X. *On the Development of the Teeth of Fishes* (Elasmobranchii *and* Teleostei).

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THE conformation of the jaws of the Elasmobranchii is such as to afford peculiar facilities for the study of the development of their teeth, and it has hence resulted that the older descriptions of the process approximate more closely to the truth than has been found to be the case in reptiles and mammals, and, I may now add, in osseous fish.

The accounts given by Prof. OWEN in his 'Odontography' (p. 35) and 'Anatomy of Vertebrates' (vol. i. p. 381) do not materially differ from one another; I will therefore make an extract from the latter work as embodying as concisely as possible the views of that anatomist, which are generally accepted as correct:—

"It is interesting to observe in it (the class of Fishes) the process arrested at each of the well-marked stages through which the development of a mammalian tooth passes. In all fishes the first step is the simple production of a soft vascular papilla from the free surface of the buccal membrane; in sharks and rays these papillæ do not proceed to sink into the substance of the gum, but are covered by caps of an opposite free fold of the buccal membrane; these caps do not contract any organic connexion with the papilliform matrix, but, as this is converted into dental tissue, the tooth is gradually withdrawn from the extraneous protecting-caps, to take its place and assume the erect position on the margin of the jaw.

"Here, therefore, is represented the first and transitory 'papillary' stage of dental development in mammals, and the simple crescentic cartilaginous maxillary plate, with the open groove behind, containing the germinal papillæ of the teeth, offers in the shark a magnified representation of the earliest condition of the jaws and teeth in the human embryo."

My own observations do not enable me to verify in its entirety any portion of the above extract, some of the conclusions expressed in which had, indeed, already been challenged by Professor HUXLEY* in a paper published in the 'Quarterly Journal of Microscopical Science' in 1853.

* In the first part of the Philosophical Transactions for 1875 I have already given a brief *résumé* of the present state of knowledge on the subject of the development of teeth; and I have therefore incorporated in the text of the present paper references to those papers only which directly relate to the teeth of Fish. As, however, this paper will not appear in the same volume of the Transactions, I very gladly fall in with the suggestion that I should notice one or two salient points lately established as true of other teeth.

Prof. HUXLEY (Quart. Journ. Micros. Sci. 1853), while accepting the views of GOODSIR as true of mammalian teeth, combated the idea that all reptilian and piscine teeth were developed from free papillæ; GUILLOT (Annal.

To confine the discussion for the present to the Elasmobranch Fishes, Professor OWEN, as shown in the above quotation, holds that their teeth stop short at a "papillary" stage equivalent to that supposed by him to exist at an early stage of the formation of a human tooth; while against this we have the opinion of Professor HUXLEY, that "the process seems to correspond with something more than the first and transitory papillary stage of the development of the mammalian teeth."

The application of modern methods of microscopic research has rendered it possible to obtain sections showing the relation of the various structures over a far larger area than was formerly practicable; and the facts thus brought to light appear to me to be of sufficient interest to merit careful description, although in many of the essential points I have been anticipated by Professor HUXLEY, as is shown by the extract here subjoined.

"In the Skate, as is well known, the young teeth are developed in longitudinal rows within a deep fold of the mucous membrane of the mouth, behind the jaw. So far as my examinations go, however, I find that this is not a mere simple fold, such as it has been described to be, but its two walls behave just in the same manner as those of the primitive dental groove in man—that is, they become closely united in lines perpendicular to the direction of the jaw, so that partitions are formed between every two rows of teeth; transverse partitions again stretch between the separate teeth of each row, but these did not appear to me to be complete, terminating by an arcuated border below. Each longitudinal canal, therefore, answers to a single elongated mammalian follicle, or to that prolongation of the alveolar groove from which the posterior permanent molars are formed in man (see GOODSIR), only the process does not go so far as in this case, the separate capsules remaining imperfect anteriorly and posteriorly. The lateral walls of the capsule, however, seem to me to have as much (or as little) 'organic

d. Sci. Nat. 1850) gave figures of young mammalian tooth-germs, which were very nearly correct; but the more precise knowledge which we now possess of the sequence of events in the formation of a tooth-germ is due to Prof. KÖLLIKER (Zeitschr. f. wiss. Zool. 1863, and Gewebelehre, 5th edition).

KÖLLIKER demonstrates that an ingrowth of epithelium (termed by him "enamel-germ"), which was afterwards destined to become the enamel-organ, was first recognizable before the dentine-pulp became visible; and, further, that the enamel-germ of a permanent tooth was derived from a part of the enamel-organ of its deciduous predecessor, this constituting the sole genetic relation between the two tooth-germs. LEGROS and MAGITOT added (Journ. de l'Anat. et Phys. 1873) an account of the origin of the tooth-germs of the true molars. Of fish, Prof. KÖLLIKER in his earlier work (Mikroskopische Anatomie, 1854, B. ii. p. 114) states, agreeing with Prof. OWEN, that the teeth of Plagiostomes are developed from free papillæ, and that they have therefore no enamel, never having been enclosed in sacs. This last inference is not confirmed by my own observations, nor by those of HERTWIG, quoted at a later page.

Prof. KÖLLIKER goes on to say that the teeth of all other fish (than Plagiostomes) are developed in sacs, sometimes enclosed within the jaw, sometimes only in mucous membrane, the successional teeth being developed anew from the mucous membrane of the mouth, behind the older teeth. The presence of an enamel-organ he considers to depend upon the existence of an enamel-like layer upon the teeth; in this last respect I have arrived at a different conclusion, being convinced that an enamel-organ is of universal occurrence, although the degree of its after development does in a great measure depend upon the amount (if any) of enamel to be formed.

connexion with the pulp and attachment to its base' as in man; and the process seems to correspond with something more than the 'first and transitory papillary stage of the development of the mammalian teeth.'

"Each pulp is invested by a very distinct basement membrane, whose continuity with that of the mucous membrane of the follicle is very obvious. The epithelium of the follicle forms a thick layer, which sometimes, when the upper wall is stripped back, adheres to it—sometimes remains as a cap investing the papilla. Even when the latter does not take place shreds of the epithelium frequently adhere to the papilla in the form of irregular, more or less cylindrical nucleated cells; as often, however, the papilla, whether any of the proper tooth substances be formed or not, has nothing adherent to it, but presents a perfectly smooth sharp edge."—"On the Development of the Teeth," Quart. Journ. Microsc. Science, 1853, p. 151.

Any fortunate transverse section through the jaws of a rather young dogfish affords an excellent view of the relation of the various parts to one another.

The dense gum or mucous membrane covering the convexity of the jaw is seen to be continuous with the softer and less fibrous tissue from which spring the dentine-papillæ near to the base of the jaw (Plate 31*. fig. 1), and this again is continuous with the connective-tissue framework of the protecting "thecal" fold. The sheet of tissue from which, at the base of the jaw, young dentine-papillæ originate becomes more fibrous as it passes upwards over the jaw, while those portions which intervene between the bases of the formative papillæ have their fibres specially arranged with reference to the teeth, so as to form in some sort ligaments to secure them in place (see fig. 2), running from the base of one tooth to that of the next.

The youngest dentine-papilla is a simple hemispherical eminence; that next in age is conical, while above this point the characteristic form of the future tooth is more closely approached.

In the youngest dentine-germs of the dogfish the cells near to the surface are larger than those more deeply situated, and measure about $\frac{1}{2000}$ of an inch in length; in older germs the larger size and greater abundance of the cells upon the surface is noteworthy, but nothing at all comparable to the distinct odontoblast layer or membrana eboris, characteristic of the formative organs of hard unvascular dentine, is met with.

It is not, however, so much in the dentine-papillæ as in their epithelium that the chief interest lies, especially when the facts described by myself in a former communication upon the development of the teeth in Batrachia and Reptilia† are kept in view for the sake of comparison.

Tracing the epithelium downwards from the exposed convex surface of the jaw (*a*, fig. 1) it is seen, opposite to the interspace between the third and fourth teeth, to leave the jaw and spring across to invest the thecal fold. In the specimen figured it has been

† As well as the sequence of events occurring in the formation of mammalian germs as demonstrated by Prof. Kölliker, *loc. cit.*

torn at this point, as often happens, and the continuity is therefore interrupted at *f* in the figure.

All that lies below this point is situated, therefore, not in an open groove, but in a closed space, roofed in and filled in by epithelium; the significance of this fact only becomes fully apparent when taken in conjunction with what is observed in other creatures.

Below this point the epithelium is continued down in the interspace between the jaw and the thecal fold, and forms investing caps to each of the dentine-papillæ—attaining, opposite to the youngest of the latter, a degree of development apparently in advance of and almost disproportionate to the stage of evolution of the papilla.

Their homologies, and the degree of development which they attain, entitle these epithelial caps to the name of "enamel-organs"*; and it was first pointed out by Professor HUXLEY, in the paper to which I have already referred, that enamel-organs are "nothing more than altered epithelium"†.

The structure of these enamel-organs is not very dissimilar to that of the corresponding organs in other Fish and Reptiles; their most conspicuous part is a layer of regular large columnar cells ("enamel-cells"), furnished with nuclei at their attached ends, and measuring from $\frac{1}{500}$ to $\frac{1}{700}$ of an inch in length. These "enamel-cells" are larger than, and different in appearance from, the cells to be met with elsewhere in the epithelium of the mouth; their occurrence, as well as the character of the residuum of the enamel-organ, justify us in saying that the epithelium "has in this situation undergone a special transformation into an 'enamel-organ.'"

Unless the specimen has been treated with acid the enamel-cells are often found to be firmly adherent to the cap of forming dentine; but after prolonged maceration in chromic acid they become detached, as is the case in the sections figured.

The extent to which enamel is formed upon the teeth of Elasmobranch Fishes is variable: it may seem an easy matter to pronounce whether there is or is not enamel upon any particular tooth; but in actual practice it is a matter of extreme difficulty to pronounce with any thing approaching to certainty upon the presence of an exceedingly thin layer of enamel upon the exterior of a tooth.

No one can doubt the existence of enamel upon the teeth of some skates; as the formative organs of the teeth of the skates are precisely similar, save in some details of form, to those of the dogfish, I do not doubt that the thin clear external layers upon the teeth of the latter are to be regarded as enamel.

The residual part of the enamel-organ is inconspicuous; it consists of very much smaller cells, branched and intercommunicating and forming a firmly fibrillated tissue; it is best seen in the youngest enamel-organ (fig. 2).

The enamel-organs of the successional teeth are so closely and intimately connected

* *Cf.* the "enamel-organs" of the dermal spines of dogfish, as described and figured by HERTWIG, Jenaische Zeitschrift, 1874.

† Prof. KÖLLIKER (Mikros. Anatomie, B. ii. p. 114) by inference denies the existence of an enamel-organ in the Plagiostomes; I am not aware of his having since altered his opinion.

that they may almost be termed a "compound enamel-organ;" and they thus recall the manner in which successive enamel-organs bud off from the necks of their predecessors in the newt.

The columnar cells (enamel-cells) remain upon the surface of the formed tooth until it has arrived at a point above the protection of the thecal fold (see the third tooth in fig. 1); after this they get worn off and lost.

In the interspaces of the teeth the "enamel-organs" lose their distinctive character, and between the older teeth do not markedly differ from the epithelium of other parts of the mouth.

In young dogfishes the partitions between the successional teeth, and also between the contiguous vertical rows, are formed solely by epithelium; but, as was pointed out by Professor HUXLEY, in older specimens septa of connective tissue separate each vertical row from those on either side of it, so that a tooth and its successors are contained in a sort of longitudinal canal, the whole series being connected together by the continuity of their enamel-organs.

In very young specimens, before any lip is formed, the transition of the dermal spines on the under surface of the head into the teeth is readily demonstrable.

Thus in fig. 3, which represents a section of the lower jaw of a very young dogfish, the spines upon the skin are seen to pass without breach of continuity into the teeth, from which they differ mainly in size, and to a very slight extent only in shape*.

It is stated by GEGENBAUR (Manuel d'Anatomie Comparée, p. 738) that in *Selachia* the mucous membrane of the mouth, as far back as the pharynx, is clothed with spines of structure identical with that of the teeth proper, these spines often occupying those regions which in Ganoids and Teleostei are clothed with conspicuous teeth; I have not had the opportunity of myself verifying his statement†.

* Prof. WILLIAMSON (Phil. Trans. 1849) pointed out the structural resemblance of ganoid and placoid sides to teeth and their homological identity.

† To the above remarks must be added the statement of HERTWIG (Jenaische Zeitschrift, 1874), that the teeth and the dermal spines are developed in a manner precisely similar. I did not become acquainted with his paper until after this paper had been read before the Royal Society, or I should have made more frequent reference to his results. Dr. HERTWIG seems to have been working in the same groove as myself, and has published his paper relating to the development of the dermal spines and teeth of sharks a short time before mine was read; whilst a short time after my paper on the development of Batrachian teeth was read he published a contribution to the same subject. It is gratifying to find that the figures and descriptions of our independent and almost contemporaneous papers conform very closely, though there are points on which we differ.

Dr. HERTWIG gives figures of dermal spines in the process of development in which a papilliform eminence of the dermis is undergoing calcification at its tip, whilst the stratum Malpighii over it is furnishing a crust of enamel, neither the "enamel-organ" nor the "dentine-papilla," if such they can be called, being markedly specialized nor different from the parts around them, save in contour and in the size of the epithelial cells.

He holds that the increased size &c. of the dermal spines over the surface of the jaws, where they constitute teeth, is adequately accounted for on the principle of increased use; that is to say, the excitation of pressure will bring about increased vascularity, and so forth.

His figures are very clear and accurate; and he has entered into the details of the process of calcification with

Teleostei.—Sections of the jaws of the Perch, Pike, Eel, Haddock, Cod, Mackerel, and Trout have been examined, and have been found to agree so closely in most points, that it is possible to embody the leading features of the process in a general description.

The literature of the subject may be disposed of in a very few words; in the first place, there is the view held by Professor OWEN, and concisely expressed by him as follows:—"In all fishes the first step is the simple production of a soft vascular papilla from the free surface of the buccal membrane;" and "In many fishes, e. g. *Lophius*, *Esox*, the dental papillæ become buried in the membrane from which they rise, and the surface to which their basis is attached becomes the bottom of a closed sac;" and again, "Here, therefore, is represented the 'follicular' stage of the development of a mammalian tooth; but the 'eruptive' stage takes place without previous inclosure of the follicle and matrix in the substance of the jawbone." (Anatomy of Vertebrates, vol. i. p. 382.)

A much more accurate account of the process as it occurs in the mackerel is embodied in Professor HUXLEY's paper, already several times alluded to; the fact that the papilla is never free and that it is surmounted by an enamel-organ derived from and continuous with the oral epithelium is clearly laid down; and KÖLLIKER mentions that the teeth of all osseous fish are developed in sacs not altogether from free papillæ. Nevertheless the exact nature of the process has not, so far as I know, been described by any previous author.

In all cases the whole series of changes take place beneath an unbroken surface, and often at some little depth; in this respect, however, differences are met with upon different bones in the mouth of the same fish, so that this would appear to be influenced by accidents of situation.

From the deepest layer of the oral epithelium, which is very thick in many fish, there dips downwards a blunt-ended process, descending into the loose connective tissue beneath. When it approaches the surface of the bone, a dentine-pulp is developed in the subjacent connective tissue, which it eventually covers over like a cap or bell-jar.

The epithelial process, making its way downwards, is recognizable before the dentine-papilla can be distinguished; its end becomes transformed into an enamel-organ, but no very definite capsule is formed around the dental germ.

There is therefore no "papillary" stage and no "follicular" stage, in the sense in which these terms are ordinarily used; the only appearance at all suggestive of the existence of free papillæ with which I am familiar is to be met with in the haddock, in which fish the tissues above a forming tooth-germ become elevated in places into a sort of papilla, which is, however, altogether external to and distinct from any part of the dental germ, which latter constitutes less than one third of its bulk and is far below its surface.

more minuteness than I have done. But I do not think that the grounds which he has adduced for asserting the existence of a membrana preformativa in the sharks are adequate to weigh against the reasons which have led WALDEYER and others to doubt its existence; and my own researches in this direction lead me to the belief, long ago expressed by my father, that the appearances described are susceptible of a different interpretation.

The general relationship of the dental germs to the oral epithelium, to the already formed teeth, and to the bone is shown in the perch in fig. 4, and in the sharp-nosed eel in fig. 6 ; the process in the two fish is so closely similar that it seems unnecessary to separately describe their tooth-germs.

An early stage is represented in fig. 7, in which the inward-growing epithelial process has formed an embracing cap or enamel-organ, but no calcification has as yet occurred. The enamel-cells are of very large size over the apex of the dentine-papilla, measuring about $\frac{1}{400}$ of an inch; but at a somewhat later stage (fig. 8) the large enamel-cells are seen to be confined to the immediate summit of the tooth, those a little further down (e' in the figure) being very much smaller ($\frac{1}{1000}$ of an inch). This same point is shown in the tooth-sac of a perch (fig. 5), in which the cells of the enamel-organ over the summit are large, but those extending down the sides of the tooth small and comparatively inconspicuous.

At a still later stage (fig. 9) the large cells on the apex have disappeared, and the whole enamel-organ consists of the smaller cells upon the sides of the dentine-cap, which are about $\frac{1}{1200}$ to $\frac{1}{1500}$ of an inch in length.

This peculiar configuration of the enamel-organ has relation to the partial disposition of the enamel upon the tooth; thus the tooth of the sharp-nosed eel (fig. 10) has a sharp conical cap of enamel upon its summit, the enamel being absent, or so thin that I cannot be sure of its existence, upon the sides of the tooth*.

We may thus say that we have exemplified within the boundaries of a single tooth-sac a functional and a rudimentary enamel-organ; and it is interesting to observe that the appearance of the rudimentary or lower portion of the enamel-organ closely resembles that of the entire rudimentary enamel-organ of the armadillo, which I have elsewhere described (Quart. Journ. Micros. Sci. 1874).

The fact that the development of the "enamel-cells" bears a direct relation to the thickness of the enamel to be formed also lends support to the view (which on other grounds I am strongly inclined to support) that the enamel is formed by the direct conversion of the enamel-cells into the hard tissue.

It is difficult otherwise to account for the contrast presented by the length of the cells in the different parts of the enamel-organ; and I may add that the aggregate length of the cells and the enamel cap already formed in fig. 8 just makes up the thickness of the enamel cap upon an average completed tooth.

* The existence of terminal caps of enamel, a character upon which alone Professor OWEN has founded his fossil genus "*Ganacrodus,*" is apparently by no means uncommon; I have found them in the eel, the perch, the newt, and the salamander; and as they are very easily lost in making sections, it is probable that they are present upon many teeth on which their presence has not as yet been demonstrated.

The positive determination of the absence of a thin layer of enamel upon the exterior of a tooth is a matter of no little difficulty, although it might at first sight appear easy enough: the double contour which is due to the thickness of the section can hardly be with certainty distinguished from a very thin structureless external layer, though the use of the dark-ground illumination will often bring the enamel layer out distinctly, owing to the difference in its refractive index. However, as I find the presence of an enamel-organ to be universal, the presence or absence of a merely rudimentary deposit of enamel ceases to be a fact of so much importance.

Of the dentine-germs or papillæ there is little to be said; they have a well-marked odontoblast layer, especially in the eel, and their bases contribute nothing to the formation of a special capsule. In fact the tooth-germs are only bounded by adventitious capsules, due to the condensation of the loose connective tissue around them. The enamel-organs long retain a connexion with the oral epithelium, which, however, becomes lost after a time, as by the elongation of the tooth its summit soon passes upwards into the substance of the oral epithelium; the "neck of the enamel-organ" is seen at *b* in figs. 5, 6, 7, 8, and 9.

The formation of new dental germs is perpetual, each enamel-germ being formed *de novo*, without being derived from any part of the earlier germs.

So far I can confirm the statements of Prof. OWEN, that "the germs of the new teeth are developed, like those of the old, from the free surface of the buccal membrane throughout the whole period of succession—a circumstance peculiar to the present class."

But I cannot agree in the further statement that "it is very conspicuous in the cartilaginous fishes, &c.;" for in these the enamel-organ of each new tooth is derived from a part of that of its predecessor, in a manner closely analogous to that observed by myself in reptiles, and by KÖLLIKER in the formation of the germ of the permanent teeth in man. To the manner of attachment of the teeth of the eel I may briefly allude, as it is shown in fig. 10, although I have already described it more fully elsewhere (Transactions of the Odontological Society, 1874). Each tooth is perched on the summit of a hollow bony column, into which its formative pulp extends for a short distance.

This little column of bone, which is specially developed for and renewed again after the loss of each tooth, is formed around the base of the tooth-pulp, which contracts below the point where dentine ceases to be formed.

The dentine ends sharply where the bone begins; not the smallest fusion of the two tissues appears to take place; and if we imagine dentine to be formed in the lower portion of the pulp, where it enters the hollow bony support, we should have a sort of rudimentary socket formed. This, however, never takes place in the eel: the dentine ends in a slightly rounded border at a point altogether above the bone.

The teeth of the perch, and indeed of many other fishes, are similarly attached; indeed I think the generalization may safely be laid down that in all cases a special development of "bone of attachment" takes place.

The tooth of the mackerel (fig. 13) is somewhat differently attached; it is developed in a furrow running round the thin edges of the jaws, and when it is completed and erupted it becomes attached to the permanent bony walls of that furrow by a development of little bony trabeculæ which bridge over the interval and so fix it in its place.

The development of the teeth of the mackerel does not in essential respects differ from that described in the eel and the perch, save that the situation of the tooth-germ is peculiar, as has already been mentioned (fig. 12).

The enamel-organ, which attains but a feeble development, was seen by Prof. HUXLEY to be continuous with the oral epithelium; to his description I have only to add that the first step towards the formation of a new tooth-germ is the budding inwards of the oral epithelium (which has been lost from the surface of the section figured).

The tooth-germs of the pike originate in precisely the same manner as those above described; but it is not unusual to see two tooth-germs of different age apparently destined to succeed to the same tooth, a thing which I have not observed in the haddock, the eel, or the perch.

The enamel-organ of the pike attains to a development intermediate between that of the mackerel and that of the eel or perch; from the regular appearance and considerable size of its component cells, which measure from $\frac{1}{1000}$ to $\frac{1}{800}$ of an inch, I should anticipate that a layer of enamel would be found upon its teeth, which is apparently the case, though it is not very thick.

Although the enamel-organs of all these fish consist primarily of two rows of cells, and traces of their original formation may be in places discerned, as at the base of the enamel-organ in fig. 11, yet that layer of columnar cells which goes by the name of the "enamel epithelium" so greatly preponderates that the outer layer is soon lost sight of.

No stellate reticulum separates these two layers in any fish or reptile with which I am acquainted.

There are many points of importance which I have not touched upon in this short and imperfect paper—such, for example, as the presence or absence of a basement membrane or membrana preformativa upon the dentine-papillæ, as well as the subsequent details of the process of calcification. My object has, however, been merely to give a general outline of the subject, which I hope at some future time to fill in with greater detail.

My examination of the process of the development of the teeth having been now extended to a considerable number of Mammals, Reptiles, Batrachians, and Fish, justifies me in drawing some general conclusions as to the structure of the tooth-germs, the more important of which may be summarized as follows:—

1. It is desirable to entirely abandon the terms "papillary," "follicular," and "eruptive" stage, inasmuch as these are hypothetical and arbitrary, and correspond to no serial conditions verified by observation.

2. In all animals the tooth-germ consists primarily of two structures, and two only—the dentine-germ and the enamel-germ.

The simplest tooth-germ never comprises any thing more. When a capsule is developed it is derived partly from a secondary upgrowth of the tissue at the base of the dentine-germ, partly from an accidental condensation of the surrounding connective tissue.

3. The existence of an enamel-organ is quite universal, and is in no way dependent upon the presence or absence of enamel upon the completed tooth, although the degree to which it is developed has distinct relation to the thickness of the future enamel.

The presence of an enamel-organ in the fœtal narwal has been described by Professor TURNER (Journal of Anatomy and Physiology, 1873); its occurrence in a fœtal armadillo by myself (Quart. Journ. of Micros. Science, 1874); while in the present paper instances of its occurrence where little or no enamel is formed are noted.

4. So far as my researches go, a stellate reticulum, constituting a large bulk of the enamel-organ, is a structure confined to the Mammalia † (it is absent in the armadillo, and I should infer, from Mr. TURNER's description, in the narwal).

5. As laid down by Professor HUXLEY and Professor KÖLLIKER, the dentine-papilla is beyond all question a dermal structure, the enamel-organ an epithelial or epidermic structure.

As I believe it can be shown that the enamel is formed by an actual conversion of the cells of the enamel-organ, this makes the dentine dermal, and the enamel epidermic structures.

6. In *Teleostei* the new enamel-germs are formed directly from the oral epithelium, and are new formations arising quite independently of any portion of the tooth-germs of the teeth which have preceded them. In mammals and reptiles, and in some, at all events, of the Batrachia, new tooth-germs are derived from portions of their predecessors.

7. In all animals examined the phenomena are very uniform: a process dips in from the oral epithelium, often to a great depth; the end of the process becomes transformed into an enamel-organ coincidently with the formation of a dentine-papilla beneath it.

The differences lie rather in such minor details as the extent to which a capsule is developed; and no such generalization as that the teeth of fish in their development represent only an earlier stage of the development of the teeth of Mammalia can be drawn.

DESCRIPTION OF THE PLATE.

PLATE 31*.

Fig. 1. Transverse section of the lower jaw of a young dogfish, *Scyllium canicula*.

To the right is seen the thecal protecting fold of mucous membrane, slightly displaced. Between this and the jaw is seen the chain of enamel-organs, which, if the parts were exactly *in situ*, would solidly fill up the whole interspace. The epithelium, where it passes across from the jaw to the thecal fold, between the third and fourth tooth, is torn across.

a. Oral epithelium.

b. Neck of enamel-organ connecting it with oral epithelium.

c. Special "bone of attachment."

† It is also to be found in the poison-canal of the partly calcified tooth-germs of poisonous snakes, as I have described and figured in a paper upon the development of poison-fangs, in course of publication in the Philosophical Transactions.

d. Dentine-papilla.

e. Enamel-organ.

e^1. Rudimentary portion of enamel-organ.

f (fig. 1). Point of passage of the oral epithelium across on to the thecal fold.

g. Cap of enamel.

h. Bone of jaw (or cartilage in figs. 1, 2, 3).

l. Formed dentine, or completed tooth.

sp. Dermal spines.

(The lettering applies to all the figures.)

Fig. 2. More highly magnified portion of the same section, showing the structure of the enamel-organs, the relation of the dentine-papillæ to the mucous membrane, and the manner of fixation of the teeth.

Fig. 3. Section of the lower jaw of a dogfish about 3 inches long. The continuity of the skin carrying dermal spines with the mucous membrane and its teeth is well seen.

Fig. 4. General view of the relations of the oral epithelium to the young tooth-sacs; three teeth in place, which have lost their enamel tips, are shown, while on the right the lip is seen in outline. From the lower jaw of a perch, × 30.

Fig. 5. Tooth-sac of a perch, showing the continuity of the oral epithelium with the enamel-organ, the large enamel-cells at the upper part of the latter, and its rudimentary lower portion, &c., × 70.

Fig. 6. Transverse section of the lower jaw of a sharp-nosed eel; for the sake of clearness the subepithelial connective tissue has been left out.

Fig. 7. Very young tooth-sac of an eel, × 100.

Fig. 8. Tooth-sac a little more advanced, in which more dentine and enamel have been formed: the aborting of the enamel-cells at the lower edge of the enamel-organ is noticeable, × 70.

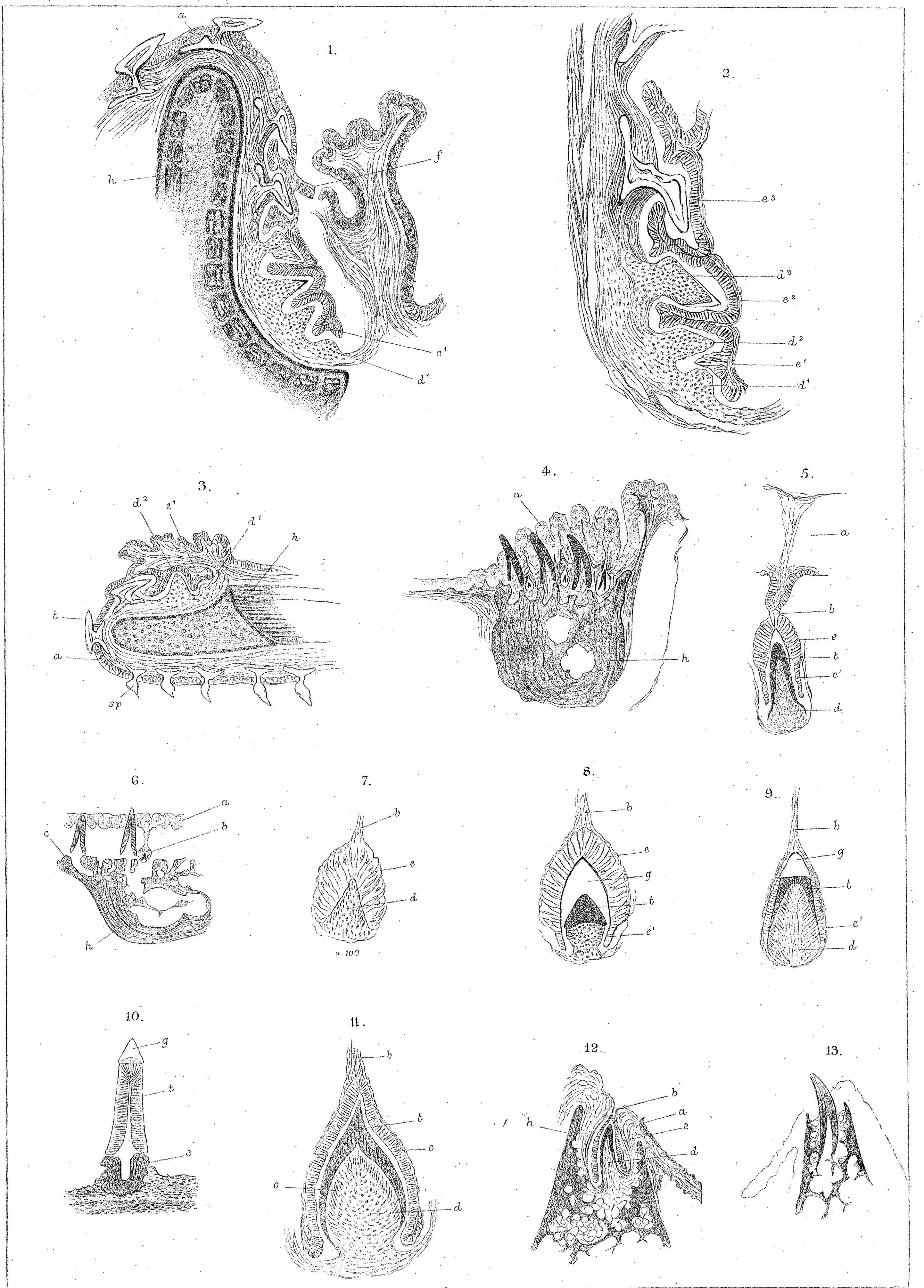
Fig. 9. Tooth-sac yet more advanced, in which the terminal cap of enamel is complete, and the enamel-organ has almost disappeared at the upper end of the sac, × 30.

Fig. 10. Single tooth of a sharp-nosed eel, showing its enamel cap and its supporting hollow column of bone, × 20.

Fig. 11. Young tooth-sac of a pike, × 70.

Fig. 12. Section of the lower jaw of a mackerel. The young tooth-sac is seen to be lodged in a groove in the edge of the bone: the oral epithelium is lost over the surface of this groove, but the neck of the enamel-organ is distinguishable, × 40.

Fig. 13. Tooth of a mackerel, showing the peculiarity of the attachment of the perfected tooth, which is fixed in place by numerous slight trabeculæ of new bone, which unite it to the margins of the groove in the edges of the jaws, × 15.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