XXVIII. *On the Structure of the Dental Tissues of the Order Rodentia.*

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In a memoir on the Structure of the Dental Tissues of Marsupial Animals, printed in the second Part of the Philosophical Transactions for 1849, I pointed out certain peculiarities in the structure of the enamel common, with one known exception only, throughout that order of quadrupeds, and found in other mammalian teeth in a few isolated cases only*.

* Having in a former paper† stated that the continuation of the dentinal tubes into the enamel appears to be a constant character in the teeth of marsupial animals, excepting only in those of the Wombat, I can now add that I have found it to hold good in many other members of the families from which I have already given examples; and also in members of those families which are not mentioned in my paper; and moreover, that further research has exposed no other exception to the rule than that which I have already cited.

I find that in *Macropus penicillatus* most, if not all, of the coronal dentinal tubes are continued into the enamel, and in the latter part of their course are bent rectangularly downwards towards the fang of the tooth. In *Halmaturus Derbianus* the dentinal tubes are continued into the enamel, but are not subject to the terminal flexure observed in the preceding example. The dental tissues of the *Dasyurus viverrinus* closely resemble those of the *Dasyuri* already described. The teeth of *Didelphis californica* and *Didelphis cancrivora*, approach very closely in structure to those of the *Didelphis virginiana*.

I am indebted to Mr. Gould for opportunities of examining the teeth of *Myrmecobius fasciatus, Perameles nasuta* and *Chœropus*. In each of these creatures the dentinal tubes are continued into the enamel. In *Phascolarctos fuscus*, the dentinal tubes that proceed towards the tubercles of the teeth are continued in considerable numbers into the enamel; but on the sides of the teeth their continuation is less frequent. Here the enamel fibres are more strongly marked, and larger than in any other marsupial tooth that I have examined.

Several specimens of fossil marsupial teeth have been examined, and are found to correspond in structure with those of the recent species, to which the fossil ones are most nearly related.

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† Philosophical Transactions, Part II. for 1849.

It is the purpose of the present communication to lay before the Society results obtained from an examination of the teeth of various members of the order Rodentia. I have had the opportunities necessary for extended researches in this division of Odontography, partly through the assistance of numerous friends, but principally through the liberality of the Council of the Zoological Society, who granted me the privilege of examining teeth from the duplicate specimens of their large collection of skulls. At the time I commenced the investigation, there seemed but little hope of finding any strongly marked and characteristic differences of structure in the dental tissues of the several families of this order of quadrupeds. The teeth of many rodents had already been submitted to the microscope, and the results published*. I had not proceeded far, however, in the investigation of this highly interesting subject, before it became apparent to me that the family Hystricidæ and the Sect. Bathyergina of WATERHOUSE have a constant and exclusive character in the structure of the enamel; that the Sciuridæ have another character; that the first and second sections of the family Muridæ possess a third; and that the remaining sections of that family possess a fourth well-marked character, and the Leporidæ a fifth. I am told by Mr. WATERHOUSE that these results are of great importance, as affording evidence on the position of several species whose place in the order has not been definitely fixed, either by their external characters or by the structure of the skull, and hence they have been variously placed by naturalists, and even by the same author at different times.

Before entering on a description of the structural characters that pertain to the teeth of the rodential families, or of individual teeth, it will be desirable to state those conditions which are common to the whole order, otherwise it would be necessary to repeat frequently the same fact. It has long been known that the incisors of Rodentia have the property of unlimited growth, and that the rate of growth equals the rate of loss by wear; hence the exposed portion of the tooth is, in the normal state of the dental apparatus, maintained of uniform length. The pulp-cavity in a longitudinal section of the tooth is irregularly conical or wedge-shaped, and in a transverse section corresponds in some measure with the outline of the tooth. The dentinal tubes pass from every part of the cavity outwards and upwards towards the surface in more or less curved lines.

The tubes which proceed from the cavity near the base of the tooth, are in many cases perceptibly larger than those that are situated higher up; hence it follows, that, as the latter were once near the base of the tooth, the dentinal tubes undergo a diminution of calibre after their formation. In the teeth of the Sciuridæ, I have found a difference of size amounting to a third or half between the tubes near the base and those near the surface, in wear. Professor OWEN has observed that the tubes in the posterior or lingual half give off larger and more numerous branches than those constituting the anterior half of the tooth. My own observations lead to the conclusion, that this difference does not always exist near the surface of the pulp-cavity,

* Odontography, Prof. ERDL.

but is generally present towards the outer surface of the tooth. The tubes in the anterior half gradually diminish in calibre from their commencement, while those in the posterior half retain their dimensions until they arrive near the surface, where they break up into branches.

At and near the apex of the pulp-cavity the development of dentinal tubes is suspended. The tooth at this point is rendered solid by the conversion of the pulp into a clear laminated subgranular mass, into which very few, if any tubes are continued; and the few that are sometimes found are usually small in size, irregular in form and direction, and never reach the centre. The ends of the dentinal tubes are perfectly sealed up, and their connection with the pulp-cavity and its vascular contents completely cut off in the manner shown in Plate XLIII. fig. 1. The perfected part of the tooth is rendered by this process in the fullest sense of the word extra-vascular. A similar condition may be seen in the molars of persistent growth, and offers a striking difference to the condition of the rooted teeth, in which the dentinal tubes retain their connection with the pulp-cavity until the tooth becomes diseased or dead, or the crown worn down by mastication. In the latter case, as the crown wears down, the pulp is converted into secondary dentine, in which but few tubes exist, and these do not reach a vascular surface like that which lies in contact with the surface of the pulp-cavity in the normal state of the tooth.

Professor Owen*, after describing the manner in which the incisor teeth of rodents are developed, says, "The tooth thence projecting consists of a body of compact dentine, sometimes with a few short medullary canals continued into it from the persistent pulp-cavity, with a plate of enamel laid on its anterior surface, and a general investment of cement, which is very thin upon the enamel, but less thin, in some rodents, upon the posterior and lateral parts of the incisor."

The medullary canals described by Professor Owen, pursue a course parallel with the dentinal tubes, form a narrow loop, and return to the pulp-cavity. The dentinal tubes never radiate from them, but enter through the medium of lateral branches only (fig. 5). Hence the teeth so constituted do not form an exception to the law, that the incisors of rodents are formed of a single denticle†, which, exclusive of the enamel, is comparable to an Haversian system.

* Odontography, page 399.

† It is proposed to restrict the term *dentinal system* to a canal from which dentinal tubes radiate (fig. 2), and *denticle* to a dentinal system coated with enamel or cementum; and that a tooth composed of a series of dentinal systems, each coated with enamel and united into one tooth by cementum, shall be described as a tooth composed of denticles. The molars of the Capybara afford an excellent example of a tooth constituted in the latter manner, while the Orycteropus affords an equally good example of a tooth compounded of a series of dentinal systems—a tooth in which we have a number of medullary canals from which dentinal tubes radiate, the terminal branches of which inosculate with the terminal branches from neighbouring systems, either by confluence or the intervention of small cells (fig. 2). Teeth composed of a series of dentinal systems may or may not have an external investment of enamel; in the Orycteropus enamel is absent, while in the *Labyrinthodon, Varanus* and *Lepidosteus,* it is present near the upper extremity of the tooth, The dentinal systems commonly run into each other at some

In those rodents whose molars are of persistent growth, whether the tooth is composed of denticles or confluent denticles, the dentinal tubes of that part of the tooth which is protruded and exposed to wear, are cut off from their connection with the pulp-cavity in the same manner as in the incisors. This beautiful provision of nature for rendering solid and extra-vascular parts that are about to be exposed to mecha nical abrasion from external objects, is not confined to the teeth of rodents, or to dental tissues alone.

The Orycteropus has teeth which are permeated by a series of canals, which take a parallel course at tolerably regular intervals in the length of the tooth. From each canal a system of dentinal tubes radiates, the terminal branches of which inosculate with corresponding ones from neighbouring systems. In the protruded portion of the tooth, the medullary canals are rendered solid by the development of a clear non-tubular tissue, whereby the once open extremities of the tubes are closed (fig. 2).

The teeth of reptiles of the genus *Varanus* are at their middle part and base composed of a series of dentinal systems, as are those of the Labyrinthodon* (fig. 3). In

parts, in the same manner as the Haversian systems do in bone. But there are many instances in which parallel dentinal systems are united to each other, throughout their whole length, by a thin longitudinal lamina of dentine, the tubes of which belong as much to the one as to the other system, while the free parts of each system are coated with enamel, and this with cement. The molar teeth of the Water-Rat and Ondatra offer good examples. It is desirable to have a term to express this condition; *confluent denticles* would, I think, answer the purpose, and *confluent dentinal systems* where a like condition is observed, without the presence of enamel or cementum as a uniting medium.

* It has been usual to describe the tooth of the Labyrinthodon as being divided into numerous compartments, by tortuous inflections of the cementum from the surface towards the centre. I believe it is admitted by writers on Odontography, that when enamel and cementum are present in the same tooth, the latter tissue holds a position external to the enamel. Professor Owen, in his paper on the teeth of the Labyrinthodon, printed in the Geological Transactions, says of the Ichthyosaurus, "In this extinct Saurian the external layer of cement (for the enamel ceases at the base of the crown) is inflected at pretty regular distances around the circumference of the tooth towards its centre:" then again, "The plan and principle of the structure of the tooth of the Labyrinthodon are the same as those of the tooth of the Ichthyosaurus, but are carried out to the highest degree of complication." But in a beautiful series of sections of the tooth of the *Labyrinthodon Jaegeri* in the possession of Dr. Mantell (to whom I am indebted for their use), it is clearly shown that the division of the tooth into numerous compartments takes place within a general investment of enamel, external to which the cementum would be placed if it existed on this part of the tooth.

The inflections of the cementum, observed by Professor Owen in the tooth of the Ichthyosaurus, and compared by him to the supposed inflection in the tooth of the Labyrinthodon, take place, as he observes, below the terminal line of the enamel; hence the two cases do not admit of comparison. Similar cells to those which occupy the line which lie between the dentinal system and serve as a medium of connection between the dentinal tubes of adjoining systems in the latter animal, are found in equal or even greater numbers near the periphery of the dentine, and within the enamel of very many teeth. Hence the presence of these cells in the tooth of the Labyrinthodon is not sufficient to prove the existence of cement between the dentinal systems, unless it is at the same time shown that they are external to the enamel, or that that tissue is absent. The tooth of the Labyrinthodon is in truth made up at its apex of a single dentinal system coated with enamel; below, it is divided into numerous systems, which have a peculiar and characteristic outline and position. Each system usually coalesces at one part of its circumference with a neighbouring system, by a narrow vertical process of fish we have the teeth of the Dendrodus, the Lepidosteus, Myliobates, and sharks of the genus *Lamna,* also composed of a series of dentinal systems. In all of these the open extremities of the dentinal tubes are closed previous to the part being exposed by wear. A similar condition, in a beautiful state of preservation, is found in many fossil fish teeth, especially in the Cestracions. I cannot refrain from noticing one other instance of this condition. The antlers of the Stag are composed of Haversian systems of medullary or vascular canals, surrounded by concentric laminæ of osseous tissue interspersed with lacunæ, the canaliculi of which anastomose freely, and those situated near a vascular canal terminate by open mouths on its surface. Previous to the shedding of the antler, each of the larger canals becomes lined with a layer of transparent, dense and almost structureless tissue, which completely closes the mouths of the canaliculi and cuts off the connection of the elaborate system of tubes and lacunæ with the vascular canals (fig. 4).

The division of the enamel of the incisors into two layers, described by Professor Owen, I have found common throughout the order, excepting in the incisors of the Hares and the Rabbit: the Lagomys I have not had an opportunity of examining, but from their close relation to the Hares, it is more than probable that in their incisors the enamel is not divided into an outer and inner layer.

The term layer is open to objection, as the two parts are made up of continuous fibres. In the inner part they decussate, while in the outer they are parallel, but their continuity may be distinctly traced (fig. 6 to 50). In the molars of many Hystricine teeth, the usual order is reversed; in the inner portion the fibres are parallel, and in the outer part of the enamel they decussate.

Professor Owen, in the passage cited, and in other parts of his great and valuable work, states that the cementum is continued over the enamel in the incisors of rodents, and objects to some of Professor Erdl's figures printed in his work on the Microscopic Structure of the Molars of *Rodentia,* because this tissue is left out. He says Professor Retzius failed to recognize the cementum from its being coloured. Professor Owen*, in his description of the incisor of the Water Vole, says, "The layer of cement becomes thinner at the margin of the enamel, where it is continued from the dentine upon that part, but soon increases in thickness, acquiring the bright brown tint, and separated by a well-defined line from the outer clear layer of the enamel."

I have sought with care for cementum on the anterior surface of the incisors of the Water Vole, of which the foregoing quotation is a description, and also in numberless other teeth, but have failed to find that tissue. In most, if not in all incisors of rodents, cementum may be seen investing the posterior surface, and it may be traced

dentine, much in the same manner as the confluent denticles of the molar teeth of *Rodentia* are united. In the teeth of the *Lepidosteus* and Lizards of the genus *Varanus,* the dentine of the middle and basal portions is divided into systems somewhat in the same manner as in the Labyrinthodon, and in the upper part of the tooth within a general circumferential investment of enamel. I have in my possession sections from two species of *Varanus, V. Bellii* and *V. Niloticus,* in which this point is incontrovertibly shown. I am indebted to the kindness of Dr. Andrew Smith for the teeth of these species.

* Odontography, page 405.

on to the edge of the enamel, where it speedily thins and is lost. The bright brown coloured part is very distinct in many teeth, and when the section is thick and a little oblique looks like a distinct layer; but if the section be reduced in thickness, all appearance of a layer will be lost. The colour graduates insensibly into the enamel, and no defined line of separation between the coloured and colourless parts can be distinguished. The colour has the aspect of a stain, deepest at the surface, and fading as it proceeds inwards. In a favourable section, the enamel fibres may be traced through the coloured part to the surface of the tooth, as shown in many of the figures. In the molar teeth of continuous growth, the cement may be traced over the whole surface of the enamel, and as a thin transparent layer devoid of lacunæ. In these teeth it is however separated from the enamel by a sharply-marked boundary line. In no instance have I found it graduated into the latter tissue in the manner Professor Owen supposes it to be in the coloured external portion of the enamel of the incisors. In the incisors of the Wombat, the cementum is continued over the enamel, but the two tissues are separated from each other by a sharply-marked line. The cementum is nowhere graduated into, or "blended with*" the enamel. It is more than probable that the thin transparent and almost structureless basement tissue of the enamel-pulp becomes calcified with the attached columns of the pulp itself, but this tissue is quite distinct from the cementum matrix, and exists in those teeth in which we have an external investment of cement.

The rootless molars of rodents have generally a very close resemblance in structure to the incisors, especially in the structure of the enamel. But the rooted molars are less like the front teeth, and in many instances cannot be distinguished by their structure from other small teeth. In the Rat-tribe, however, the enamel near its terminal edge assumes an arrangement similar to that of the incisors. In those molars which have an intermediate character, the structure of the enamel in the upper part of the tooth resembles that of the rootless molars†.

* Odontography, page 405.

† In describing individual teeth, it will be necessary to repeat frequently the same expression, I will therefore state once for all the meaning I attach to such terms. Thus by a vertical or longitudinal section of an incisor, I mean a section from back to front through the median line of the long axis of the tooth; by an oblique section through the long axis of the tooth or oblique longitudinal section, I mean that the section should pass from the mesian side of the anterior to the outer side of the posterior surface of the tooth, or *vice versâ*; by longitudinal section from the anterior surface, I mean a section by which a portion of the anterior convex surface is removed with a portion of enamel at each end of the section; by a transverse section, a section at a right angle with the long axis of the tooth; by an *oblique transverse section*, or a section parallel with the surface in wear, a section crossing the long axis of the tooth obliquely from back to front. The surface in wear will be described as the upper surface, both in upper and lower teeth; and the angle at which the enamel layer leaves the dentine, will be that formed between the enamel lamellæ and the surfaces of the dentine immediately above them.

When the thickness of the enamel and the dentine is given, the measurements will be taken from back to front, throuhg the centre of the long axis of a transverse section.

Teeth obtained from the Zoological Society are indicated by the Society's name being affixed to the name of the species.

In the genera *Sciurus* and *Pteromys*, I have examined the dental tissues of many species, and find the teeth so like the one to the other, that the microscope affords no aid in the distinction of species. Under these circumstances it will be necessary to describe minutely the structure of the component tissues of the teeth of one species only.

Sciurus niger, LINN. (Zoological Society).—The anterior surface of the incisors is coated with an extremely thin layer of enamel, scarcely exceeding in thickness the 428th part of an inch. The dentine measured from the front to the back, is about the 8th part of an inch in thickness. A longitudinal section, taken from the centre of an upper incisor, exhibits the dentinal tubes in their length. Those destined for the anterior half commence at the surface of the pulp-cavity, and proceed with slight secondary undulations, and a decreasing calibre upwards towards the enamel. In the earlier part of their course, a few short, minute, rectangular branches are given off, and are soon lost; but when nearing the enamel, the tubes break up into a lash of branches, which pass onwards with but slight divergence, and after becoming excessively minute, are lost at the juncture of the external tissue; a few, however, terminate by forming loops. The dimensions of the dentinal tubes vary at different parts of the same tooth. At the lower part of the pulp-cavity the tubes destined for the anterior and posterior surfaces have a diameter of the 6000th of an inch, while those that proceed from the upper and narrowed part of the pulp-cavity, and from the central line of the solid part of the tooth, seldom exceed the 14,000th of an inch, and are often reduced to a scarcely perceptible line. Usually they do not preserve this small size, but quickly dilate to the 10,000th or 12,000th of an inch; these conditions are not however peculiar to the teeth of this group. The tubes that form the posterior part of the incisors give off branches pretty freely throughout the whole of their course, and when near the surface break up into a rich plexus of anastomosing tubules, in addition to which they occasionally dichotomize. Many of the earlier branches are small and short, but a few are large, go off at a right angle, and may be traced for some distance crossing the course of the neighbouring tubes. In the median line of the sides of the tooth, independent of the secondary curves or undulations, the dentinal tubes pursue a tolerably straight course, as do those in the median line of the anterior and posterior surface. But the dentinal tubes of the anterior halves of the sides describe one large curve, the convexity of which is turned towards the anterior surface of the tooth; and those composing the posterior part of the tooth follow a similar curve, the convexity of which is directed towards the posterior surface; similar relations between the tubes and the several parts of the incisor may be observed in the teeth of other rodents.

Professor OWEN*, when treating on the teeth of rodents, says, "The substances of the incisor diminish in hardness from the front to the back part of the tooth; the enamel consists of two layers, of which the anterior and external is denser than the

* Odontography, page 399.

posterior layer." He does not however anywhere state that the incisors of Sciuridæ have any structural peculiarity resident in the enamel, by which their teeth are distinguished from those of other rodents; neither am I aware that any subsequent author has noted its existence. Nevertheless so great a peculiarity exists throughout this family of Rodents, that a vertical section of an incisor, either of a *Sciurus*, *Pteromys*, *Tamias* or *Spermophilus*, may be recognized at first sight as belonging to the family Sciuridæ.

It has been usual to describe the enamel fibres from the view obtained in a longitudinal section of the tooth, from which circumstance the true structure has not been recognized. The supposed fibres are composed of layers of fibres, and each layer of a single series, the fibres of which are parallel to each other, and at right angles with those composing the layers immediately above and below. In the outer part of the enamel the fibres of all the layers become parallel, and the lamination ceases.

The enamel layers, as seen in a vertical section of an incisor of *Sciurus niger*, and portrayed in fig. 6, are about the 6000th of an inch in thickness, and have straight and even margins. They form a right angle with the surface of the dentine, increasing slightly in thickness in their course outwards (fig. 6 E). Each layer is composed of a single series of squarish fibres, laid side by side, and closely united. During the first part of their course they are straight and parallel, and proceed to the right in one layer and the left in the next, at such an angle as to produce a square pattern over the inner part of the enamel. The appearance thus produced in the central part of the enamel of a transverse section is shown in fig. 7 E. On the side of the incisor the decussation is less strongly marked, and at the thin terminal edges is almost lost. The fibres, after traversing in a diagonal course in the horizontal plane of the tooth two-thirds of the thickness of the enamel, turn abruptly upwards and outwards at an angle of 45 degrees with their original direction. In this, the outer third of their course, the whole of the fibres become parallel, and in proceeding outwards make a gentle curve, the convexity of which is turned towards the cutting edge of the tooth. In the change of direction, the fibres which have followed a diagonal course make an angle not only in the vertical, but in the horizontal plane of the tooth, while those situated near the terminal edge of the enamel are bent in the vertical plane only.

The colouring matter resident in the enamel of the incisors of squirrels, is seen in a thin transverse section to be confined to the outer third, and looks like a stain in the terminal ends of the fibres, which diminishes in intensity from without inwards until it is lost.

In a vertical section through the centre of an incisor, viewed by transmitted light, the superimposed laminæ of enamel fibres will, to an inexperienced eye, appear as parallel fibres; a little patience will however enable the observer to see that they are composed of fibres cut obliquely (fig. 6 E). In places, faint transverse markings will be seen, which indicate the oblique sections of the fibres. Not unfrequently, however, the lateral union of the fibres is so perfect, that in the layers near the cutting edge of the tooth no transverse marking can be traced. If a section be made obliquely in the vertical plane of the tooth, so as to cut the fibres of one set of layers in their length and the others transversely, we shall have straight fibres with intervening rows of fibres cut across (fig. 8 E). If the section be taken from the protruded portion of the tooth, the cut extremities will be nearly square; but if it be taken from near the base, where the enamel has not attained its full solidity, they will have a less regular outline. Sections of this kind show that the fibres are a little longer than broad, and that the longer axis is placed in the length of the tooth.

A vertical section will however show most strongly the peculiarities that belong to this family of rodents, namely, the small relative amount of enamel, the uniform character of the layers, the uniform lines that mark their junction, and their straight and rectangular course outwards from the surface of the dentine, together with the angle at which they are bent in the external portion of the enamel.

An incisor in which these several conditions of the enamel are found to exist, may I think be safely pronounced to belong to a species included in the family Sciuridæ, and in all probability a member of the genus *Sciurus* or *Pteromys*.

The molar teeth of *S. niger* present no sufficient peculiarity in the structure of the dentine to render a description necessary. Neither can I find any point of difference worthy of notice in the corresponding teeth of *S. vulgaris, capistratus* or *cinereus*. In *S. erythropus* the dentinal tubes are continued, the 1500th of an inch, into the enamel, and in this short course branch in the manner shown in fig. 11 E. I have not found this peculiarity in any other squirrel which has come under my notice.

The cementum of the molar teeth is not very abundant, even at the extremity of the fang; I cannot discover that it is continued over the surface of the enamel. If a vertical section of a molar tooth from either of the species I have named be carefully examined, it will be seen that the cementum, where it commences in a thin layer, at the neck of the tooth is composed of uniform rods, directed from without inwards and a little downwards. When this tissue is thicker the rods are seen near the surface, but are lost amongst the lacunæ and their canaliculi. The cemental rods are subgranular in structure, and exceed the enamel fibres in dimension. They average the 3450th of an inch in diameter, and are portrayed in fig. 10 C. I am not aware that this character of the cementum has been previously noticed, it is not however confined to the molars of the Sciuridæ.

In the molar teeth of Squirrels the enamel is far less peculiar than in the incisors, and offers no strongly marked characters by which the teeth can be recognized. The fibres are less regular in form, less clear and transparent, and less free from minute cells than in the front teeth; neither have we a terminal portion taking suddenly an altered direction; nor is there any evidence that the fibres are arranged in parallel layers transverse to the long axis of the tooth. Their course is however, throughout, more or less waved; and although many cross each other, yet all do not; and when they do, the definite and constant angle preserved in the incisors is not observed in the molar teeth. A vertical section of a molar of *S. niger* exhibits the usual characters of the dental tissues in these teeth (fig. 9). In *S. cinereus* the enamel fibres are in a vertical section, seem to be minutely granular, well-marked, and subject to one or two gentle curves near the surface; they are in the outer part of the tooth very strongly marked, from being highly granular, and less perfectly united laterally than in some other teeth.

Tamias Lysteri, Rich. (Zoological Society).—I have been able to procure a lower incisor only of this creature. The structure of the tooth very closely resembles the incisors of squirrels: the dentine is similar, as are the enamel layers both in shape and arrangement; and the component fibres of the contiguous layers cross each other at the same angle. The decussation however ceases, and the parallel arrangement is assumed in about the middle of the enamel; this difference, if found constant in all the species, will serve to distinguish the Tamias from the Squirrels.

Spermophilus (Zoological Society).—The structure in the incisors of this animal deviates a little from that in the Squirrels; in thickness, the enamel, as seen in a transverse section, is about 300th and the dentine the 12th of an inch; the dentine is much the same as in the genus *Sciurus*, excepting that the dentinal tubes of the anterior half of the tooth measure about the 7500th of an inch in diameter, while in the posterior half they average the 6000th of an inch: the enamel is different, and advances a step towards another type. The enamel layers incline upwards at an angle of 78°, instead of preserving the rectangular position, and they are less regular in their course, and less uniform in size than in the former genus. A transverse section shows that the component fibres of the adjoining layers decussate one another throughout the inner half of the enamel, and then become parallel. An oblique section in the long axis of the tooth will expose alternate straight fibres and rows of ends of fibres cut transversely; and in the latter it may be observed that they have an oval rather than a square section, the long diameter of which is one-third greater than the short; this is best seen near the cutting edge of the tooth. If the section be taken from near the base, the fibres in their transverse section are more circular, less compressed, and much less intimately united to their fellows, while at the opposite extremity of the tooth they are so closely connected, that in places the enamel seems a dense transparent structureless mass.

The enamel layers in a vertical section have a thickness of about the 5000th of an inch. In a transverse section, the fibres have a diameter of about the 10,000th of an inch in their smaller, and the 5000th in their greater diameter.

Arctomys Empetra, Schreb. (Zoological Society).—In a lower incisor the enamel has an average thickness of 75th of an inch, and the dentine the $\frac{3}{20}$th of an inch. The dentinal tubes have an average diameter of the 10,000th of an inch: I do not find any difference in the dimensions of the dentinal tubes at the anterior and posterior parts of the incisor. They terminate at the enamel in a peripheral layer of minute irregular cells, much in the manner shown in fig. 12 and 13. Those directed towards the back part of the tooth, in the terminal fifth of their course, form a rich plexus of branches, and finally terminate in minute irregular cells. Then comes a thin investment of transparent cementum, which terminates at the margin of the enamel. The dentine is dotted throughout with fine cellular markings, which seem to indicate the form of the cells of the dentinal pulp previous to its calcification, and give a coarse appearance to the tissue. The dental tissues of this tooth are not distinguishable from those of the next species.

Arctomys pruinosus, GMEL. (Zoological Society).—In an upper incisor the enamel averages the 75th, and the dentine the 5th of an inch; as the dentine closely resembles that of the Quebec Marmot, the description need not be repeated. The enamel exhibits a considerable departure from that of the Sciuridæ, though not wholly different in type of structure. The fibres in the first part of their course are arranged in parallel layers, which have a thickness of about the 4580th of an inch, as seen in a longitudinal section and illustrated in fig. 12 E. The layers lie at right angles with the surface of the dentine, and extend across the inner two-fifths of the enamel, at which point the uniform lamelliform arrangement is broken up by a change in the direction of the component fibres. In a transverse section of the tooth the component fibres of the enamel layers are seen arranged in a single series, lying side by side, and crossing those of the adjoining layers at an angle so as to form a diamond pattern over the inner part of the tissue (fig. 13). The decussating fibres of the superimposed layers, after traversing the inner two-fifths of the enamel, change their direction, become more parallel, and in waved course advance upwards and outwards till they reach the surface of the tooth. But although the course is much more parallel in the outer three-fifths than in the inner two-fifths of the enamel, yet if the focus of the instrument be carefully changed, alternate layers of fibres may be seen crossing each other at an angle to form very elongated and irregular diamond-shaped figures.

The line at which the change of direction takes place is not definitely marked as in the Sciuridæ and many other rodents. In a longitudinal section, it will be seen that the fibres in the terminal part of their course are directed upwards at an angle of 70° with the surface of the dentine, and that small cells are scattered through this part of the enamel. In addition to these minute irregularly disposed cells, lines of cells may be seen commencing at the surface of the dentine, pursuing a curved course, and finally crop out at the surface of the enamel: I have not seen similar out-cropping lines of cells in the enamel of any other rodential teeth. The enamel fibres may in a transverse section be traced through the coloured portion of the enamel to the surface of the tooth.

Castor fiber, LINN. (Zoological Society).—In an upper incisor the enamel is about the 100th and the dentine the 5th of an inch in thickness.

It has been observed by Professor OWEN, that vascular canals are continued from the pulp-cavity a short distance into the dentine. In the specimen before me, the middle third of the dentine is traversed by vascular canals, which turn short upon themselves and return to the pulp-cavity not far from whence they started. The canals in radiating from the pulp-cavity pass directly outwards and a little upwards parallel with the course of the dentinal tubes, excepting where they turn to reverse their course, in doing which they do not occupy more than twice or thrice their own diameter. I have not observed that they ever branch or anastomose with neighbouring canals; many indeed so quickly return to the pulp-cavity, that there would scarcely be space enough for branching, while others advance a considerable distance.

The dentinal tubes destined for the anterior part of the tooth commence with a diameter of about the 7500th of an inch and give off branches in the earlier part of their course, which connect themselves with the vascular canals. The disposition to branch ceases however after they have passed the vascular portion of the dentine, and is not resumed until they come near the enamel, when they form a plexus, towards the surface of which is a layer of elongated cells, placed obliquely both to the course of the tubes and the surface of the dentine; the cells are shown in their relative position in fig. 14. Previous to the formation of the peripheral plexus, the dentinal tubes make several curves in a contour line with the length of the tooth. This point is not shown in the figure, as it occurs internal to the part represented. The dentinal tubes of the posterior part of the tooth commence with a diameter of about the 6000th of an inch.

The vascular canals measure from the 750th to the 2500th of an inch in diameter. Those situated near the worn surface are the smallest, from being lined or filled with a transparent tissue, into which the branches of the dentinal tubes do not penetrate.

In the enamel we find a further deviation from the Sciuroid type than was observed in the Marmots. The layers of enamel fibres no longer lie at a right angle with the surface of the dentine, but are directed upwards at an angle of 60°, and moreover describe a slight sigmoid curve, which terminates a little short of the centre of the enamel, from whence the fibres become parallel and proceed at an angle of 30° with the surface of the dentine. These appearances are best seen in a longitudinal section, and are shown in fig. 14 E. In a transverse section made parallel with the course of the layers, as seen in a longitudinal section, the arrangement of the fibres composing the layers becomes apparent. Each layer is composed of a single series of fibres, which pass in straight lines alternated to the right and left in the adjoining layers, and produce an infinite number of minute square tracings over the inner portion of the enamel. When near the middle the decussation ceases, the fibres become parallel and proceed upwards and outwards; but instead of proceeding directly outwards, they bear towards the median line of the skull, as shown in fig. 15. In examining the fibres in the terminal part of their course, a section must be made parallel with their length.

The enamel fibres, as seen in a transverse section, measure about the 6000th of an inch, and may be traced to the surface.

Professor Owen says, "In a transverse section of the incisor (of the Beaver), the distinction between the two layers of enamel is still more obvious: the fibres of the inner half, being cut across, give the appearance of fine decussation, oblique lines; while those of the outer half run transversely to the surface, and are crossed by traces of concentric layers*." That the appearance of decussation here mentioned is due to the crossing of fibres, and not to the direction of the section, is proved beyond doubt by taking a thin transverse section and breaking it across the centre, when the fibres of the layers included in the section may be viewed projecting from the broken edges; or it may be even more distinctly demonstrated by removing a little of the partially calcified enamel from the lower portion of the tooth, and placing it with a drop of water between two pieces of glass.

In the dentine of the molar teeth of the Beaver, I can find no characteristic peculiarity that needs description. The root of the tooth is composed partly of cementum, into which the dentine graduates, and through which vascular canals lead to the pulp-cavity.

The fibres of the enamel correspond in arrangement with the external portion of those which form the enamel of the incisor teeth, and like them have a greater and less diameter, the former of which is placed in the length of the tooth.

The enamel fibres are usually directed upwards at an angle of 30° with the surface of the dentine, and near the surface curve a little outwards; but they may be found in some parts of the tooth making two slight curves before arriving at the surface.

Near the upper part of the tooth the fibres are so closely united, that the enamel in places seems almost structureless; but toward the roots, and where it is reflected into the depressions, the fibres are sufficiently distinct to be examined and measured.

The enamel, where it attains its greatest thickness, is marked by oblique lines, which proceed from within outwards and speedily crop out on the surface. They appear to result from a difference of density rather than from the presence of minute cells, such as are found in the incisors of the Marmots.

The cementum of the molars is granular, plentifully supplied with lacunæ, and arranged in concentric laminæ round the vascular canals and the roots of the tooth; here and there a slight tendency to the arrangement in rods, similar to that of the Sciuridæ, may be observed.

Spalax typhlus, Pall. (Zoological Society).—This animal, though placed by Mr. Waterhouse in a section between *Murina* and *Arvicolina* in the family Muridæ, resembles the Beaver in the structure of the enamel more closely than any other animal, which circumstance offers a sufficient reason for describing the dental tissue in this place.

In an upper incisor the dentinal tubes present an oval transverse section with the long diameter placed in the long axis of the tooth. The long diameter attains the 5000th, while the short diameter does not exceed the 10,000th of an inch. In their passage outwards they describe a sigmoid curve, with the general direction a little

* Odontography, page 407.

upwards, and from their commencement at the pulp-cavity give off rectangular branches which take a downward course. When near the enamel, the dentinal tubes bend upwards and emit branches from the convex surface only, as shown in fig. 16 D. These are lost at the junction of the enamel and dentine, and terminate without the presence of peripheral cells, such as are found in the Beaver.

The enamel in the inner part of the tissue is arranged in transverse layers, which in a longitudinal section are seen to proceed from the surface of the dentine at an angle of 73°. Each layer measures about the 6000th of an inch in thickness, and extends about half-way to the surface, where the component fibres of the different layers assume a more parallel arrangement. The layers in a favourable section have even margins, but if the section inclines slightly from the centre of the tooth in either direction, the margins will be a little irregular; indeed this observation applies with equal force to similar sections of other rodential teeth.

In a transverse section the contiguous layers cross each other at a right angle, and at places look as though plaited, as in the Sciuridæ. In the outer division of the enamel, the fibres proceed in straight lines to the surface (fig. 17). An oblique section in the length of the incisor will expose alternate layers of straight fibres, and fibres divided transversely; the appearances thus produced are delineated in fig. 16 A. On the whole, the enamel is more transparent and the structure is less distinctly marked than in any other incisor I have as yet described; indeed the peripheral division in a longitudinal section frequently seems structureless.

The enamel varies a little in thickness in different parts of the tooth, the average being about the 200th of an inch, the inner or decussating and outer or parallel being nearly equal in breadth.

The rooted molars of the Spalax present a slight structural resemblance to those of the Sciuridæ. The dentinal tubes leave the pulp-cavity with about the 7500th of an inch, which is preserved till they arrive near the enamel. In the upper and middle part of the tooth the tubes describe a sigmoid curve in passing outwards, and give off branches during the two outer thirds of their course. In a longitudinal section, the enamel is seen to be composed of fibres which pass upwards and outwards with a slight curve, and have a diameter of the 6000th of an inch.

The cement resembles that of squirrels' molars in being composed of rods arranged transversely to the length of the tooth.

In the family MURIDÆ of WATERHOUSE *, a distinguishing character in the enamel runs through the various sections, excepting the three first, the fifth and seventh, and in the first of those (genus *Myoxus*) it exists partially. The teeth of the Dormice are in structure intermediate between those of the Squirrel-tribe and the Rat-tribe. The incisors of the Jerboas are however wholly different from any other members of this family, and the incisors of Bathyergina resemble those of the Hystricidæ. The Spalax I have already described.

* Johnston's Physical Atlas.

Myoxus avellanarius (LINN).—In the upper incisors of the Dormouse may be observed the first indications of the peculiar arrangement of the enamel layers, which holds in the great majority of the members of the family Muridæ.

The arrangement of the component layers of the enamel is, however, not alike in the incisors of the upper and lower jaws; hence a description of each is needed.

In the upper incisors, the enamel is composed of flexuous layers of fibres arranged transversely to the long axis of the tooth. In a longitudinal section each layer is seen to proceed upwards, then obliquely outwards, and afterwards again upwards, the general direction being at an angle of 70° with the surface of the dentine. The layers have serrated margins through the first curve, but during the after part of their course the margins are even, as in the Sciuridæ. The layers, after extending the 500th of an inch across the enamel, are broken up and the fibres are continued in parallel lines through the 750th of an inch to the surface, and at an angle of 30° with the surface of the dentine: these characters are shown in fig. 18 E.

The enamel layers are subject to a little variety in thickness, the average being about the 7500th of an inch; and here and there a layer may be found which gradually diminishes till it comes to a point and is lost before reaching the external portion of the enamel. An oblique section in the length of the tooth may be made at such an angle as to expose one layer of fibres in their length and the adjoining layer cut transversely. This view is shown in fig. 19. It will be seen that the fibres have a greater breadth than thickness.

In a transverse section the component fibres of one layer are shown crossing those of the layer above and below at a right angle, thus producing a square pattern over the lamelliform portion of the enamel, which is represented in fig. 20. The fibres give a transverse measurement of the 8823rd of an inch. The fibres in the outer division of the enamel are straight, and lean obliquely towards the median line of the skull.

In the lower incisors of this little creature the position of the enamel layers is reversed. A transverse section exhibits them extended in the length of the tooth, presenting an appearance similar to that seen in a longitudinal section of the corresponding upper tooth, excepting that they make but one curve with a flattened and slightly enlarged middle portion (fig. 22). A longitudinal section of a lower incisor presents an appearance similar to a transverse section of the corresponding upper tooth, as shown in fig. 21.

The dentine of the incisors of the Dormouse is not sufficiently peculiar to render a minute description necessary. The tubes are perceptibly larger at the lower than at the upper part of the tooth, and those in the posterior half of the tooth retain their full dimensions till near their termination.

The enamel is about the 300th, and the dentine the 23rd of an inch thick.

In the molar teeth, the lamelliform arrangement of the enamel exists in a perceptible degree near the terminal edge only, and so far establishes a resemblance to the molars of the Rat-tribe. The dentine offers no peculiarity worthy of notice in this communication.

Jerboa Ægyptius.—The teeth of this animal present great structural peculiarities. The upper and lower incisors are subject to the same difference in the arrangement of the lamellæ of the enamel as the corresponding teeth of the Dormouse; while the molars resemble in structure the teeth of marsupial animals. In the long axis of a transverse section of an incisor, the enamel measures the 150th and the dentine from the 17th to the 20th of an inch.

The dentinal tubes radiate from the pulp-cavity without exhibiting a specific peculiarity. Many of those distributed to the anterior as well as those to the lateral and posterior parts of the tooth, dichotomize once or twice in the early part of their course, and afterwards give off small branches. When near the enamel the dentinal tubes break up into a rich plexus of branches, many of which uniting, form a series of loops, and give a greater opacity to this than to any other part of the section. External to this plexus the dentine is comparatively transparent and traversed by a diminished number of dentinal tubes, a few of which are continued into the enamel; these, after following the course of the lamellæ, are lost in the peripheral portion of that tissue. The dentinal tubes at their largest parts do not exceed the 7500th of an inch.

The peculiar character of the enamel of the upper incisor is best seen in a longitudinal section, in which the lamellæ are shown proceeding from the dentine in straight lines directed obliquely upwards at an angle of 60°. In this section each layer appears slightly fibrous and a little indefinite in outline; in both respects differing from the teeth of this and the preceding family. These conditions are partly due to the presence of tubes continued from the dentine, and are portrayed in fig. 23.

The layers, after proceeding for about the 250th of an inch across the enamel, suddenly change their direction, and the component fibres lose the lamelliform arrangement, become parallel, and in tolerably straight lines pass upwards at an angle of 21° with the surface of the dentine. In this, the external part of the enamel, the tissue is very transparent, the fibres are rather indistinct, and the indistinctness increases the nearer we approach the worn extremity of the tooth. Here and there one or two tubes may be seen emerging from the lamelliform portion, and advancing into the outer transparent part of the enamel, but they are soon lost in their own minuteness.

An oblique longitudinal section may be so made as to expose alternate layers of fibres cut in their length, and the intervening ones cut transversely. The latter are oval, and present a long diameter of about the 5550th and a short diameter of about the 8824th of an inch. And it will also be seen, that although the fibres have their long axes placed in the length of the tooth, and hence transversely to the adjoining fibres longitudinally exposed, yet that the long axes are not at a right angle or any constant angle with them, but present various degrees of obliquity, as shown in fig. 24. This want of regularity in the arrangement of the fibres no doubt contributes to the fibrous appearance of the layers in the longitudinal section of the tooth, in which the component fibres are of course cut across with various degrees of obliquity.

In a transverse section of an upper incisor the fibres of the alternate layers are seen crossing each other at something short of a right angle; in the inner and in the outer part of the enamel they are seen proceeding in straight lines to the surface, without inclining to either side.

A thin layer of cement may be distinguished on the posterior part of the tooth, but is lost when it has passed over the terminal edge of the enamel.

In the lower incisors of the Jerboa the enamel lamellæ are arranged in the long axis of the tooth, much in the same manner as in the corresponding teeth of the Dormouse. A longitudinal section will expose the decussation of the fibres of the contiguous layers, the one set proceeding upwards and outwards, and the other downwards and outwards. The fibres in the external division of their course lose the lamelliform arrangement and proceed upwards and outwards in a gentle curve (fig. 26).

An oblique section in the length of the tooth will cut across the layers in their breadth, and show them arranged in lines parallel with the surface of the dentine. Each layer has in this view a denticulated margin, similar to the lamellæ in the Rats.

A transverse section of a lower incisor exposes the enamel lamellæ divided transversely to their length. Those which arise from the median side of the tooth are directed forwards and towards the median line, while those that start from the anterior and outer surface of the dentine, are directed in a curved line outwards in an opposite course. Each layer thickens slightly as it advances outwards, and exhibits slightly serrated margins.

The component fibres have their long axes placed obliquely (fig. 28). Transverse sections made with different degrees of obliquity, will give variety in the appearance of the enamel layers. Thus a longitudinal section of one set of fibres, and a transverse section of another may be obtained, as partly shown in fig. 28. But if the section be oblique to each axis of the tooth, the enamel may present a confused intersection of lines, from which little or nothing can be made out. This observation may be applied with equal truth to similar sections of other rodential teeth.

The dentinal tubes in the lower incisor are oval in section, and have the long diameter placed transversely to the length of the tooth, hence they appear larger in the transverse than in the longitudinal section (figs. 26 and 28). In the molar teeth, the dentinal tubes leave the pulp-cavity for the crown of the tooth with a diameter of about the 10,000th of an inch, and are very closely packed. They give off very few, if any branches, till near the periphery of the dentine, and here they are far from numerous, as compared with those seen in other molar teeth. The branches are short and bristle-like, and the parent tubes, or a large branch, is usually continued into the enamel. The dentinal tubes of the fangs commence with a similar diameter to those of the crown of the tooth, but they speedily dilate to the 7500th of an inch, and give off branches during the greater part of their course.

Previous to entering the enamel the dentinal tubes are reduced to about the

15,000th of an inch, which dimensions are retained after they have passed with that tissue. The tubes pass onwards with slight tortuosities in a line with the direction of the enamel fibres, until they reach the outer third, when they are lost or turn suddenly at a right angle, and after advancing a short distance downwards, disappear. These conditions are shown in fig. 29. The fibres of the enamel show no disposition towards a lamelliform arrangement, excepting near the terminal edge, where the lamellæ have, in a longitudinal section, serrated margins. The fibres leave the surface of the dentine on the sides of the tooth at an angle of about 50°, and in the outer third of their course come a little outwards. In the depression on the masticating surface, they proceed at a right angle from the surface of the dentine.

The molars of the Jerboa, though like those of marsupial animals in having the dentinal tubes continued into the enamel, differ from them in having serrated lamellæ in the enamel near its terminal edge, and hence may be distinguished both as not belonging to the marsupial order, and as belonging to the Muridæ.

I have been obliged to make upwards of twenty sections of the teeth of this interesting animal before I could fully satisfy myself on the various points of the dental structures; indeed in the early part of the investigation I despaired of making out the arrangement of the component fibres of the enamel.

The next animal on the list is *Pedetes Cafer*, but as the teeth resemble more closely the teeth of the Hystricidæ than any other group of animals, and are altogether dissimilar to those of the Muridæ, I shall postpone the description till I have gone through my specimens of Hystricine rodents.

The teeth which have come within my reach from members of the following genera, *Mus*, *Hapalotis*, *Gerbillus*, *Hydromys*, *Hesperomys*, *Arvicola* and *Lemmus*, so closely resemble each other in the general characters of the structure of the dental tissues, that it will be necessary to describe minutely those of a typical species only, and afterwards to note any specific differences that are found in teeth from other members of these genera. I will therefore take the teeth of the common Rat (*Mus decumanus*) as being typical of the family, and also on account of the ease with which the teeth may be obtained by any subsequent observer.

Mus decumanus.—From a longitudinal section of a lower incisor, we learn that the dentine presents no specific or generic peculiarities. The dentinal tubes from their commencement give off numerous minute pilose branches, and terminate near the surface of the dentine by forming a dense plexus of minute ramifications. Their course is straight, or nearly so, excepting the secondary undulation, which exists in a greater or less degree in almost every specimen of dentine that has come under my observation. The tubes are oval in their transverse section, having a short diameter of about the 15,000th of an inch, and a long diameter which is placed in the length of the tooth, and averages the 10,000th of an inch.

In the anterior part of the tooth the tubes gradually diminish in diameter from their commencement, while those in the posterior part retain their original size till near their termination, when they form a plexus, but less dense than that in the anterior part of the tooth.

The enamel is seen to be composed of fibres arranged in serrated lamellæ, which leave the surface of the dentine with a short but gentle curve, and then proceed upwards and outwards in nearly a straight line till about to terminate in the outer division of the enamel, when they make a slight sigmoid curve with the terminal portion directed upwards, their general course being at an angle of 50° with the surface of the dentine (fig. 30).

At the outer fifth of the thickness of the enamel the layers are broken up, and their component fibres take a parallel course upwards and outwards, and with a slight curve, which is strongest near the outer extremity, when they reach the surface of the tooth, their general courses being at an angle of 30° with the surface of the dentine.

Each lamella commences at the surface of the dentine with a diameter of about the 7500th of an inch, which gradually increases till at the distal extremity it attains the 6000th of an inch. The margins of the lamellæ are strongly serrated, and the projections of one layer fit into corresponding depressions in the contiguous lamellæ. This peculiar form and arrangement, as exhibited in a longitudinal section, may be regarded as typical of the enamel of this family of Rodentia.

In an oblique transverse section cut nearly parallel with the worn surface of the tooth, it may be seen that each layer is composed of a single series of enamel fibres, and that the fibres of contiguous layers cross each other at such an angle as to produce a diamond pattern over the lamelliform portion of the enamel; and also that the fibres curve a little in their course outwards (fig. 31). The upper and lower surfaces of the component fibres of each lamella appear to be a little uneven, and these irregularities no doubt contribute to the development of the serrations observed in the longitudinal section of the tooth, but in the section now under consideration these appearances are seen but obscurely. When the crossing sets of fibres have arrived within the 750th of an inch of the surface, the decussation ceases and they proceed outwards in parallel lines directed obliquely towards the median line of the skull; and in the latter 3000th of an inch of their course they turn directly outwards in a line with the long axis of the section.

If a section be so made as to display one set of fibres in their length, and the adjoining ones divided transversely, the latter will exhibit an oval section, while the former are seen to be armed with minute processes which fit into the small interspaces that would otherwise be left between the non-touching surfaces of the oval fibres. These conditions are shown in fig. 32. To these lateral processes the serrated margins of the lamellæ, as seen in the longitudinal section, are due, as are the irregularities of surface seen in the transverse section.

The outer ends of the enamel fibres are best seen in the middle and lower part of the tooth. Near the cutting edge, in the outer portion of the enamel, the union between the component fibres is so perfect that all appearance of structure is lost. This observation applies equally to other scalpriform teeth. The coloured surface presents the character of a stain, through which the fibres are continued. If the section be tolerably thick and a little oblique, the two cut edges will give the appearance of a coloured lamina. But the structure of the enamel may be demonstrated, though in a less complete manner, by taking a little of the soft partially developed tissue from the base of the tooth, and with a little water placing it between two slips of glass. The decussation of the fibres will be then shown, and some will present a beaded outline; small portions may also be found in which development is more forward, and some of the fibres armed with small lateral processes will appear in the field of the microscope. Some of these appearances are shown in fig. 33.

The upper have a somewhat thicker coat of enamel than the lower incisors; it averages about the 211th of an inch, of which the lamelliform portion occupies about the 333rd and the outer or fibrous portion the 666th of an inch.

In a longitudinal section the lamellæ leave the surface of the dentine at an angle of 55°, which is a little wider than that formed by the corresponding parts in the lower incisors. The layers describe a gentle curve upwards and outwards, and the margins are serrated through the greater part of their course, but less strongly than in the corresponding lower teeth; in addition to which the layers are frequently marked by transverse lines. Towards the outer part of their course, the serrations become faint and ultimately give place to a smooth outline. The fibres in the outer part of the enamel run at an angle of 25° with the surface of the dentine.

In the molar teeth the dentine presents no generic peculiarity, neither does the enamel about the cusps of the teeth, but at and near its terminal edge on the neck of the tooth, the lamelliform arrangement with the serrated edges holds good, both in the Rat and in other rooted molars of the genera *Mus, Hapalotes, Hydromys* and *Hesperomys*. The cementum about the neck of the tooth is arranged in rods, similar to those already described in the corresponding teeth of the Squirrels.

The teeth of *Mus rattus* present no structural peculiarities by which they can be distinguished from *M. decumanus*, neither do those of the following rodents, excepting in size:—*Mus Alexandrinus, sylvaticus, musculus, minutus* and *fusipes*. In examining the molar teeth of *Mus giganteus*, I find a peculiarity which may perhaps be specific. The fibrous enamel on one side of the cusps is separated from the dentine by a layer of perfectly transparent and apparently structureless enamel, which is thickest near the apices of the cusps, and gradually thins till it is lost at the bottom of the fissures. On the sides of the tooth the serrated laminæ of the enamel are strongly marked, and extend through a larger portion of the tissue than is common in the corresponding teeth of any other rat which I have examined.

In the teeth of *Hapalotes albipes* and *longicaudatus* of New South Wales, I find a very close structural resemblance to those of the Rat, the principal difference being in the more blunted shape of the serrations of the enamel lamellæ, and the greater frequency and strength of their transverse markings. In a longitudinal section of a lower incisor the layers leave the dentine at an angle of 40°, and have a thickness of about the 7500th of an inch. The whole thickness of the enamel is about the $\frac{13}{1500}$ths of an inch, of which $\frac{11}{1500}$ths is occupied by the lamelliform, and $\frac{2}{1500}$ths by the outer or fibrous portion of the enamel. The latter lies at an angle of 15° with the surface of the dentine.

It will be seen, on referring to the description of the corresponding teeth and sections of *Mus decumanus*, that the angle at which the laminæ of enamel fibres leave the surface of the dentine, is sufficiently different from that in the *Hapalotes* to distinguish the teeth of these creatures from each other.

The molars of the *Hapalotes* resemble those of the Rat. I am indebted to the kindness of Mr. GOULD for an opportunity of examining the teeth of these animals.

Gerbillus Shawii (DEVERN.) stands next on my list. The dentine of the incisors of this small rodent is peculiar in having a few vascular canals extended from the pulp-cavity a short distance into its substance, which in a transverse section gives an uneven outline to the surface of the pulp-cavity. The dentinal tubes give off branches throughout the whole of their course, are interspersed with small cells, and are subject to irregular secondary undulations; in addition to which, the whole substance of the dentine has a cellular appearance as though the developmental cells had retained their outline during the process of calcification, instead of becoming confluent and homogeneous.

In a longitudinal section the laminæ leave the surface of the dentine at an angle of 55°, and curve upwards and outwards through about $\frac{6}{1500}$ths of an inch: they then give place to the fibrous portion in which the fibres curve upwards and outwards, their general course being at an angle of 20° with the surface of the dentine.

The laminæ are bordered by blunt serrations, and are subject to transverse markings, in both particulars resembling the enamel of the corresponding teeth of the *Hapalotes* more closely than that of the Rat.

In a transverse section the enamel of the incisors could not be distinguished from that in the Rat.

In the molar teeth the dentinal tubes are continued into the enamel the 1500th of an inch. In no part of the latter tissue could I distinguish a lamelliform arrangement in the enamel.

The teeth of *Hydromys chrysogaster* of New South Wales resemble those of the Rat. The incisors of the Hamster, *Cricetus fumentarius* (PALL.), can scarcely be distinguished from those of *Mus decumanus*.

Hesperomys Darwinii (WATERHOUSE) possess teeth so like in minute structure to those of *Mus decumanus* that a special description is unnecessary.

Geomys umbrinus (RICH.), though not placed by Mr. WATERHOUSE in the family Muridæ, have incisors so Rat-like, that it would require the presence of sections of the teeth of this creature and of the Rat to distinguish the one from the other, and even then there would be some difficulty in finding characteristic differences sufficiently well-marked to render the conclusion trustworthy if any doubts were thrown on the authenticity of either of the specimens.

Arvicola amphibius (LINN.).—It would be extremely difficult to point out the characters by which sections of the incisor teeth of this creature could be distinguished from the corresponding ones of several teeth I have already described, especially those of the common Rat (*M. decumanus*). The serrated enamel lamellæ leave the dentine at nearly the same angle; the serrations are perhaps finer and less strongly marked, and the lamellæ are more frequently crossed by equidistant transverse lines. The rootless molar teeth, however, are sufficiently different from those of the Rat. In a longitudinal section, it will be seen that on one side of each denticle the enamel is composed of an inner lamelliform portion, with the edges of the lamellæ serrated as in the incisors, and another portion in which the enamel fibres are parallel; while on the opposite and posterior surface of the denticles the lamellæ are absent, and the enamel fibres pass across the structure in a curved line to the surface. In a transverse section, it is seen that the two conditions pass insensibly into each other at the bottom of the longitudinal grooves, where the component denticle coalesces, and also immediately behind the longitudinal ridges which mark the sides of the teeth.

In the Field Vole, *Arvicola nivalis* (MARTIN), the teeth, both molars and incisors, structurally resemble those of the *A. amphibius*.

The incisors of the Bank Vole, *Arvicola glareolus* (SCHREB.), are rat-like; but in the molar teeth the serrated lamelliform arrangement of the enamel is very indistinct. In the lower incisors the serrations of the lamellæ are shallow, while the transverse markings are rather strong. The appearances presented in a longitudinal section are delineated in fig. 34.

The incisors of *Lemmus Norwegicus*, DESM. (Zoological Society), do not offer any structural differences from the preceding group worthy of description.

Fiber zibethicus (LINN.).—This animal is placed by Mr. WATERHOUSE in the family MURIDÆ, section *Arvicolina*. The dental tissues do not well accord with that position, but seem to indicate a nearer relation to the Beaver and Dormouse. In the molar teeth, however, the enamel in places resembles that in the corresponding organs of *Arvicola amphibius* and *A. nivalis*, but the serrated lamelliform arrangement is not as uniform or as well-marked as in those animals. Yet Mr. WATERHOUSE's arrangement of Rodentia is, with but few exceptions, so strongly corroborated by the structure of the dental tissues, that in this case, where there is conflicting testimony in these tissues as to where they should be placed, I shall do well to describe them in the position he has assigned to the animal.

In the upper incisors, a few vascular canals radiate from the pulp-cavity into the dentine, but they are far less numerous, and run a shorter course than in the corresponding teeth of the Beaver. The dentinal tubes resemble those of the latter animal, excepting that they terminate at the enamel, without the presence of a peripheral layer of cells.

A longitudinal section exhibits the enamel lamellæ passing outwards in an irregular sigmoidal curve, their general direction being at an angle of 80° with the surface of the dentine. Immediately on leaving the dentine the layers make a short curve upwards and outwards, during which the margins are serrated; the serrations then become indistinct or altogether cease, and the layers pursue a tolerably straight course till near their termination, when they turn upwards, after which the component fibres become parallel and advance to the surface at an angle of 33° with the dentine.

On looking carefully over a longitudinal section, parts will be found in which the transverse direction of the lamellæ appear to be reversed. Fibres, or layers of fibres, will be seen running for a short distance obliquely in the long axis of the tooth.

In a transverse section the fibres of the alternate layers are seen to cross each other obliquely, so as to produce a diamond pattern over the lamelliform portion of the enamel. In the earlier part of their course the fibres curve a little, but afterwards become straight. In the outer part of the enamel the fibres pass directly outwards without leaning to the one side or the other.

In the lower incisors the structure of the enamel not unfrequently presents a confused appearance, as though the lamellæ were subject to some irregularity in arrangement. In a longitudinal section the enamel layers are seen leaving the surface of the dentine at an angle of 50°, and in their course curve a little outwards. The margins are pretty strongly marked with small oblique serrations and oblique transverse lines. The lamellæ have a thickness of about the 5000th of an inch. The enamel has a thickness of about the $\frac{9}{1800}$ths, the lamelliform portion of which is about the $\frac{7}{1500}$ths of an inch. In a transverse section parallel with the course of the lamellæ, the decussation of the alternate layers of fibres may be seen; and in a section a little more oblique, the fibres in the terminal part of their course may be seen passing in straight lines obliquely outwards from the median side of the tooth. In the dentine of the lower incisors, the vascular canals are much less abundant than in that of the corresponding upper teeth.

The confluent denticles of the molar teeth are coated with enamel, which is very irregularly lamelliform, with serrations so indistinctly marked and inconstant, that the appearance scarcely merits the name. A longitudinal section will best exhibit this view. In a transverse section, parts may be found in which the decussation of adjoining layers of fibres is visible, but generally the fibres seem to follow a much less regular and constant course; and in places they are parallel, as in the outer part of the enamel of the incisors. However, when we find the decussation, it will be situated on the anterior surface of the denticles; so far the structure resembles that found in the corresponding teeth of the Water-Rat, and, as in that animal, the enamel on the posterior surface of the denticles is uniformly free from the lamelliform arrangement. Near the masticating surface of the molar teeth the enamel fibres are so intimately blended, that little or no structure can be discerned.

The cementum, in no part of the tooth very abundant, is occupied by very large irregular cells and vascular canals. The latter are very large, have nodulated margins, and run principally in the transverse axis of the tooth. The tissue of the cementum, as seen in a transverse section, is unusually clear and transparent.

I am indebted to Mr. WATERHOUSE for a list of those rodents which he considers the most typical species of the several divisions of his family Hystricidæ, and have been fortunate in obtaining the teeth of all he has enumerated, excepting *Echimys*.

In the dentine of these teeth, I find nothing that is characteristic of the group. But the enamel is very peculiar, and the peculiarity is constant in each species I have examined. So strongly is the family characteristic marked by the peculiar arrangement of the fibres of this tissue, that it is necessary to have seen the structure in one hystricine tooth only, to be enabled to recognize at first sight the tooth of any other species as a member of the same group. We no longer see in a longitudinal section of an incisor uniform laminæ separated in the lamelliform portion of the tissue by well-defined lines, but in their stead find thick and confluent layers of obliquely placed fibres, which in a transverse section are seen to pursue a serpentine course from the dentine towards the surface, near to which they become straight and parallel as in the corresponding part of the enamel of the teeth previously described. Hence in this as in the preceding group, I need describe minutely the structure of the incisors of one species only. The molar teeth offer greater variety in the arrangement of the component tissues, and may require farther notice.

Hystrix cristata (LINN.).—In the incisors, the enamel attains a thickness of about the 45th and the dentine the 4th of an inch. The latter tissue offers no striking peculiarities; near the enameled surface it is tenanted by obliquely placed elongated cells, similar to those found in the incisors of the Beaver and many other teeth: they are shown in fig. 35 D.

In a longitudinal section, the enamel presents a very beautiful and, as compared with the tissue as it occurs in the preceding families, a very novel appearance. Large confluent laminæ of from the 1000th to the 1500th of an inch in thickness, leave the dentine at an angle of 80°. Each layer is composed of enamel fibres directed obliquely, and the obliquity varies in the adjoining layers, but corresponds in the alternate ones, in the manner delineated in fig. 35 E. But the fibres are not oblique in one direction only; one extremity of each fibre may be traced to dip into or under those of the contiguous layers, while the other extremity is usually cut obliquely across, and exhibits a diameter of about the 5000th of an inch. When within the 250th of an inch of the surface the layers gradually disappear, and their component fibres take a parallel course, and at an angle of 30° proceed to the surface.

In an oblique transverse section parallel with the course of the enamel laminæ, the appearances are even more striking than in the longitudinal one. The enamel looks as though the fibres were thrown into waves, the furrows of which commence at the surface of the dentine, and proceeding obliquely outwards, crop out where the fibres become parallel, and form the external portion of this tissue; their direction is shown in fig. 36. A close inspection of a favourable section will enable the observer to see that the enamel fibres pursue a serpentine course, and in the lamelliform portion describe three tolerably uniform curves (fig. 36 E.). Then again, by altering the focus of the microscope, without changing the position of the section, it may be seen that the fibres immediately above and below those already observed, pursue a similar serpentine course, but arranged so that the concavities and convexities point in opposite directions, like the two sides of the figure 8. The appearance thus produced is shown in fig. 39, which in this particular must be regarded as a diagram rather than an accurate portrait. This crossing and re-crossing in curved lines, together with the cropping out of the curves of the contiguous fibres, produces a most complex appearance; and if the section be not parallel with the length of the fibres, the structure appears, to one who has not given attention to the subject, so confused as to defy explanation. If the section be so made as to expose in their length the enamel fibres of the middle of the anterior part of the tooth, those near the sides will be cut obliquely and present a penniform arrangement. An oblique longitudinal section will exhibit the fibres of alternate layers divided almost transversely, while those of the intermediate ones are exposed, taking an oblique course: this point is shown in fig. 37. In addition to the peculiarities already enumerated, small rounded cells are scattered through the enamel of this and most other Hystricine teeth.

The dentine of the molar teeth of *Hystrix cristata* is peculiar in having its tubes unusually free from lateral branches during the greater part of their course. The secondary undulations are strongly marked; and on approaching the enamel, the terminal branches are comparatively few in number and large in size, and commonly pass the 750th of an inch into the enamel.

Near the termination of the dentine in the root of the tooth, the dentinal tubes radiate from a number of centres, and the tissue graduates into the cementum, which is very abundant in this situation, and forms a considerable portion of the root.

In a longitudinal section the enamel fibres are seen to proceed upwards and outwards in parallel lines till near the surface, when they assume a similar arrangement to that seen in the incisor teeth. When the enamel is thin, the lamelliform arrangement is scarcely seen; but where it exists in a tolerably thick layer, the confluent laminæ commence near the dentine. It should be remarked that in the Hystricine molar teeth, the usual position of the fibrous and lamelliform divisions of the enamel is reversed. Hitherto we have found the fibrous enamel placed externally; but here and in the succeeding family, the lamelliform enamel occupies the external position in the molar teeth.

Hystrix prehensilis (Linn.).—The incisors in microscopic structure closely resemble those of the common Porcupine. In the molar teeth, the dentinal tubes are continued about the 1000th of an inch into the enamel.

Dasyprocta Aguti (Linn.).—A longitudinal section of an incisor shows that the dentine of the anterior part of the tooth is bordered by a layer of obliquely placed elongated cells, about the 750th of an inch broad. The enamel is composed of confluent laminæ of obliquely placed enamel fibres, which have a diameter of about the 5000th of an inch, while the layers have a thickness of from the 1362nd to the 2150th of an inch, and leave the dentine at an angle of 65°. In the outer division of this tissue the fibres lie at an angle of 35° with the surface of the dentine.

Prof. OWEN describes the structure of the teeth of the Agouti from a longitudinal section of an upper incisor, and says, "The fibres composing the inner and more opake part of the enamel proceed obliquely, but almost transversely across that substance, with a gentle curve in the opposite direction to the last curve of the contiguous dentinal tubes, viz. with the convexity towards the crown: the fibres of the peripheral layer of the enamel make a slight bend towards the crown; these enamel fibres are as thick as two of the dentinal tubes with their interspaces; their ends are lost in the clear peripheral substance to which the distinct, apparently structureless brown layer of cement is attached, and to which the colour of the convex surface of the incisor is due*."

Had Prof. OWEN made transverse sections of this tooth, he would I think have been led to give a wholly different account of the enamel; he would have seen the waved appearance which closely corresponds with that I have described in the incisor teeth of the Porcupine, and is produced by a similar flexuous arrangement of the component fibres; he would also have seen that the brown colour is resident in, and is due to a stain in the terminal ends of the enamel fibres. The enamel of the molar teeth of this animal resembles that of the corresponding teeth of the Porcupine.

Dasyprocta Acouchy (ERXL.). The dental tissues of this creature closely resemble those of the preceding species.

Cœlogenys Paca (SCHREB.).—The dentine of the incisor teeth does not differ very perceptibly from that of the corresponding teeth of the Agouti and Porcupine. It measures about the 5th of an inch, while the lamelliform portion of the enamel is about the 107th, and the fibrous 300th of an inch in thickness. In a longitudinal section the confluent layers of enamel fibres leave the dentine at an angle of 70°, and the fibres in the outer fibrous part of the tissue lie at an angle of 40°. The layers have a thickness of from the 1000th to the 1667th of an inch; and the fibres are about the 5000th of an inch in diameter. In an oblique transverse section the waves of the enamel fibres are more strongly marked than in the enamel of the Porcupine, as shown in fig. 38.

An oblique longitudinal section shows with great distinctness alternate layers of fibres divided more or less transversely, and intermediate ones pursuing an oblique course. Fig. 37 illustrates faithfully this strongly-marked and peculiar appearance.

Capromys Fournieri (DESM.).—The dentine terminates at the enamel without the presence of oblique elongated cells, but small rounded cells are present and intermingled with the terminal anastomosing branches of the dentinal tubes. The dentine of a lower incisor measures about the $\frac{3}{25}$th, the lamelliform portion of the enamel the

* Odontography, page 404.

83rd, and the external about the 500th of an inch. In a longitudinal section the confluent laminæ leave the dentine at an angle of 55°, while fibres of the outer part are placed at an angle of 20° with the surface of the dentine (fig. 40). The layers have a thickness of from the 1500th to the 3000th of an inch.

Myopotamus Coypus, Molina (Zoological Society).—The dentine of the incisors at its anterior termination is occupied by small rounded cells, with which the terminal branches of the dentinal tubes freely communicate, and in addition to which many areolar-shaped cavities exist similar to those found in imperfectly developed human and other dentine*.

The enamel presents the true Hystricine character, but the layers in a longitudinal section are more confluent than in the teeth previously described. They leave the dentine at an angle of 56°, and the fibres in the outer portion of the texture lie at an angle of 40° with the surface of the dentine.

In an oblique transverse section of an incisor parallel with the worn surface of the tooth, the fibres are seen to make four undulations, but they are less deep than those seen in the ***Porcupine*** and ***Paca***. Near the terminal edge of the enamel on the sides of the tooth, in this as in other Hystricine incisors, the fibres make but one or two gentle curves. The confluent laminæ, as seen in a longitudinal section, have an average thickness of about the 1000th of an inch, and the enamel fibres a diameter of the 5000th of an inch.

I find in the enamel of this tooth here and there irregularly rounded interspaces, vacant or occupied by a transparent structureless mass. This perhaps may be a peculiarity confined to the individual specimen. The dentine of the lower incisor has a thickness from back to front of the 3rd, the lamelliform portion of the enamel the 40th, and the external fibrous part the 500th of an inch. The cementum is continued from the sides of the tooth a short distance upon the enamel, but does not blend with the terminal ends of the enamel fibres. On the contrary, the two tissues are separated by a well-defined line.

Octodon Degus, Molina (Zoological Society).—In the lower incisors the dentinal tubes of the anterior half of the tooth terminate in fine branches, with which few if any cells are intermingled. The tubes at their commencement in the pulp-cavity are comparatively large, and attain a diameter of about the 5000th of an inch.

The enamel of this small tooth is truly Hystricine in character. The confluent layers leave the dentine at an angle of 45°, which in the outer fibrous part of the texture is reduced to 20°. The 1500th of an inch is the average breadth of the layers, the component fibres of which have a diameter of from the 7500th to the 5000th of an inch. The dentine has a thickness of about the $\frac{3}{55}$th, the lamelliform portion of enamel the 1ı6th, and the external part the 750th of an inch.

In the molar teeth the enamel fibres describe a faint sigmoid curve in their passage

* Lectures on Dental Physiology and Surgery.

outwards, where the tissue exists as a thin layer; but in those parts in which it is more abundant in quantity, the fibres in the external part of their course assume the confluent lamelliform arrangement.

Schizodon fuscus (WATERH.).—In the incisor teeth, a few vascular canals are continued from the pulp-cavity into the posterior half of the dentine. The dentinal tubes branch from their commencement and terminate in the anterior part of the tooth in fine tubules without the presence of peripheral cells. They have a diameter of about the 6000th of an inch.

The enamel has a general resemblance to that described in the last species. The confluent laminæ have a thickness of about the 2300th of an inch and leave the dentine at an angle of 50°, which in the fibres of the exterior is reduced to 15°. The dentine has a thickness of about the 15th, and the enamel the 166th of an inch, of which 13 parts are lamelliform and 5 parts fibrous and external.

In the molar teeth the enamel fibres advance one third of their course in parallel lines, and then fall into the confluent lamelliform arrangement, but with less precision than in the incisor teeth.

Spalacopus Pœppigii (WAGNER).—The dental tissues of the incisor teeth of this animal resemble pretty closely those of the preceding species. The posterior half is not however permeated by vascular canals. The enamel has a thickness of about the 150th of an inch, of which seven-tenths is lamelliform, and three-tenths external and fibrous. The inner part of the external division is tenanted by small rounded cells, which confuse the fibrous character of the part. The laminæ lie at an angle of 50° with the surface of the dentine, while the fibres of the outer part pass upwards at an angle of 25°, and finally turn outwards and advance to the surface at an angle of 90°.

Habrocoma Bennettii (WATERH.).—In the incisors of this creature, a few vascular canals are continued from the pulp-cavity for a short distance into the posterior half of the dentine. The dentinal tubes give off short branches from their commencement, undulate irregularly, and are not very uniform in size. They end without the presence of an anterior peripheral layer of cells. The confluent layers of enamel fibres leave the dentine at an angle of 50°, and have a thickness of about the 1666th of an inch. The fibres of the outer portion of this texture lie at an angle of 15°, the thickness of this part being about $\frac{2}{14}$ths, while the lamelliform portion occupies $\frac{12}{14}$ths of the whole thickness, which measures about the 108th of an inch in thickness: fig. 42 and 43 show the texture in a longitudinal and a transverse section. The molar teeth of this species of *Habrocoma* closely resemble those of *Schizodon fuscus*.

Chinchilla lanigera (MOLINA).—The dental tissues both of the molar and incisor teeth strongly resemble those of the four preceding species. In the incisor the dentine is without a peripheral layer of cells in the anterior half, and without vascular canals in the posterior half of the tooth. In a longitudinal section the confluent layers of enamel fibres have a thickness of about the 1500th of an inch, and leave the dentine at an angle of 50°, which is diminished to 20° in the fibres of the outer portion of the tissue. In a transverse section, it is seen that the fibres in the outer part of the enamel are directed obliquely from the median line of the skull. The enamel fibres have a diameter of about the 6000th of an inch, and are intermingled in the lamelliform portion of the tissue with minute rounded or oval cells, which contribute to give the structure a confused appearance.

Cavia Aperea (Erxl.).—A layer of obliquely placed cells occupies the periphery of the enamel-coated anterior of the incisors. The dentinal tubes have slightly irregular parietes, and the intervening tissue has a mottled cellular appearance. In the posterior half of the tooth, the tubes as they approach the periphery throw out numerous characteristic thick branches, which from their number and size render a section of this part very opake.

The enamel is strongly Hystricine in character, and is dotted over with minute rounded and branchless cells*. In a longitudinal section of a lower incisor, the confluent laminæ leave the dentine at an angle of 45°, which is reduced to 20° in the fibres of the external part of the tissue, and the layers are about the 1500th of an inch thick: these characteristics are shown in fig. 44. The whole thickness of the enamel amounts to the 170th of an inch, of which two-thirds is occupied by the lamelliform portion of the tissue.

In the upper incisors the angle of 60° is that at which the lamellæ leave the surface of the dentine, while the terminal extremities of the fibres lie at an angle of 20° with the dentine. The enamel does not exceed the 212th of an inch in thickness, of which five-sevenths is lamelliform.

Cavia Kingii (Bennett).—The dental tissues of this animal are very similar in structural character to those of the common Guinea Pig. The enamel is however less crowded with cells, and hence is much more transparent.

Hydrochœrus Capybara (Erxl.).—Many vascular canals are continued from the pulp-cavity into the posterior half of the dentine in the incisor teeth of this great rodent. A few branches pass from the dentinal tubes throughout the whole of their course, and become more numerous near the periphery of the tissue, which in the anterior part of the tooth is bordered by a dense layer of irregular-shaped cells, that occupy a line the 500th of an inch thick, as shown in fig. 46.

The enamel exhibits the true Hystricine character, both in the longitudinal and transverse sections, but less strongly marked than in any of the previously described teeth belonging to animals of this group. The laminæ are more confluent, and the component fibres occupy a less oblique and more parallel position than we have been accustomed to see them; in a longitudinal section the enamel near the dentinal surface is crowded with small cells, and the laminæ are at this part indistinctly marked. A little farther out they become more strongly developed, and have the

* The cells in the enamel of this and in all the species described in this paper, have no proper parietes, and should be regarded as interspaces rather than cells in the sense now attached to that term.

appearance of being in pairs, the fibres of which proceed obliquely outwards from a central line common to the two, as shown in fig. 46. In the outer division of the tissue the component fibres are so intimately united, that in places only can their course be traced. In a longitudinal section the lamellæ leave the dentine at an angle of 70°, which is reduced to 30° in the outer part of this substance. The layers have a thickness of about the 700th of an inch, and the component fibres a diameter of the 7500th of an inch. The whole thickness of the enamel amounts to the 79th of an inch, of which $\frac{16}{19}$ths is lamelliform.

In a transverse section of an upper incisor, the enamel fibres are seen to make one bold sigmoid curve in the lamelliform portion of the tissue. In fig. 45, a layer of fibres is shown with as much of the one immediately beneath as could be seen without shifting the focus of the instrument.

The enamel of the molar teeth exhibits much the same structural appearance as that of the incisors, excepting that the cells which occupy the inner part of the tissue in the latter teeth, are absent in these.

Brathyergus maritimus, GML. (Zoological Society).—This animal has been placed by Mr. WATERHOUSE in a section immediately preceding Hystricidæ*. The teeth are however Hystricine in structural character, and might be described either in this place or at the beginning of the family.

The dentine of the anterior parts of the tooth is bordered by a narrow layer of cells. The dentinal tubes have small hair-like branches through the whole of their course. In a longitudinal section of an upper incisor confluent layers of enamel fibres leave the surface of the dentine at an angle of 50°, and after extending about the 210th of an inch, are insensibly lost in the parallel arrangement of the fibres in the unusually thick external division of the tissue, which in this tooth amounts to the 120th of an inch in thickness, as shown in fig. 47. The tissue is dotted near the surface with minute cells. A transverse section is not altogether unlike a corresponding one from the incisor of the *Capybara*.

Pedetes Cafer (PALL.).—This animal is placed by Mr. WATERHOUSE in the family *Muridæ*, section *Dipodina*. The dental tissues of the incisor teeth have the Hystricine character strongly marked, while those of the molars are intermediate between the Hystricidæ and Leporidæ. The true position of the tissues in this family can only be determined after the majority of the species have been examined, which in itself will be a work of some labour, apart from the difficulty of obtaining authentic specimens. In the absence of correct information of its position, I have as a matter of convenience placed my description at the end of the Hystricine group.

In the incisors the dentine has several minor points of peculiarity. The pulp-cavity in a transverse section of a lower incisor approaches a triangular figure with the angles extended and rounded at their extremities, two of which are directed to the lateral anterior angles of the tooth, and the third extends in the median line into the

* Johnston's Physical Atlas.

posterior half, in addition to which the walls of the cavity have two deep indentations on the median side and one on the outer side of the tooth. From each of the angles a line of small vascular canals is continued a short distance into the dentine, which tissue is marked by numerous concentric and broad, but ill-defined and interrupted contour lines, which follow the involutions of the surface of the pulp-cavity. They seem to be produced by a greater density of the tissue in these than at other parts. The dentine has a generally diffused cellular appearance. The dentinal tubes have an irregular outline, and have small lateral branches throughout the whole of their course. When divided transversely they show thick and strongly-marked parietes, and have an internal diameter of about the 6000th and an external one of the 3000th of an inch. On nearing the enamel, the tubes give off larger and more numerous branches, and ultimately terminate in small oval or rounded branching cells.

In the upper incisors the vascular canals are more abundant in the posterior than in the anterior part of the tooth. The pulp-cavity is occupied near its apex with secondary dentine, the tubes of which proceed from the surface towards the centre and give off many branches; when viewed by transmitted light they resemble tufts of moss. The enamel is strongly Hystricine in character. In a longitudinal section of a lower incisor the confluent laminæ leave the dentine at an angle of 60°, which in the external division of the tissue is reduced to 25°. The enamel has a thickness of the 79th of an inch, of which $\frac{13}{19}$ths is lamelliform. The component fibres of the lamellæ have a diameter of about the 7500th of an inch.

The dentinal tubes in the molar teeth proceed from the pulp-cavity in nearly a straight course upwards and outwards at an angle of 20°. When within the 500th of an inch of the enamel, they turn a little more outwards and afterwards a little upwards, thus describing a small final curve, the convexity of which is directed towards the base of the tooth. But few branches pass off till the dentinal tubes make their final curve, when many leave both their convex and concave sides. Vascular canals are continued from the pulp-cavity into the dentine, as in the incisor teeth. The arrangement of the component fibres of the enamel in the molars is peculiar, and probably characteristic of the tooth of this creature. In a longitudinal section the fibres in the first two-fifths or half of their curve are straight and parallel, and lie at an angle of 40° with the surface of the dentine. Afterwards they suddenly fall into the confluent lamelliform arrangement, and with this disposition reach the surface of the tooth, as shown in fig. 48. In the folds which lie between the confluent denticles, the enamel is thinner than on the exterior of the tooth; the loss of thickness is principally at the expense of the outer lamelliform portion. In a transverse section the fibres of the lamelliform portion are seen to make a open letter *ſ* curve, which is reversed in direction in the contiguous layers, but parallel, or nearly so, in the alternate ones. The appearances seen in this section are delineated in fig. 49. Both in the transverse and longitudinal sections the lamelliform portion of the enamel is crowded with small branchless cells.

The uniform presence and more constant breadth of the inner fibrous portion of the enamel is rather unusual in Hystricine teeth, while it is constant and exists in even a greater degree in the molars of the Hare. In this particular therefore the molars of the Helamys show a slight relation to those of the Leporidæ.

LEPORIDÆ.—In this family of rodents my observations have been confined to members of the genus *Lepus*. The incisors exhibit a type of enamel which I have seen in the teeth of no other rodents. This tissue is no longer divided into an outer and inner portion, with the component fibres arranged in lamellæ in one and not in the other, and at different angles in the two parts; but, on the contrary, the fibres without a lamelliform arrangement proceed with but slight flexures from the surface of the dentine to the outer surface of the enamel. Neither is the enamel dotted over with cells, as is that of Hystricine teeth in the lamelliform portion of the texture.

Lepus timidus (LINN.).—In the Hare the dentine is permeated by vascular canals, both in the anterior and posterior half of the incisors; but they are more numerous in the latter than in the former part. These canals become in the extruded portion of the tooth lined by a layer of dense non-tubular tissue, presenting the appearances delineated in fig. 51. The anterior enameled part of the incisors is bordered by a peripheral plexus of branches interspersed with a few branching cells, and the posterior half by a plexus of branches without cells. In a longitudinal section, such as that shown in fig. 50, the dentinal tubes from their commencement in all parts of the tooth branch, but in a transverse section the branches seem rather less numerous; hence it would appear that they extend principally in the long axis of the tooth. Prof. OWEN has observed that "the tubes which pass to the opposite or posterior surface of the tooth are less numerous, less parallel, and less closely packed together; they send out more and larger branches, which decussate each other in an elegant arborescent manner*." In addition to these peculiarities, the tubes are sensibly larger in the lateral and posterior than in the anterior part of the tooth. In a longitudinal section, such as that shown in fig. 50, the enamel fibres may be traced through the whole thickness of the tissue. Generally their course is straight, or nearly so, and at an angle of from 50° to 70° with the surface of the dentine, but in places the angle is varied, and the fibres are a little bent in the one or other direction. The tissue is rendered rather unusually transparent by the close union of the component fibres, and its comparative freedom from small cells.

A corresponding section from an upper incisor differs from the one already described principally in the diminished thickness of the enamel. The enamel fibres have a diameter of about the 6800th of an inch.

The molar teeth of the Hare have dentine, which is traversed by vascular canals, that extend from the pulp-cavity to near the peripheral surface of the tissue. Previous to the part coming into wear the canals are lined with a non-tubular tissue, and ultimately become almost or quite obliterated. The dentinal tubes are sensibly larger,

* Odontography, page 405.

and branch much more freely than in the incisors: I do not know a more beautiful microscopic object than a fine longitudinal section of the molar tooth of a common Hare. The enamel, where it exists as a thin layer lining the inflected parts of the confluent denticles, is composed of short fibres, which leave the dentine at a wide angle, and towards their terminal extremities turn a little downwards. But when this tissue invests the outer and more exposed parts of the tooth the amount is much greater; in these parts the enamel is divisible into two portions, the inner of which is composed of straight, uniform and parallel fibres, and the outer part of continuations of the same fibres, but bent about somewhat irregularly, and approaching in places to a confluent lamelliform arrangement. The appearances presented in a transverse section of a molar tooth are delineated in fig. 52; but even in this the arrangement of the enamel fibres in the outer portion of the tissue is regular as compared with what is seen in many parts of the tooth. In the outer part the fibres have the appearance of being smaller than those which lie next the dentine, as shown in the figure.

Lepus cuniculus (Linn.).—The dental tissues in the teeth of the Rabbit so closely resemble those of the Hare, that I doubt the possibility of telling the one from the other, excepting by the external form and size of the entire tooth. The vascular canals are perhaps less numerous in the Rabbit.

Of the following animals I have been able to obtain the molar teeth only.

Lepus Americanus, Erxl. (Zoological Society).—The vascular canals are very numerous and extend to within a short distance of the enamel, where they usually terminate in dilated extremities. In their passage they branch rectangularly and anastomose with neighbouring canals, a circumstance I have not before observed in the vessels of vascular dentine. Each canal becomes surrounded by a layer of transparent tissue, in which are a few lacunæ very similar to those seen in the cement; eventually the canals are lost by the encroaching inwards of the transparent tissue, and lines of branching cells alone remain to mark their former position.

The enamel could not be readily distinguished from that seen in the molars of *Lepus timidus*; a tendency to confluent lamelliform arrangement of the fibres is found in places, and as it appears in a longitudinal section is shown in fig. 53.

In the molar teeth of *Lepus aquaticus* (Bachm.) and *Lepus sylvaticus* (Bachm.), I find no characteristic differences in the dental tissue by which they could be distinguished from each other, or from the teeth of either of the preceding species of Hares.

Before leaving the subject of Hares' teeth, I should state that occasionally fine supplemental enamel fibres may be seen crossing the course of the ordinary ones at a right angle. They do not exceed the 15,000th of an inch in diameter, and are not constantly present; indeed I have only seen them near the basal half of the tooth, where the enamel is not perfectly hardened.

The facts which are recorded in the foregoing pages have been gathered from careful and repeated observations made upon upwards of 350 sections, cut from the teeth of various members of the order Rodentia. When a doubt as to the nature of a tissue has arisen, I have made numerous sections from different parts, and in different directions of the same tooth. In some instances I have made as many as twenty-five from the teeth of one species; and have seldom contented myself with less than three sections.

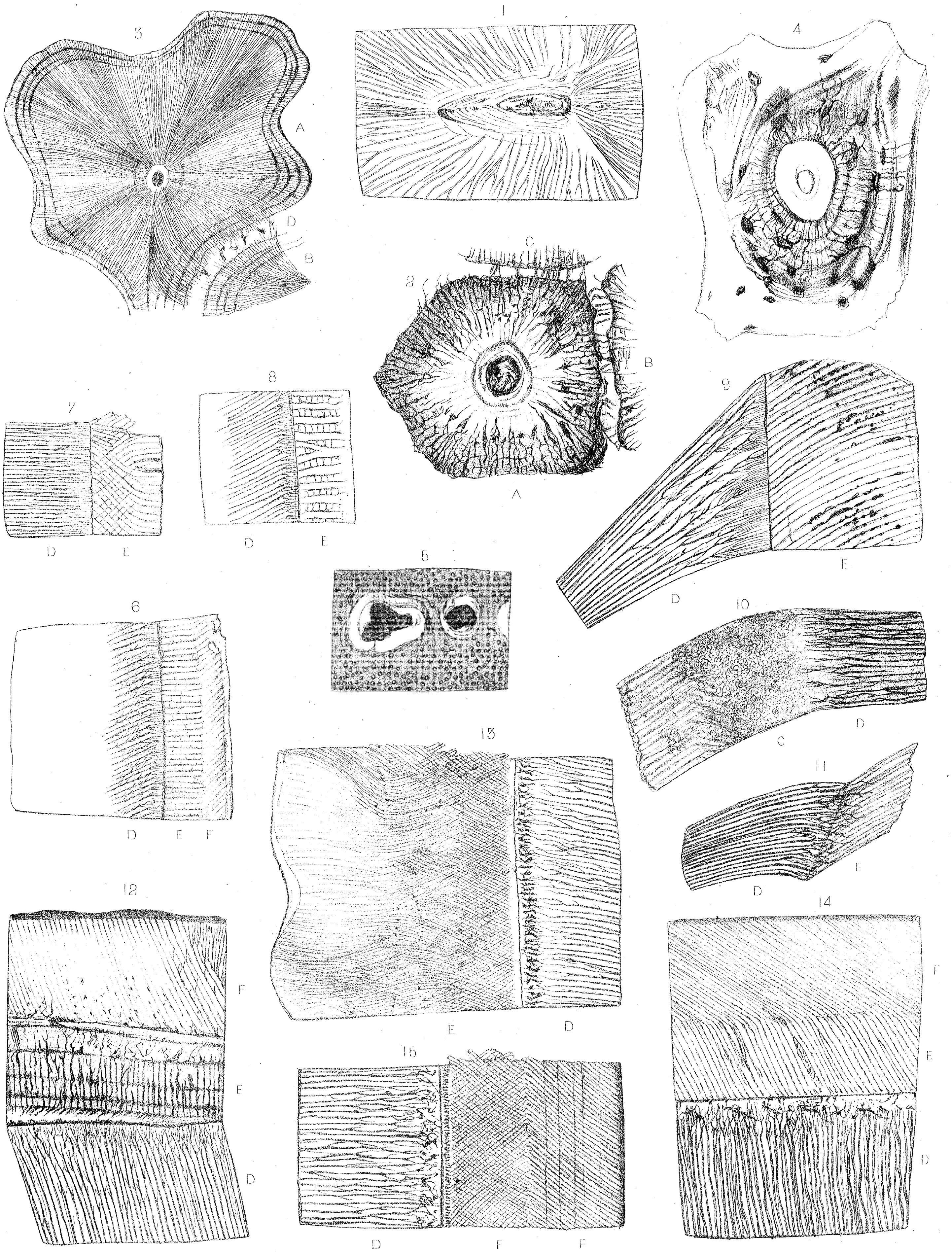
The conclusions which these researches justify depend mainly on the accuracy with which the observations have been made and recorded.

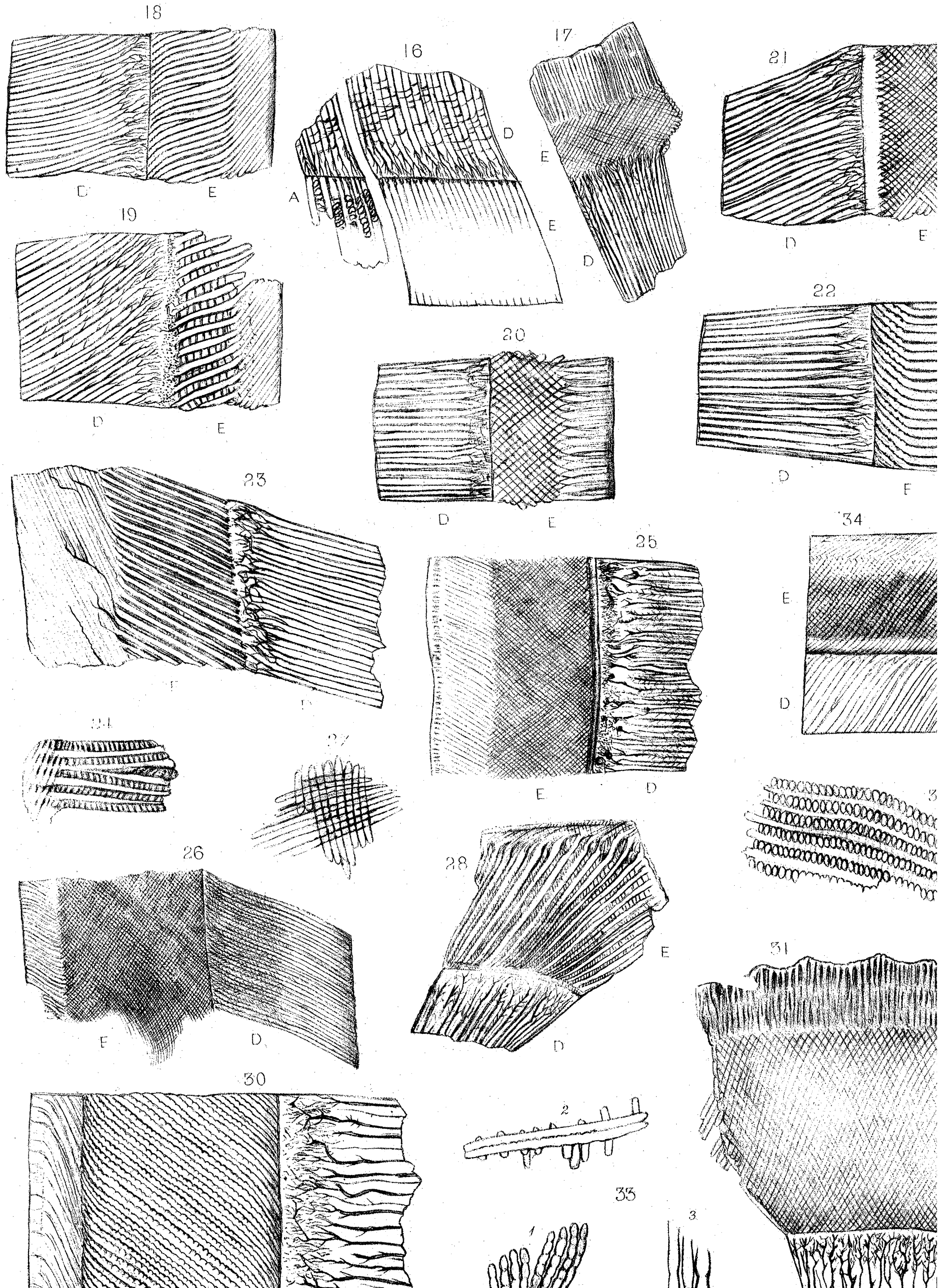
Fortunately, preparations of dental tissues can be preserved for an unlimited period: hence my statements can at any time be tested by an examination of my own or corresponding sections.

Those who will go over the field of observation through which I have passed, will I do not doubt justify me in the following conclusions:—viz. That the teeth of some species of the order have specific structural characters by which they can be distinguished from any other known teeth. That in the teeth of all the Rodentia, excepting the family Leporidæ, a portion of the enamel has a lamelliform arrangement of its fibres. That the enamel lamellæ have a different and distinctive character in each of the larger groups, and that the variety of structure is constant throughout the members of the same group; we may take for examples, the Sciuridæ, the Muridæ, and Hystricidæ, in each of which the structure of the enamel is different, and in each is highly distinctive. And that the varieties in the structure of the dental tissues, with a few isolated exceptions, justify and accord with the arrangements of the members of the order into the several divisions proposed by Mr. WATERHOUSE, and deduced by him from the relations of the several parts of the skull.

The manner in which these various modifications in the structure of the enamel are brought about in its development, together with the adaptation of the varied forms of enamel-tissue to the wants of its possessors, will form the subjects of a future communication.

Feb. 16, 1850.

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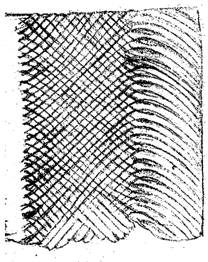

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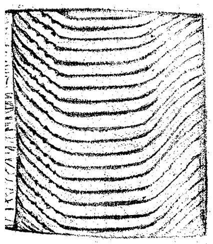

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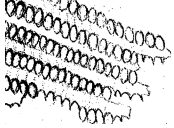

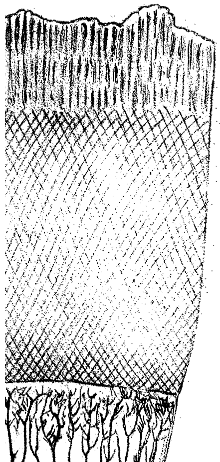

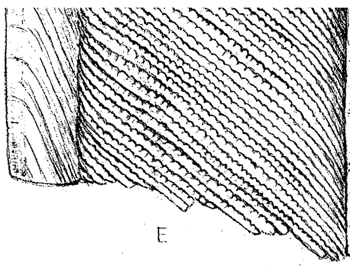

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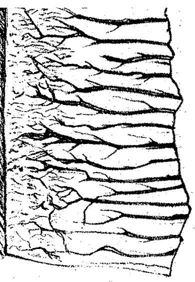

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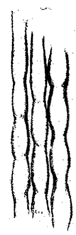

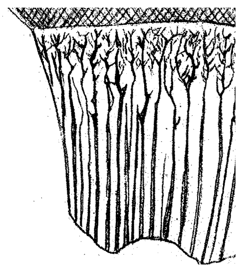

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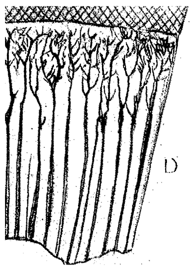

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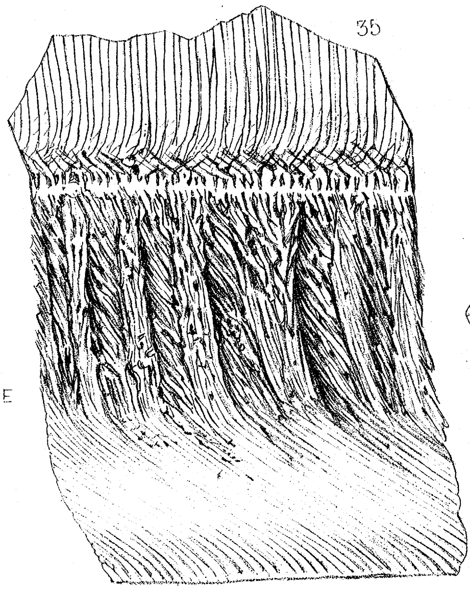

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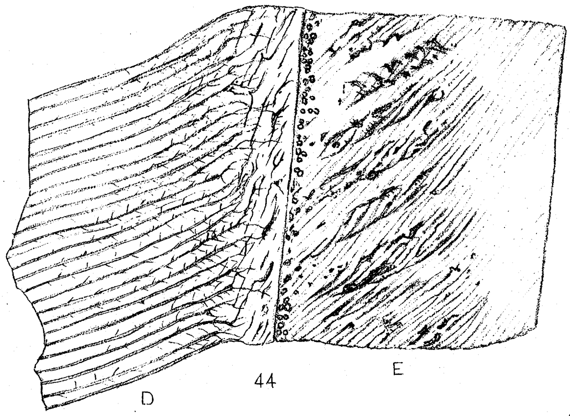

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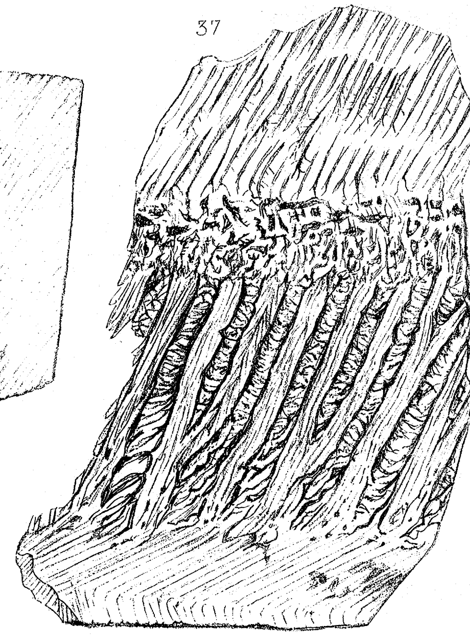

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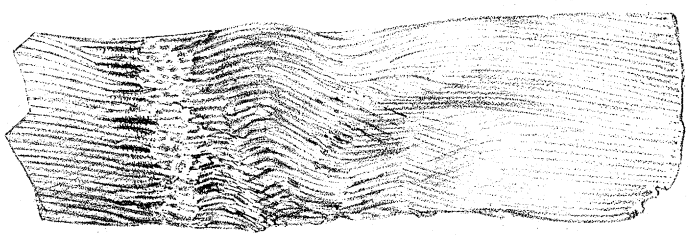

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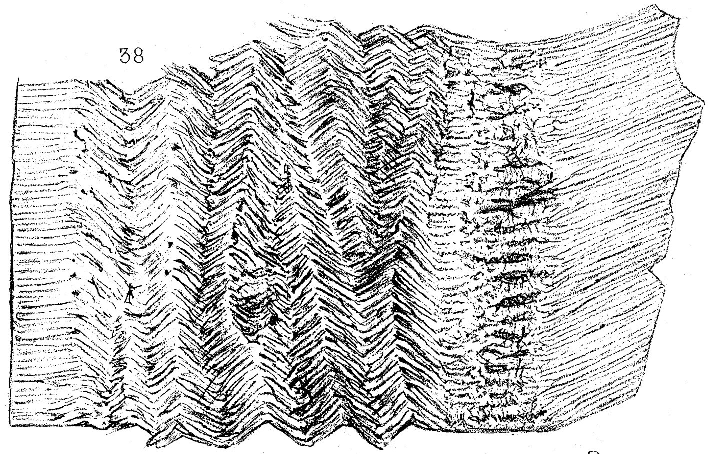

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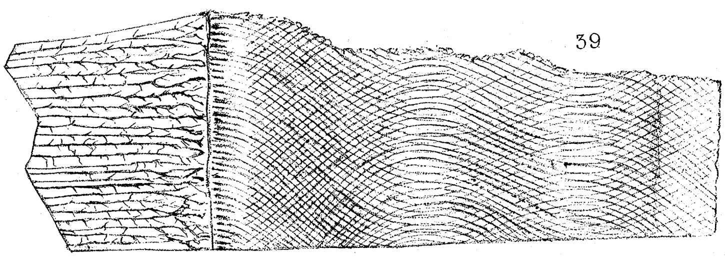

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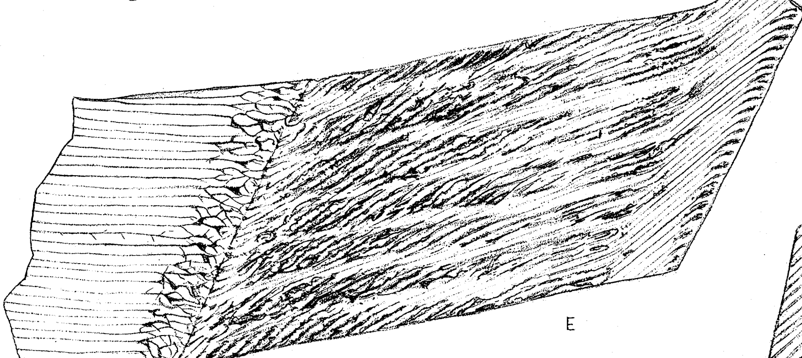

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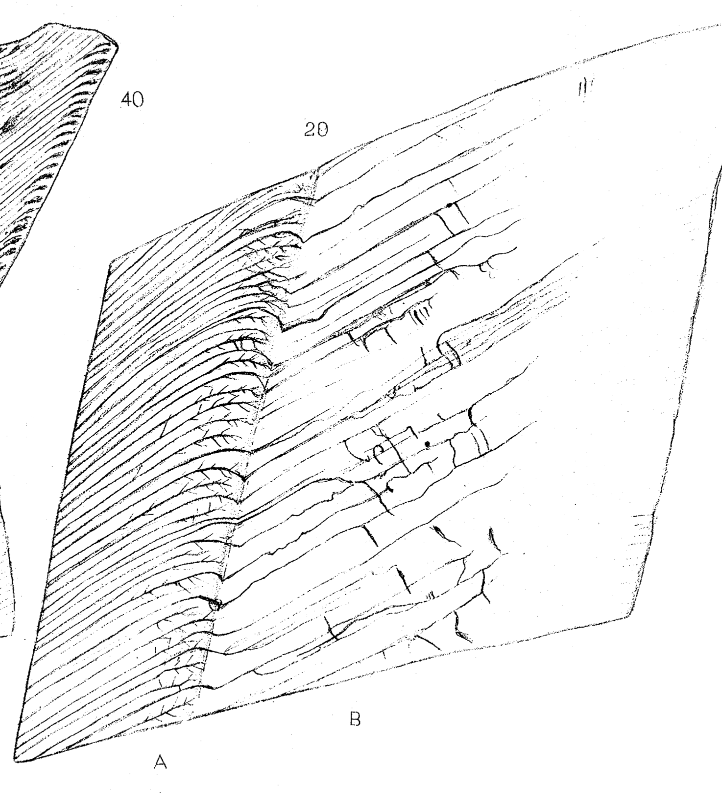

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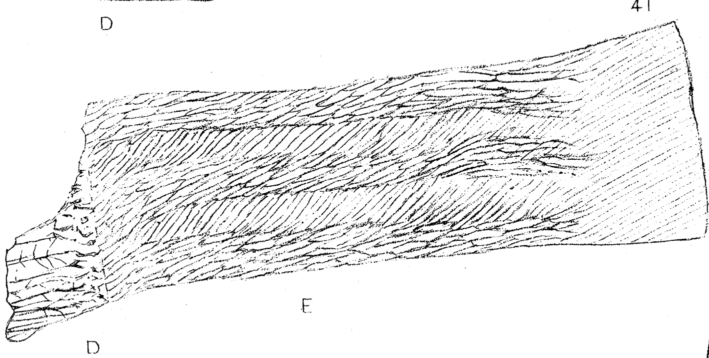

W. Wing, del. et lith.

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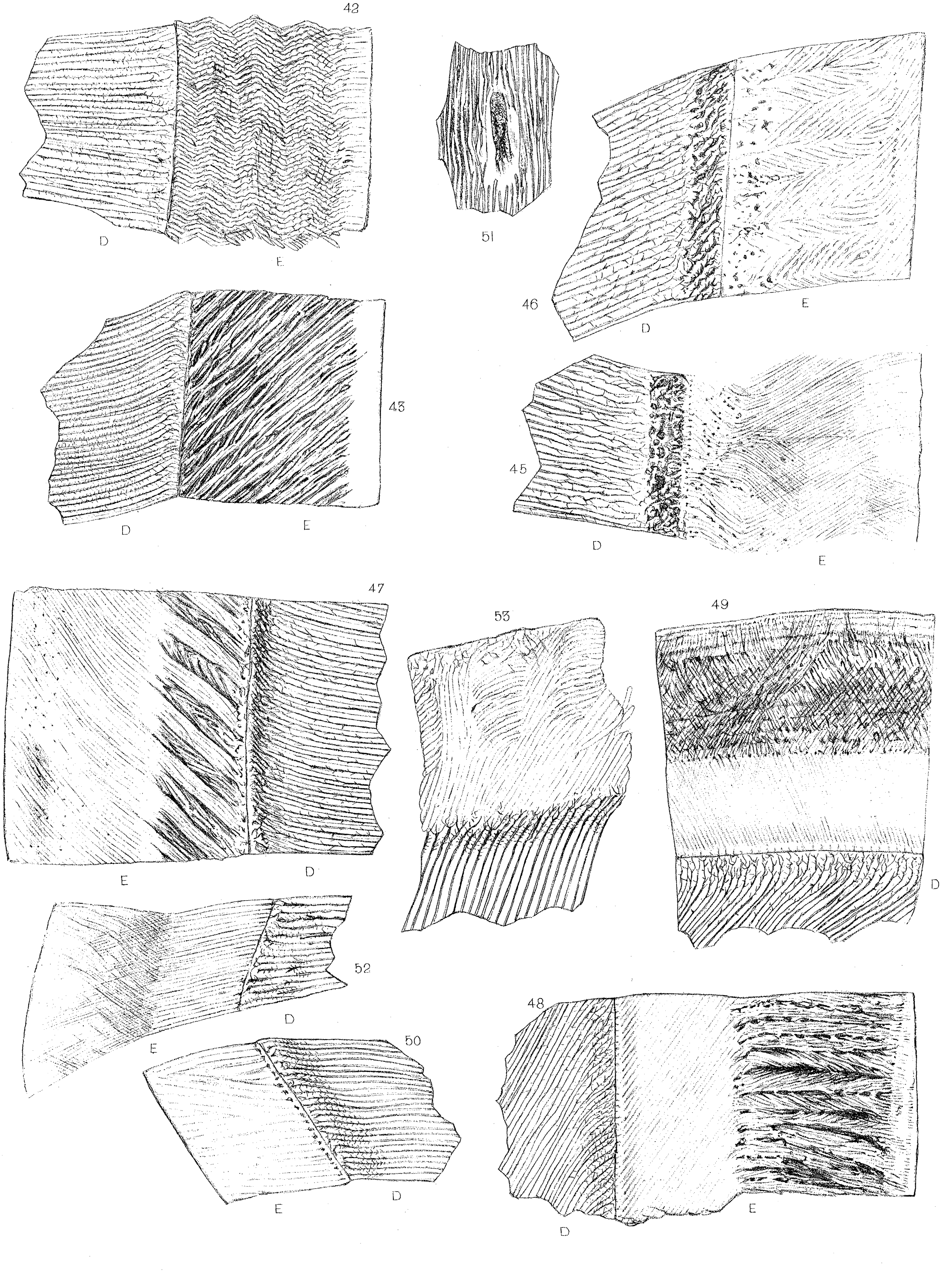

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Ford & George, lithographers 54 Hatton Garden.

EXPLANATION OF THE FIGURES, in each of which D refers to the dentine, and E to the enamel.

PLATE XLIII.

Fig. 1. The middle portion of a transverse section of the lower incisor of *Tamias Lysteri*, showing the manner in which the dentinal tubes are disconnected from the pulp-cavity in that part of the tooth which is about to come into wear by the development of a laminated subgranular tissue. 150 linear.

Fig. 2. A transverse section of a dentinal system, A, and peripheral portion of two contiguous ones, B and C, from the tooth of Orycteropus, showing the manner in which the connection of the dentinal tubes with the surface of the pulp-cavity is cut off by the development of a laminated mass of transparent and apparently structureless tissue.

Fig. 3. A transverse section of a dentinal system, A, and a portion of a contiguous one, B, from the tooth of *Labyrinthodon Jaegeri*, showing the disconnection of the tubes with the pulp-cavity in A, and the process, C, by which this is connected with a contiguous system ; also the peripheral line of cells which intervene and partially connect the terminal branches of the tubes of adjoining systems. (This drawing was made from a section, No. 4 of a series lent to me by Dr. MANTELL.) 75 linear.

Fig. 4. A transverse section of a Haversian system from a Stag's antler which had been cast, showing the transparent tissue lining the canal, and thus cutting off the connection of the canaliculi with the surface of the canal.

Fig. 5. A transverse section from the extruded portion of a molar tooth of *Lepus timidus*, showing that the medullary canals of vascular dentine become lined with a dense non-tubular tissue previous to the part coming into wear.

Fig. 6. A portion of a longitudinal section from an upper incisor of *Sciurus niger*, showing, D, the dentine, E, the enamel lamellæ in their rectangular position, and F, the terminal or fibrous part of the enamel, in which the extent of the colour is marked by a vertical line. 225 linear.

Fig. 7. A transverse section of the same tooth, showing, D, the dentine, and E, the enamel, in which the component fibres of two layers, the decussation and their continuance in the external part of the tissue, are seen. 225 linear.

Fig. 8. An oblique longitudinal section from the base of the same tooth, in which E, the alternate layers of the enamel lamellæ, are cut transversely and longitudinally. In this part of the tooth the external part of the enamel is not fully developed.

Fig. 9. A portion of a longitudinal section from the crown of a molar tooth of *Sciurus niger*, showing, D, the dentine, and E, the enamel, with the fibres interspersed with irregular cells.

Fig. 10. A longitudinal section from the fang of the same tooth, showing, D, the dentine, and C, the cementum, in the outer portion of which the tissue is arranged in rods, and is free from lacunæ.

Fig. 11. A portion of a longitudinal section from the crown of a molar tooth of *Sciurus erythropus*, showing, D, a part of the dentine with the tubes combined into E, a portion of the enamel.

Fig. 12. A portion of a longitudinal section of an upper incisor of *Arctomys pruinosus*, showing, D, the dentine, E, the enamel, with the lamellæ leaving the surface of the dentine at a right angle, and F, the outer fibrous division of the enamel. 150 linear.

Fig. 13. A transverse section from the same tooth, showing, D, the dentine, and E, the enamel.

Fig. 14. A portion of a longitudinal section from the upper incisor of *Castor fiber*, showing, D, the dentine with a peripheral layer of cells, E, the lamelliform portion, and F, the outer fibrous portion of the enamel.

Fig. 15. A transverse section from the same tooth, showing, D, the dentine, E, the enamel, with the decussation of the component fibres of two laminæ, and F, the outer part of the enamel.

PLATE XLIV.

Fig. 16. A portion of a longitudinal section from an upper incisor of *Spalax typhlus*, showing a peripheral portion of dentine with the downward direction of the branches of the dentinal tubes, and E, the enamel; A, an oblique longitudinal section, showing the fibres of alternate laminæ divided transversely. 150 linear.

Fig. 17. A transverse section from the same tooth; D, the dentine, E, the enamel. 150 linear.

Fig. 18. A longitudinal section from an upper incisor of a Dormouse (*Myoxus avellanarius*); D, peripheral portion of dentine, E, the enamel, showing the curved enamel lamellæ and the fibres in the outer part of the tissue. 300 linear.

Fig. 19. An oblique longitudinal section from the same tooth, showing at E alternate layers of enamel fibres divided transversely with the intermediate ones exposed in their length. 300 linear.

Fig. 20. A transverse section of the same tooth. 300 linear.

Fig. 21. A longitudinal section of a lower incisor of *Myoxus avellanarius*, showing at E the decussation of the parallel layers of enamel fibres, and the downward direction of the external ends.

Fig. 22. A transverse section of the same tooth, showing the outward course of the enamel lamellæ, their serrated margins near the dentine, and their vertical position.

Fig. 23. A vertical section from the upper incisor of a Jerboa (*Dipus Ægyptius*), showing, D, the dentine at its anterior peripheral surface, and E, the enamel with a few tubes continued into the outer part. 150 linear.

Fig. 24. An oblique longitudinal section, showing enamel fibres divided transversely and longitudinally. 300 linear.

Fig. 25. A transverse section of an upper incisor of the Jerboa, showing, D, the dentine, and E, the enamel, with the decussation of the fibres of contiguous layers in the lamelliform portion of the tissue, and their parallel course in the outer part of the enamel. 150 linear.

Fig. 26. A longitudinal section of a lower incisor of the Jerboa from near the base of the tooth, showing, D, the dentine, and E, the enamel, with the lamellæ arranged in the length of the tooth. 150 linear.

Fig. 27. Enamel fibres scraped from the partially calcified tissue near the base of the tooth. 600 linear.

Fig. 28. A transverse section of a lower incisor of the Jerboa, showing the enamel lamellæ divided transversely with the fibres of alternate layers cut obliquely, and the intervening one longitudinally.

Fig. 29. Plate XLV. A longitudinal section of a molar of the Jerboa, showing the periphery of the dentine and the dentinal tubes continued into the enamel, with the manner of termination of the tubes in the latter texture.

Fig. 30. A longitudinal section of a lower incisor of a Rat (*Mus decumanus*), showing, D, the terminal portion of the dentine, and E, the enamel, with its serrated lamellæ and its outer fibrous portion. 300 linear.

Fig. 31. An oblique transverse section from the same tooth, showing the crossing of the fibres of contiguous layers, and the pattern thus produced. 300 linear.

Fig. 32. A section from the same tooth, in which the fibres of alternate layers are divided transversely, and the intermediate ones exposed in their length, and show minute denticulations.

Fig. 33. Enamel fibres in various stages of development, obtained from the partially calcified tissue about the base of the incisor.

Fig. 34. A longitudinal section from a lower incisor of the Bank Vole (*Arvicola glareolus*), showing at E the denticulated character of the enamel lamellæ and their transverse markings.

PLATE XLV.

Fig. 35. A longitudinal section of the upper incisor of the Porcupine (*Hystrix cristata*), in which is shown, D, the terminal portion of the dentine with its obliquely placed elongated cells, and E, the enamel with its confluent layers of obliquely placed fibres and the parallel fibres of the outer portion of the tissue. 120 linear.

Fig. 36. A transverse section from the same tooth, showing, D, the dentine, and E, the enamel fibres pursuing a serpentine course in the lamelliform part of the tissue, and a straight parallel course in the external division of the tissue. 120 linear.

Fig. 37. An oblique longitudinal section from a lower incisor of the Spotted Cavy (*Cœlogenys Paca*), showing, D, the dentine with its peripheral layer of cells, and E, the enamel with the confluent layers, and with the fibres of alternate ones divided more or less transversely.

Fig. 38. An oblique transverse section from the same tooth, showing, D, the dentine, and E, the enamel with the fibres in their waved course in the lamelliform portion, and parallel course in the outer portion of the tissue.

Fig. 39. An oblique transverse section from a lower incisor of *Capromys Fournieri*, showing, D, the dentine, and E, the enamel, which in this figure is rather a diagram illustrating the arrangement of the enamel fibres, than a faithful delineation of the appearance presented in the section.

Fig. 40. A longitudinal section from the same tooth, showing, D, the dentine, and E, the enamel, with its confluent laminæ and the oblique constituent fibres.

Fig. 41. An oblique transverse section from the same tooth, showing at E the appearance assumed by the enamel laminæ near the sides of the tooth when the fibres are exposed in their length in the middle part of the section.

PLATE XLVI.

Fig. 42. An oblique transverse section from the upper incisor of *Habrocoma Bennettii*, showing, D, the dentine, and E, the enamel, with the direction of the enamel fibres.

Fig. 43. A longitudinal section from the upper incisor of *Habrocoma Bennettii*, showing, D, the dentine, and E, the enamel with its confluent laminæ. 150 linear.

Fig. 44. Plate XLV. A longitudinal section from a lower incisor of the Guinea Pig (*Cavia Aperea*), showing, D, the peripheral portion of the dentine with its terminal layer of oblique elongated cells, and E, the enamel and its confluent laminæ. 200 linear.

Fig. 45. A transverse section from an upper incisor of the Capybara (*Hydrochœrus Capybara*), showing, D, the dentine, and E, the enamel. 150 linear.

Fig. 46. A longitudinal section from the same tooth, showing the peripheral layer of cells, D, and E, the enamel with the penniform character of the confluent lamellæ. 150 linear.

Fig. 47. A longitudinal section from an upper incisor of *Brathyergus maritimus,* showing, D, the dentine, and E, the enamel with its peculiar Hystricine enamel laminæ, and the large amount of the external division of the tissue. 150 linear.

Fig. 48. A longitudinal section of a molar of *Pedetes Cafer,* showing, D, the dentine, and E, the enamel, with the inner portion fibrous, and the outer lamelliform.

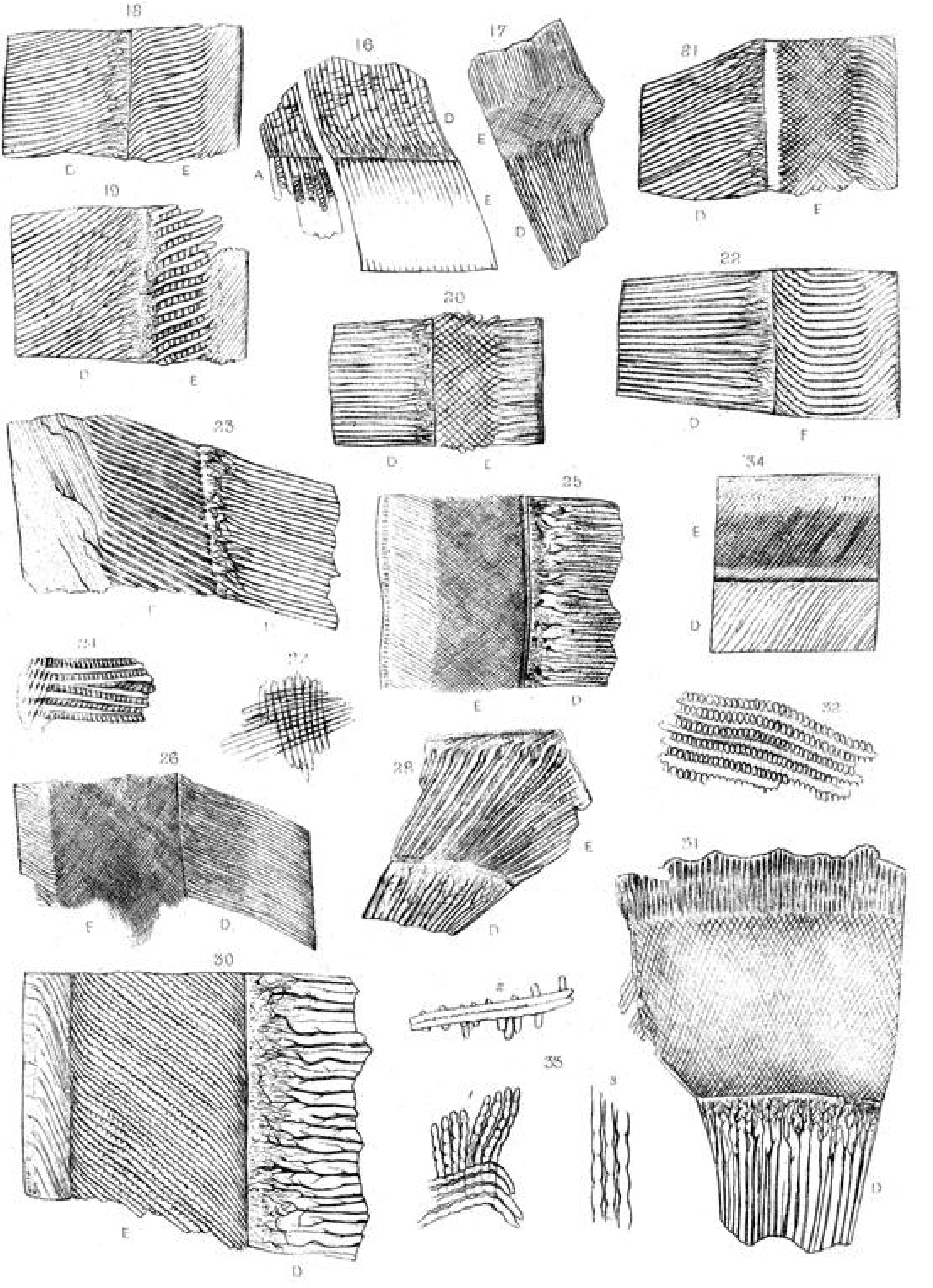
Fig. 49. A transverse section from the same tooth; D, the dentine, and E, the enamel.

Fig. 50. A longitudinal section from a lower incisor of the Hare (*Lepus timidus*), showing, D, the dentine, and E, the enamel fibres, without a lamelliform arrangement, and without a division into an external and internal portion. 200 linear.

Fig. 51. A vascular canal surrounded by a layer of non-tubular tissue, as seen in a longitudinal section of an incisor of the Hare. 300 linear.

Fig. 52. A transverse section from a molar of the Hare (*Lepus timidus*), showing, D, the dentine with its large tubes, and E, the enamel with the fibres in the inner portion parallel, and in the outer curved and irregularly Hystricine. 200 linear.

Fig. 53. A longitudinal section from a molar of *Lepus Americanus,* showing the irregular lamelliform character of the outer portion of the enamel. 200 linear.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