

structure of any one scaly type by these feathered vertebrates; those reptilian qualities and excellencies which are best and highest have become theirs; but how much more! This exaltation of the 'Sauropsidan' or oviparous type by the substitution of feathers for scales, wings for paws, warm blood for cold, intelligence for stupidity, and what is lovely instead of loathsomeness,—this sudden glorification of the vertebrate form is one of the great wonders of Nature.

III. ON *ACRODUS ANNINGLÆ*, AGASS.; WITH REMARKS UPON THE AFFINITIES OF THE GENERA *ACRODUS* AND *HYBODUS*.

By E. C. H. DAY, F.G.S.

[Plates III. and IV.]

FEW amongst the Fish-remains preserved to us in the Secondary rocks are more commonly met with than those of Sharks of the genera *Acrodus** and *Hybodus*;† yet, notwithstanding the frequency of their occurrence, we have but little exact knowledge of the form and affinities of the fish to which these remains belonged. Their cartilaginous skeletons have, excepting a few fragments, altogether perished; and it is quite impossible to guess at their outlines, undefined as these were either by scales or hard plates. Nay, more, the remains that are known of these extinct forms present such great differences from the corresponding structures of living fish, that, although a relationship to a single existing genus has long been indicated, the degree of that affinity is still very uncertain.

Of the two genera, the remains of *Acrodus* are the less frequently met with; and its structure is, in consequence, the less known. At the time that Agassiz wrote his celebrated work upon fossil fishes,‡ detached teeth and one or two incomplete palates, or groups of teeth associated in their normal order, and some traces of the shagreen, or skin of the shark, were all the materials at his disposal for determining the characters of the genus. Relying upon these, he referred *Acrodus* and *Hybodus* to different families, assigning the former to the Cestracionts,§ of which the Port Jackson Shark, *Cestracion Philippi*, is one of two existing examples, and making the latter the type of a new family, the Hybodonts.||

* Agassiz, 1838.

† Ibid. 1837.

‡ The volume containing those that form the subject of the present paper was published 1833–43.

§ Agassiz, 'Poissons Fossiles,' vol. iii. p. 139.

|| Ibid. p. 206.

The chief grounds upon which this separation was made appear to have been, firstly, differences of form of the teeth of the two groups; secondly, an assumed diversity, in kind, of their structure; and, thirdly, a difference in the degree of variation of the teeth upon similar jaws. The most important external character, given by Agassiz, of a Cestraciont tooth is its depressed and expanded form, fitted for crushing hard substances;* of that of a Hybodont, on the other hand, the characteristic is the presence of a greater or less number of cones, of which the median is the most elevated, adapting it to retain prey when seized.† These differences of form are associated with a different arrangement of the enamel which covers the teeth; and upon this, and a co-existent diversity in the internal arrangement of the dental elements, Agassiz lays much stress.‡ Such differences, however, as we now have proof, do not amount to differences in *kind*, but are merely of *degree*; and if it can be shown that the external characters of *Acrodus* pass gradually into those of *Hybodus*, when traced through a series of teeth from the same mouth, we may admit, even without a special examination, that the internal structure would likewise be graduated from the character of one extreme form to that of the other. The third argument is based upon the fact, that the teeth in the mouth of some *Hybodi* differ less amongst themselves than do those upon the palates of some *Acrodi*;§ but this reasoning is altogether useless, except to support the generic distinction, if it be proved that the teeth of the two groups are but modifications of the same type. Another item of negative evidence that perhaps influenced the judgment of Agassiz upon this point was that the dorsal spines, or ‘Ichthyodorulites,’ of *Acrodus* were still unknown;¶ the possibility of such spines showing a close affinity to *Hybodus* being thus ignored.

We have now fortunately sufficient evidence to justify us in attempting to form a clearer idea of the relationship that existed between these two genera; and this evidence lies in a complete

* Agassiz, ‘Poissons Fossiles,’ vol. iii. p. 159.

† Ibid. pp. 178, 179.

‡ Ibid. p. 139, and again at p. 207, where, after speaking of the internal structure of Hybodont teeth, he goes on to say: ‘Cette structure des dents s’oppose comme on le voit, au rapprochement que M. Owen’ (in his ‘Odontography’) ‘a tenté entre les dents des Hybodontes et celles des Cestraciontes, en effet les couronnes plates qui distinguent les dents des Cestraciontes et qui font des instruments propres à broyer la nourriture n’ont rien de commun avec les couronnes élevées et coniques des Hybodontes, qui quoique obtus dans quelques, espèces étaient évidemment destinées à saisir et à retenir une proie.’ It must be remembered, however, that, when Agassiz made this generalization, he had classed as a Hybodont *tooth* the cephalic spine of *Hybodus*. Ibid. p. 208.

§ Ibid. pp. 141 and 182.

¶ Ibid. p. 140.

palate of *Acrodus Anningiæ* and in a pair of dorsal spines, associated with teeth, of another individual of the same species. The palate (Pl. III.) consists of an almost complete series of teeth, retaining the position that they must have occupied upon the jaw during life. The bone upon which they were based has altogether disappeared; this fact and the absence of spines or any other remains anywhere near where the specimen was found, suggest the probability of its belonging to a detached lower jaw, of which the cartilaginous structures have perished. Counting from either extremity of the series to the middle, we have on each side eight transverse rows of teeth, with a central row resting where the symphysis, or line of junction, of the jaw-bone would have been. Two very small displaced teeth at the right extremity seem to indicate that there were originally nine rows upon each side. The two sides are not quite symmetrical, the right-hand series appearing more flattened and expanded than the left; and it is probably owing to this distortion that fewer teeth are discoverable in each row (excepting two) of the latter than in the corresponding ones of the former. Commencing from the extremities of the series, the first row on the right side is indicated by the two small teeth above-mentioned: all trace of this row is wanting on the left.

The second row on the right contains 4 teeth,* ditto on the left 4 teeth			
" third	"	" 6 "	" 6 "
" fourth	"	" 7 "	" 6 "
" fifth	"	" 8 "	" 6 "
" sixth	"	" 8 "	" 6 "
" seventh	"	" 7 "	" 6 "
" eighth	"	" 6 † "	" 5 "
" ninth	"	" 6 ‡ "	" 5 "
And the central row contains 5 "			

Looking at the characters of the various teeth, thus grouped together, one at first feels doubtful whether the specimen should not be assigned to a *Hybodus* rather than to an *Acrodus*; for, although the teeth of the posterior rows are marked with the fine striæ characteristic of the latter genus, and are of a more or less depressed form, yet they all show some tendency to develop slight elevations, towards the apices of which the lines of enamel converge. In the more forward teeth we find, in the seventh row, the median elevations becoming more distinctly conical, and the ridges of enamel, which converge upon them, becoming coarser and more widely separated; and in the eighth, ninth, and central rows these characters are so strongly brought

* One of these is displaced to the outside of the third row.

† The single detached tooth outside these appears to belong to the central row.

‡ The sixth tooth of this row is scarcely visible.

out that, apart from the rest of the specimen, I should certainly have regarded these teeth as belonging to a small individual of *Hybodus Delabechei*, Charlesworth.*

Agassiz, however, has figured an incomplete series of similar teeth under the name of *Acrodus Anningia*;† but, though his representation is sufficiently clear to enable us to recognize the specific identity of the two specimens, the markings of the teeth are not shown well enough to render any exact comparison of their characters in the various rows possible. One remarkable discrepancy between his figure and mine is observable, namely, that in the series figured by Agassiz there are portions of as many rows of teeth upon a fragment as there are upon the entire of one side of my specimen. It may perhaps be that the two specimens belonged, the one to an upper and the other to a lower jaw, and that the number, arrangement, and size of the teeth differed upon the two, as I find they do in the recent *Cestracion*s. In the Museum of Practical Geology there is a specimen that agrees very well with Agassiz's figure, and amongst the teeth there are many that are unmistakably similar to those now figured; the differences that are apparent may, in addition to the reason given above, be likewise partly due to the larger size of the individual to which they belonged. I am the more inclined to believe in considerable variations in the teeth of individuals from seeing in the specimen before us that the teeth of one jaw varied, without regularity in size and appearance, not merely according to position upon the same side, but even in the same relative position upon opposite sides. We may observe this especially in the fourth rows, in which the teeth on the right hand are considerably larger and longer than those on the left. In the right-hand teeth there are indications of five elevations, of which the most prominent is not the median, but the most anterior; hence these teeth have a peculiar aspect not observable in those of the corresponding row.

Regarded as a whole, this palate indicates that the mouth of this species was of an expanded form, exhibiting but the slightest tendency towards that contraction of the anterior portion, which is so characteristic of the jaws of the recent *Cestracion*.

* I believe this species to be identical with *H. pyramidalis* of Agassiz.

† Some of the teeth answer likewise to his figure of *A. gibberulus*. Agassiz appears to have been acquainted with the latter teeth before he named the fragment of *A. Anningia*, which I cannot find that he has anywhere described. As the two species are, however, figured side by side, and were consequently, I presume, published together, I feel justified in taking my choice of the two names; and I prefer *A. Anningia*, as belonging to the best characterized specimen, and as preserving the name of one to whom Palæontologists are deeply indebted.

The dorsal spines which, by means of the teeth associated with them, we can assign to this species are in the British Museum,* and were formerly in my collection. Having personally taken part in the extraction of these remains, I can speak confidently of the authenticity of their association; and as they were not mixed up with Saurian remains, or those of any other species of *Hybodus*, &c., there is no reason to suppose that their juxtaposition was in any way accidental, as some such groupings undoubtedly are.†

In order to show conclusively the existence of teeth in this collection similar to those in the palate described, I have figured (Pl. IV.) four teeth which, perhaps not more so, than the others, are easily referable to certain positions upon a similar jaw. Thus fig. 1 corresponds with those of our eighth row, fig. 2 with our seventh, fig. 3 with our sixth, whilst fig. 4 is a larger specimen of the curious teeth already mentioned as occurring in one of our fourth rows; fig. 5 is a still more remarkable variation from the general type.

The spines which accompany these teeth are the anterior and posterior dorsal, easily distinguishable from each other by good characters. The *anterior* (Pl. IV. fig. 6) is $17\frac{3}{4}$ inches in length, but the point had been broken off before it was embedded, so that it was probably from one to two inches longer when perfect; the part not inserted into the body of the fish measures along the anterior line $13\frac{1}{4}$ inches, leaving $4\frac{1}{2}$ inches for the inserted base. On comparing this spine with an anterior spine of similar dimensions (also now in the British Museum and formerly in my collection), and which is one of those usually confounded, by reason of the figures given by Agassiz, with *Hybodus reticulatus*, but which in reality belongs either to *H. Delabechei*, Charlesw., or to *H. medius*, Ag., we are struck with the resemblance that they have to each other. They are similarly proportioned and curved, and the ridges upon the sides and anterior face are very similar in depth and

* I take the opportunity of acknowledging the courtesy of G. R. Waterhouse, Esq., and of Dr. Günther, of the British Museum, as also of Professor Huxley, of the Museum of Practical Geology, in affording me every facility for the examination of specimens under their care, and in drawing my attention to several which were of much interest, as elucidating my subject, and which otherwise I might not have noticed.

† In Lord Enniskillen's magnificent collection, at Florence Court, there is a portion of a Saurian containing between the ribs two spines and many large teeth of *Acrodus nobilis*; and in the Museum of Practical Geology there is a smaller fragment of a Saurian 'interior' which displays teeth, two cephalic spines, and part of a dorsal, of *Hybodus reticulatus*, associated with teeth and part of a dorsal spine of *Acrodus latus* (?). These specimens are very suggestive of the destructive capabilities of the *Ichthyosauri*.

character. That of *Hybodus* differs, however, from that of *Acrodus Anningiæ* in being gently and regularly curved off from the sides to the centre of its posterior face, instead of this forming almost a right angle with the side; the ridges of the former are more numerous than in the latter; and a still better distinction is found in the largeness and fewness of the denticles upon that of *Acrodus*. Of the *posterior* spine (Pl. IV. fig 7) about an inch of the base is missing; the length of the spine, as it is, is about $11\frac{1}{2}$ inches, of which the fragment of the base measures $2\frac{1}{2}$ inches. The exposed part of the spine would thus have measured 9 inches, or $4\frac{1}{2}$ less than what is preserved of its anterior fellow. From the latter it differs also in its much stouter proportions; and it has moreover a slight angle at the upper part of the base, which gives a somewhat distorted appearance to the spine, and the effect of which doubtless was to give to the exerted portion a more backward inclination than that of the anterior spine; the inserted portions probably penetrating the body in parallel directions. The line formed by the termination of the polished ridges, at the upper edge of the base, in the smaller spine is not so sharply sloped from the posterior to the anterior edge, but takes a deeper curve than in the larger. In the squareness of the posterior side, and in the comparatively large size of the denticles, the two spines resemble each other.

After a careful comparison of several spines more or less closely resembling the one described with the figure of *Hybodus curtus* given by Agassiz, I am strongly of opinion that that is nothing more than the posterior dorsal spine of *Acrodus Anningiæ*; whilst the anterior spine is generally marked in collections as *Hybodus grossispinus*.

Since Agassiz published his work certain spines, obtained at Lyme Regis, have been assigned to *Acrodus*, having been found associated with teeth of the genus. One of these in my possession, and which appears to be an anterior, differs from those described in being almost smooth, the elevations being nearly lost, though the polished markings are preserved; in its shorter and stouter proportions, and moreover in being scarcely, if at all, curved. Such spines probably belonged to *A. nobilis* or to *A. latús*; but the differences between them and those of *A. Anningiæ*, or of undoubted Hybodonts, are clearly only differences of degree.

The fact that these two genera are more closely allied than supposed by Agassiz has long been admitted by many,* though

* Charlesworth, Mag. of Nat. Hist. 2nd ser. 1839, p. 245. Owen, 'Odontography,' as quoted above by Agassiz. Ibid. 'Palæontology,' p. 108. Mackie, The Geologist,

the grounds of the relationship have not, that I am aware of, been definitely stated.

From an examination of various remains of *Hybodus* now accessible, it is evident that, although the teeth in this genus do not differ so much, upon the posterior and anterior portions of the jaw, as they do in *Acrodus* or *Cestracion*, yet there is always some amount of variation;* and it appears to me that the more elongated the cones are, the less the variation in the entire series of teeth in any species; therefore this difference again is only one of degree. From heads of *Hybodus basanus*, Egerton, we learn that *Hybodus* possessed an expanded jaw, similar to that indicated by our figure of *Acrodus*; nor must much stress be laid upon the presence of cephalic spines with the former genus and their never having been found with the latter, since we have them positively associated only with a few species of *Hybodus*, of which the remains are far more frequently met with than those of any *Acrodus*. In fact, regarding these two genera as one group, such a group would be for convenience divisible by dental characters into three sub-divisions; the first, with very elongated cones, represented by *Hybodus basanus*; the second, with the cones more obtuse, by *H. Delabechei*; and the third, almost or altogether wanting conical elevations, by *Acrodus nobilis*; *A. Anningia* would then be intermediate in characters between the second and third groups, and, by thus intervening, would tend to show the artificiality of the whole arrangement.

Understanding now the close affinity between the two genera, I will add a few words upon their affinities to existing forms. Agassiz indicated a close affinity between *Acrodus* and *Cestracion*, from a consideration of the structure of their teeth; but as his own classification, viewed by the light now obtained, shows, the resemblance, somewhat close in typical *Acrodi*, becomes altogether lost as we pass to the true Hybodonts, which, on the same consideration, show a relationship to the ordinary Sharks. Again, the mouths of Hybodonts (that is, including *Acrodus*) were not only very different in form from that of the Port Jackson Shark, but they differed from the mouth

1863, p. 243. On the other hand, Pictet, in his 'Paléontologie,' 1853-7, vol. ii. pp. 254 and 260, retains the error of classifying the two in different families; as is likewise done in Morris's 'Catalogue of British Fossils,' on the authority of Professor Owen's 'Lectures on Comparative Anatomy,' vol. ii. p. 47. A less comprehensible oversight occurs in Owen's 'Palæontology,' where a side view of the head of *Myliobates* is apparently copied from Agassiz and referred to in the text as that of *Cestracion Philippi*, p. 106.

* The most marked exception to this generalization is *Hybodus basanus*, described by Sir P. Egerton, Quart. Jour. Geol. Soc., vol. i. p. 197.

of the latter, which is situated at the extremity of the head, in position, being placed under a projecting muzzle, as is the case in the majority of Placoids. From various mistaken statements on the subject, there exists a very general impression that the nearest existing approach to the Ichthyodorulites of *Hybodus* is to be found in the spines of *Cestracion*. The former have, however, a far greater resemblance to the single spine of a *Chimæroid* fish; we see this, not only in the elongated form, but in the distinct prolonged tapering root and the two rows of curved denticles upon the posterior edges; and this spine, marked with fine longitudinal striæ, is so hollow that even in the recent specimen its slight walls are crushed in, just as we find the Ichthyodorulites of the Lias.* In all these points, as our figures (Pl. IV., figs. 8 and 9) show, the spines of both *Hybodus* and *Chimæra* differ from those of *Cestracion*. This similarity between the single spine of a *Chimæroid* and the pair of a Hybodont indicates not only an affinity between the orders to which they belong, but affords, I believe, a clue to the explanation of the disparity of size between the two spines of the latter; a disparity greater than obtains in any existing Sharks possessing such defences. Agassiz himself inferred a relationship between the Sharks and *Chimæra* from dental characters,† *Cochliodus* being one of the links (and *Cestracion* surely another?) which indicated the connection of forms whose teeth are otherwise so totally dissimilar in every character. Charlesworth, in 1839,‡ suggested ‘an apparent analogy’ between the single ‘frontal spine’ of *Hybodus* and the peculiar apparatus upon the head of the male *Chimæra*; and although *Hybodus* has, as we now know, at least four of these cephalic spines,§ yet I believe that Charlesworth’s suggestion is a good one. An examination of a remarkably fine slab of *Chimæroid* remains from Solenhofen, now in the British Museum, showed me that the numerous hooklets, terminating the large cephalic spine there preserved, have a marked resemblance on a small scale to the enamelled portion of the ‘*Sphenonchi*,’|| and it would thence appear that the one large bony support may be analogous to the four tricuspid bases. Considering the wide difference that there must be between *Hybodus* and *Chimæra*, we should not expect that the resemblance in structure of

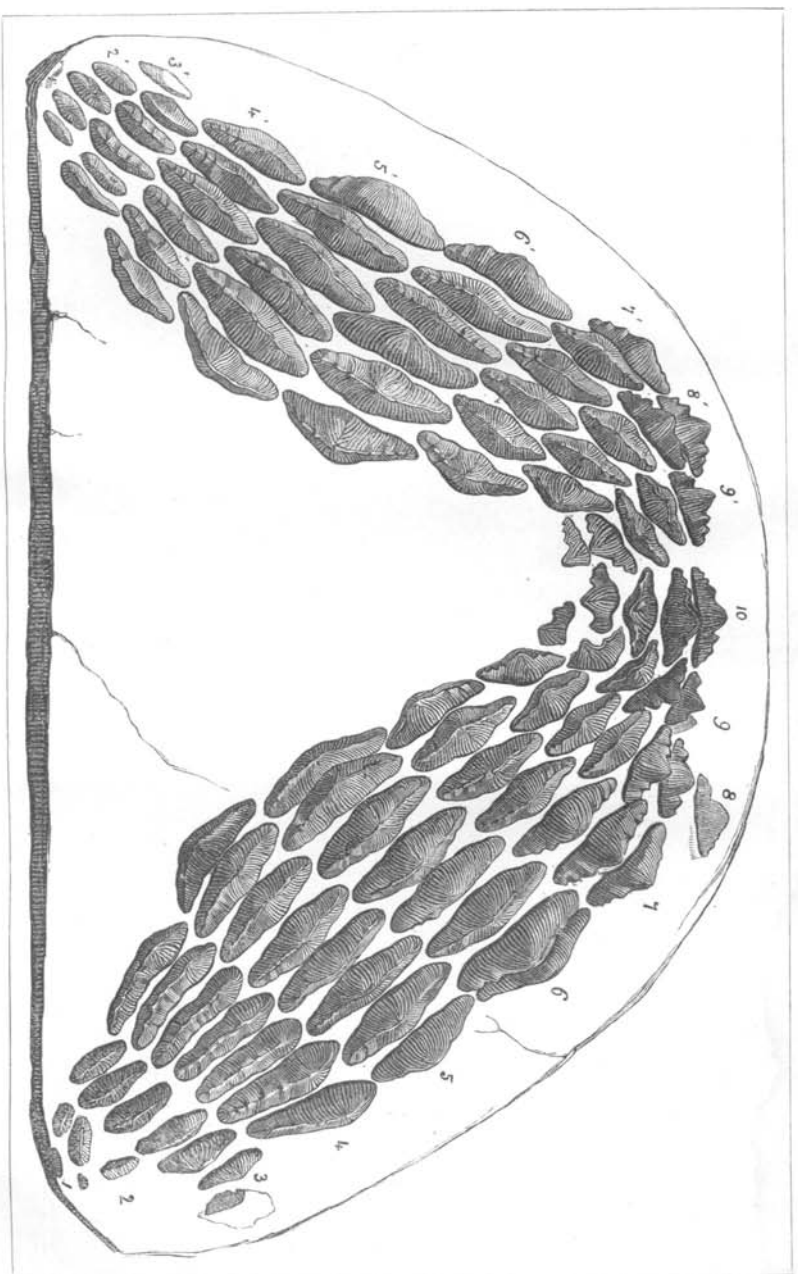
* Is not the spine which Agassiz called *Leptacanthus*, and classed with the Hybodonts, that of a *Chimæroid*? At least, it has only occurred in strata in which *Chimæroid* jaws have likewise been met with.

† Ag. ‘Pois. Fos.’ vol. iii. p. 336.

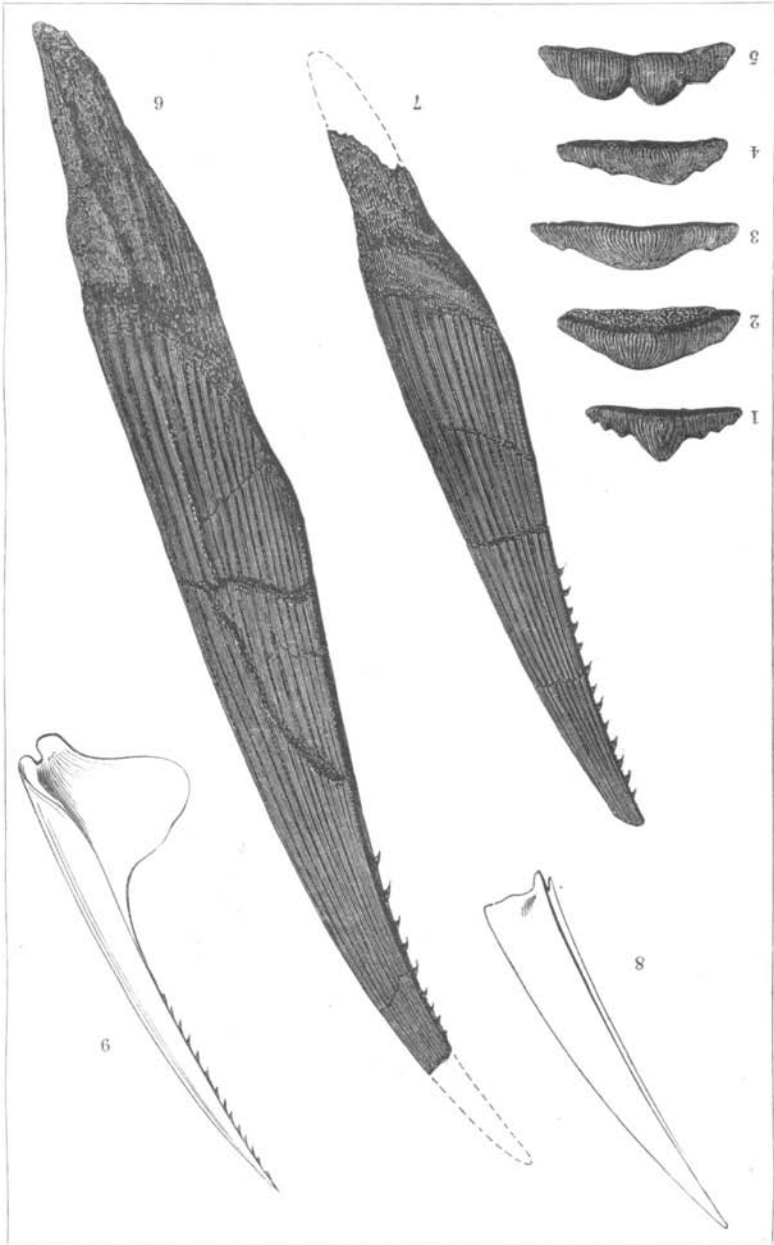
‡ Mag. Nat. Hist. 2nd ser. vol. iii. p. 245.

§ See note by Miss Anning, *ibid.* p. 605, and which statement I myself have been frequently able to verify.

|| The name given by Agassiz to these fossils, which he considered to be the teeth of a Hybodont.



LOWER JAW OF *ACRODUS ANNINGIA*, AG. (NAT. SIZE). FROM THE LOWER LIAS OF LYME REGIS.



FIGS. 1-7. TEETH AND SPINES OF *ACRODUS ANNINGIA*, AG. FROM THE LOWER LIAS OF LYME REGIS. (FIGS. 1-5, NAT. SIZE; FIGS. 6 AND 7, $\frac{1}{3}$ NAT. SIZE).

FIG. 8. SPINE OF RECENT *CESTRACION* (NAT. SIZE).

FIG. 9. SPINE OF RECENT *CHIMERA* ($\frac{1}{2}$ NAT. SIZE).

organs destined for the same functions would necessarily be very great; and being quite in the dark as to what use the Chimæroid duplicate arrangement may serve (beyond that it is probably of a sexual character), we cannot say that the cephalic spines of *Hybodus* were not suited for a similar purpose.*

We thus see reason to believe that the Hybodonts were a family well distinguished from all now existing. They more or less resembled the Cestracionts in the structure of their teeth; but they agreed rather with ordinary Sharks in the form of the head and the position of the mouth; whilst the dorsal spines, not to mention the cephalic spines, point to a remote affinity with *Chimæra*. Nor is this conclusion other than we may well be prepared to receive; since in a single form of a distant geological period, we constantly find characters associated together, the analogies of which are now only to be found scattered in widely separated groups. It is therefore no more anomalous to seek for the nearest representative of the spine of *Acrodus* in *Chimæra*, and of its teeth in *Cestracion*, than it is to collect illustrations of the structures combined in a Plesiosaur amongst widely removed orders of existing reptiles.

EXPLANATION OF THE PLATES.

PLATE III.

Lower (?) Jaw of *Acrodus Anningiæ*, Agassiz, from the Lower Lias of Lyme Regis. In Mr. Day's cabinet.

PLATE IV.

Figs. 1-5. Teeth of *A. Anningiæ*, from the Lower Lias of Lyme Regis.

6. Anterior } spine of the same Fish.

7. Posterior }

8. Posterior spine of recent *Cestracion* from Japan.

9. Spine of *Chimæra monstrosa*, Linn.,† living on the west coast of Norway.

The specimens figured in this plate are all in the Geological and Zoological Collections of the British Museum.

IV. ON THE COPPER-BEARING ROCKS OF ALDERLEY EDGE, CHESHIRE.

By EDWARD HULL, B.A., F.G.S., of the Geological Survey of Great Britain.

THE age of the sandstones and conglomerates, containing copper and other ores, at Alderley Edge, has until lately been a matter of some uncertainty; and, as far as I am aware,

* The very rough shagreen with which *Hybodus* was covered is not so well exemplified by that of *Cestracion* as by that of *Centrina* (another genus of spined Sharks), in which the coarse, tooth-like asperities very much resemble those of the fossil.

† Dissected and drawn (from a specimen preserved in spirits) by Mr. Henry Woodward.