Tooth-Genesis in the Caviidæ. By H. W. Marett Tims, B.A., M.D., F.L.S., F.Z.S., Lecturer on Biology and Comparative Anatomy, Charing Cross Hospital Medical School; Lecturer on Zoology, Bedford College, London.*

[Read 17th January, 1901.]

(Plate 26.)

Though much has been already written concerning the dentition of the Rodentia, no paper has yet appeared, so far as I am aware, dealing with the tooth-genesis of that Order. Previous research has been mainly, if not entirely, in the direction of attempts to discover the germs of teeth no longer functional in the adult, more particularly in the region of the diastema and premaxilla, and thereby to endeavour to homologize the existing incisors of the Rodents with those of other mammals.

The morphological value of an enquiry into the tooth-genesis is due to the fact that several views have been advanced from time to time to account for the origin of the complex crown of the mammalian molars from the Haplodont type of tooth.

In 1896, in a paper dealing with the tooth-genesis in the *Canidæ* [22], I adopted the suggestion of Forsyth Major that there was the possibility that the Rodentia may have been derived from the Multituberculata, even though the teeth of the Dogs could not be so derived. I was led to do this mainly for two reasons:—(1) the similarity between the dentitions of the Multituberculata and the Rodentia; and (2) the value of the Palæontological evidence collected by Dr. Forsyth Major and published by him in numerous papers. It was therefore with the object of testing the validity of this suggestion from the embryological standpoint, that I commenced this research, the results of which are here set forth.

The selection of *Cavia* as an animal upon which to work was chiefly due to the fact that my friend Mr. Martin F. Woodward had very kindly given me a series of fœtal Guinea-pigs. Upon this material ready to hand, I commenced the investigation. I have also examined specimens of fœtal rats, mice, and rabbits (with which I hope to deal more particularly in the future). These, though showing differences in detail, nevertheless appear to me

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to confirm the conclusions upon the broader issues with which I am here mainly concerned. If my identification of the individual teeth in *Cavia* be correct, it then follows that the identification usually accepted of the teeth of the Rodents in general may in many instances be incorrect. This being so, I have deemed it advisable to limit myself, in the present instance, to the teeth of the *Caviidæ*, and not to deal with the Order as a whole as was originally my intention.

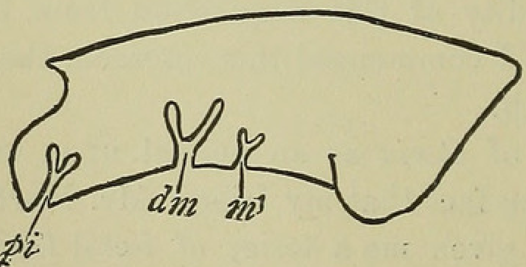
The method I have followed has been that of cutting and examining serial transverse sections of the jaws, after staining in bulk. In some cases the stain used has been borax-carmine; in others Tomes's ferric-perchloride and tannic-acid method was adopted. The jaws were decalcified in a 2 per cent. solution of each of the following, viz.:—hydrochloric acid, nitric acid, and ferric perchloride. The object in using a combination of the two acids being to neutralize the shrinkage of the tissues caused by the former by the swelling caused by the latter. After decalcification, the iron in the tissues was reduced by a 3 per cent. solution of tannic acid. Wax models of the younger stages of the teeth have been made, while in the older the teeth were examined *in situ* by clarifying the jaws in oil of cloves.

I shall commence with a detailed description of each stage, comparing my results in each case with those of other writers, and will leave a general consideration of the problems involved to be dealt with in the latter part of the paper.

CAVIA COBAYA.

Stage 1. Circumferential head-length...... 1·5 cm.
„ body-length ... 4 cm.

Fig. 1.



Reconstructed diagram, showing the number and position of teeth present in Stage 1. *pi.*, permanent incisor; *dm.*, deciduous molar; m^1, first molar.

In this, the youngest stage examined, rudiments of three teeth were to be found in the upper jaw, none, however, showing any traces of calcification. The three teeth present are the incisor, the deciduous molar, and the molar immediately behind it, the two latter being usually interpreted as *dpm.*1 and *m.*1, but which, as will be seen subsequently, I believe must be regarded in a somewhat different manner. The enamel-germ of the upper incisor has assumed the characteristic bell-shape. There is a decided labial downgrowth of the dental lamina (Pl. 26. fig. 5), which is, I believe, to be regarded as the vestigial remains of the deciduous incisor. That it cannot be looked upon as affording evidence of a pre-milk dentition is clear from an examination of the later stages, the bell-shaped germ of this stage growing continuously to form the permanent incisor of the adult. This labial downgrowth is also extremely well marked in the case of the lower incisors. I was not able to detect any trace of a tooth anteriorly or posteriorly to this in the incisor region in the upper jaw. Throughout the several succeeding sections the dental lamina can be traced definitely running through the diastema, but without any indications of enamel-germs. It then dips deeply into the substance of the jaws both upper and lower, and gives rise to a well-marked enamel-germ. This germ has slight traces of both labial and lingual downgrowths in the upper jaw; while in the lower jaw the latter only is present, but more distinct than is the case with the corresponding process in the upper jaw. From a consideration of the reconstructed diagrams of this and the subsequent stages, I think it will be evident that this is the germ of the deciduous tooth. From the wax model it is seen to consist of a cone surrounded by a cingulum. The latter structure projects to form a very definite upwardly-directed and somewhat pointed process arising from the inner side of the main cone. There is a corresponding, though less pronounced projection on the outer side. Some little distance behind this tooth the dental lamina again becomes distinctly enlarged at its deeper extremity, forming a flask-shaped mass, as yet not invaginated by any appearance of the dental papilla. No further trace of any germ is visible at this stage.

With regard to the labial downgrowth of the dental lamina in connection with the functional incisor, which I have represented (Pl. 26. fig. 5), it is interesting to compare it with thec ondition found in other Rodents. Huxley was the first [12] to note the existence of minute milk predecessors to the large functional incisors in the rabbit. This discovery has been verified by Pouchet & Chabry [14], Freund [10], and Woodward [27].

Writing in 'Nature' [11], referring to these vestigial teeth, Huxley pointed out that "it would be interesting to examine fœtal guinea-pigs in relation to this point; at present they are known to possess only the hindermost deciduous molars, so far agreeing with the marsupials." Freund [10] has also discovered the existence of vestigial milk-incisors in the squirrel in both jaws. Though he inclines to the belief that these vestiges are to be interpreted in this manner, yet he implies the existence of some doubt. From his description of the connection between the neck of the permanent teeth and that of the vestigial teeth, and from the fact that the rudimentary enamel-germ and the large incisor are included in the same thickened connective-tissue capsule, I think there can be little doubt but that they are vestigial milk-incisors, and that Freund, as Woodward says, is "over-cautious and inclined to underestimate the facts which suggest that condition." Again, Mr. M. F. Woodward (*l. c.*) has described in the mouse "a pair of very minute calcified tooth-rudiments in connection with the two large upper incisors, one each side of the jaw." These rudiments he considers to represent "the last stage in the reduction of a vanishing tooth, the earlier stages of which are to be seen in the rabbit and squirrel." The guinea-pig will thus be seen to add a still further stage in the degeneration of this tooth, forming a very complete and interesting series.

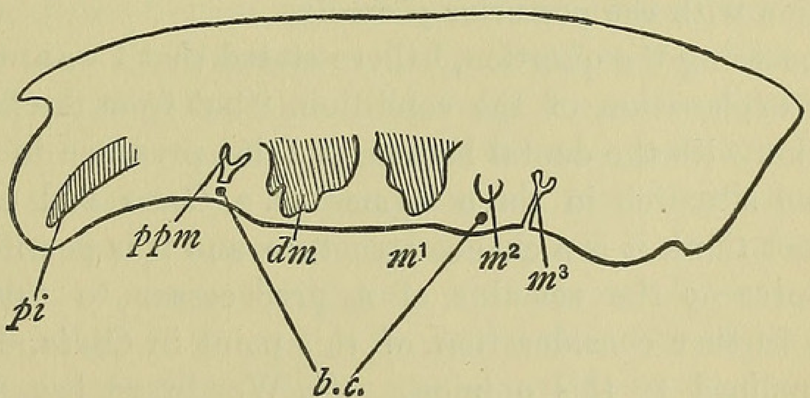
Two observers, Freund [10] and Adloff [1], have also examined specimens of *Cavia* at this stage; their measurements differ considerably from my own, and possibly the discrepancy may be due to the method of measuring: as I estimated the length from the tip of the snout to the root of the tail circumferentially, this would obviously give a greater length than if measured in a straight line. Freund has also examined two younger stages, the earlier one having a cephalic length of 4·5 mm., the measurement of the other not being given. This writer gives but few details as to the condition found in these three young stages, merely stating that he found no trace of a germ for the second incisor, and nothing in the diastema beyond a few thickened cones of epithelium, which he could not satisfy himself were to be regarded as tooth-rudiments. Adloff, on the other hand, gives more details of the examination of his specimens at this stage, and accompanies his description by three figures. His description of the tooth which he identifies as *Pd.*3

corresponds with the first cheek-tooth of my specimen, except that he mentions and figures a lingual downgrowth only, whereas in mine both lingual and labial downgrowths were present in the upper jaw, but only the former in the lower. This point is, I think, worthy of mention, for the reason that I have already [22] expressed my adherence to the current belief that the upper jaw retains the more primitive condition. In neither of these cases is the labial downgrowth present in the lower jaw, while in the upper it is present in the one case and not in the other. The conclusion appears to me to be that this labial downgrowth has already ceased to exist in the lower jaw, while in the upper jaw it is in the process of disappearance. The lingual downgrowth is present in both upper and lower jaws in Adloff's specimen as well as in my own. In this I think one may find further confirmation of the view that the dentitions present in the Mammalia tend to disappear from without inwards.

Adloff makes no mention of any indication of the incisors, which are well marked in my specimen. He also says that *m*.1 and *m*.2 were not yet to be found; whereas *m*.1 was present in mine as a flask-shaped non-invaginated mass, *m*. 2 not being indicated. Possibly mine may have been a slightly older specimen, which would not invalidate, but rather strengthen, the deductions I have drawn.

Stage 2. Circumferential head-length ...... 2·7 cm.
„ body-length ...... 7·5 cm.

Fig. 2.



Reconstructed diagram of Stage 2. *pi.*, permanent incisor; *ppm.*, permanent premolar; *dm.*, deciduous molar; m^1, first molar; m^2, second molar; m^3, third molar; *b.c.*, "concentric epithelial bodies."

The incisors are now teeth of considerable size and curve backwards deeply in the substance of the jaw. They are well-calcified, but the enamel appears to be deficient on the posterior surfaces. No trace of any downgrowth, lingual or labial, is visible. Some distance from the anterior end of the jaw, in a position posterior to where the permanent incisor cuts the gum, the dental lamina grows deeply into the substance of the jaw; it persists through some sections and then ceases, it is bilaterally symmetrical. Possibly this may mark the position of *i.*2, which has disappeared.

Throughout the diastema no trace of any tooth-germs is visible. The most anterior cheek-tooth is the so-called *ppm.*1, it is in a somewhat rudimentary condition and as yet quite uncalcified. It consists of a single cone with a blunted summit. The internal cingulum is present, and also indications of an external. I would here specially note the presence of a spherical body, composed of concentrically arranged cells, lying in the line of the connecting neck of dental lamina (Pl. 26. fig. 9). I have already figured [22] a precisely similar structure in connection with *pm.*4 of the dog, the only difference being a slight one of position. In the latter case, it lies at the free extremity of a labial downgrowth of the dental lamina; whereas in the present instance, it is directly in the line of the dental lamina running between the oral epithelium and the tooth. In the guinea-pig this structure is present on both sides of the upper jaw, and persists for some time. A similar structure is also to be found in connection with the so-called *m.*2. I have already referred (*loc. cit.*) to the fact that Mr. M. F. Woodward has found a similar structure in *Gymnura* in the same position, viz., in connection with the posterior premolar.

In discussing the question, I there stated that I was not able to give an explanation of the condition, "but from the fact of its connection with the dental lamina and its presence in precisely the same situation in these forms" (i. e. *Canis* and *Gymnura*) "I do not think it is a chance structure, and it is possible that it may represent the remains of a predecessor to this tooth." From a further consideration of this point in *Cavia*, I am still more inclined to this opinion. Mr. Woodward has figured a calcified vestigial incisor in the mouse [25] which, as he describes, appears in section "as a narrow loop forming about $\frac{3}{4}$ of a circle, a few of the mesoblast-cells having flattened themselves against the outer surface of the dentine." From a comparison of the two conditions, it is easy to imagine that a still further stage of degeneration would give the appearance seen in the dog, guinea-pig, and *Gymnura*.

Just as the rudimentary germ of the premolar is on the eve of disappearing, the tooth immediately behind it, the so-called *dpm.*, is commencing to appear, but placed much more deeply and lying altogether underneath the preceding tooth. Tracing it backwards, it is seen to be well-calcified, but has not yet reached the surface of the gum. No labial or lingual downgrowths are to be seen, though traces of both have been noted in Stage 1. There is an interval of 70 sections between the neck of this tooth and that of the preceding: consequently I think there can be no possible morphological connection between the two. If such be the case, then these two teeth can no longer be regarded as the morphological predecessor and successor, the one of the other. I believe the correct interpretation to be that the more anterior tooth is a premolar, probably *pm.* 4, belonging to the successional series, and the so-called *dpm.* is the first true molar. The reasons which lead to this conclusion will be discussed below. I shall therefore in what follows speak of the five teeth in the upper jaw of the guinea-pig as *pm.* 4, *ms.* 1, 2, 3, 4.

The deciduous tooth at this stage (Pl. 26. fig. 1) possesses two antero-posterior rows of cusps, and has the appearance of two similar portions one behind the other, the anterior being the larger. This remark applies to all the cheek-teeth both at this and later stages; and for this reason I think there is a possibility of the correctness of the Concrescence theory. The external row has three distinct cusps, of which the centre one is the more pronounced and the posterior slightly smaller than the anterior. The internal row also consists of three cusps, the anterior being the largest. The middle cusps of the two rows are separated one from the other by a wide depression; while the first and third cusps of both rows are connected respectively by ridges which bound the depression anteriorly and posteriorly. Behind the posterior ridge is a second smaller depression separating the outer from the inner posterior portions of the tooth which do not possess any definite cusps. The anterior and central cusps form the anterior larger portion of the tooth; the third cusps with the posterior portion of the tooth together forming a miniature of the anterior part. The first and third cusps of the external row are slightly undermined at their bases, representing the involution of enamel which is carried to such extremes in the teeth of some other Rodents.

The second molar, or second cheek-tooth of the adult dentition, resembles the anterior part of the tooth just described. There are two external cones, the posterior being of considerable size, the anterior inconspicuous, and the same may be said of the two internal cusps. The antero-internal and antero-external cusps are partially fused with each other transversely, whereas the two posterior cusps are separated by a deep but narrow cleft (Pl. 26. fig. 3). The posterior part of the tooth is made up of a mass of considerable size with a rudiment of a cusp, both internally and externally, the latter being slightly the larger. At the base of the tooth, on both its outer and inner aspects, is a well-marked rounded prominence which I think must be regarded as the cingulum.

The third molar is not calcified. It presents a broad, transversely elongated surface with an external and an internal cusp, the former being the larger. There is a well-marked lingual downgrowth of the dental lamina. In connection with this tooth there is one of the concentric epithelial bodies to which I have already referred.

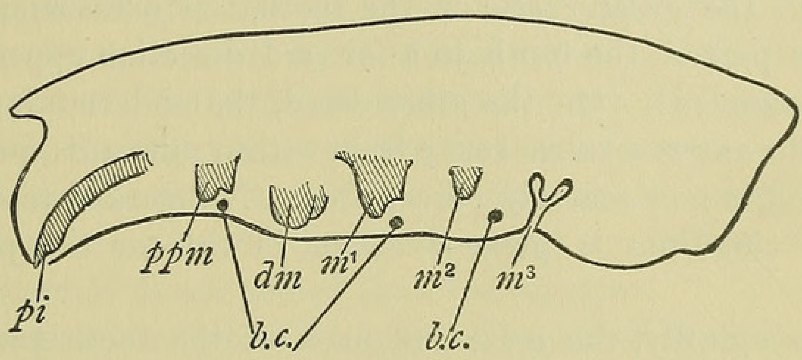
If these bodies really do represent the last stage in the disappearance of a tooth, we have here in connection with an undoubted molar tooth evidence of three dentitions, from the central one of which the permanent tooth developes. Adopting the line of argument I have previously used when referring to the Marsupial dentition [21], it would seem to show that the molar teeth do belong to the successional series—a view which, though held by many, is not universally accepted. The fourth molar is present in a very rudimentary condition.

The second, and last stage of *Cavia cobaya* examined by Adloff had a head-length of 3 cm. This measurement corresponds exactly with my Stage 3; but from the description given, it is evident that Adloff's was a much younger specimen, the difference being no doubt due to a difference in the method of measuring. From a comparison of the results, I am inclined to think that his specimen must have been slightly younger than my Stage 2. He finds that the first "Anlage" in the hinder portion of the jaw is that of the premolar of the first dentition, that is of the deciduous tooth. This is in agreement with what I have found namely, that this tooth commences to develope earlier than the tooth in front of it, which I believe to replace it.

In connection with *m.* 2 he describes and figures both lingual and labial downgrowths of the dental lamina; the latter he interprets as a pre-milk vestige. This interpretation I shall discuss subsequently. The posterior molar (*m.* 3) he states is not at this stage developed.

Stage 3. Circumferential head-length...... 3 cm.
„ body-length...... 9·3 cm.

Fig. 3.



Reconstructed diagram of Stage 3. Lettering as before.

The incisors are now large teeth which have just cut the gum. No trace of any vestigial tooth is to be seen, here or in the diastema.

The first cheek-tooth is well-developed though not calcified. The "concentric epithelial body" is clear and distinct. It appears to occupy a similar position relative to the edge of the jaw as in the previous stage; but the tooth with which it is connected is now more deeply placed. Its connection with the surface being severed, the relative position of the "concentric epithelial body" to the neck of the enamel-germ can no longer be definitely ascertained. The tooth itself is transversely elongated, its axis in this direction being double that of the antero-posterior axis. Excluding the internal and external cingula, representatives of two antero-posterior rows of tubercles are present about the centre of this tooth, as is seen in Pl. 26. fig. 2. Of these, the outer is more pronounced, and becomes the antero-external cone of the adult tooth. The second cusp from the outer side is the second largest; it attains its maximum at a point in a plane slightly posterior to that of the principal cone, where the latter is gradually shelving upwards. In the posterior part of the tooth these two cones are indistinguishable the one from the other, having fused to form a solid mass. The second cheek-tooth (Pl. 26. fig. 4), which is the deciduous tooth, is well calcified, and on the verge of cutting the gum. It consists of a large antero-external cone, the apex of which has an elongated cutting-edge, still showing indications of two tubercles. On comparison with the model of this tooth at the previous stage, this cone appears to be formed by a fusion of the anterior and central external cusps. The well-marked median internal cone of the earlier stage has now entirely disappeared. The postero-external and postero-internal cusps are relatively much smaller. Owing to the greater size of the tooth, the excavation of the posterior part of the tooth in a forward direction appears to be more pronounced. On the other hand, the undermining of the base of the antero-external cusp from within outwards, previously mentioned, is now scarcely perceptible. No marked trace of the external cingulum is present either in this or the preceding stage.

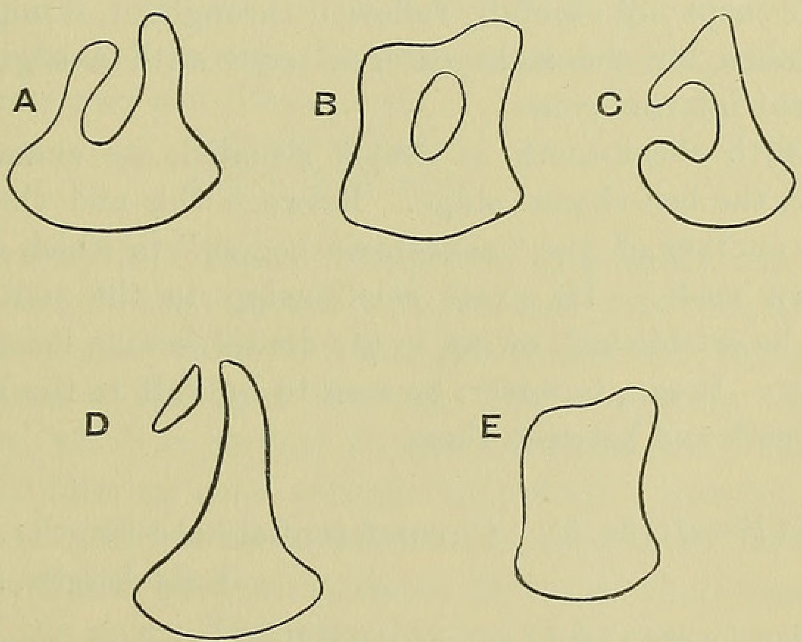
Microscopically, the epithelial neck of the tooth-germ is no longer visible; and I have not been able to detect any lingual downgrowth such as would suggest that this tooth had any morphological successor.

The condition of the third cheek-tooth has become complicated by the presence of infoldings of the enamel. Here again, there is a large external cone which has to the outer side of its base two minute cusps, which I consider as belonging to the external cingulum. The well-marked inner cone, described in the preceding stage, appears to have fused by its apex with that of the external cone, the two being separated at their bases, giving in section the appearance of an elongated foramen. It might be thought that this foramen was due to the tunnelling forwards of the substance of the tooth from its posterior end, such as was found in the second cheek-tooth. Such, I believe, cannot be the cause, for two reasons: (1) in the previous stage no trace of any tunnelling is observable; and (2) the external and internal cones are separated by a deep fissure extending down to almost the root of the tooth. This foramen seems, therefore, to be due to a fusion of the apices of the two cones cutting off the deeper part of the fissure from the surface. This occurs towards the anterior part of the tooth. About the centre a communication takes place between this cavity and the internal surface of the tooth, separating the internal cone from its base; and as this detached portion is fused by its apex with the external cone, the tooth in section has the appearance of an inverted V, the external limb of which is considerably longer than the internal. How this communication is brought about, whether by the rupturing inwards of the central cavity, or by the extension into the latter of a channel running outwards from the internal surface, I am not in a position to say.

If the condition of this tooth be traced still further backwards, the communication is still seen to be present; and, in addition, the central cavity communicates with the surface, the apices of the external and internal cones being separated. This may have been brought about by the formation of a cleft from without inwards, or from within outwards; or, what I think the more probable is, that the apices of the two cones have here remained separate, not having undergone fusion, as in every instance the posterior moiety of the tooth seems to be in a somewhat earlier stage of development than the anterior.

In a section through this region, the apex of the internal cone

Fig. 4.



Diagrammatic sections through Third Upper Cheek-tooth. A from Stage 2. B, C, D, E, from Stage 3.

lies as an isolated mass to the inner side of the external, the latter retaining its connection with the fused bases of the two cones, appearing almost identical in section with that through the centre of the deciduous tooth. This I regard as being a fact of some importance, and to which I shall again have to refer. In quite the posterior part, the tooth forms a solid transverse mass with a blunted apex, slightly more prominent on the outer side. The accompanying illustrations will, perhaps, render this description more intelligible (fig. 4).

I would here add that I have found a similar condition in *m*.1 of the rat, the only exception being that in this animal there is the further complication of a channel of communication between the central cavity and the external surface of the tooth, which cuts off the apex of the external cone from its basal attachment. As the apex of this tooth in the guinea-pig now nearly reaches the surface of the gum, its epithelial connection is broken up, no labial or lingual downgrowths of the dental lamina nor any appearance of a "concentric body" being visible.

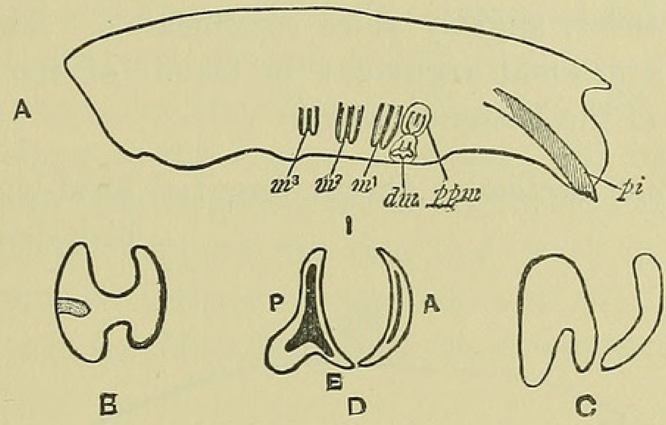
The fourth cheek-tooth is almost identical in pattern with that of the third as seen in Stage 2, and the description afore given would apply equally to the tooth under consideration; the only addition which it is necessary to record, is the presence of a relatively large tubercle to the outer side of the main cone in the posterior part of the tooth. It attains to such a size, that were the cusps not carefully followed throughout, it might easily be mistaken for the main external cone with a slightly more prominent internal cone.

The fifth cheek-tooth is deeply situated, its enamel organ being in the bell-shaped stage. Between this and the tooth in front is another of the "concentric bodies" to which reference has been made. Its exact relationship to the tooth behind cannot be established, owing to the dental lamina being difficult to follow. It can, however, be seen to lie well to the labial side of the teeth and between them.

Stage 4 (*Fœtal*) (fig. 5). Circumferential head-length.. 4 cm.
„ body-length.. 10 cm.

The jaws were examined by clarifying in oil of cloves. The condition is interesting as the deciduous tooth is about to be shed, having entirely disappeared in the subsequent stage; it is therefore lost either just after birth, or, as is more generally stated, at quite the late period of intra-uterine life. All five teeth are well-calcified, the deciduous tooth lying between the crown of the anterior permanent tooth and the free margin of the gum, somewhat to its lingual side. The anterior cheek-tooth of the adult consists of two plates, an external and an internal, separated one from the other by a deep oblique cleft, so deep that the plates are but slightly connected by their bases and are easily separable. The position of the tooth is partially rotated through an angle of about 45°, so that the external and more prominent cone lies antero-externally, the internal being postero-internal. When examined from the internal surface, the apex of the outer cone appears to be folded inwards so as to reach the apex of the internal cone, but without being fused with it. The folding gives rise to a transverse groove crossing the apex of the external cone.

Fig. 5.



A. View of teeth in Left Upper Jaw (Stage 4), seen from the inner side.
B. Crown surface of Deciduous Tooth.
C. „ „ Successional Tooth.
D. „ „ Fourth Cheek-tooth.

The inwardly-folded apex is supported by a vertical ridge upon the inner face of the external cone, so that this cone would on horizontal section have a triangular shape, the curved base being external, the apex internal with a slightly backward inclination, which is applied to, but not fused with, the outer face of the internal cone towards its posterior margin, as seen in fig. 5 C. It lies in a separate capsule of its own, quite distinct from that of the deciduous tooth, which is nearer the margin of the gum. The latter has not undergone any rotation, is very minute and its cusps complete, the enamel not having disappeared from their apices.

The third and fourth cheek-teeth had already assumed the characters of adult teeth, the former being the larger.

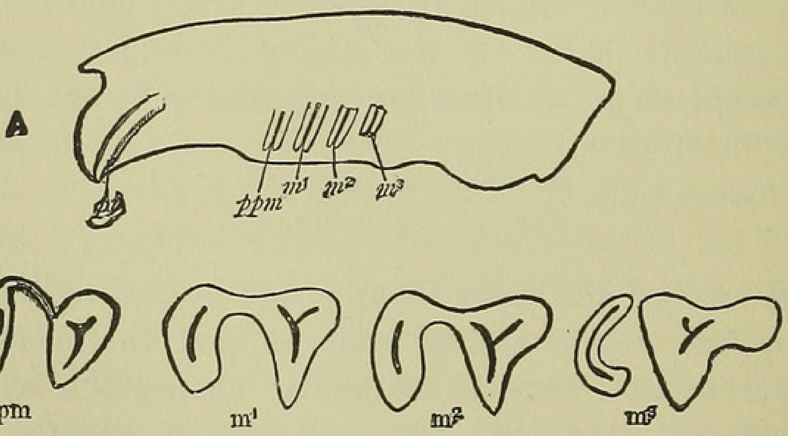
With regard to these teeth, I would note the absence of tubercles from the crown-surface, the enamel having partially disappeared even though the teeth had not cut the gum. This confirms the observation made by Saint-Loup [18], which led him to ask the question whether this is a case of the hereditary transmission of acquired characters, since it cannot be due to wear.

The posterior tooth is much smaller; its characters I was not able definitely to ascertain owing to its position and the difficulty of dissecting it out from its osseous surroundings.

The surface view of the deciduous tooth is seen in outline in fig. 5 B; a comparison of this with the teeth shown in Pl. 26. figs. 7 & 8 is, I think, suggestive, the same general pattern being noticeable: more particularly is this the case on comparison with the tooth of *Stichomys* of the Lower Eocene; the latter is, however, slightly more complicated. This fact may afford some additional argument in favour of the multituberculate origin of the Rodent molars.

Stage 5 (*Post partum*). Circumferential head-length 5 cm.
" body-length 12 cm.

Fig. 6.



A. View of teeth in Left Upper Jaw (Stage 5), seen from outer side.
B. Crown-surface of permanent premolar and three molar teeth.

Examination of the clarified jaw shows the presence of four cheek-teeth only, all traces of the deciduous molar having disappeared. Of these teeth the second is the largest, and is the only one in addition to the incisor which has actually cut the gum. All have assumed the characteristics of the adult dentition. The enamel is absent from the crown-surfaces, all trace of definite cusps being wanting. A side view of the teeth *n situ* is shown in fig. 6 A, while the crushing surfaces are represented in fig. 6 B.

Having now given an account of the conditions found in these various stages, the question arises as to what interpretation may be placed upon them. In the first place, it will be noted that the deciduous tooth is the first to arise, or at least is the more advanced in the first stage examined. In tracing its subsequent development, it does not appear to be connected with any germ which could be interpreted as either a predecessor or a successor: in other words, this tooth seems to be represented in one dentition only, and it might be either a milk-tooth the successor of which had become suppressed, or *vice versa*; and I know of no definite data upon which to form a decided opinion. The fact of its early appearance, and of its being shed *in utero*, might seem to favour the former alternative. I am inclined, however, to regard it as a permanent tooth accelerated for the following reasons:—(1) its development is but little in advance of the incisor or of the molar immediately behind it, both of which are known to belong to the second dentition; (2) in the dog the carnassial tooth of both dentitions is developed in advance of the other teeth, which supports the view that teeth in this position have a tendency to become accelerated; and (3) I believe that the dentitions in the Mammalia tend to disappear from without inwards.

This being so, I would regard all five tooth-germs found in the guinea-pig as belonging to the permanent series, the first and fourth having, in my opinion, vestigial remains of milk predecessors in the "concentric bodies" afore described (Pl. 26. fig. 7).

Though the pattern of the so-called molars and premolars in the adult *Cavia* are practically identical, still in their earlier stages they are somewhat different, the anterior cheek-tooth being transversely broader and more multituberculate than the posterior ones. The deciduous tooth appears to me to partake more of the nature of the latter; and I am inclined to believe that it is to be regarded as the anterior molar, thus agreeing with the suggestion first made by Woodward in relation to other mammals.

The tooth which replaces the deciduous is the anterior cheek-tooth, which is not therefore its true morphological successor, but merely drops backwards and occupies its position.

In this connection it is interesting to note what Forsyth Major says [8] in referring to *Prolagus sardus*:—"The anterior of the three deciduous teeth is not situated directly above the anterior premolar, but slightly backward, closely appressed to the second deciduous, so that with its anterior moiety it covers only the posterior part of the premolar; besides it could not possibly cover the latter completely, being much smaller." And, as he points out, Fraas [9] states that the anterior premolar in *Prolagus* has no deciduous predecessor, but that it "comes into place through the same lacuna." Clearly, then, this is not a unique condition in the Rodents, and I have referred [22] to what I believe to be a somewhat similar condition in *Canis*. Regarding the deciduous tooth as the first molar, its successor in position would be *pm.*4. Connected with the latter is a "concentric body." Though this tends to support my contention, too much weight must not be attached to it, since a similar structure has been referred to in relation to the posterior teeth in *Cavia*.

Another question opens up: If these "concentric epithelial bodies" are really tooth-vestiges, since they are found in the posterior part of the jaw, either the posterior cheek-teeth must be regarded as premolars, or else these bodies are the vestiges of deciduous molars, and therefore the usually accepted distinction between molars and premolars breaks down. I am inclined to the latter opinion, having always held that the molars belong to the permanent series. If this be a correct interpretation, then in this particular the Rodents retain an extremely primitive condition; and the statements made by Fraas with regard to the tooth-change in *Prolagus* may not be far wrong, and certainly do not merit the unfavourable comments which have been made upon them.

It will have been seen that the cheek-teeth above described arise as a single Primitive cone to be soon followed by the appearance of external and internal cingula. As the tooth elongates, two antero-posterior rows of cusps arise; the primary cone becoming the median-external in position and the largest in size. The anterior and posterior cusps of each row respectively become united forming transverse ridges, the median cones remaining separated by a cleft. The anterior cusp and median cone of the outer row together with the anterior transverse ridge form a crescentic edge, and this gives rise to the anterior moiety of the adult tooth. The median-internal cone disappears. The postero-internal cusp, together with a subsequent backward extension of the end of the tooth, forms the posterior part of the adult tooth, while the narrow band connecting the anterior and posterior portions represents the posterior transverse ridge. In the younger stages the teeth are decidedly more multitubercular than in the adult. Compare fig. 2 (Pl. 26) with the adult teeth of *Cavia* as shown in fig. 7 B.

In the posterior molars a further small postero-external extension of the tooth arises in the form of a rounded process. It is also present, though to a much less extent, in the anterior cheek-teeth. It is very pronounced and plicated in the posterior molar of *Dolichotis*, and its size forms the principal difference between the molars of this fossil rodent and those of the existing *Caviidæ* (Pl. 26. fig. 7).

It may here be noted that the root of the tooth is frequently seen to be lateral in position, as shown in Pl. 26. fig. 10. This is not usually so marked in other animals, in which the obliquity of the adult teeth is not present to the same extent as in the Rodents.

Within the limits of the Mammalia comparative odontologists have referred to the existence of *four* distinct dentitions—a Pre-milk, a Milk or Deciduous, a Permanent or Successional, and a Post-permanent. The existence of all four at one and the same time has not, so far as I am aware, been shown to be present in the same animal. The Pre-milk dentition is said by Leche and others to be present in the Marsupials, but such an interpretation of the vestigial representatives, such as undoubtedly occur in *Myrmecobius*, *Phascologale*, *Dasyurus*, and others, depends upon the functional teeth of the Marsupials representing the true milk dentition. I have previously [21] expressed my belief that another and more probable explanation is forthcoming, and in this opinion I am supported by Wilson & Hill [24] and by Tomes [23]. I would regard therefore Leche's vestiges as remains of a deciduous dentition. The evidence as to the existence of traces of a Post-permanent dentition in many mammals is, I think, undoubted: they have been described in Man, Seal, Hedgehog, and Dog; and if my interpretation be correct, it is also to be found in Kükenthal's lingual downgrowths of the dental lamina as described by him in *Didelphys* and in the Cetacea.

In the Rodentia there are well-marked evidences of at least two dentitions—the milk and permanent, though the former seems tending to disappear.

The only evidence of the existence of prelacteal vestiges that I have as yet been able to meet with, is to be found in a paper by Adloff [1]. He describes and figures such vestiges in connection with $\underline{Id.\,3}$ and $\overline{Id.\,2}$ in *Spermophilus citillus* (head-length 1·5 cm.), and $\underline{Pd.\,2}$ and $\underline{Pd.\,3}$ and $\overline{I.\,2}$, $\overline{Pd.\,2}$, and $\overline{Pd.\,3}$ in *Spermophilus leptodactylus* (head-length 2·1 cm.); also in *Sciurus Brookei* in connection with $\underline{Pd.\,2}$ and $\overline{Pd.\,3}$, though he does not mention their existence in two other species which he examined, viz., *Sciurus Prevosti* and *S. vulgaris*. He further notes their presence in connection with $\underline{Pd.\,3}$ and $\underline{m.\,2}$, $\overline{m.\,2}$ in *Cavia cobaya* (1·5 cm.). Thus there seems, at first sight, abundant evidence in favour of the existence of the Pre-milk dentition in these animals; but before implicitly accepting these statements, it is necessary to examine them somewhat more critically. Firstly, Adloff's interpretation in connection with the molars of *Cavia* depends entirely upon his belief that the molars belong to the Deciduous or Milk dentition. In this opinion he follows Hoffman, Beauregard, Owen, Leche, and others; on the other hand, Woodward, Lataste, and Magitot believe the molars to belong to the successional series, and in this opinion I concur. Consequently, according to the latter view the vestiges mentioned by Adloff in this position would be regarded as vestiges of the milk predecessors of the molar teeth; and, indeed, I have already described the existence of such a vestige on the labial side of the molar teeth in a fœtal pup of about the seventh week [22], as well as the presence of a "concentric body" to the labial side of the molars in the guinea-pig; in both of which cases I have interpreted them as vestiges of a milk dentition, the lingual downgrowth representing a Post-permanent dentition.

With regard to the existence of prelacteal vestiges in the premolar region in the afore-mentioned forms, I may point out that I believe them to be the only examples recorded, Leche's and Woodward's discoveries being confined to the outer incisor region; the very region in which I found well-marked evidences of three dentitions in the dog, but in that instance the three undoubtedly being the Milk, Permanent, and Post-permanent.

With regard to the presence of Pre-milk vestiges in connection with $\underline{Pd.\,2}$ of *Sciurus Brookei*, there are certain points to be borne in mind.

As I understand Adloff, this tooth $\underline{Pd.\,2}$ is the anterior of the two premolars so generally present in the *Sciuridæ*. He only mentions having examined one stage of this species with a head-length of 1·5 cm., and he mentions that neither $\underline{m. 2}$ or $\underline{m. 3}$ were developed. Now in *Cavia* we have seen that the anterior cheek-tooth present does not develope until after the appearance of the second and third. Similarly, in the dog I have shown (*loc. cit.*) that the small anterior premolars do not appear until some time after the larger posterior ones. According to Flower and Lydekker [5, p. 450] the first upper premolar is "small and deciduous." It therefore seems possible, if not probable, that the tooth which Adloff identifies as $\underline{Pd. 2}$ is in reality $\underline{Pd. 3}$, that is the posterior deciduous tooth. Now the deciduous tooth in the guinea-pig I have shown to be developed in series with the molars, and in them I have shown the presence of "concentric bodies" which I regard as milk vestiges. In like manner, therefore, the so-called Pre-milk representative in connection with this tooth might be so interpreted. Whether this be the correct explanation or not, I do not consider it possible to identify the teeth from the examination of the condition found in a single specimen.

With regard to $\underline{Pd. 3}$ in *Cavia*, I think the interpretation given by Adloff is erroneous, since he appears to have missed the peculiarity of the tooth-change; the "prälakteale Anlage" in this case being identical with the "concentric body."

As to the incisors in *Spermophilus* I am unable to express a definite opinion, not having had an opportunity of examining a specimen; nevertheless I would point out that I am not in accord with Adloff in his identification of dentitions, and the interpretation previously given with regard to the incisors in *Cavia* probably applies equally in the case of *Spermophilus.*

I claim to have shown reason for believing that the existence of pre-milk vestiges in the Rodents is still "non proven"; and I cannot refrain from quoting Woodward, who, though a believer in their existence, and having carried out extensive researches on the dentition of the Rodents, says [27]:—"I do not think it is probable that we should find traces of such a vestigial structure persisting in a specialized group like the Rodentia; the ancestry of which are to be sought according to Cope in the generalized Tillodontia, who in all probability possessed a typical milk-dentition which has become gradually suppressed as their descendants became more and more specialized."

Of the various theories which have been propounded to account for the origin of the complex crown of the Mammalian molars from the Haplodont type, it will be necessary to refer to three only. They are the Tritubercular, the Multitubercular, both of which are well known, and the theory of Cingulum-Cusp development suggested by me in my work on the Canidæ.

Tritubercular Theory.—This view, so ably advocated by Cope and Osborn in America, and so widely accepted both in this country and on the continent, is too well known to need any re-statement. One of the important arguments advanced against this theory is that the Paracone, and not the Protocone, is ontogenetically the first to appear. This has been found to be the case in Marsupials [15], Carnivores [22], Ungulates [20], some Insectivores [28], and Primates [16 and 17]. To these may now be added *Cavia*, as representing the Rodents. The other cusps are secondarily added.

The *Multitubercular Theory*, first put forward by Forsyth Major, suggests the primitive condition of the mammalian cheek-teeth to have been multituberculate, and that during the course of evolution a diminution in the number of cusps has taken place. This theory does not appear to me to be applicable to such Orders as those just mentioned with their full complement of teeth, and in which embryology has shown that the teeth develope by the addition of cusps to a single primitive cone. It is evident that this theory presupposes the acceptance of the Concrescence theory as set forth by Dybowski, Gervais, Röse, and more particularly by Kükenthal. Though I am unable to accept these combined views as a whole to account for the origin of the Rodent molars, nevertheless they afford a certain amount of satisfactory evidence; the suggestion which I would offer will be discussed subsequently.

Theory of Cingulum-Cusp development.—The uniformity of development of the antero-external cones in both jaws suggests the Paracone and Protoconid as being homologous, and as representing the primitive reptilian cones. The remaining cusps I believe to have been mainly derived from the Cingulum, a structure of great antiquity as shown both embryologically and palæontologically. The details of the subsequent development of the cusps I need not here repeat, as they have been already published [22]. This view is in harmony with the Tritubercular theory up to the point at which the rotation of the cusps is presumed to have taken place.

In tracing the course of the molar evolution in *Cavia*, it has been found that the tooth begins by the formation of a single cone, which subsequently becomes the antero-external cone of the adult tooth, so far agreeing with what has been noted in other mammalian orders. In the development of teeth from a multituberculate type as usually understood, one would not expect to find the development of a single cone taking place first, as is the case here and elsewhere, but of several. As I have already shown, this single cone of the guinea-pig has both external and internal cingula, the latter being the better marked. Both develope secondary cusps, which disappear in the course of the subsequent development of the tooth. There is thus a tendency to the suppression of cusps after a certain period, the adult tooth being less multituberculate than at an earlier stage, though more so than in its youngest condition. Consequently there is evidence in the later stages of development in favour of the Multitubercular theory.

Though I have not personally met with any direct embryological evidence in support of the Concrescence theory, yet upon general grounds I am disposed to accept it to a certain extent. This theory supposes a fusion to have taken place not only antero-posteriorly of teeth of the same dentition, but also transversely of teeth of different dentitions. The former would account for the diminution in the number of teeth of the same dentition in the transition from the Reptiles to the Mammals; while the latter was suggested in order to explain the existence of the triple longitudinal rows of cusps as seen in the fossil Multituberculata. It is the latter part of this theory that I find myself at present unable to accept.

The progressive shortening of the jaws would naturally tend to a crowding of the teeth, which may be conceived to have become fused antero-posteriorly as a result, and Ameghino [2] has adduced some presumptive evidence in support of this; and I have already referred to the fact that the cheek-teeth in the guinea-pig have similar anterior and posterior portions. It is possible to believe that there may be some close connection in the way of cause and effect between the two processes, though actual evidence is as yet wanting. On the other hand, it is difficult to imagine how shortening of the jaws could have had any effect in bringing about a fusion of teeth of different dentitions; nor, indeed, can one perceive any other change which would produce such an effect. The suggestion I would offer is, that the three longitudinal rows of cusps are due to the primitive cones with cingulum-cusps developed to their inner and outer sides respectively. It may be objected, that these inner and outer secondary cusps are as pronounced and of equal size as the central primitive cones in the true Multituberculata. I do not, however, consider this to be any great difficulty, since the Multituberculata must have been extremely specialized animals, as is shown by their dental formulæ; and, moreover, a very similar condition of the cusps is to be seen in the molars of existing frugivorous bears. Each molar tooth of the *Plagiaulicidæ* and *Polymastodontidæ*, in which there are three longitudinal rows of cusps arranged in numerous transverse rows, would consequently represent an antero-posterior fusion of several teeth with their external and internal cusps. In other members of these families, for example *Bolodon*, in which the molars bear only two antero-posterior rows of tubercles, one of the three rows is non-developed.

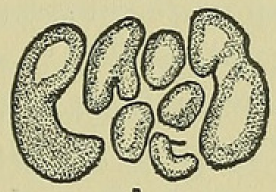
From a comparison with the teeth of existing mammals, I am inclined to believe that the series in this form which is wanting is that of the external cingulum, it being quite exceptional to find this series well-developed, though it is to be found in some of the Insectivora and in *Otocyon* among the *Canidæ*. This conclusion receives some confirmation from a comparison with the teeth of several species of the *Polymastodontinæ*. In a paper by Osborn and Earle [13] describing these, they state that in *P. taoensis*, " although the lower molars typically exhibit but two rows, we occasionally observe a postero-external accessory row upon the first and second molars ; " and again, " the comparison with *Meniscoessus* shows an average *addition* of two cusps to the first molars in both jaws, and an apparent degeneration of the outer row in the second upper molar."

In the course of the development of the molars in the guinea-pig, the three longitudinal rows of tubercles are present as a transitory condition, the external cingulum disappearing giving rise to a tooth with but two antero-posterior rows of tubercles (Pl. 26. fig. 6).

The next point to which I would refer is, the similarity of dentitions found in the Rodentia and Multituberculata. In both, the incisors are reduced in number, there is an absence of canines with the presence of a diastema. The number of cheek-teeth in some of the Multituberculata is in excess of that found in most Rodents, while in others it is not in excess of that present in the Lagomorpha. In any case, this is only what might be expected, as it ~~is~~ well known that a progressive reduction in the number of cheek-teeth is, and has been, taking place throughout almost the whole mammalian series.

There still remain other points to be considered in the same connection. Within the limits of the existing Hystricomorpha very different patterns of cheek-teeth are to be found. The crown-surfaces of the so-called anterior permanent premolar of *Hystrix leucura* (Camb. Zool. Mus. 861 D) is shown in fig. 7,

Fig. 7.



Crown of First Upper Permanent Premolar of *Hystrix leucura* before eruption. Enlarged. (Camb. Univ. Zool. Mus.)

and of *Cavia cobaya* in Pl. 26. fig. 7 B. The former is decidedly multituberculate, the latter is not. In all the *Hystricidæ* the tooth-change is now known to occur and comparatively late in life, whereas in *Cavia* the deciduous tooth is shed *in utero.* It may, therefore, justly be inferred that the *Hystricidæ* are more primitive in this respect than are the *Caviidæ.* Though this may not altogether justify any conclusions as to the pattern of the molar crowns, nevertheless, taken in conjunction with what has been said above, I think it affords some additional evidence in favour of the conclusion that the multituberculate is the primitive pattern of the Rodent molars.

Lastly, there is a large amount of evidence collected by Forsyth Major in favour of this view, which he was the first to set forth in his paper on the Miocene Squirrels [6].

This opinion, however, was not shared by Cope, and is not by Osborn. Cope derived the Rodentia from the Tillodontia, a suborder of the Bunotheria, from a type closely allied to *Esthonyx*, *Psittacotherium* being not far from, if not on the direct, line of ancestry [4]. His arguments are based mainly on the presence or absence of the first and third incisors; and the condition found in *Esthonyx*, *Psittacotherium*, *Calamodon*, and *Tillotherium* are referred to as evidence in support. An elaborate theory is then drawn up to show how the Rodent molars may have been produced mechanically from the molars occurring in the above-mentioned fossil forms. This theory, though very ingeniously worked out, is but a theory, and cannot be admitted as evidence. As to the incisors, though I admit that these forms may be so arranged that different stages in their reduction may be made to appear, and the increase in the size of *i*.2 to become evident, nevertheless it must not be forgotten that a similar condition is to be met with in the Multituberculata, two incisors only being characteristically present in the genus *Polymastodon*, of which one is very large and "rather slender, sharply grooved, restricted enamel-band, and a deep postero-external groove. The lateral incisor [*i*.3] is a very small conical tooth, compressed antero-posteriorly, with its enamel confined to the anterior surface."

Further, in a note (" Note on the Marsupialia Multituberculata ") appended to his paper (*loc. cit.*), Cope stated that the incisors of the *Plagiaulacidæ*, *Chirogidæ*, and *Polymastodontidæ* are similar in structure and functions to those in the Rodentia. Osborn and Earle also say (*loc. cit.*) that the condyle of the lower jaw is " oval, and its long axis is placed obliquely, not antero-posteriorly as in the Rodents." Cope refers to this latter fact as an objection; but it appears to me to be only an objection to his " mechanical theory," and not to the multituberculate theory of descent of the Rodents, for, according to Osborn and Earle (*loc. cit.*), the obliquity is "greater in some specimens than in others," which shows that this is a character which is not stable but undergoing modification.

A further objection may be cited from the joint paper of these authors, as they say that *Polymastodon foliatus* is the most primitive type of the genus, being " distinguished by small size and very few tubercles." With regard to size, I do not think it is necessarily any proof of primitiveness ; and as to the number of tubercles, surely the statement partakes somewhat of the nature of " begging the question."

To sum up the matter, it appears to me that the balance of evidence is distinctly in favour of the multituberculate origin of the Rodents.

This leads to a consideration of the fossil Rodents, for a knowledge of which, especially of the South American forms, we are indebted very largely to the researches of Ameghino, whose work on the fossil mammals of the Argentine [3] forms the source from which other writers have largely drawn. Winge [25], Schlosser [19], and Forsyth Major [6, 7, 8] have also added much that is of value upon the same subject.

Four genera of the *Caviidæ* are reputed to be found in the Tertiary and Pleistocene of Brazil and the Argentine. The members of this family are easily recognized by their high molars composed of two or several triangular prisms which generally form straight lamellæ, and "determinent une arête tranchante sur la face interne des dents à la mâchoire supérieure, et une arête externe à la mâchoire inférieure."

From a consideration of the characters of the post-tympanic and jugular processes and of the masticatory muscles, Winge [25] regards *Cavia*, *Dolichotis*, and *Hydrochœrus* as descendants of the American *Capromyinæ* and places them close to *Dasyprocta* and *Cœlogenys*. Ameghino [3], dividing the Hystricomorpha into eight families, places the *Capromyidæ*, the *Eromyidæ*, and the *Caviidæ* in close affinity, and these three families together close to *Octodontidæ*, the points of difference being mainly dental. It will thus be seen that these two authorities agree in their general conclusions. A careful study of the tooth-pattern of the fossil *Caviidæ*, as figured by Ameghino, throws but little light upon the evolution of the molar crowns, there being apparently but little change of pattern from the Eocene, though a comparison of the posterior upper molar of *Dolichotis* from the Pliocene and of *Cavia* shows a reduction in the latter (Pl. 26. fig. 7).

In the table of genealogical descent suggested by Ameghino (*loc. cit.*), he would derive *Cavia* from *Hedimys* through *Paleocavia*, *Eocardia*, and *Phanomys*; there is, however, practically no difference between the molars of these forms such as would throw any light upon the tooth-genesis. If the *Euromyidæ* of the Inferior Eocene be compared with the later Pliocene forms, there is a simplification of the molar crowns though obviously of the same pattern. The more so is this the case on comparison with the *Octodontidæ*.

The same may be said with respect to the *Hystricidæ*. The diagram (Pl. 26. fig. 8) shows the outline pattern of *Stichomys*, *Spaniomys*, and the recent *Hystrix leucura* (Camb. Zool. Mus.), fig. 7, p. 283. As the teeth are much worn, no information can be obtained as to the original disposition of the tubercles; nevertheless, the outline-pattern, though simpler, is sufficiently similar as to suggest a possible line of descent.

Though it is difficult to obtain any decided results from a comparison of the fossil teeth, owing to the wearing-down to which they have been subjected, still it seems evident that the complexity of the molars, which is undoubtedly more common in the existing forms than in the earlier ones, is due to the external and internal plications of the enamel rather than to the development of new tubercles. These animals, which are undoubtedly Rodents with the characteristic dentition and molar pattern, extend back to the Inferior Eocene. The Tillodontia are not found before the Lower and Middle Eocene, at which period, as we have seen, typical Rodents are present. It is difficult to conceive that the well-developed canines should have disappeared so rapidly and so suddenly together with at least two premolars, and that the incisors, which are only "becoming scalpriform" [26] in the Tillodontia, should have so quickly developed, if we are, with Cope, to regard them as the ancestors of the Rodents. And again, the Rodent molars have already assumed their characteristic pattern, whereas the molars and premolars of *Tillotherium* are "distinctly tritubercular, while those of *Esthonyx* are quite unlike any Rodent molars" [4]. There is also the fact that the humerus in the Tillodontia possesses an entepicondylar foramen, which is not present in any existing Rodent. On the other hand, some of the Multituberculata are considerably older than the earliest known fossil Rodent, extending back into the Jurassic Period. In them the canines and several of the premolars have already disappeared, the incisors reduced in number, one being large and functional, and the pattern of the cheek-teeth in some instances approaching even in some degree to the unworn teeth of the existing *Hystricidæ*.

Summary and Conclusions.

1. That the deciduous tooth in *Cavia* is the first cheek-tooth to develope, the tooth immediately behind it being the next to appear.

2. That the deciduous tooth is replaced by the tooth which developes in front of it, which is its successor in position only, and is not its true morphological successor.

3. The general pattern of the deciduous tooth resembles more closely that of the posterior cheek-teeth than of the anterior tooth. Consequently, the deciduous tooth may possibly represent the first of the so-called molar series.

4. No trace of any representative of a true pre-milk dentition has been discovered.

5. The presence of "concentric epithelial bodies" has been noted in connection with the first and third cheek-teeth. It is suggested that these bodies represent the last traces of milk-teeth. If this be correct, then it would tend to confirm the view, which is not accepted by all, that true molar teeth belong to the permanent series. It would also lead to the conclusion that the usually accepted fundamental difference between premolars and molars did not always hold good, the molars having milk predecessors, of which these bodies are the vestiges.

Moreover, the presence of a similar structure in connection with *pm.*4 of *Gymnura* and of *Canis*, tends to confirm the opinion expressed above that the deciduous tooth is the first tooth of the molar series.

6. That in the evolution of the cheek-teeth there is a tendency to the suppression of some cusps and a fusion of others. This conclusion, in conjunction with the evidences of Palæontology, is in favour of the multituberculate origin of the Rodentia.

7. That the first cusp to develope is the antero-external, the so-called Paracone, and not the Protocone as should be the case according to the Tritubercular theory.

8. That a rotation of the whole tooth takes place through an angle of about 45°, probably due to the peculiar conformation of the Rodent jaw, so that the anterior part of the adult tooth is represented chiefly by the external cone, the posterior part chiefly by the postero-internal cone.

9. The complexity of the Rodent molars is further increased by involutions of the enamel, the first to appear being at the lingual side of the tooth, and followed by another on the external surface in the teeth of the Rat.

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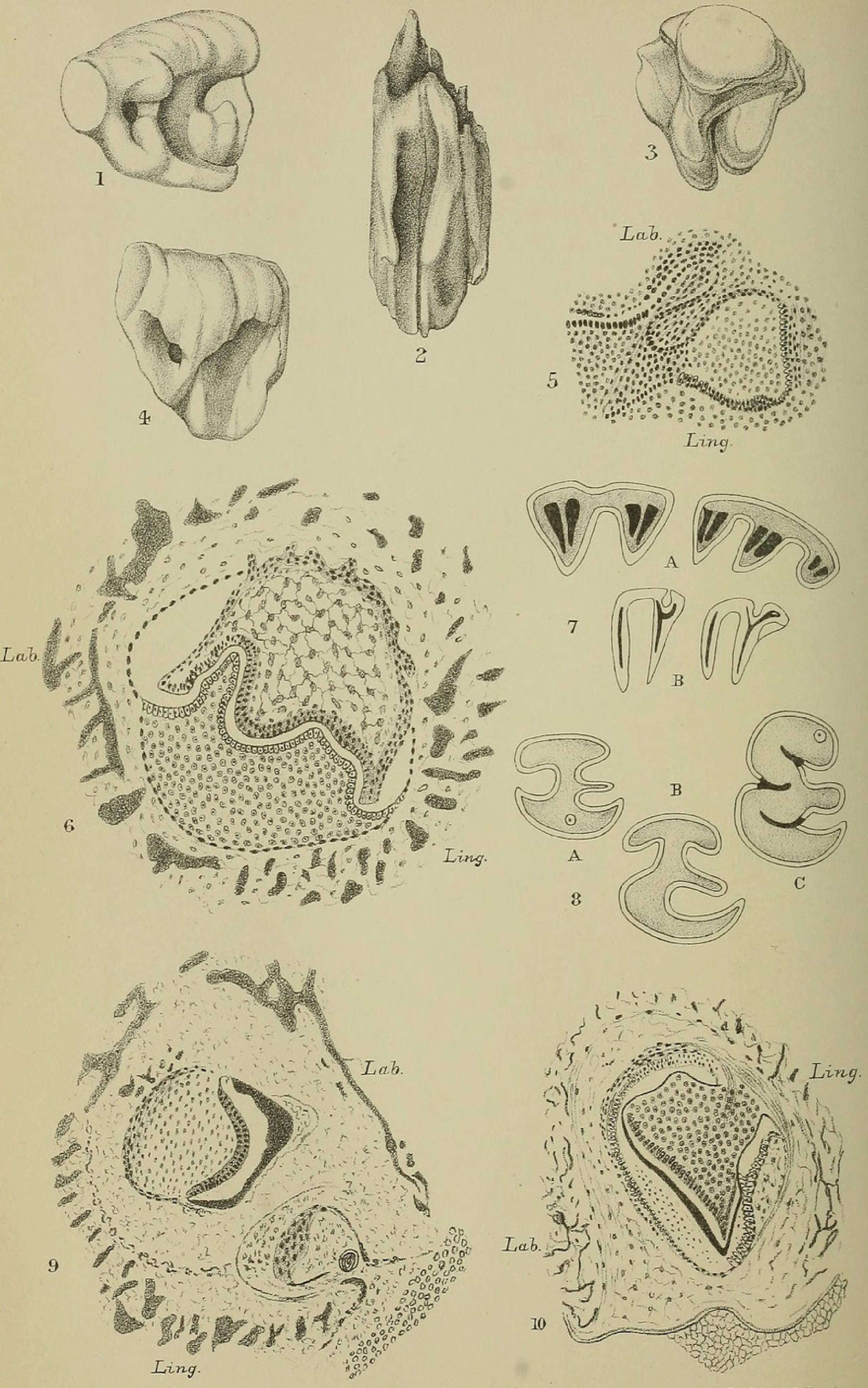

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EXPLANATION OF PLATE 26.

Fig. 1. Drawing of wax model of Left Upper Deciduous Molar. Postero-internal view. Stage II.

2. Drawing of wax model showing crown-surface of Left Upper Successional Molar. Stage III.

3. Drawing of wax model of Left Third Upper Cheek-tooth. Posterior view. Stage II.

Fig. 4. Drawing of wax model of Left Upper Deciduous Molar. Postero-internal view. Stage III.

5. Section through Left Upper Permanent Incisor, showing Labial down-growth of Dental Lamina. Stage I.
6. Section through Successional Molar. Stage III.
7. Crown-surfaces of the last two Upper Molars of
   A. *Dolichotis platycephalica* (after Ameghino).
   B. *Cavia cobaya*. Both much enlarged.
8. Crown-surface of Upper Molar of
   A. *Stichomys constans*. Inferior Eocene (after Ameghino).
   B. *Spaniomys riparius*. " " " "
   C. *Hystrix leucura*. Recent. (Camb. Univ. Zool. Mus.)
9. Section through Deciduous and Successional Molars of *Cavia*, showing "concentric epithelial body" in connection with the former. Stage II.
10. Section through a Posterior Molar, showing lateral position of the root.

Contributions to the Malacostracan Fauna of the Mediterranean.

By Alfred O. Walker, F.L.S.

[Read 7th March, 1901.]

(Plate 27.)

The following results of a short stay at Cannes and Hyères are interesting as showing what may be done in a few hours' dredging from an open boat, in depths never exceeding 35 fath., and with the simplest apparatus. This consisted of a tow-net of tiffany (such as is used by gardeners for shading greenhouses), strengthened at the bag end by cheese-cloth sewn over it for about 2 ft. in length, and attached to a cane rim 6 or 8 in. in diameter. The cane is important, as the net should be as light as possible so as not to scoop up the sand, in which case it fills up immediately. This net is attached to a stone heavy enough to remain on the bottom while the boat is rowed rather quickly; the distance of the net from the stone varying from 3 feet on coarse sand to 6 feet or more on mud. The stone stirs up the Crustacea, which find their way into the net with a certain amount of sand, though far less than in the case of a dredge (however light), or metal-rimmed tow-net. This, with two small buckets such as are used by children at the sea-side, a small muslin-bag attached to a brass rim with a brass grating on the top, two or three glass jars (*e. g.* French-plum jars), 75 fathoms of line, and plenty of tubes large and small, constitute the