides that which is rendered so clearly evident in the diagrams, marked [Pl. C. 7] Pulp No. 6, B.; [Pl. C. 8] *Pulp, Ossification, or Developement of ivory*, Nos. 9, 10, 16, 11, 12; [Pl. C. 9,] *Pulp, Ossification or Developement of Ivory*, Nos. 13 and 14, and which is plainly neither more nor less than a process of ossification;—a view of it totally opposed to that which has been taken by previous inquirers into the formation of ivory.*]

* To enter into a full description of the details of these drawings was impossible on an occasion like the meeting at Birmingham, and I was therefore compelled to trust in some measure to the ocular demonstration they afford for conveying to the audience an impression of the nature of the interesting process by which ivory is formed. Aware of the limited extent of time which could be granted me for the exposition of this complicated and comparatively uninvestigated subject, I, as far was possible, made it speak for itself in the drawings above mentioned.

It appears to me that the framework of the reticulation, or cells of the pulp, constitutes the fibres of the tooth, which, while in this state, are spirally coiled, and fit into one another. At all events, the diameter of these fibres of the reticulations is precisely that of the fibres of the ivory; the points or projections rising from the framework correspond to the centres of the cells, and may be traced to belong to their structure. [The fibres composed of granules of animal matter, and which I describe as the framework of the reticulations, become, upon the deposition of ossific matter within the cellules of those reticulations, the fibres of the ivory. The only change which they appear to undergo during the process of transition, is, that they are then drawn out from the coiled-up state in which they exist between the collapsed cells of the reticulations into the more longitudinal but still spiral form in which they are found in the ivory. This will be fully understood by an examination of the diagram [Pl. C. 9.] No. 15.] The fibres of the ivory are frequently very spirally curved, like those of the pulp, and as we should conclude they must be from the manner of their evolution, as seen in diagram, Ivory, No. 8.* Pulp No. 15, [Pl. C. 9], shows the appearances presented by a portion of a recent tooth, which has been submitted to the action of acid. Part of the pulp is visible in con-

* This I cannot give in the present publication: it is of no essential importance.

nexion with the ivory, and the spiral fibres are seen as they are evolved on the surface of the former. It appears to me, on microscopic examination, that this convoluted fibre is made up of single successive granules, which are developed one after the other from the body of the pulp, until the fibre is complete. I have, moreover, already shown that the fibre of decomposed teeth is resolved into separate granules or compartments, as is seen in the diagrams marked "Ivory deprived of Earth," [Pl. C. 6], Nos. 1 to 4.

The manner in which the osseous matter is deposited in the cells of the interfibrous substance, I have not been able to discover. It would appear, however, that these cells are subdivided into minute cellules, for they present the appearance of being filled with granules in certain progressive stages of developement, as is shown in diagrams [at Pl. C. 8], Pulp Nos. 9, 10, 11, 12, [and C. 9], No. 13.

In whatever aspect we view the formative organs of the tooth, and the dental tissues themselves, and whether we examine the latter during the process of their developement, or after their formation has been completed, we are everywhere met by appearances which denote a cellular or reticular arrangement.

I must allow that these views of the formation and structure of the teeth are both bold and novel, but I do not claim for them infallibility; I simply submit them to the Association as the results of actual observation. I fully recognize and respect the authorities ranged in support of very different

theories, though I still venture to think that, were not my limits confined, I could easily show how what I hold to be fallacies and incongruities have arisen. As, for instance, from want of practice in the manipulation of materials, the precise nature of which has not been attended to: want of familiarity with microscopic appearances; ocular deception; the want of a well-defined magnifying power, and imperfect light in the microscope used, have been doubtless, also, causes of many of the conflicting conclusions to which almost all inquiries in this region of anatomy have arrived. I think that the view I have taken of the subject more satisfactorily explains than any other, facts of daily experience. The laminated arrangement of the osseous cells explains the concentric fracture of the tusks of the mammoth, and of other teeth, when left to decompose spontaneously. The cells being in imbricated apposition, and held together by earthy salts, being moreover arranged in layers conformably with the periphery of the pulp, must be regarded as concentrically laminated. The existence of this structure explains the phenomena daily noticed by ivory-cutters, and also Mr. Hunter's experiments of feeding animals with madder, the result of which is incompatible with any other theory of the structure of dental bone.

No view hitherto taken of the structure of dental bone has afforded a satisfactory explanation of the ordinary morbid appearances of the tooth, but many of these I think may be explained, if we

regard the latter as cellular. Still I do not conceive that I have in any way exhausted the subject; far from it; I am quite alive to the imperfect nature of my researches, and am prepared for correction on many points, when more extended and varied investigations shall have been undertaken.

I find that Schwann, in a recent work, teaches that all the primary tissues of the animal frame are cellular, and has given to the world some remarkably interesting details on this subject. He says that he has remarked the characteristic "cellular nuclei," or elementary cells, on the enamel-membrane, that they are continued in minute fibres, and that these are similar to the epithelium cylinders in mucous membranes. He notices what he calls cylindrical cells on the surface of the pulp, and he supposes that these cylindrical cells of the pulp are the fibres of the tooth in their first stage, which does not at all coincide with my observations. He regards the dental substance simply as the ossified pulp, whilst my observations lead me to conclude that the cells of the ivory are altogether a distinct formation.* He acknowledges,

* To show the unwarrantable means which have been had recourse to in order to misrepresent my views of the formation of ivory, I beg to quote from an article in the Medical Gazette the following passage, exposing the manner in which the above statement has been tampered with and misrepresented:

"At p. 507, of the last week's number of this journal, he (Mr. Owen) manufactures what he is pleased to call Mr. Nasmyth's

however, that he is ignorant of the process of transition, and he regards the dental pulp as a simple cartilage. In fact, he starts with a ready-made hypothesis, and founds his opinion rather on the observations of others, and on the inferences he draws from them, than on his own actual researches: with respect to what he himself gives as his own, it accords for the most part with the details I have just communicated.

The following is the account contained in his work on the structure and function of the pulp.

"According to Purkinje and Raschkow, the pulp consists at first of nearly uniform globules, without vessels and nerves; afterwards, vessels

emphatic statement of September 1839, 'that so far from being the ossified pulp, it (the dental substance) was altogether a distinct formation.' Now of this passage, which he gives as quoted from the Literary Gazette, p. 598, only *the four last words* will be found, on reference to that journal," (and to the original paragraph itself in the paper above,) "to be correctly copied: *all the first part of the passage is the composition of Mr. Owen.* Mr. Nasmyth, by this perversion of his report, is made to say that the dental substance is altogether a distinct formation: whereas he never mentions the dental substance at all, and his real meaning evidently is, as we have shown above that the cells of the ivory have undergone a distinct formative process in their transition from the cells of the pulp. Such unfair and unworthy tactics must inevitably defeat the purpose for which they were adopted. Mr. Owen's unscrupulous violence, far from concealing, as he seems to calculate it may do, the weakness of his arguments, will only still further damage his cause, in the eyes of every dispassionate reader."—*Medical Gazette* for July 3, 1840.

arise in it, and at last nerves also. On the surface the globules are more regularly arranged, and more longitudinally extended, and turned in an external direction under right or slightly acute angles.

" These longitudinally drawn out globules are plainly cylindrical cells. They contain very evidently in recent (fresh) teeth the characteristic cellular nucleus with its nucleus-corpuscles, and are very similar to the prisms of the enamel membrane. The interior of the pulp consists of round cells, also with a nucleus, and between these cells run vessels and nerves. If we draw the pulp of a young tooth out of its cavity, and then examine the dental substance, whether deprived or not of its calcareous salts by muriatic acid, we shall find on its internal surface, at any rate inferiorly, where the already formed dental substance is still thin and soft, a layer of the cylindrical cells of the pulp. These have about the same thickness as the solid fibres of the dental substance, and also the same course; and inasmuch as they, on the one hand, plainly belong to the pulp, on account of their conformity with the cylindrical cells adhering to the remaining surface of the pulp, and, on the other hand, as they cohere more firmly with the dental substance than with the pulp, and remain attached to the former, I presume that here a transition takes place, and that the cylindric cells of the pulp are only the fibres of the tooth in their first stage, and change into the latter by filling with organic

substance, becoming solid and ossifying. Sometimes these cylindriculi are not found on the dental substance, but then in their place are found a number of cellular nuclei. These are of a very pale colour, and are intimately connected with the dental substance, so that they are easily overlooked; but when the attention is once directed to them, it is impossible not to recognize them: the spaces between them are very narrow. Against the theory that the dental substance is the ossified portion of the pulp, the facility with which the one is separated from the other has been adduced; and I allow the force of this objection. Nevertheless it is at any rate weakened by the circumstance that a portion of the pulp actually remains attached to the dental substance, and by the fact that in half ossified ribs, for instance, the cartilage can be easily separated from the ossified portion, and it must be remembered that in the tooth the separation must be easy in proportion to the difference between the consistence of the pulp and of the dental bone."*

* I consider it a duty to acknowledge with gratitude the obligation I am under to the editor of the Literary Gazette for the extended report of my communications which he inserted in his excellent journal. When I placed in that gentleman's hands a rough draft of my papers to assist him in drawing up his report of them, I did not expect that he would have given me the benefit of so extensive a report as that which made its appearance. I was not able, however, to see a proof of it, or I should certainly have endeavoured to explain more fully the allusions to the diagrams, and to introduce a few

of the oral observations in explanation of the latter, without which it is possible that some portions of the paper, referring as they do exclusively to the diagrams, may appear rather incomplete. An omission which was made in the Literary Gazette with respect to my account of Schwann's researches, has given rise to some ridiculous observations. The mistake consisted in the editor's omitting in his report the sentence immediately preceding my account of Schwann's researches.

MEMOIR No. III.

Investigations into the Structure of the Epithelium, presented to the Medical Section of the British Association for the Encouragement of Science, at its Meeting held at Birmingham in August, 1839.

By Alexander Nasmyth, M.R.C.S., &c. &c.

In a former part of this communication I have endeavoured to prove that the pulp, the formative organ of the tooth, is composed of cells. I have also shown, that the character of the teeth themselves is more or less cellular; and the observations which I have made on the structure of the epithelium have led me to a conviction, that it also is composed of cells. Although some of the facts which I am about to relate, have, since the prosecution of my researches, been noticed by Henle and Schwann in Germany, I think it right, neverthe-

less, to state concisely all the results of my investigations.

Leeuwenhoek, who did so much towards the advancement of structural anatomy, was the first to give an accurate account of the structure of the epithelium. His researches on this subject are contained in letters to the Royal Society in the years 1674, 1684-85, which will be found in the third and fourth volumes of his collected works. He there states, that the human epidermis and epithelium are composed of scales, and of these he has left very accurate descriptions and delineations. He spoke of the scales of the epithelium as existing upon the mucous membrane of the mouth. The researches of subsequent observers tend to prove that these scales or cells exist in various forms upon the surface of all mucous and serous membranes, upon the inner membrane of the vascular system, &c. With respect to the existence of these scales on almost all these membranes, I agree with the authorities whom I have just quoted; and having premised thus much, I shall now proceed to treat, firstly, of the structure of the epithelium generally; and, secondly, of the epithelium as existing in the cavity of the mouth.

Structure of the Epithelium generally. — The epithelium is a layer of substance destitute of vessels, which covers the vascular surface of mucous membranes. Though destitute of vessels, it cannot, however, be considered as inorganic, as I shall presently show. If the surface of a mucous

membrane (for instance, the conjunctiva or the buccal) of a living animal be slightly rubbed, it will be found, on microscopic examination, that numerous small particles have been detached from it. At the first glance they present precisely the appearance of scales, for they are flat bodies with a thick portion or nucleus in their centre, and with very thin and transparent margins. It was Leeuwenhoek who first gave to these bodies the name of scales. They are found not unfrequently with a curved margin and without a central spot or nucleus, and their surface often presents numerous transparent points, with very fine lines. The nucleus of the scale generally contains a small body which has been termed the nucleus-corpuscle. But by this simple method of observation we do not obtain an insight into their true structure. If we remove the secretion from the surface of an irritated mucous membrane, we shall find another class of bodies which differ from these first mentioned, in being smaller and more globular. They have a nucleus of the same size as those of the so-called scales, and also a nucleus-corpuscle, but the surrounding structure is in the form of a cell, and is much smaller. Here and there may also be observed a nucleus with its accompanying corpuscle, lying in substance which presents no appearance of a cell. The structures here described may also be seen on a careful examination of a section of the epithelium and mucous membrane of a young subject. On the surface of, and

in immediate apposition to, the mucous membrane, are seen numerous nuclei, which more externally are surrounded by a cell; and on approaching still nearer to the surface, we find this cell, from having increased considerably in size, and become compressed, assuming the appearance of a scale, which retains the nucleus, and its corpuscle of primitive size. The various stages of the developement of the epithelium may be satisfactorily traced, by removing, after a short maceration, the layer of epithelium from the under surface of the tongue of a young calf, and placing it upon a piece of glass, when, if the external surface of the object be brought into focal distance, large scales only with their central nuclei are observable; but if the object be approximated to the glass so as to bring the internal part of it into the proper focal distance, numerous small scales are brought into view; and if the object be still more approximated to the lens, so as to bring its internal surface into the proper focal distance, numerous rounded cells become apparent.

In the fœtus, the defined and well-formed scales of the epidermis are not unfrequently distinctly seen externally; the *rete Malpighii* consists of newly-formed cells, and between the two may be observed other cells in a state of progressive developement. On the surface of the vascular mucous membrane minute cells are found with a nucleus in their interior, round which the cells grow; and this, in short, is the process of developement of the mi-

nute bodies which constitute the epithelium. An interesting subject of investigation, and one which I believe has not been entered upon by those who have hitherto treated of this department of anatomical science, is the manner in which the component parts of the epithelium are connected. The cells on the surface of the mucous membrane are separated from each other by considerable spaces, which are occupied by a gelatinous substance, interspersed with minute granular bodies. But the scales forming superficial layers of the epithelium are separated by very minute linear spaces, but are still connected together by a translucent, gelatinous substance.

This latter displays considerable elasticity, as is easily rendered evident by an attempt to lacerate the epithelium in a moist state, if the latter be examined at the same time by the aid of a magnifying power. Each time that the laceration is attempted, the membrane yields, and the scales separate to a certain extent; but regain their original position, on the cessation of the effort to draw them apart. In some instances a fibrous structure is evident in the gelatinous substance between the scales, See Diagram, No. 3. (Pl. C. 10.)

The scales towards the free surface are distinctly observed to overlap. The gelatinous substance above alluded to, presents distinct granular bodies, which give to the epithelium, *en masse*, a rather dense aspect, the individual scales being sometimes covered by these granules; the latter can, however,

be separated from the scales by compression; by which means, indeed, the granules themselves may be made entirely to disappear. In certain parts of the epithelium of the calf, distinct fibres are observed, which pass over the surface of the scales, and connect them together, thus forming a very delicate net-work. This appearance is most evident upon compression of the thick epithelium on the anterior part of the alveolar arch of the upper jaw.

In these cases, where the small scales, or small clusters of scales, are being continually thrown off, as on the surface of the body, and of the mucous membranes of man and animals generally, the scales composing the external layer will be found to overlap each other, and thus the gradual pressure of scales below, which are increasing in size, is the cause of the throwing off of these cuticular lamellæ. After these have been detached, their place is occupied by newly-formed scales. But there is another form in which the external layer of cuticle is removed, viz. in a continuous layer. The cuticle of the frog is composed of minute scales, the borders of which do not overlap, but are held in direct apposition, so as to form one lamina, which has a beautiful continuous tesselated appearance. This layer, of which I here display considerable portions covering the whole body, is thrown off entire by frogs and efts; and I am disposed to believe that it is this covering which, according to naturalists, is swallowed by the animal after having been thrown off. As soon as this layer is

removed, another lamina of scales is seen on the surface of the animal's skin. If after the death of a frog it be immersed in water, this thin external translucent layer generally separates; but upon prolonging the maceration, another lamina is found to be gradually separating from the cutis, which is dense, and sometimes measures a quarter of a line in thickness. Internally it will be found to be composed of very numerous cells, while externally the regular series of scales is evident. The tesselated lamina alluded to above evidently takes its origin from this layer of cuticle. An examination of the specimens which I here present to your notice, and a consideration of the facts which I have related, cannot, I think, lead to any other conclusion than that the cuticle and epithelium are organised tissues. It would appear that they are formed from a fluid secretion on the surface of the vascular corion. The various stages of developement being, 1, the formation of nuclei and corpuscles; 2, that of cells; 3, the growth of the latter effected by vital imbibition; 4, their compression and gradual conversion into minute lamellæ or scales. [See Pl. C. 10. Nos. 2 and 3.] In short, it appears a rational conclusion that the component parts of the cuticle and epithelium have within themselves a power of growth; and it remains for pathologists to determine what share the derangement of this function has in the production of cutaneous diseases. Another argument in favour of the organic nature of the epithelium is derived

from the circumstance, that under certain modifications it presents various vital phenomena, among which may be mentioned the ciliary motions.

I now proceed to describe my researches on the structure and developement of that portion of the epithelium which lines the cavity of the mouth. In the fœtal subject, previous to the extrusion of the teeth, it forms on the alveolar arch a dense, projecting layer, distinguishable from the surrounding membrane by its whiteness, and by the existence on its surface of ridges and sulci, having a waving course and a variable direction. The alveolar epithelium is thicker in proportion to the youth of the subject examined. It is most prominent where it corresponds with the molar teeth: its internal surface is concave, receiving the projecting mucous membrane. This portion presents various objects for investigation.

Firstly, as regards its composition:—It is made up of a mass of scales, lying one on the surface of the other. This disposition shows that the terms "dental cartilage," or the "cartilage of the gum," which have hitherto been applied to this structure, give an erroneous idea of its true nature, for cartilage always presents the corpuscle discovered and described by Purkinje. As in other portions of the epithelium, the external scales here are the larger, and this holds good generally, until we come to the surface of the vascular mucous membrane, which presents simple cells with their corpuscles.

In the interior of this alveolar epithelium, where it corresponds to the molar teeth, small vesicles may be frequently observed, varying in size from one quarter to one-eighth of a line in diameter. They appear to the naked eye to be transparent; under the microscope their parietes are found to consist of attenuated scales, and their cavity to contain a fluid abounding in minute granules and cells.* The internal surface of the epithelium covering the alveolar arch frequently presents concavities or indentations which are from a line and a half to three or four lines in circumference : they correspond to projections from the mucous membrane formed by a larger species of vesicle. The latter is deeply implanted in the vascular mucous membrane. The parietes of these vesicles are composed of a very delicate membrane ; they contain a transparent fluid which coagulates on the application of heat, or acid, or on immersion in spirit, and in this fluid float numerous globules and scales similar to those of the epithelium generally. The internal or attached surface of the alveolar epithelium also presents numerous fringed processes measuring from one line to one and a half lines in length, and half a line in breadth, which sink into the substance of the subjacent mucous membrane. Under the microscope these

* The vesicles here alluded to are most probably those which Serres describes as glands for the secretion of tartar : they are very numerous even after the extrusion of the incisor teeth of the calf, and are seen with great facility internally.

fringes are found to be composed of elongated scales connected together, forming masses which divide and subdivide until they attain such an extreme tenuity that the most minute terminations consist but of two scales in marginal apposition. If the epithelium be carefully separated from the surface of the mucous membrane corresponding to the unextruded molar teeth, and placed in water or in diluted spirit of wine for some little time, its internal or attached surface presents these fringes much enlarged and forming a mass more considerable in size than the dense epithelium itself.

The epithelium covering the mucous membrane of the palate presents transverse rugæ, corresponding to those of the mucous membrane. If these palatal rugæ of the epithelium of the calf be carefully examined from the internal surface with a magnifying power of one inch focal distance, each will be found to consist, or to be composed of, numerous depressions or cul de sacs which receive prolongations or pointed processes of the subjacent mucous membrane.

They are of extreme tenuity, and, when viewed by the aid of high magnifying powers, are observed to consist of distinct scales.

A question of much interest, and one to which I have paid considerable attention, is whether recent investigators are warranted in considering mucus and epithelium as identical ; I am disposed to think that they are formations quite inde-

pendent of each other; but my reasons for arriving at this conclusion are numerous, and the details of my investigations upon this part of the subject I propose to treat of at length elsewhere.

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