

Plagiostomata of the Pacific. Pt. I. Fam. Heterodontidae / by N. de Miklouho-Maclay and William Macleay.

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Publication/Creation

[Sydney] : [Linnean Society of New South Wales], [1878]

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FROM THE
PROCEEDINGS OF THE LINNEAN SOCIETY
OF
NEW SOUTH WALES.

[Read 28th October, 1878.]

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Plagiostomata of the Pacific,

BY

N. DE MIKLOUHO-MACLAY and WILLIAM MACLEAY.

PART I.

Fam. HETERODONTIDÆ.

(With 5 Plates.)

INTRODUCTION AND DESCRIPTION.

BY

WILLIAM MACLEAY, F.L.S.

The Sharks and Rays of the Pacific Ocean have, as a whole, from time to time, attracted their full share of the attention of Naturalists, in so far as the observation and examination of dried

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or spirit preserved specimens admitted. But all who have studied the Anatomy of Fishes, as indeed of most of the vertebrates, must have ascertained that a true knowledge of an animal can only be attained by its examination in a perfectly fresh state. It is in this view that Baron M.-Maclay has occupied himself, during his stay here for the benefit of his health, in the continuation of his study of the Brains of the Sharks and Rays,* a species of investigation, which, above all others, requires the supply of fresh specimens.

While chiefly directing his attention to the Brain, the Baron has, at the same time, made such notes and illustrations of the general appearance and anatomy of the different species as seemed desirable or necessary to fill up gaps in their history.

share I take in this paper is at the Baron's request, to and describe the species to which his anatomical details and if in doing this, I appear, in some instances, to be ribing species already well known, it is because I have that even for the most simple specific characters, dried ens cannot be relied upon; and I am anxious to take age of this opportunity to give careful and correct des- ns from living subjects.

he subject proposed in the heading of this paper is an ive one, and the Baron's work will proceed in whatever on specimens may be procured for dissection, these papers ot appear in any particular order, and consequently, any es as to classification, &c., must be reserved to the last.

a paper will be limited to the Family of HETERODONTIDÆ, ISTRACIONTIDÆ, of *Gunther, Cat. Fish, Brit. Mus., vol. VIII,*

many years it was believed that the only living repre- ive of this once numerous family of sharks was the fish ll known as "The Port Jackson Shark." And though other species have since been found in other parts of the Pacific, it may still be looked upon as almost exclusively an Australian group. The period of their existence in other parts of the world is long since past.

* Vide N. von Mikluho-Maclay Beiträge zur Vergleichendur Neurologie der Wirbel- thiere. Th. 1 and 2. Leipzig, 1870.

With the exception of a few fishes of a Ganoid character, which appear in some of the upper Silurian strata, the *Cestracionts*, as they are named by Geologists, are the oldest of known Fishes. Teeth and spines resembling those of the Port Jackson Shark are abundant in the Devonian Rocks of Europe, and they are to be traced all through the Carboniferous and Permian Periods. They are found also throughout the whole of the Mesozoic or Secondary series of Rocks, but are most abundant during the Jurassic period. The teeth of another kind of Shark (*Notidanus*) occurs during the same period for the first time. It is noticeable, as has been observed by Palaeontologists, that the Jurassic Fauna and Flora of Western Europe were very similar to those of Australia at the present day. Among plants, *Cycads* and *Araucariæ*; among fish, the *Cestracionts*; among molluscs, *Trigonia*; and among mammals, *Marsupials*.

It may be necessary here to give some explanation of our reasons for rejecting the term *Cestracion* of Cuvier, which has been extensively used by the most eminent Ichthyologists for many years, and for adopting Blainville's name of *Heterodontus*, as used by Dumeril, in his Hist. Nat. des Poiss., tome 1, p. 423.

The word *Cestracion* (from *κεστρα*, a pickaxe, and *αχης*, a point), was first used by Klein, in 1742 (*Missus tertius*, p. 12), as a name for the hammer-headed shark (to which it seems properly to apply), and is now used by Dumeril (*Hist. Nat. des Poiss.* tome, 1, p. 380) to designate the sharks termed by Cuvier *Zygaena*. Cuvier has also (*Regm. Anim.* 1817, t. 11, p. 129) given the generic name *Cestracion*, without assigning any reason, to the Port Jackson shark, although Blainville (*Nouv. Bull. des Sciences*, p. 121) had a year previously (1816) given to that species the generic name *Heterodontus*. It seems, then, that not only on the ground of priority, but from the meaning of the respective words, Dumeril is right in adopting Blainville's nomenclature.

As the family consists of one genus only, the characters of the group are given in the description of the genus.

HETERODONTUS, *Bl.*

Head short, high, with an elevated ridge over each eye. Two dorsal fins, each with a strong spine; the anterior fin opposite the space between the pectoral and ventral fins, the posterior in advance of the anal. Nostrils and buccal cavity confluent. Mouth narrow, inferior, almost terminal. Spiracle small, below and behind the eye. Teeth alike in both jaws, numerous, pavement like, and convex, those in front small, and more or less tri-cuspid, those behind large, and much longer than broad.

HETERODONTUS PHILLIPI.

Port Jackson Shark, Phillipps, Voy., p. 283.

Tabbigaw of the Sydney Aborigines.

Squale Phillipp, Lacep. 1, p. 218.

Squalus Phillippi, Bl. Schn., p. 134.

Cestracion Phillipi, Cuv. Regm. Anim; Less. Voy. Coq. Zool. 2, p. 79, Poiss. pl. 2; Mull. and Henle, p. 76. pl. 31; Schleg. Faun. Japon, Poiss., p. 304; Strüver, Nov. Act. Acad. Carol. Leopold, Nat. Cur. 23, 1864.

Cestracion Philippi, Gunth. Cat. Brit. Mus. 8, p. 415.

Heterodontus Philippi, Blain. Nouv. Bull. Sc. 1816, p. 121; Gray, Catal. Chondropt, p. 65; Dum. Elasm, p. 424.

Cestracion Zebra, Gray, Zool. Misc, p. 5; Richards, Ichth. Chin., p. 195.

Heterodontus Zebra, Gray, Chondropt. p. 64; Bleek. Verh. Bat. Gen. 26, Nieu Nalez. Japan. p. 127, and Act. Soc. Sc. Neerl. 1, Amboyna, p. 71.

General form elongate, subcylindrical, tapering gradually from the head. Height of head at the orbit, one-seventh of the total length of the fish; length of head, from the snout to the first gill opening, one-sixth of the same, and equal to the length of the tail; profile, from the top of the head to the extremity, nearly straight, the slope being less than an angle of 45° from the vertical.

The snout is rounded anteriorly, with the mouth and nostrils on the under surface, but nearly terminal. The upper lip occupies the whole width of the head, and is much divided. At each

side there is, first, a large flat lobe, free and notched at the extremity, which overlaps the outer part of the fold of the lower lip; then there is a broad, nearly circular fold, which all but surrounds the large sub-elongate nostril, then a broad lobe terminating in a skinny flap, and in the middle, a thin semi-circular lip, exposing completely the mass of teeth on the outside of the symphysis of the mandibles. The lower lip has a large elongate fold or flap on each side, while the centre, as in the upper lip, exposes the front teeth. The jaws are identical in form and dentition. At the symphysis they seem narrow, but open out sufficiently to leave a small more or less oval space between the rami, behind that the rami approach almost to touching, and then gradually expand and spread outwards to the back of the mouth. The teeth are somewhat pavement like, but more or less round and convex, and not flat and angular, as in *Myliobatis*. The front teeth are rather small, and transversely ovate, in 10 rows, and in quite 15 series; those on the inner series more or less tri-cuspid, according to age; those in use, or which come into contact with the teeth of the opposite jaw, so far worn as only to show a transverse blunt point, and the obsolete ones, on the outside of the jaw, without trace of armature at all. The teeth on the hinder part of the "rami" are in about eight rows, and the same number of series, large, of an oblong shape, smooth, convex surface, spirally disposed, and with the 4th and 5th series very large, and twice as long as broad; in young specimens the teeth are acutely pointed.

The supra-orbital ridges are elevated, are situated on each side of the top of the head, and are about the same distance apart as the anterior angle of the orbit is from the top of the first gill opening; they can be traced in front for some distance towards the snout, in a direction approaching one another, and they terminate behind gradually above the first gill opening.

The eyes are situated on the side of, but close to, the top of the head, and immediately below the supra-orbital ridges; the pupil is horizontal and elliptical, with the upper surface less convex than the lower, and the orbit is large and twice as long as deep.

The spiracle is small, nearly circular, and about half the largest diameter of the orbit beneath the posterior margin of the eye. The gill openings, five in number, are placed at gradually decreasing distances apart; the first is more than twice the length of the fifth. The first dorsal fin takes its rise immediately behind the vertical from the root of the ventrals; the spine is very strong, blunt, compressed, three-fourths covered with skin, and about one-half the height of the fin to which it is attached; the fin itself is of a somewhat triangular shape, the anterior edge rather rounded, the summit also rounded, the hinder edge obliquely truncated, and the posterior angle rather pointed and produced. The second dorsal is situated a short distance in advance of the vertical from the anal, and is the exact counterpart of the first dorsal, excepting that it is one-third smaller. The caudal fin is rather short and deep, the antero-inferior lobe is convex on its anterior edge, about the size of the first dorsal, separated from the posterior lobe by a profound excavation which is rounded at its base, and with the posterior edge of the anterior almost parallel to the anterior edge of the posterior lobe; this last is small, triangular, and separated almost to the very extremity of the fin from the superior lobe by the prolongation of the vertebral portion. In the adult female, the space between the inferior lobes is more open. The extremity of the tail is obliquely truncate.

The anal fin is smaller than the second dorsal, but of much the same form; its apex is distant more than its own length from the commencement of the tail. The pectoral fins are very large, equal in length to one-fifth and in width to one-seventh of the total length of the fish. The ventral fins are nearly square, and are equidistant between the vertical from the first and second dorsal.

The skin is roughly shagreened, and has a slightly sericeous lustre. The colour in the fresh specimen is reddish-brown above, and yellow with a pinkish tinge beneath. A dark band crosses the inter-orbital space, and extends down the cheeks as far as the plane of the middle of the gill openings; a second dark band commences on the occiput, a

little behind the transverse band mentioned above, and extends along the middle of the back to near the first dorsal, when it divides and forms a band on each side, extending to and on the ventral fins. On that part of this black band which lies exactly between the posterior part of the base of the first dorsal and pectoral fins there is a concave curve, and from that point a black band extends to the pectoral fin. There is also another black band anterior to this, which extends from the first band in front of the first dorsal fin, and joins the second band on the pectoral; this band is a little curved (the concavity forwards), and forms with the other bands a small enclosed light-coloured triangular space. Another broad dark band extends along the back from the base of the first dorsal, and on each side of the second dorsal, to the tail. There is a lateral line along the body and tail, marking rather distinctly the line of demarcation between the dark colour of the back and the light colour of the belly. Both the dorsal fins and the anal are rather light-coloured, the caudal is darker, and the pectorals and ventrals are blackish above, and pinkish below and on the edges.

In specimens preserved in spirits, or dried, these markings entirely disappear, and they are never so vividly marked in adult specimens as in the young, as will be seen by reference to the very young specimen figured in plates 22 and 23.

The average size of the adult of both sexes is a little over three feet, and they seldom, if ever, attain a length of four feet. As the relative size of the different parts has been rendered with the greatest exactness in the accompanying plates, along with an accurate scale, I do not think it necessary to give a series of measurements.

The sexes scarcely differ in size or marking. The egg case is large (six inches long), conical, of a tough dark brown coriaceous texture, with six revolutions of a similar material spirally wound round it, forming a broadly-flanged conical screw. A good figure of it is given in Dumeril's *Hist. Nat. des Poiss.* vol. 2, pl. 8, figs. 2-3, but that author was not then certain that it was the egg of a *Heterodontus*.

This Shark is frequently caught in Port Jackson, and seems to have been found from time to time on various parts of the Australian and New Zealand coasts. It is also stated to have been found in the East Indian Archipelago and Japan ; but there seems to be some reason to suspect the identity of the Japanese species, if not of the other. Certainly, the figures given as those of the Port Jackson Shark, in the *Voy. of the Coquille*, pl. 11, and in Muller and Henle, pl. 31, are so extremely unlike the fish they are intended to represent, as to suggest a doubt of their being the same species ; and the form of the penta-cuspid tooth, figured by the last-named authors, has never, we believe, been seen in any of the Port Jackson adult specimens. The numerous transverse bands on the back, too, in those figures, suggestive of the specific name "zebra," are utterly unknown in the true *H. Phillipi*.

But little can be added to the history of this curious Shark. The stomach is generally well filled with fragments of shells, but not so finely comminuted as might be expected from the character of the teeth, and the bowels are often well charged with cestode worms. It is remarkably tenacious of life, but if we are to believe the accounts of the fishermen, very slow of reproduction—never having more than two eggs at a time, and only one brood in the year.

HETERODONTUS GALEATUS.

Gunth. Cat. Brit. Mus., Vol. 8, p. 416.

This species has a less elongate appearance than *H. Phillipi*, but I cannot find an appreciable difference in the proportionate measurements. I shall confine my descriptions to those points only in which it differs from that species already so elaborately described.

The head is more rounded in profile. The upper lip has the lateral flap less developed, not overlapping so much the lateral fold of the lower lip. The jaws shorter and deeper, the hinder part of the "rami" of the lower jaw being very deep. The teeth are similar as to number and distribution, but very different in form, the smaller teeth towards the symphysis of the

jaws are all acutely trilobed (the middle cusp largest), even those that have fulfilled their duty outside the jaw remain tolerably acute, while the side teeth are very elongate, with an elevated ridge along the entire length, grooved or fluted on the outer side. The supra-orbital ridges are short, much elevated, bend outwards over the eye, approach towards the front, and terminate abruptly behind. The first gill opening is three times the length of the fifth. The spiracle is a little more distant from the eye, and slightly more advanced than in *H. Phillipi*. The first dorsal fin commences rather behind the vertical from the root of the pectorals. The second dorsal commences behind the ventral, and reaches almost to the vertical from the commencement of the caudal. The spines are two-thirds the length of the fins, and the fins themselves are relatively of the same size as in *H. Phillipi*, but are pointed and falcate on the summit. The antero-inferior lobe of the caudal fin is large, vertically truncate behind, and separated from the posterior lobe (which is smaller and triangular) by an acute angle; the extremity is truncate. The anal fin reaches nearly to the commencement of the caudal. The other fins are large and shaped as in *H. Phillipi*.

The colour in the dried specimen before me is a dull pale brown on the upper parts, and a brownish white beneath. The top of the head and supra-orbital ridges from the level of the eyes backwards are black; the black patch extends backwards to near the first dorsal fin, and downwards a little, though more faintly, on the cheek; there are also some faint broad black cross-bars along the whole length of the back. A light-coloured lateral line seems to divide the darker upper from the lighter under portion, as in *H. Phillipi*.

It is probable that the colour in the fresh specimens would be a sericeous reddish-brown with the black marks much more clearly defined.

To judge by the number of specimens known of this fish it might be pronounced extremely rare. The first recorded is by Dr. Gunther (Cat. Brit. Mus. vol. 8, p. 416), and all he says of it, in addition to a short specific description, is that it is a female, 25 inches long, presented by Dr. G. Bennett, from Australia.

The only other specimen known is that from which the present description is taken. It is stuffed, and in the Australian Museum, caught, I believe, in Rose Bay, Port Jackson, and presented by E. S. Hill, Esq., of Woollahra. I have, also, in my Museum, the jaws and teeth of a specimen which was caught in Broken Bay two years ago, and unfortunately not preserved. But I think it not at all improbable that the species may not after all be of such very rare occurrence. The general resemblance to *H. Phillipi* is considerable, and fishermen are generally far from being acute observers of fish which are not of a marketable character.

HETERODONTUS FRANCISCI.

Oestracion Francisci. Girard, Proc. Ac. Nat. Sc. Philad., 1854-7, p. 196; and V.S. Pac. R.R. Exp. Fish, p. 365; Gunth. Cat. Brit. Mus., vol. 8, p. 416.

Gyropleurodus Francisci. Gill. Proc. Ac. Nat. Sc. Philad, 1862, p. 490.

Heterodontus Francisi. Dum. Ichthyol. tome 1, p. 426.

I have one specimen of this very distinct species, an adult male, 2 feet 6 inches long, from the Bay of Monterey, California. It is represented in plate 26, and is, I believe, now figured for the first time. It is a spirit specimen, and the markings, if any, cannot, of course, be represented; but in other respects, the figures may be trusted, as the specimen is in a good state of preservation and not contorted in any way. I regret that the dentition cannot be shown in the same way as in the other two species, as to do that would be to spoil the specimen.

The chief points in which it differs from *H. Phillipi* are as follow:—The head is proportionally broader and less high; the profile less steep and more convex; the supra-orbital ridges less prominent, almost continued to the snout and terminating abruptly behind the eyes; the teeth in front strongly tricuspid—the middle cusp large and pointed, those on the sides longitudinally ridged, but not as in *H. galeatus*; in fact, the lateral teeth in this species seem to be intermediate between those of *H. Phillipi* and *galeatus*. The spiracle larger and farther from and more behind the eye; the first gill opening scarcely twice

the length of the fifth, and much farther from the second than the distance between the second and third; the dorsal spines very strong, and more than half the length of the fins; the fins themselves more broadly rounded at the apex, and slightly emarginate behind; the first dorsal fin commences a little in advance of the vertical from the posterior root of the pectoral; the anal fin reaches almost to the caudal, in this particular alone, agreeing with *H. galeatus*; the antero-inferior caudal lobe large, and obliquely truncate at right angles to the anterior edge of the posterior lobe, which is small and narrowly incised at its junction with the other; the pectoral fins very large and rounded at the apex. The colour seems to have been brownish black above, and brownish white beneath; the scattered black spots on the body and fins mentioned in the descriptions of the fish are not traceable in my specimen.

HETERODONTUS QUOYI.

Cestracion Quoyi. Freminv. Mag. Zool. 1840, pl. 3; Gunth. Cat. 8, p. 416.

Cestracion pantherinus. Valenc. in Voy. Venus, Zool. p. 350, pl. 10, fig. 2.

Heterodontus Quoyi. Dum. Ichthyol. tome 1, p. 427; teeth pl. 3, figs. 16—17.

The figure (pl. 26) is copied from the Mag. Zool. Only one specimen of this species is known; it is about 2 feet long, and was taken at the Gallapagos Islands during the voyage of the "Venus." The descriptions given by Dumeril and Gunther, the only authorities attainable by me, are short, and leave out much that it would be desirable to know, such as the form of the caudal fin, &c.; but sufficient is given to shew that the species it most resembles is *H. Phillipi*, and that it is quite distinct from that. According to those descriptions the head is proportionally smaller than in *H. Phillipi* the snout less obtuse; the first dorsal fin commences well behind the extremity of the base of the pectorals, and has its posterior extremity prolonged over to the vertical from the ventrals; the second dorsal more distant from the posterior border of the ven-

trals ; the anal fin does not reach close to the caudal ; the spines of the dorsal fins are shorter, and the anterior teeth, figured by Dumeril, are acutely tri-cuspid, the centre cusp large and resembling those of *H. galeatus*. The colour is described as being of a reddish-brown on the superior and lateral regions, and on the fins, with round black spots irregularly disposed over the whole surface.

We thus find, that out of the vast numbers of *Heterodont* sharks which peopled all parts of the globe for myriads of ages, from the first appearance of vertebrate animals on the earth to the present day, but four species remain in existence, or, if my suspicions relative to the Japanese fish be correct, at the most only five, and those are for the most part so rare, and found in such remote and limited localities, as to lead to the belief that, as a race, they are in process of extinction. The history of these extraordinary animals is, however, not more remarkable and instructive than that of many others which geology tells us have existed and passed their allotted period on the earth, and then passed away, seemingly without a cause. But what is extraordinary is, that the Evolutionists of the present day should be able to manufacture, out of this constant succession of Life, arguments in favour of their theory. When the *Heterodonti* first made their appearance, their development seems to have been as advanced as at the present day ; they were preceded by no forms of fishes, except a few *Ganoids*, from which they could scarcely be evolved, and the first subsequent record of the existence of Sharks was the teeth of *Notidanus*, a genus having no apparent affinity to *Heterodontus*. The traces of these Sharks have been found continuously for a vast succession of geological periods, without any appearance of deviation from the original, or approach to any subsequent creation, and the succession of these fossil evidences have been so unbroken and unvarying, that the usual excuse of the Evolutionist when met with a difficulty, "That an unexampled gap exists in the continuity of the geological periods," will scarcely avail him in the present instance.

ANATOMICAL REMARKS.

By N. DE MIKLOUHO-MACLAY.

"Those whose specific gift of inclination leads them to the pursuit of other branches of biology, as morphology, physiology, embryology, etc., must have definite names for the objects they observe, depict, or describe, and are dependent upon the researches of the systematic zoologist for supplying them, and should not neglect to take his counsel, otherwise much of their work will lose its value."

W. P. Flower.

Address in Zoology.

NATURE, Aug. 15, 1878. Rep. of Brit. Assoc., 1878.

These words of Professor Flower express with perfect correctness the principal consideration which induced me, in addition to my work in comparative neurology, to collect, also, sufficient material for a systematic treatise, which should serve as a supplement to, or commentary on the former.

The present work I regard, then, as nothing more than an *illustrated catalogue* of the group of fishes which interest me from the standpoint of comparative neurology; and, since a favourable opportunity presents itself, the appendix or commentary appears before the body of the work (the continuation of my "Contributions to Comparative Neurology").*

During my travels from 1870 to 1878, I have never neglected to collect materials for my studies on the brain, and, wherever it was possible, to carry on investigations on that subject. But, since the books necessary for the more exact determination of the objects under investigation were not everywhere at my command, I have always taken ample notes, and above

* N. von Miklucho-Maclay. Beiträge zur Vergleichenden Neurologie der Wirbelthiere, I. und II., Leipzig, 1870. Verlag von W. Engelmann.

all, as far as possible, made exact sketches, in order afterwards to identify the species in places where libraries or Museums exist. So, by degrees, a considerable quantity of notes and drawings have accumulated, and of these, after making a critical selection, I intend to publish the more important.

In order to satisfy all the demands of Systematic Zoology, I requested my esteemed friend, the Hon. William Macleay, to take in hand the systematic descriptions, as well as the entire editing of the first section of the work, limiting myself, for my part, in addition to the descriptions of the plates, to some anatomical remarks. Since our respective points of view do not agree in all cases, it is possible that considerable contradictions may appear in the text. But the most faithful, and as far as possible, *objective* representation of the observed facts seems to both of us a *sine quâ non* of scientific investigation, so I believe that the colouring of particular parts of the text (provided on that account with our respective signatures) due to subjective outlook, does not run counter to the demands of a scientific co-partnership.

As exact figures, in addition to their greater clearness, render unnecessary long descriptions, I have always put great weight upon them; yet I must state, in accordance with truth, that I can by no means declare myself satisfied with the accompanying lithographic plates, and have, on that account, determined in future to have all my sketches (those of the Catalogue of the *Plagiostomata* included) reproduced by means of photo-lithography.

There remains for me, in this case, therefore, no other resource than to attempt to correct "verbally," in the explanation of the plates, the most important inaccuracies of the drawings as compared with nature.

Besides, the Hon. William Macleay, to whom I am very much indebted for the greater part of the material investigated, I must also express my obligations to Mr. E. P. Ramsay, Curator of the Australian Museum, who has obtained for me material of various kinds for my neurological studies, and has also always allowed me, in the most friendly manner, to make use of (to draw, photograph, and measure) the collection under his care, which was

important for purposes of comparison. Lastly, I have to thank Mr. W. A. Haswell, who has taken the trouble to translate into English my German manuscript.

In writing down these remarks, the incompleteness of the research, in many parts, has often struck me; questions which I was not in a position to answer presented themselves on all sides. Fain would I have filled up these hiati, time, however, would not permit. I allow myself, then, to publish these imperfect researches, since much that is new (the brain of *H. Phillipi**, the dentition of *H. galeatus*) has been gained by this investigation; and since, in the second place, I cannot tell, on account of my nomadic mode of life, when and where I shall have the opportunity of prosecuting this work further.

As regards the *material*, which has served for the carrying out of this part of the work, for the species *H. Phillipi*, I have had no lack of material; during the now seven months of my stay in Sydney, I have obtained for investigation, thanks to the assistance of the Hon. William Macleay and Mr. E. P. Ramsay, seven or eight fresh specimens. No embryos, unfortunately; the youngest animal of this species that I have seen was 225 mm. (8·9 inch) in length, the largest 1010 mm. (4·33 in.)

For the species *H. galeatus*, I had only *one* specimen (belonging to the Australian Museum) "to look at," as well as a pair of jaws of this shark in the Macleay-Museum.

Of the species *H. Francisi*, I have also had only *one* specimen "to look at"—that preserved in spirit in the Macleay-Museum.

ON THE DENTITION OF THE HETERODONTI.

1.—DENTITION OF THE YOUNG HETERODONTUS PHILLIPI. *Bl.*

The peculiar dental armature of the *Heterodonti*, assigning them as it does a characteristic and seemingly isolated position

* The description of the brain will appear in part III. of my "Contributions to Comparative Neurology."

in the series of *Elasmobranchii*, induced me to regard the investigation of the dentition of the *embryonic* stages of that genus as a matter of high interest and importance. Unfortunately, I could procure no *Heterodontus* embryos, but this proved not to be an insuperable obstacle, as the examination in young specimens of as much as 225 mm. (8.9 in.)* in length of the form of the teeth, which differ very markedly from those of the adult, affords us a glimpse into the genealogical connection of this shark with the other *Plagiostomata*. A glance at the teeth of a young *H. Phillipi* (Pl. 24, fig. 14), magnified about five diameters, is sufficient to establish the great similarity between the dental armature of the young *Heterodontus* and that of the *Notidani***. This preparation (fig 14) shows us further that at this age (225 mm. in length) not more than seventeen series (i.e., vertical rows) are developed in the upper jaw, and thirteen in the lower. In both jaws only three horizontal rows of both series are to be seen, the others come into view after the mucous membrane of the palate has been dissected off. The teeth situated in the very front of the lower jaw have three almost similar pointed cusps, while those situated further back have five points. (Vide fig. 15, Pl. 24).***

The teeth of the middle row are more or less symmetrical, and in the posterior (reserve) teeth of this row the central cusp is the largest, while the two outer take the form of inconspicuous tubercles. The teeth of the lateral rows are also longer, in proportion to their height, than those of the middle rows. On a closer inspection we see that the two anterior cusps of the lateral teeth are more perpendicular than the others, a feature which is met with in some fossil *Notidanus* teeth. (Vide *Agassiz Poissons*

* Mr. Macleay believes that this specimen had only emerged from the egg one or two days.

** This circumstance gains greater significance, when we consider that the investigation of the brain of the *Heterodontus* leads us to a similar conclusion in regard to the connections between those two genera. The brain of *H. Phillipi* stands very near the general fundamental form of the vertebrate central nervous system, and as such, resembles the brain of the *Notidani*, of the genera *Acanthias* and *Scymnus*. (Beiträge zur vergleichenden Neurologie, I., p. 43.)

*** The difference between the teeth of the young *Heterodontus* and that of the adult has already been noticed by Müller and Henle as follows:—....."Zähne, in der Mitte, klein und spitz, aus drei bis fünf von der Basis gegen die Spitzen auseinander tretenden Zacken gebildet, von denen die mittlere am grössten ist, die bei alten Thieren abgeschliffen sind;.....(Müller und Henle, Systematische Beschreibung der Plagiostomen, 1841 pag 76.

fossiles, vol. III, tab. 27, figs. 9 and 11). In the posterior rows of both jaws the cusps of the teeth are not yet developed.

In the jaws of a 418 mm. (16.4 in.) long young *H. Phillipi*, I found in the upper and lower jaw 20 vertical row of teeth. In the upper jaw, the two posterior rows had the character of the large pavement-like teeth, while in the lower, the three posterior rows shewed this character. In the upper jaw, it was the teeth of the last row that were the largest, on the lower, the second last.

The longitudinal ridge was much more prominent in the posterior teeth of this young animal than in older specimens. In the middle row of the upper jaw I have counted six teeth, and five in each of the posterior rows; in the lower jaw, six teeth in the middle row, and six teeth in each of the posterior rows.

The anterior teeth of the not fully adult *Heterodontus* (761 mm. long) are distinctly tri-cuspidate (vide fig. 10), while those of the adult become almost pavement-like, with an inconspicuous cusp (fig. 19, A. and B.).

2.—DENTITION OF THE ADULT *HETERODONTUS PHILLIPI*. *Bl.*

A drawing of the characteristic dentition of *Heterodontus* is given with the first description of the so-called "Port Jackson Shark."* In different scientific works** there are to be found good figures of the teeth of *H. Phillipi*, and I would certainly not have been satisfied with so few drawings had I not the intention of writing further on this subject. A few points, not yet decided, prevent me from publishing my results at the present time.

I will confine myself here to only a few remarks. The number of the teeth, as well as the general form, is, on a cursory glance, almost the same in both jaws, but a closer inspection shows a difference in both those respects between the upper and lower jaws, and also between different individuals. In one case, I have counted altogether 34 vertical rows in the upper jaw, and 31 in

* (Vide the Voyage of Governor Phillip to Botany Bay. London, MDCCLXXXIX, page 283.

** *L. Agassiz*. Recherches sur les Poissons fossiles, tome III, 1833-43, tab D., figs. 11-19. *R. Owen*. Odontography (1840-45) plates 10 and 11; and the works of various other authors.

the lower ; in both jaws it was the *fifth* row (reckoning from behind forwards) that proved to be the row of the largest teeth*. In another case there were 33 rows in the upper jaw, and 32 in the lower ; the row containing the largest teeth was the fourth in the upper jaw, and the sixth in the lower.

In an upper jaw of a *H. Phillipi* much younger (smaller) than the two just mentioned, I count 36 rows, the fifth being the row containing the largest teeth. The number of the teeth in the vertical rows are subject to variation ; the middle row** of the upper and lower jaws has, in this case, 12 teeth, while the row of the largest teeth contains 5 in the upper jaw, and 6 in the lower. In the upper jaw of the young *H. Phillipi* already mentioned, the middle row numbers 14 ; the row of the largest teeth consists of 7. The *size* of the teeth in proportion to one another seems also to be by no means constant, while in some specimens the length of the largest teeth exceeds that of the teeth next in size by almost one-third ; the largest teeth of another individual scarcely differed perceptibly in size from the others.

I could not ascertain whether all these variations in the number and size of the teeth are dependent on sex and age. The material employed for the above descriptive remarks on the dentition of the adult *H. Phillipi* consisted of dried jaws, to which no note of the size and age of the animal had been appended. I have been unable to find time to fill up this hiatus in the subject.

3.—DENTITION OF *HETERODONTUS GALEATUS*. *Günth.*

If we compare the teeth, in a longitudinal row, in the adult *H. Phillipi* from the anterior to the posterior members of the series, we find that the cusps in the lateral teeth (in the anterior third of the jaw) become blunter and blunter the larger the teeth become, so that it takes the form of an elongated tubercle,

* Dumeril says that it is the *fourth*. (Hist. Nat. des Poissons, Tom. I., p. 137.) This point may vary with the age or with the sex of the specimen.

** Since, as is well known, the teeth of the Selachians are independent of the endoskeleton. (Vide Gegenbaur Grundzüge der Vergleichenden Anatomie, 2 Aufl. Leipzig, 1870, p. 783), a mesial row of teeth corresponding to the middle line of the body, though occasionally present, is not always to be found. Dumeril made the same observation. (l. c. p. 133.)

which, in the large posterior teeth, is represented by a slightly elevated longitudinal line.* This longitudinal line is more or less distinctly visible in *H. Phillipi*, according to the individual.

Now, if we suppose this median longitudinal line on the posterior teeth developed into the form of a cutting edge or crest, we obtain some idea of the chief peculiarity of the dentition of *H. galeatus*.

The figures 30 and 31 are accurately drawn, with the aid of compasses, from a shrivelled, and not quite perfect pair of jaws preserved (labelled only with the name of the locality—Broken Bay) in the Macleay-Museum.

As the jaws are in the meantime preserved in the Museum as "unique," I have been unable to use them to obtain a transverse section of the large teeth.

The *only* perfect specimen of *H. galeatus* in Sydney at present is one in the Australian Museum, and as it is a stuffed specimen, one could merely see the anterior teeth, and only with some trouble get a glimpse of the crest of the posterior teeth. Mr. E. P. Ramsay had the kindness (for which I here express my gratitude) at my request to order the jaws to be taken out from the stuffed specimen. The stuffed museum-specimen has been in no wise injured by this, and the museum has thereby acquired a valuable anatomical preparation. Both jaws are in excellent preservation; and I am thus placed in a position to give a more complete description of the teeth** than I could otherwise have given.

I do so chiefly because the form of the teeth of *H. galeatus*, so far as I am aware, has not yet been described.***

* "*Côte longitudinal*," of Agassiz. Poissons fossiles. Tome III., page 83.

** I regret that I have only received this second jaw of *H. galeatus* after all the plates for this paper were prepared, so that I could not exchange figures 30 and 31, which only shew a part of the jaws, for a complete drawing of the well-preserved preparation in the Australian Museum. But although figs. 31 and 32 only shew a single horizontal row of teeth (the jaws from which the drawings were taken not being perfect), yet they give a correct notion of the form of the sequence of the rows, and of the number of the teeth (in a horizontal row). The curve of the row (figs. 30 and 31) is, however, only approximately correct; the preparation, which served as the original of my sketch, was so unsymmetrically shrivelled up that it permitted me to copy only the form of the teeth and the arrangement of the rows, and not the shape of the jaws.

*** In the description of *H. galeatus* by Dr. Günther (Catalogue of Fishes, vol. I., p. 416) there is nothing said about the teeth.

As in *H. Phillipi*, so in *H. galeatus*, the general form of the anterior part of the tooth-bearing surface is somewhat broader in the lower jaw than the same section of the upper, and somewhat quadrangular in shape. Figs. 30 and 31 give a pretty good representation of the form of the teeth. The anterior teeth are tri-cuspidate, the middle cusp being the most prominent, as a result of which, the front teeth appear high and narrow. In the antero-lateral teeth, the middle cusp is proportionally less elevated than the others; further back, most notably in the *reserve teeth* (*dents d'attente*) of the medio-lateral rows, a principal cusp is no longer to be recognised, the front pointed cusps being represented by a sharp sinuous ridge, provided with an obscurely dentate upper contour. This ridge is particularly well-developed in the upper jaw, while in the lower it remains always sinuous and thin. The transverse section of one of the large (elongated) teeth of the upper jaw (which, as already mentioned, I was, from lack of material, unable to make) would have a pyramidal form with one side slightly convex, and the other concave, *i.e.*, the outer surface of the elongated (lateral) teeth is concave; the inner convex. The complete jaws in the Australian Museum afford me an opportunity of describing also the numerical characters of the teeth of *H. galeatus*.

In the upper jaw, I have counted altogether 30 vertical rows of teeth; the number of teeth in the antero-median rows proved to be 11 (of which, however, the 10th and 11th were worn down); the number of the lateral elongated teeth in the penultimate vertical row was 9. In the lower jaw I found altogether 26 vertical rows; in the middle rows I counted 15 teeth*; there were 10** in the vertical row, containing the largest teeth (the third row, counting from behind.)

* The three posterior reserve-teeth of the middle row were displaced, so that possibly this number (15) may not be quite correct.

** In this jaw, I have also remarked the two following peculiarities. The postero-lateral rows are unsymmetrical; *i.e.*, two teeth on the one side correspond to one on the other. If we examine the teeth of these lateral rows, one after another, from without inwards, the three first elongated teeth prove to be normal, with a straight longitudinal ridge; on the fourth and fifth reserve teeth, we see a slight curving inwards of the ridge; on the sixth, the ridge is interrupted, and the base of the tooth is also somewhat incurved at the corresponding place. The places of the following reserve-teeth are each occupied by two smaller teeth. While we notice this *division* in the posterior rows, we find, on the other hand, in one of the antero-lateral rows, a *coalescence* of two tricuspitated teeth. I will not omit in the contemplated "Monographic Sketch of the Dentition of *Heterodontus*," referred to above, to give illustrations and a more thorough description of these peculiarities.

I have already mentioned that the chief peculiarity of the dentition of *H. galeatus* is the longitudinal ridge on the posterior teeth; which character, if found in fossil Plagiostomous teeth, would very probably have induced Agassiz to describe them as belonging to a new genus. If disregarding the anterior (tri-cuspidate) and the middle (multi-cuspidate) teeth, and regarding only the posterior (elongated and ridged), we compare the latter with the fossil Plagiostome teeth (or to speak more correctly, with the Fig. of the Atlas of the Poisson fossiles of L. Agassiz) we find (on plate 12 of the 3rd vol. of the Atlas) several figures which have very much the appearance of the lateral teeth of *H. galeatus*. These are the different teeth of *Psammodus linearis*, Agass. I must, however, add that this resemblance struck me more from looking at the illustrations (figs. 9—13) than from reading the text (Tome III., p. 107 and 108.) I believe, however, that one would be only entitled to come to a decisive conclusion after examining the fossils themselves and not merely the drawings of them.

4.—DENTITION OF *HETERODONTUS FRANCISI*. *Girard*.

After I had carefully examined the form of the teeth of *H. Phillipi* and *H. galeatus*, it was very interesting to me also to investigate those of *H. Francisi*. Unfortunately, there was at my service only one specimen, which, as a "Museum specimen," I could examine only from without. The anterior teeth were perfectly visible, and could be sketched without interfering with the specimen. It was otherwise with the important posterior teeth, to see which, in detail, a lateral incision of a few inches, from the margin of the gape into the cheeks would have proved very useful. I was obliged, however, to content myself with looking in through the aperture of the mouth, so that the sketching of the posterior teeth was rendered a matter of great difficulty. I succeeded, however, in making the accompanying sketch (fig. 37). The form of the teeth in *H. Francisi* resembles, on the whole, that of a young *H. Phillipi*; the front teeth were tri-cuspidate. In the posterior rows of large teeth there were no teeth so large as are found in many adult

specimens of *H. Phillipi*, as is shown in figs. 16 and 17 (pl. 24). The posterior teeth of *H. Francisi* were all of almost the same size, and shewed a distinct mesial line on their upper surface. The mesial line of some teeth was nodose.

In the upper jaw I found 25 vertical rows of teeth; in the lower jaw, 23. As regards the number of teeth in the vertical rows, I could not attain to any certainty, as the mouth could not be opened far enough to enable me to count them with precision.*

ON THE EXTERNAL GENITAL ORGANS OF THE MALE *H. PHILLIPI*.

As I have before me a large number of sketches of these parts, as seen in various species of sharks, in which, in spite of a similarity in many points, there are yet considerable variations, it appears to me expedient to postpone giving a comparative *resumé* of these drawings until in proper order, a selection of the sketches in question has been given.

In the mean time I may observe that the drawings Figs. 20—24, pl. 24—are the more deserving of attention, that they were made from fresh preparations, the parts being carefully preserved *in situ* during the preparation of the transverse and longitudinal sections.**

* Figures of the anterior-teeth of *H. Quoyi* are to be found both in the *Magasin de Zoologie*, 1839, and also in Dumeril. (Atlas, pl. 3, figs. 16 and 17.)

** A description—on the whole correct—of the external sexual parts of the male Plagiostomata (*organes copulateurs* or *appendices externes* or *membres accessoires*), is to be found in A. Dumeril. (*Histoire Nat. des Poissons*. Tome I., 1865, pag 233 et seq.) A short dissertation on the significance of these organs as "*organes destinés à une véritable intromission*," is to be found in the same work. (Pag 240, et seq.)

specimens of *M. phillipi* as is shown in figs 16 and 17 (pl. 24). The posterior teeth of *M. phillipi* were all of almost the same size and showed a distinct mesial line on their upper surface. The mesial line of some teeth was nodose.

In the upper jaw I found 25 vertical rows of teeth; in the lower jaw, 22. As regards the number of teeth in the vertical rows, I could not attain to any certainty, as the mouth could not be opened far enough to enable me to count them with precision.*

ON THE EXTERNAL GENITAL ORGANS OF THE MALE *M. phillipi*.

As I have before me a large number of sketches of these parts, as seen in various species of sharks, in which, in spite of a similarity in many points, there are yet considerable variations, it appears to me expedient to postpone giving a comparative résumé of these drawings until in proper order, a selection of the sketches in question has been given.

In the mean time I may observe that the drawings figs. 20-24, pl. 24—are the more deserving of attention, that they were made from fresh preparations, the parts being carefully preserved in situ during the preparation of the transverse and longitudinal sections.*

* Figure of the posterior teeth of *M. phillipi* are to be found both in the *Memorie de l'Academie*, 1798, and also in *Journal*, (figs. 16, 17, and 18). A description of the whole extent of the external genital parts of the male of *M. phillipi* is given in *Journal*, (figs. 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 55, 56, 57, 58, 59, 60, 61, 62, 63, 64, 65, 66, 67, 68, 69, 70, 71, 72, 73, 74, 75, 76, 77, 78, 79, 80, 81, 82, 83, 84, 85, 86, 87, 88, 89, 90, 91, 92, 93, 94, 95, 96, 97, 98, 99, 100, 101, 102, 103, 104, 105, 106, 107, 108, 109, 110, 111, 112, 113, 114, 115, 116, 117, 118, 119, 120, 121, 122, 123, 124, 125, 126, 127, 128, 129, 130, 131, 132, 133, 134, 135, 136, 137, 138, 139, 140, 141, 142, 143, 144, 145, 146, 147, 148, 149, 150, 151, 152, 153, 154, 155, 156, 157, 158, 159, 160, 161, 162, 163, 164, 165, 166, 167, 168, 169, 170, 171, 172, 173, 174, 175, 176, 177, 178, 179, 180, 181, 182, 183, 184, 185, 186, 187, 188, 189, 190, 191, 192, 193, 194, 195, 196, 197, 198, 199, 200, 201, 202, 203, 204, 205, 206, 207, 208, 209, 210, 211, 212, 213, 214, 215, 216, 217, 218, 219, 220, 221, 222, 223, 224, 225, 226, 227, 228, 229, 230, 231, 232, 233, 234, 235, 236, 237, 238, 239, 240, 241, 242, 243, 244, 245, 246, 247, 248, 249, 250, 251, 252, 253, 254, 255, 256, 257, 258, 259, 260, 261, 262, 263, 264, 265, 266, 267, 268, 269, 270, 271, 272, 273, 274, 275, 276, 277, 278, 279, 280, 281, 282, 283, 284, 285, 286, 287, 288, 289, 290, 291, 292, 293, 294, 295, 296, 297, 298, 299, 300, 301, 302, 303, 304, 305, 306, 307, 308, 309, 310, 311, 312, 313, 314, 315, 316, 317, 318, 319, 320, 321, 322, 323, 324, 325, 326, 327, 328, 329, 330, 331, 332, 333, 334, 335, 336, 337, 338, 339, 340, 341, 342, 343, 344, 345, 346, 347, 348, 349, 350, 351, 352, 353, 354, 355, 356, 357, 358, 359, 360, 361, 362, 363, 364, 365, 366, 367, 368, 369, 370, 371, 372, 373, 374, 375, 376, 377, 378, 379, 380, 381, 382, 383, 384, 385, 386, 387, 388, 389, 390, 391, 392, 393, 394, 395, 396, 397, 398, 399, 400, 401, 402, 403, 404, 405, 406, 407, 408, 409, 410, 411, 412, 413, 414, 415, 416, 417, 418, 419, 420, 421, 422, 423, 424, 425, 426, 427, 428, 429, 430, 431, 432, 433, 434, 435, 436, 437, 438, 439, 440, 441, 442, 443, 444, 445, 446, 447, 448, 449, 450, 451, 452, 453, 454, 455, 456, 457, 458, 459, 460, 461, 462, 463, 464, 465, 466, 467, 468, 469, 470, 471, 472, 473, 474, 475, 476, 477, 478, 479, 480, 481, 482, 483, 484, 485, 486, 487, 488, 489, 490, 491, 492, 493, 494, 495, 496, 497, 498, 499, 500, 501, 502, 503, 504, 505, 506, 507, 508, 509, 510, 511, 512, 513, 514, 515, 516, 517, 518, 519, 520, 521, 522, 523, 524, 525, 526, 527, 528, 529, 530, 531, 532, 533, 534, 535, 536, 537, 538, 539, 540, 541, 542, 543, 544, 545, 546, 547, 548, 549, 550, 551, 552, 553, 554, 555, 556, 557, 558, 559, 560, 561, 562, 563, 564, 565, 566, 567, 568, 569, 570, 571, 572, 573, 574, 575, 576, 577, 578, 579, 580, 581, 582, 583, 584, 585, 586, 587, 588, 589, 590, 591, 592, 593, 594, 595, 596, 597, 598, 599, 600, 601, 602, 603, 604, 605, 606, 607, 608, 609, 610, 611, 612, 613, 614, 615, 616, 617, 618, 619, 620, 621, 622, 623, 624, 625, 626, 627, 628, 629, 630, 631, 632, 633, 634, 635, 636, 637, 638, 639, 640, 641, 642, 643, 644, 645, 646, 647, 648, 649, 650, 651, 652, 653, 654, 655, 656, 657, 658, 659, 660, 661, 662, 663, 664, 665, 666, 667, 668, 669, 670, 671, 672, 673, 674, 675, 676, 677, 678, 679, 680, 681, 682, 683, 684, 685, 686, 687, 688, 689, 690, 691, 692, 693, 694, 695, 696, 697, 698, 699, 700, 701, 702, 703, 704, 705, 706, 707, 708, 709, 710, 711, 712, 713, 714, 715, 716, 717, 718, 719, 720, 721, 722, 723, 724, 725, 726, 727, 728, 729, 730, 731, 732, 733, 734, 735, 736, 737, 738, 739, 740, 741, 742, 743, 744, 745, 746, 747, 748, 749, 750, 751, 752, 753, 754, 755, 756, 757, 758, 759, 760, 761, 762, 763, 764, 765, 766, 767, 768, 769, 770, 771, 772, 773, 774, 775, 776, 777, 778, 779, 780, 781, 782, 783, 784, 785, 786, 787, 788, 789, 790, 791, 792, 793, 794, 795, 796, 797, 798, 799, 800, 801, 802, 803, 804, 805, 806, 807, 808, 809, 810, 811, 812, 813, 814, 815, 816, 817, 818, 819, 820, 821, 822, 823, 824, 825, 826, 827, 828, 829, 830, 831, 832, 833, 834, 835, 836, 837, 838, 839, 840, 841, 842, 843, 844, 845, 846, 847, 848, 849, 850, 851, 852, 853, 854, 855, 856, 857, 858, 859, 860, 861, 862, 863, 864, 865, 866, 867, 868, 869, 870, 871, 872, 873, 874, 875, 876, 877, 878, 879, 880, 881, 882, 883, 884, 885, 886, 887, 888, 889, 890, 891, 892, 893, 894, 895, 896, 897, 898, 899, 900, 901, 902, 903, 904, 905, 906, 907, 908, 909, 910, 911, 912, 913, 914, 915, 916, 917, 918, 919, 920, 921, 922, 923, 924, 925, 926, 927, 928, 929, 930, 931, 932, 933, 934, 935, 936, 937, 938, 939, 940, 941, 942, 943, 944, 945, 946, 947, 948, 949, 950, 951, 952, 953, 954, 955, 956, 957, 958, 959, 960, 961, 962, 963, 964, 965, 966, 967, 968, 969, 970, 971, 972, 973, 974, 975, 976, 977, 978, 979, 980, 981, 982, 983, 984, 985, 986, 987, 988, 989, 990, 991, 992, 993, 994, 995, 996, 997, 998, 999, 1000.

EXPLANATION OF THE PLATES.

REMARKS ON THE ILLUSTRATIONS.

Since a faithful figure, in addition to the considerable saving of time (as well to the author as to the reader), which it is the means of effecting, has the advantage over a lengthy description of being demonstrable to the eye, and gives the reader a better idea of the object. I have, as already observed (page 319), regarded the illustrations as of primary importance. In order to obtain, as far as possible, correct outlines, which is the most important point, I have had recourse to photography, and to a convenient, if somewhat primitive method. This consisted in the preparation of outlines of the object laid on paper; the natural-size sketches, thus obtained, were then reduced by the orthodox method. To the figures prepared from photographs, the respective scales* are annexed, in order to render possible a *rough* estimate of the amount of reduction or enlargement, since the method of preparing photographs to scale is yet unknown to me.

LETTERING FOLLOWED THROUGHOUT ALL THE FIGURES (WITH THE EXCEPTION OF PLATE 24).

a—Superior oral fold.

b—Inferior oral fold.

n—External orifice of the nasal groove.

n'—C Border of the internal fold of the nasal groove.

n''—Orifice of the nasal groove in the oral cavity.

sp—Spiracle.

PLATES 22 AND 23.

(*HETERODONTUS PHILLIPI*, *Bl.*)

Figs. 1, 2 (pl. 22) 5, 6, 7 (pl. 23).—Young *H. Phillipi*, 225 mm. in length drawn from a fresh specimen.

Fig. 1.—Posterior view of the same. The young animal shewed the peculiar marking, somewhat different from that of

the adult, very distinctly, as the brownish-black stripes stood out very markedly on the light-colored skin of the young at this stage.

*—Transverse black bar which passes over the head from eye to eye, and loses itself on the cheeks. **—Characteristic mark between the dorsal and ventral fins.

Besides the very remarkable marking, the rounded form of the head and the proportionally large tail are peculiar to this stage.

Fig. 2 (pl. 22).—Ventral surface of the same (from a photograph). At this age, the male copulatory organs are shorter than the lower border of the ventral fin.

fa.—Anal fin.

Fig. 5 (pl. 23).—Lateral view of the same. The figure only shews the external contour, in addition to the marking. The undulating contour-line is meant to represent the extent of the rougher parts of the skin, covered with large and prominent bony plates (*scutellæ*). The anal fin, whose position and length are accurately rendered, has its form rather too diagrammatically represented in the figure, which does not shew that the fin has become somewhat shrivelled by the drying, which took place while the drawing was being executed.

Fig. 6 (pl. 23).—A very miserable rendering of a photograph of the head *from before*. The outlines, however, are correct.

Fig. 7. (pl. 23).—Head of the same animal viewed from before, and to some extent from below. From a photograph, about three times the natural size. Scale applicable only for the anterior part of the mouth (the anterior teeth for instance).

Figs. 3, 4, 8 (pl. 23).—Full-grown* *H. Phillipi*, of about 795 mm. (31·4 in.) in length. The sketches are from a specimen in

* N.B.—The scale can only be relied on for a certain part of the object (the part on the same plane with it), and must, therefore, be used with caution.

* The largest specimen I have seen in Sydney was a female of about 1,232 mm. (48·5 in.) in length. As the specimen was a dried and stuffed one (by which means the shape of the head is considerably altered), its length in the fresh state was probably greater. From the external point of the one fin to that of the other it measured 602 mm. (which number also is to be regarded as only approximate).

† I received the first fresh specimen of *H. Phillipi* on the twentieth day after my arrival in Sydney; but could make drawings much earlier from specimens preserved in spirit in the Macleay Museum. As the proportions of the different parts of the body as well as the form of the fins are not much altered by the action of alcohol for a moderate time on the specimen, I found it unnecessary to waste time in making any fresh drawings.

the Macleay-Museum, which had been preserved in spirit for a moderate period (2-3 months†), to which circumstance is also to be attributed the stiffness of fig. 8. The marking characteristic of the species, however, I have represented as seen in perfectly fresh specimens, since it becomes indistinct only a few hours after death.

Fig. 3 (pl. 22).—View of the dorsal surface. The dorsal fins are somewhat bent to one side. The eyes are not to be seen, when the head is viewed from above, on account of the overhanging eyebrows (vide. fig. 9).

Fig. 4 (pl. 22).—Ventral aspect. (The black line, drawn with the pen, on the lower part of the body, between the abdomen and the anus, and the anal fin is an *unnatural* representation of the slightly depressed mesial line.)

Fig. 8 (pl. 23).—Lateral view of the same.

Fig. 9 (pl. 23).—Head of a young *H. Phillipi*, about 761 mm. (22.1 in.) in length, drawn from a fresh specimen (with the aid of the camera lucida and compasses).

Fig. 10 (pl. 23).—Anterior part of the head of the same young fresh specimen viewed from the ventral aspect.

[After looking at fig. 10, compare it with fig. 29 (pl. 25) in order to obtain a correct idea of the *nasal grooves* with both their orifices.]

Figs. 11, 12, 13 (pl. 23) represent three profile-views of the mouth of the same (761 mm. or 22.1 in. long) *H. Phillipi*.

Fig. 11 (pl. 23).—Mouth closed.

Fig. 12 (pl. 23).—Mouth half open.

Fig. 13 (pl. 23).—Mouth open to its utmost extent.

PLATE 24.

HETERODONTUS PHILLIPI, Bl.

Figs. 14 and 15.—Teeth of the upper and lower jaws of the young *H. Phillipi*, figured on plates 22 and 23 (figs. 1, 2, 8.)

The sketch, of about five times the natural size, was made from a photograph (by which the increase in size was effected.) Through the carelessness of the artist who copied the photo-

graph, the contours of the teeth are not at all satisfactorily rendered. The general form of the teeth and the number of the pointed cusps, however, is correct. The posterior reserve-teeth of both jaws are covered by the oral mucous membrane.

Figs. 16 and 17.—Teeth of the upper and lower jaws of an adult *H. Phillipi*. (The preparation which formed the original of these figures is in the Macleay Museum.)

Fig. 18.—Anterior teeth of a specimen 761 mm. (22.1 in.) in length, with three distinct cusps. A—those of the upper jaw; B—those of the lower.

Fig. 19.—Anterior pavement-like teeth of an older specimen. A—two teeth of the middle row of the upper jaw; B—four teeth of the three middle rows of the lower jaw.

Figs. 20—24.—Male sexual appendages of an adult *H. Phillipi*.

Fig. 20.—Appendage in section from above, from the ventral aspect. The undulating lines indicate the rougher dermal covering, armed with scates. c and c'—groove; d—spine on the outer border of the groove; f—fissure leading into a pouch situated on the under side of the appendage.

The dotted lines marked I, II, and III shew the points where the vertical transverse sections (fig. 21) are carried through.

Fig. 21, I.—Vertical transverse section through the base of the appendage and through the ventral fin; g—cartilage of the appendage and of the fin; m—muscles of the same; i—the muscular pouch ("*poche musculieuse*" of Dumeril) opening into the groove and situated on the under surface of the ventral fin.

II.—Vertical transverse section through about the middle of the appendage.; g—cartilage; m—muscles of the appendage; c—groove ("*sillon*" of Dumeril).

III.—Vertical transverse section through the end of the appendage, below the spine; c—the groove divided by a thin fold (k) of the mucous membrane; f—pouch.

Fig. 22, IV.—Longitudinal section through the appendage, to shew all the connections of the groove, with the two pouches, i and f.

(These four were all made and drawn from quite fresh specimens.)

Fig. 23.—Male sexual appendages of a larger specimen. The specimen from which the sketch was made lies on the right side the ventral surface directed forwards, with the appendages crossed over one another. (This position of the appendages I have noticed in many dying and dead specimens of *Heterodontus*.) The right appendage is stretched out along the middle line of the body, the left one hanging below; it is drawn back by means of three hooks, so that the groove (c and c') is to be seen. The spine (d) is by this means "thumblike" extended and abducted.

k—is a thin longitudinal fold. (N.B.—Fig. 23 as well as fig. 24 is a very wretched rendering of my sketch, and gives the impression of having been drawn, not from part of the body of an animal, but from a wooden model; the outlines, however, are correct.)

Fig. 24.—Extremity of the appendage viewed from the inner side, fixed with the aid of hooks, with the last joint flexed, in order to afford a view of the groove. Owing to the flexed position of the appendage and of the sac or pouch f, which is wide open.

PLATE 25.

HETERODONTUS GALEATUS, *Günther*.

Figs. 25 and 26.—Drawings of the *Heterodontus galeatus* from above and from the side from a stuffed specimen in the Australian Museum. In order not to alter further the appearance of the animal already considerably distorted by the process of stuffing, I have caused photographs of the animal in question to be copied. Although the whole of the general surface of the skin, with the exception of the ventral portion, is very dark, six transverse bands are visible. The band on the upper surface of the head is the most distinct. Though the colouring of this dried specimen may be somewhat different from that of the same animal in the fresh state, yet it is decidedly different from that of *H. Phillipi**.

Fig. 27.—Front view of the head (necessarily very diagrammatic, owing to the condition of the specimen), to shew the two very prominent supra-orbital ridges characteristic of the species.

Fig. 28.—Ventral view of the anterior end of the head (also very diagrammatic) to shew the front teeth (very wretchedly rendered by the artist, but with the number correct.)

Fig. 29.—Ventral view of the anterior end of the head of a *H. Phillipi* (from a perfectly fresh specimen). The lower jaw, the labial folds, and the upper jaw are removed, to shew the nasal grooves with their two openings. On the right hand side the parts are *in situ*; on the left, a horizontal section has been made on a plane passing through both the external and the buccal narial apertures, displaying the whole course and relation of the groove.

Figs. 30 and 31.—Part of the upper and lower jaw of the specimen in the Macleay-Museum. The shape of the teeth, and their order of sequence, is carefully rendered. Cr—longitudinal ridge.

PLATE 26.

HETERODONTUS FRANCISI, *Girard*; and *H. QUOYI*, *De Fremin*.

Fig. 32.—Profile of the spirit-specimen in the Macleay Museum. Circa 708 mm. (27.9 in.) in length. In this specimen there was no characteristic colouring (stripes, bands, or other markings) of any kind to be observed, on which account only the external outlines are given. On the uniformly dark surface the lateral line was, however, to be seen. (Through the carelessness of the artist the outline, which should separate the lower surface of the body from the pectoral fin, has been omitted.)

Fig. 33.—View of the same animal from above.

Fig. 34.—View of the head *en face* to show the form of the supra-orbital ridges.

Fig. 35.—Half-open mouth in profile, to show the labial folds and the external nasal apertures.

Fig. 36.—Anterior part of the head, regarded from the ventral side, to display the arrangement of the nasal groove, the labial folds, and the anterior teeth.

Fig. 37.—Part of the teeth of the same animal *in situ*, drawn as accurately as possible with the aid of compasses. In the lower jaw the arrangement of the accessory cusps of the lateral tri-cuspidate teeth is noteworthy. The tooth marked * shows the left, that marked ** the right accessory point of the teeth re-

markably well developed. (This is a point of importance in determining to which side a tooth may belong).

Fig. 38.—Facsimile of the drawing of *Heterodontus Quoyi* de Freminville in the Magazine of Zoology, 1840. N.B.—The figure has been reversed to facilitate comparison with the others. The explanation of the figures given by M. le Chev. de Freminville is as follows :—

“Fig. 1.—Cestracion (*Heterodontus*) de Quoyi réduit environ an tiers de sa grandeur naturelle.

“1 (a).—Sa bouche vue de face.

“1 (b).—Ses dents externes grossies.

“1 (c).—Ses dents internes grossies.”*

* Notice sur une nouvelle espece de Poisson appartenant au genre *Cestracion* de Cuvier par M. le Chevalier de Freminville.
(Magazin de Zoologie publié par F. E. Guerin-Meneville. Paris, 1839.)

