

angusticeps and it is evident that the Matabele, who are of Zulu descent and migrated from Zululand some 50 years ago, have mistaken the dark variety of *Naie haie* for that species.

Var. ANNULIFERA, Peters.

e. Bulawayo.

f (portion of skin). 15 miles south of Bulawayo.

"Ilunga."

46. NAIA NIGRICOLLIS Reinh.

a-c. Bulawayo.

d. Mazeppa Mine, Gwanda.

e, f. Deka.

I know of several instances here of this species spitting at people who have attacked it.

"Ipimpi."

47. ASPIDELAPS SCUTATUS A. Smith.

a. Empandene, Aug. 1908.

48. CAUSUS DEFILIPPII Jan.

a. Bulawayo, 9 Dec. 1907.

49. BITIS ARIETANS Merr.

a. Bulawayo.

Very common.

"Ibululu."

50. BITIS CAUDALIS A. Smith.

a, b. Bulawayo.

May 25, 1909.

Dr. S. F. HARMER, M.A., F.R.S., Vice-President,
in the Chair.

The Secretary read the following report on the additions made to the Society's Menagerie during the month of April 1909:—

The number of registered additions to the Society's Menagerie during the month of April last was 243. Of these 116 were acquired by presentation, 15 by purchase, 91 were received on deposit, 6 in exchange, and 15 were born in the Gardens.

The number of departures during the same period, by death and removals, was 161.

Amongst the additions special attention may be directed to :—

One Burchell's Zebra (*Equus burchelli*) ♂, from S. Africa, presented by F. A. R. Zurcher, Esq., on April 1st.

One Eland (*Taurotragus oryx*) ♂, born in the Menagerie on April 3rd.

One Cape Ant-bear (*Orycteropus capensis*), from S. Africa, purchased on April 17th.

One Black-fronted Bulbul (*Pycnonotus nigricans*); one Red-capped Lark (*Tephrocorys cinerea*), presented; and two Levaillant's Barbets (*Trachyphonus cafer*), new to the Collection, one Martial Hawk-Eagle (*Spizaetus bellicosus*), deposited with other S. African Birds by Major Boyd Horsbrugh, F.Z.S., on April 15th.

Mr. J. Lewis Bonhote exhibited an example of a tetragen duck, which he had bred in his Aviaries, containing Wild Duck (*Anas boschas*), Spotbill (*Anas pæcilorhyncha*), Australian Duck (*Anas superciliosa*), and Pintail (*Dafila acuta*). This bird was of the F_2 generation, *i. e.*, it had been bred from brother and sister and was remarkable in that, to all outward appearances, it was almost indistinguishable from a pure bred Wild Mallard. According to Mendel's Law it was to be expected in theory that such a bird should appear, but in practice the chance of all the Mallard characters appearing in any one individual was very remote, and the fact that they had all appeared in this bird was a striking confirmation of the truth of Mendel's Law even in a very complicated case.

The only difference to be noted between this bird and the pure-bred Mallard was the rather more defined and Pintail-like vermiculations to the flank-feathers.

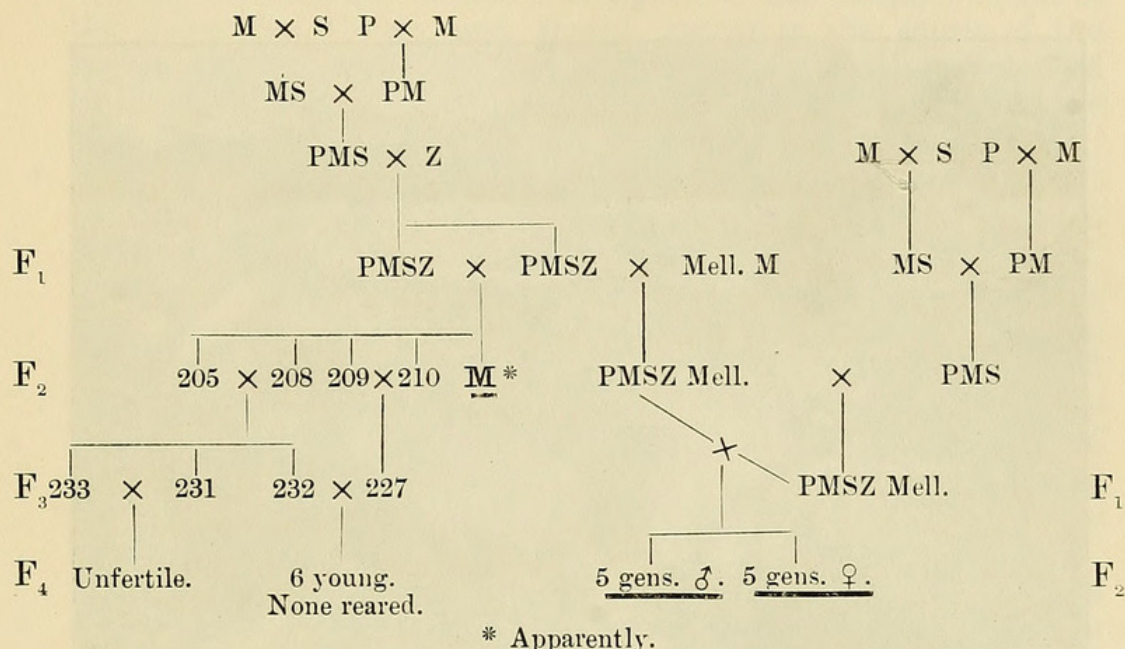
Mr. Bonhote also exhibited a pair of pentagens of the F_2 generation. These contained the blood of the following species: *Anas boschas*, *A. pæcilorhyncha*, *A. superciliosa*, *A. melleri*, and *Dafila acuta*. As yet they showed no tendency to infertility, but on the contrary proved more fertile than several less complicated crosses. The matter had become too much involved to draw any deductions from their plumage, but it would be noticed that the Mallard seemed to predominate. They were interesting, however, as showing to what extent cross-breeding could be carried among certain species, the hybrids proving fertile to at least the 4th generation since the last cross with a pure species.

Many hybrids, as was well known, were unfertile, but with those that proved fertile in the first generation, infertility was generally reached in the 3rd generation (F_3)—that is to say the 3rd generation from the last cross with a pure species; in some cases,

however, the F_3 generation proved fertile, but as yet no young of the F_4 generation had been reared.

Infertility was usually accompanied by loss of colour.

Pedigree of birds exhibited.



* Apparently.

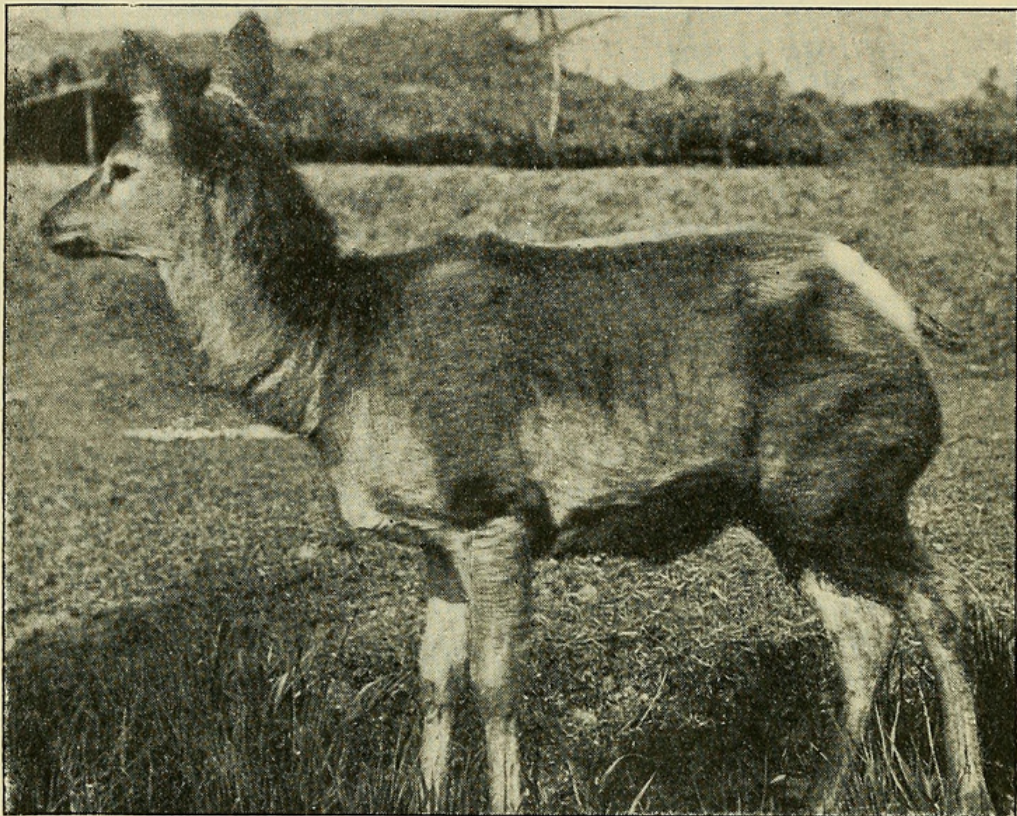
(Those underlined were the specimens exhibited.)

Mr. L. Harding Cox, F.Z.S., exhibited a living specimen of the Amblystome or transformed Axolotl, and drew attention to the following distinguishing points of the terrestrial batrachian, viz.: alteration in dentition, possession of lungs and eyelids, absence of gills and crest, and variation in colour.

Mr. Lydekker exhibited the photograph (text-fig. 182, p. 600) of a young Stag from Sikhim, now living in Nepal, which had been lent by Mr. David Ezra. This photograph Mr. Lydekker believed to represent the Shou (*Cervus affinis*); and if so, it was the first picture of that deer which had been submitted to the Society since Brian Hodgson's time. The stag depicted is noticeable on account of its large ears, thick mane, large rump-patch, and rather short, thin tail. It is in winter coat; and the general colour is approximately the same dark brown as that of the Hangul (*C. cashmirianus*), while the rump-patch is white, as in the latter. In the large size of this rump-patch, as well as in the big ears, the Sikhim deer is, however, decidedly Wapiti-like.

The photograph agrees fairly with a picture of a young stag in Hodgson's sketches, which is probably also in the winter coat. A sketch of a stag in the same series is redder, with no distinct rump-patch, and may represent the summer coat.

Text-fig. 182.



Young Shou Stag, from a photograph lent by Mr. D. Ezra.

The following papers were read :—

1. On the Skull-Characters in the Southern Sea-Elephant.

By R. LYDEKKER *.

[Received May 15, 1909.]

(Text-figures 183–185.)

The distribution of the Southern Sea-elephant (for which, following Sir W. H. Flower †, I retain the name *Macrorhinus leoninus*, despite the objection that may be raised against the origin of the generic designation) suggests the existence of several local races. The species occurs, for instance, on the island of San Juan off the coast of Chile, and in the Falklands; and it is quite

* Communicated by permission of the Trustees of the British Museum.

† Proc. Zool. Soc. 1881, pp. 145 *et seqq.*

conceivable that the same race may inhabit these two localities. On the other hand, it is scarcely likely that Elephant-seals would migrate from the Falklands to Tristan d'Acunha on the African side of the South Atlantic; and it is therefore probable that the representatives of the species from the latter island are racially distinct. The same remark will apply to the Elephant-seals of the Kerguelen, Crozet, and Heard groups in the south of the Indian Ocean; while yet another race is probably represented by those inhabiting the Macquarie and Chatham groups in the New Zealand seas.

The idea that there may be several local forms of Sea-elephant is by no means new. It was adopted, for instance, by Dr. J. E. Gray on page 180 of the fifth volume of "Griffith's Cuvier," 1827; the Macquarie Island form being designated *M. proboscidea*, while the name *Macrorhina patagonica* was proposed for the Falkland race, and Desmarest's titles *ansonii* and *byroni* were used respectively for the Sea-elephants from Juan Fernandez and the Tinian Islands, the latter being in the Ladrone group, north of Australia. Again, in the *Monatsbericht* of the Berlin Academy for 1875, p. 395, Dr. Karl Peters proposed the name *falclandica* for the Falkland, and *kerguelensis* for the Kerguelen race.

As regards these various names, it may be mentioned that the *Phoca leonina* of Linnaeus is based on a specimen brought from Juan Fernandez by Lord Anson in 1744, which was exhibited for many years in the British Museum. All that now remains of this type-specimen is the anterior portion of the jaws, which is preserved in the Museum of the Royal College of Surgeons, where it was transferred in 1809*. The specimen is too incomplete to give any idea of the distinctive skull-characters of the typical Juan Fernandez race.

Of this race, namely *M. leoninus typicus*, Peron's *Phoca proboscidea* and Desmarest's *ansonii* are synonyms.

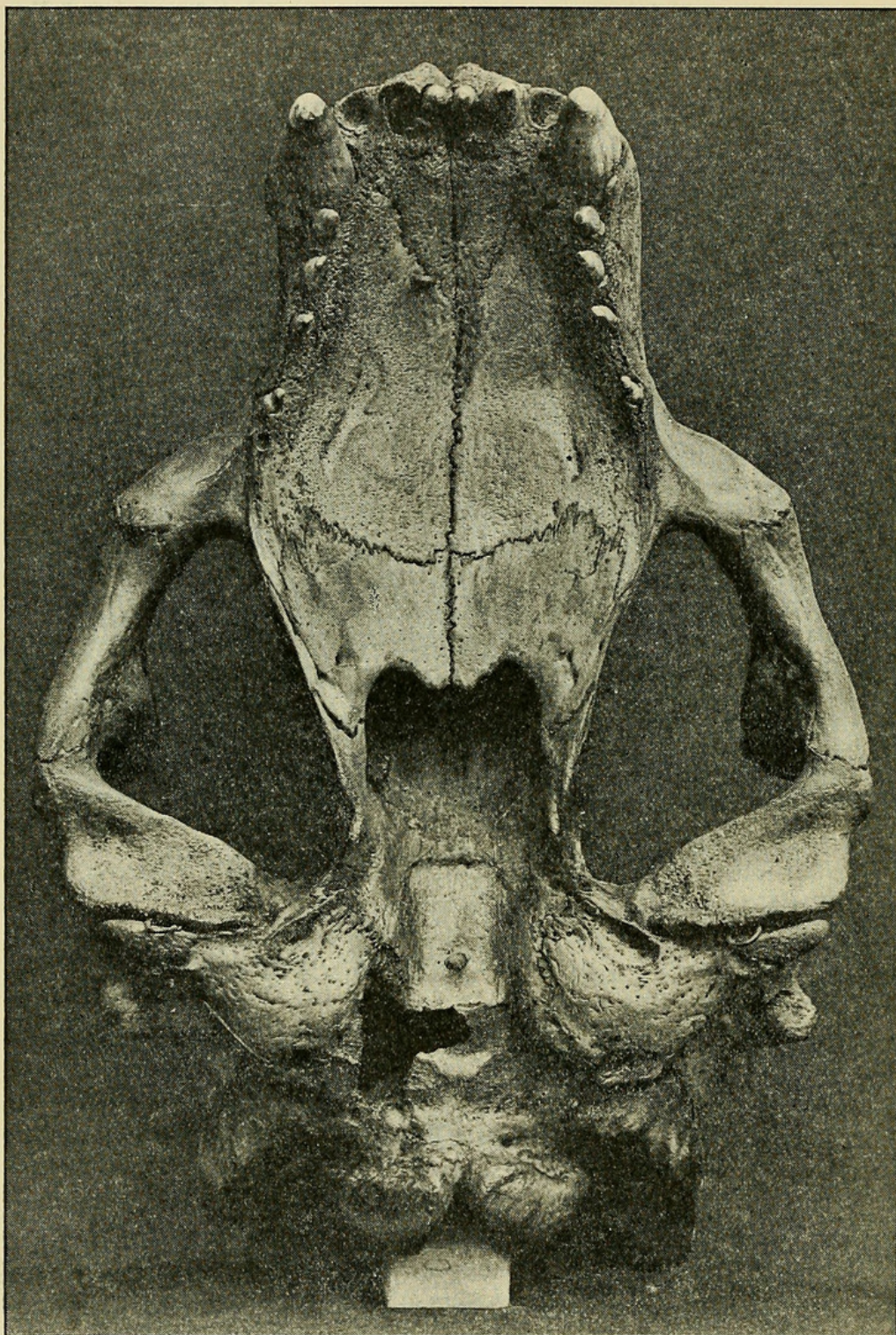
With regard to Gray's *patagonica*, this was founded on a young skull figured by F. Cuvier†, which is stated by Gray to be convex with the brain-cavity more extended and the nasal region shorter than in "*M. peronii*," while the cutting-teeth number only $\frac{4}{2}$. This, owing to the immaturity of the type, I regard as an insufficient description. On the other hand, the *falclandica* of Peters, based on the specimen figured in Pernetty's "Histoire d'un Voyage aux Isles Malouines, fait en 1763 et 1764, avec des Observations sur le Détroit de Magellan et sur les Patagons," appears to be valid; and the name *M. l. falclandica* is therefore available for the Falkland Sea-elephant, if this be distinct from the typical race. The *M. kerguelensis* of Peters cannot be regarded as more than a *nomen nudum*, and the same is the case with Desmarest's *P. byroni*, even if an Elephant-seal occurs in the Ladrone. There is also the *Phoca elephantina* of Molina, but

* See Flower and Garson, "Cat. Osteol. Specimens, Mus. R. Coll. Surgeons," pt. 2, p. 217.

† Mém. Mus. Paris, iv. pl. xiv. fig. 2.

this evidently relates to the Chilian species subsequently described as *M. angustirostris*.

Text-fig. 183.



Palatal aspect of skull of Male Falkland Sea-Elephant. About $\frac{1}{4}$ nat. size.
From specimen in Museum of R. College of Surgeons.

After this much of introduction, I turn to the proper subject of this communication, which relates to skulls of the southern Sea-

elephant now in the British Museum. These include two males from Macquarie Island presented by the Hon. Walter Rothschild, a male from Chatham Island obtained by Professor H. O. Forbes, a female from the "Antarctic Seas" obtained during the voyage of the 'Erebus' and the 'Terror,' and a male from the Crozet group. With these, by the courtesy of Dr. A. Keith, I have been able to compare an old male skull from the Falklands preserved in the Museum of the Royal College of Surgeons, being the one on which the above-mentioned paper by Sir W. H. Flower is based.

In comparing these skulls I find that the most satisfactory distinctive characters are afforded by the palatal surface, and it is to this aspect that attention will be chiefly restricted.

Great difference obtains in regard to the proportions of the length to the width of the skull in the different local forms, as is shown in the following table:—

	Falkland.	Macquarie.	Crozet.	Chatham.
Basal length	20 ins.	18 ins.	16·5 ins.	16·3 ins.
Maximum width ...	15	14	14	11·7
Length of palate ...	11	9·5	9	8·5
Width of do. ...	7·3	6·3	6·5	6·1

Taking first the Falkland race, which, as already mentioned, may be identical with *M. l. typicus*, but which it will be convenient to call *M. l. falklandicus*, the skull (text-fig. 183) is characterised by its relative length and narrowness. The palate is also long and narrow, nearly flat in the palatine region, but becoming suddenly hollowed on the line between the 4th and 5th cheek-teeth. The palatines themselves form a long median suture; the process of the pterygoid is small; and the premaxillæ are long, and V-shaped. As additional features may be mentioned the relative narrowness of the condyles, and the circumstance that the lower border of the anterior zygomatic root projects considerably behind the posterior aperture of the maxillary foramen.

A second skull in the Museum of the Royal College of Surgeons from the Falklands agrees in essential characters with the above.

Turning to the two Macquarie skulls, which are practically identical, we find the general proportions not very different from those of the Falkland specimen, but the palate (text-fig. 184, p. 604) is much more hollowed*, and this throughout its whole extent. Then, again, the inter-palatine suture is shorter and the pterygoid process much larger; while the condyles are wider, and the lower border of the anterior zygomatic roof does not project behind the hind aperture of the maxillary foramen.

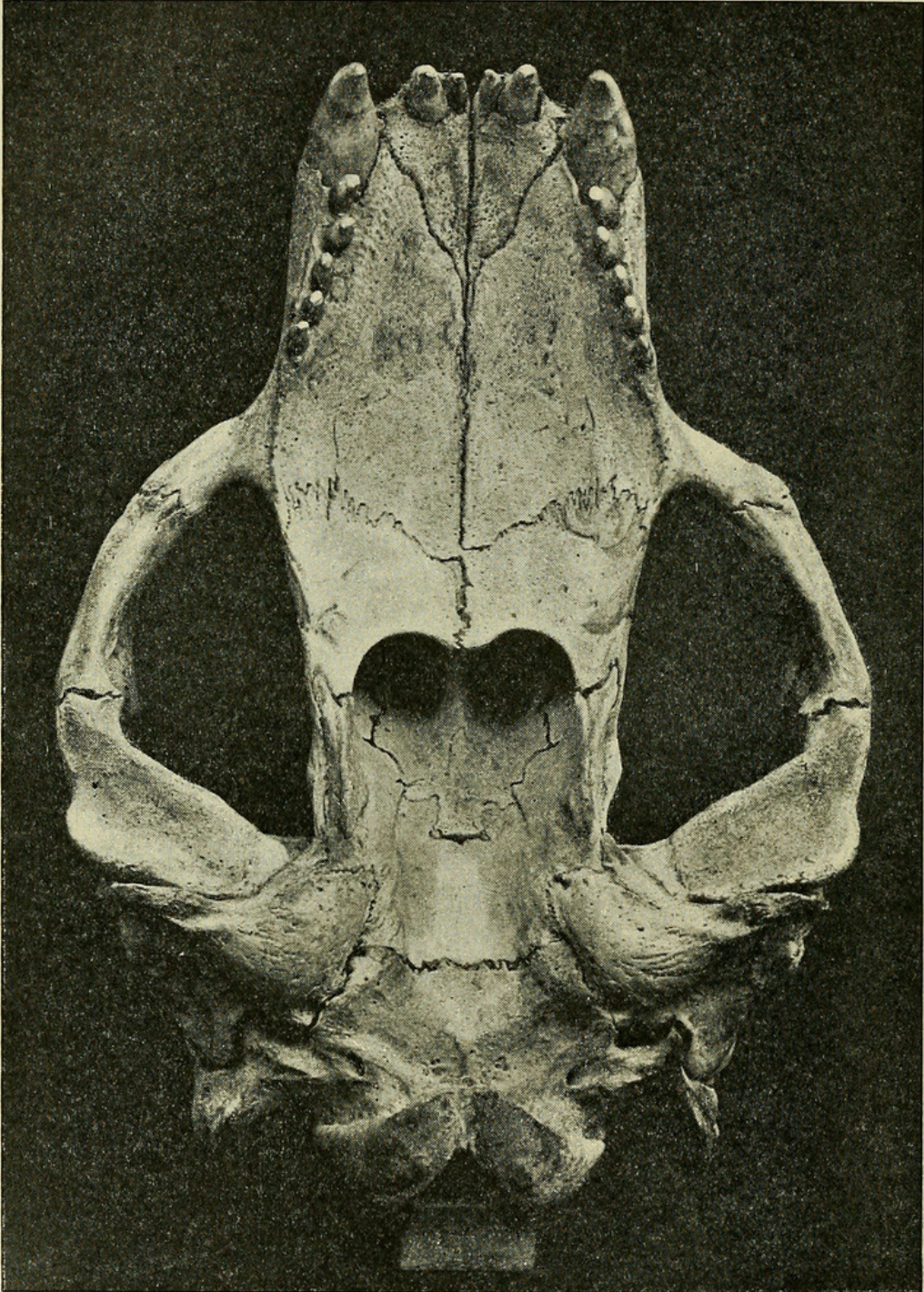
For the Macquarie race, as typified by the figured skull (B. M. No. 1.6.22.1), I propose the name *M. l. macquariensis*.

The natural supposition would be that the Sea-elephant from the Chatham Islands would be identical with the one inhabiting the Macquaries; and this appears to be borne out by a skull of

* I use the term hollowed in place of vaulted as being more convenient.

the former in the British Museum (No. 94.11.17.1), which is that of a young male. Its dimensions are given in the fourth column of the table. This skull agrees in general characters with the two

Text-fig. 184.

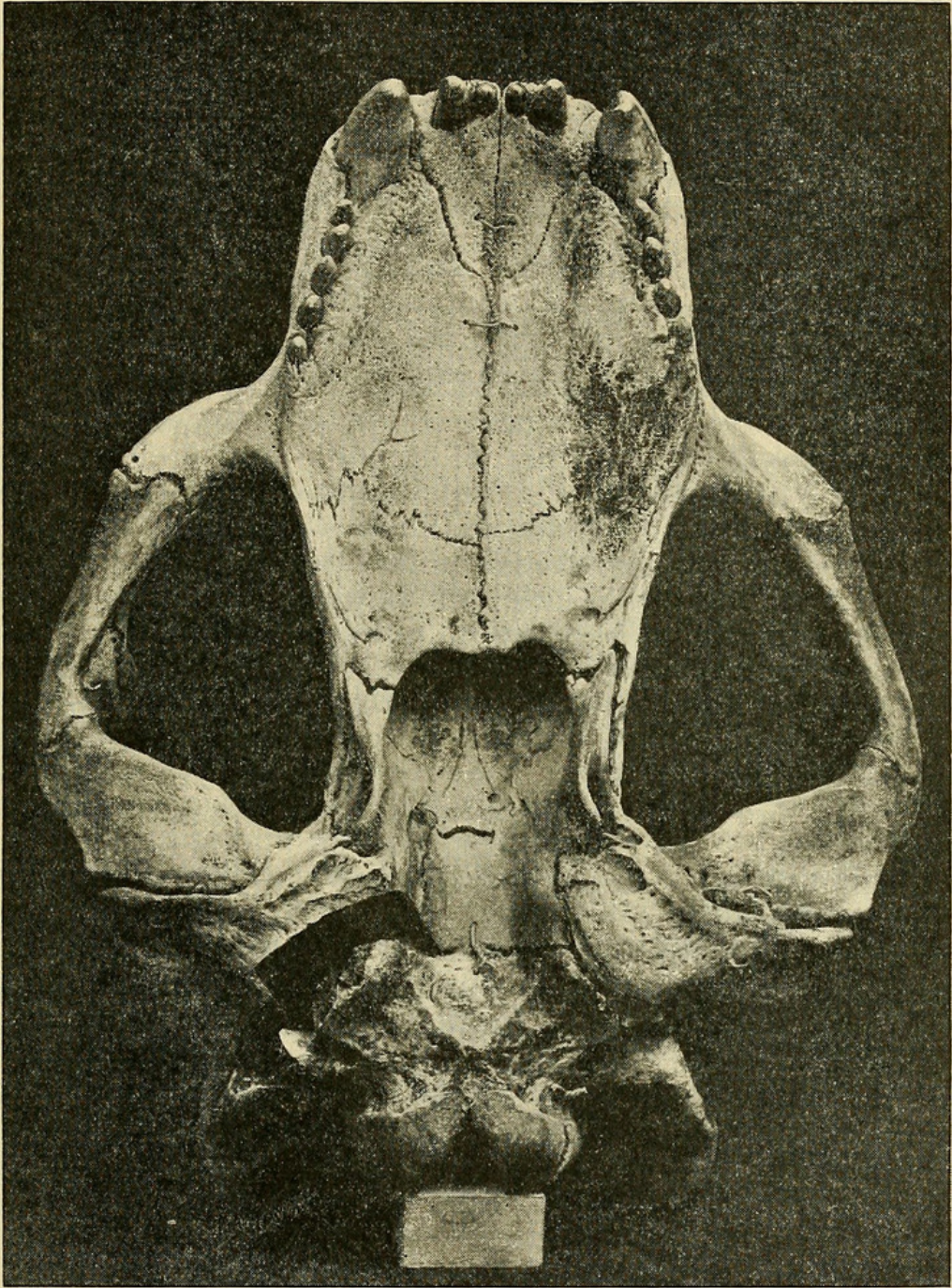


Palatal aspect of skull of Male Macquarie Sea-Elephant. About $\frac{1}{4}$ nat. size.
From a specimen in the British Museum.

Macquarie specimens, but differs by the much less deep incision of the central portion of the supraoccipital. Since, however, this is

a feature which may apparently be due to immaturity, I associate the specimen with the Macquarie race.

Text-fig. 185.



Palatal aspect of skull of Male Crozet Sea-Elephant. About $\frac{1}{4}$ nat. size.
From a specimen in the British Museum.

Coming to the Crozet skull (text-fig. 185), this is shown by the table of measurements to be broadly distinguished from the two preceding races by its shortness and width; the maximum zygomatic width being equal to that of the skull of the Macquarie race which is $1\frac{1}{2}$ inch longer, while the palatal width of the Crozet

actually exceeds that of the Macquarie skull. To this difference may be added the almost complete flatness of the palate, the longer inter-palatine suture, the much more slender pterygoid process, the U-shaped palatal aspect of the premaxillæ, and the extremely narrow condyles.

For this race as typified by the figured skull I suggest the name *M. l. crosetensis*, of which Peters' undefined *M. kerguelensis* is probably a synonym. The immature 'Erebus' and 'Terror' skull, said to be that of a female, may belong to this race; the greater prominence of the tympanic region as compared with the Crozet specimen, being not improbably a feature due to immaturity.

As the result of the foregoing comparisons, our information with regard to local races of the Southern Sea-elephant, as definable from skull-characters (and, with the present material, I can find no others of any value), may be summarised as follows:—

1. *Macrorhinus leoninus typicus*. Juan Fernandez.

Skull unknown.

2. *M. l. falclandicus*. Falkland Islands. Perhaps inseparable from typical race.

Skull long and narrow; palate flat behind and hollowed in front; palatine suture long; pterygoid process small; palatal aspect of premaxilla V-shaped.

3. *M. l. macquariensis*. Macquarie and (?) Chatham Islands.

Skull of the same general type as in the preceding, but the palate markedly hollow throughout, the palatine suture shorter, and the pterygoid process longer. Condyles wide.

4. *M. crosetensis*. Crozet and (?) Kerguelen and Heard Islands.

Skull short and wide, with the palate almost flat, the pterygoid process very slender, the premaxillæ U-shaped, and the condyles narrow. This race is said to be the largest of all.

In addition to these there may be a distinct race inhabiting Tristan d'Acunha. I know nothing of the Sea-elephants of the South Shetlands.

Although the Californian Sea-elephant (*M. angustirostris*) does not properly come within the purview of the present communication, I may take the opportunity of mentioning that the fore part of a skull at present in the British Museum shows such difference in the palatal region from all the races of the Southern form, that on this ground alone the Southern and the Northern Sea-elephants appear entitled to be regarded as specifically distinct.

[Since this paper was read Mr. Rothschild has informed me that he has evidence to show that the San Juan and Chilian Sea-elephants are identical, and that migration formerly took place between the San Juan and the Guadalupe Island animals. If this be so, I presume *angustirostris* would be regarded as a synonym of *leoninus*, while *falclandicus* would become the substantive name for the Southern species.]

2. On the Skull of a Black Bear from Eastern Tibet, with a Note on the Formosan Bear. By R. LYDEKKER *.

[Received May 1, 1909.]

(Text-figures 186 & 187.)

On page 198 of the 'Fauna of British India: Mammalia,' Dr. Blanford states that the Himalayan Black Bear is unknown in Tibet; and it is for that reason he employed for the species the name *Ursus torquatus* instead of *U. tibetanus* (or *thibetanus*, as it is spelt by F. Cuvier).

The British Museum has, however, the skull of a female of this species from the mountains of Sze-chuen, which was collected by Berezowsky and obtained by exchange with the Tring Museum in 1896. This, of course, is no proof that the species occurs in Eastern Tibet itself, although it affords a strong presumption that such may be the case. Decisive evidence on this point is, however, afforded by the skull and skin of an old and presumably male bear of this species shot by Captain Malcolm McNeill, some distance to the westward of Ta-chien, in Eastern Tibet, which have been submitted to me for determination. The skull has been secured for the Museum. The skin, which is in winter coat, differs from that of any Himalayan specimens of *U. torquatus* that have since come under my notice—and I have handled a good many—by the greater length and softness of the hair. The skull (text-fig. 186 A, p. 608), as compared with a full-grown and probably male, but rather younger, Himalayan specimen of the same approximate length (text-fig. 186 B), is characterised by the much smaller size of the cheek-teeth, as will be apparent from the following measurements and the accompanying text-figures.

	Himalayan.	Tibetan.
Basal length of skull	10.15 ins.	9.9 ins.
Maximum zygomatic width of do. ..	6.5	6.7
Length of last 3 upper cheek-teeth ...	2.6	2.13
" " " upper molar	1.3	0.98
Width " " " " "	0.7	0.6
Length " " 3 lower cheek-teeth ...	2.7	2.18
" " " lower molar	0.8	0.61
Width " " " " "	0.6	0.42
Length of penultimate lower molar ...	0.9	0.8

In this table it will be noticed that the Tibetan skull is rather broader, both actually and proportionately, than the Himalayan specimen. As regards the cheek-teeth the most important feature,

* Communicated by permission of the Trustees of the British Museum.

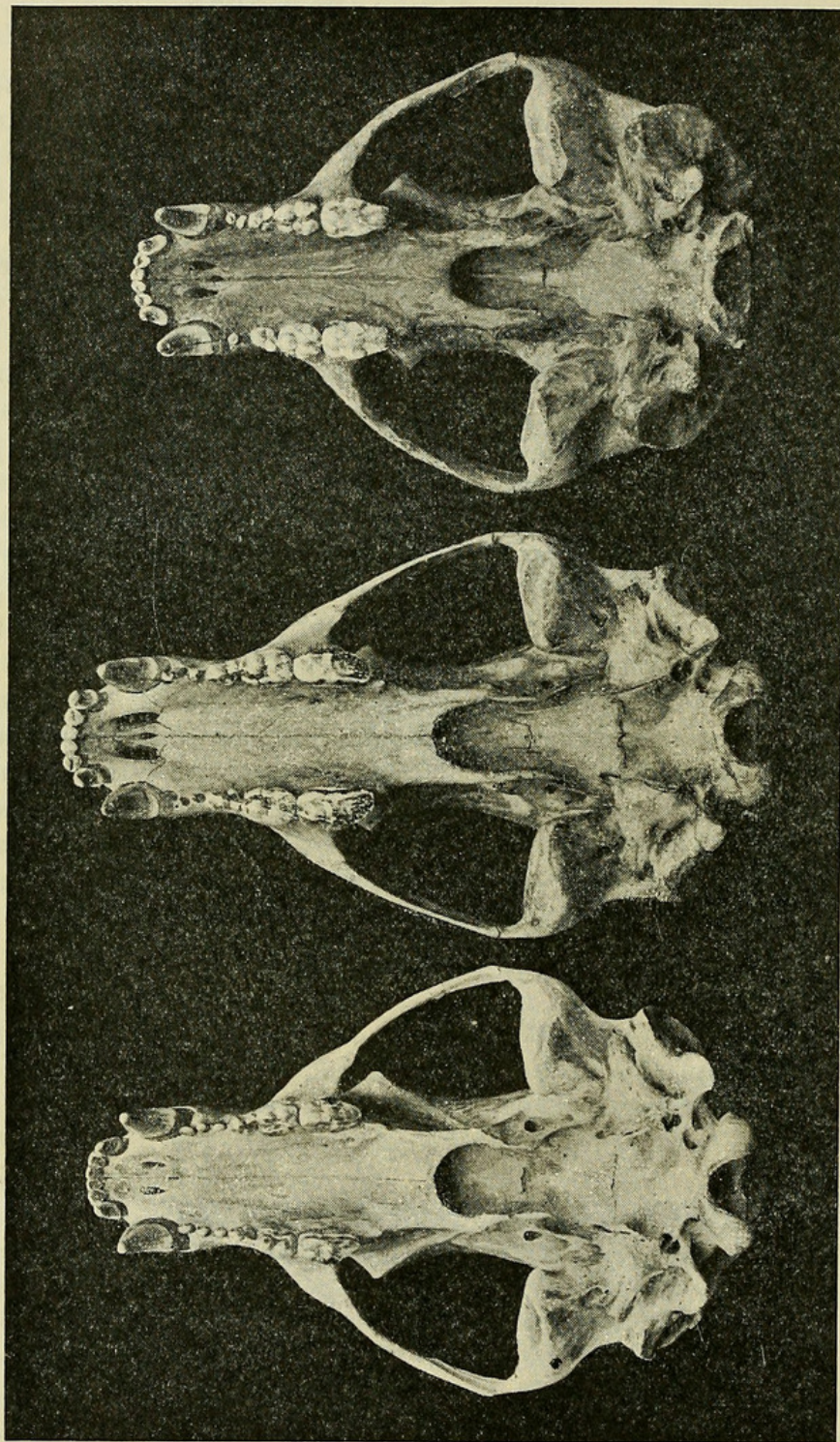
next to the conspicuously smaller size of the last three, is the narrower form of the third lower molar of the Tibetan skull which consequently, as shown in text-figure 187 A, appears to be both longer and narrower than the corresponding tooth in the Himalayan specimen.

Text-fig. 186.

A.

B.

C.



Palatal aspect of skulls of *Ursus torquatus* (A), *U. t. macneilli* (B), and *U. t. formosanus* (C). About $\frac{1}{4}$ nat. size.

In the skull of a female Black Bear from Assam recently offered to the Museum the cheek-teeth are of practically the same size

as in the Tibetan specimen, but the palate is much wider, as is shown by the following measurements :—

	Tibet.	Assam.
Length of six upper cheek-teeth	3·9 ins.	3·9 ins.
„ last 3 upper cheek-teeth ...	2·1	2·0
Width of palate between <i>m</i> 2	1·5	1·7

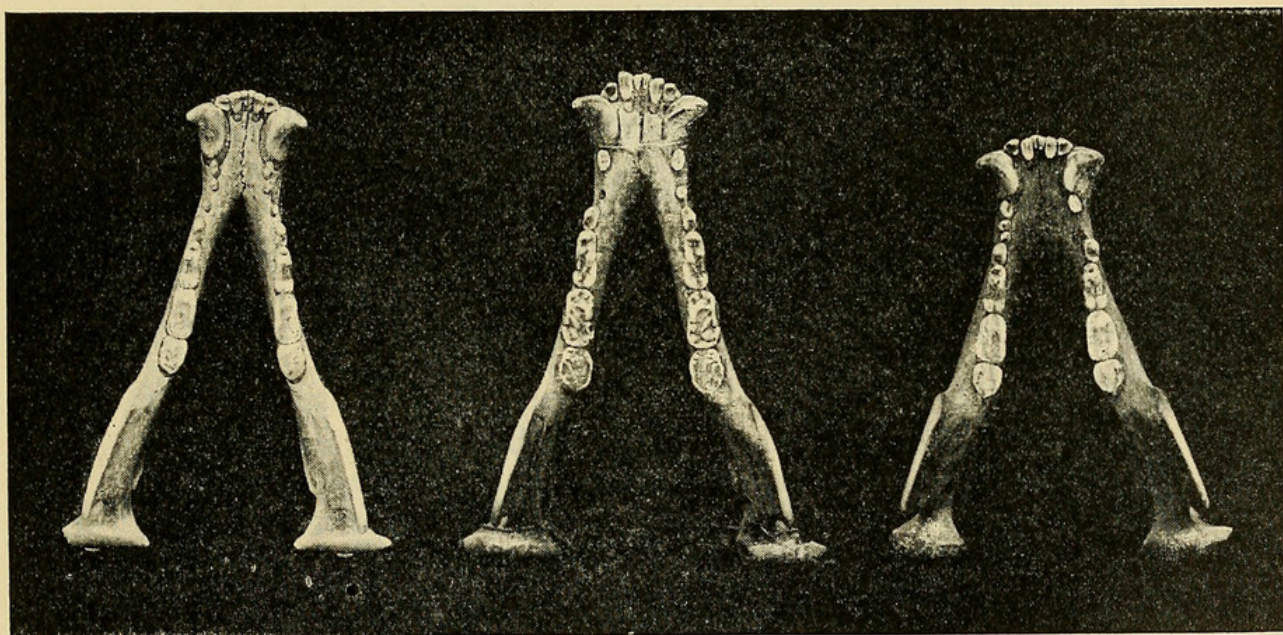
This relative narrowness of the palate in the Tibet skull is borne out by the above-mentioned female skull from Sze-chuen, in which the length of the space occupied by the last three cheek-teeth is 2·3 ins., while the palatal width between *m* 2 is only 1·25. As the Sze-chuen skull certainly belongs to the same race as the one from Tibet, and as its teeth are rather larger than those of the latter (in which the palatal width between *m* 2 is 1·55 inches), it indicates that the narrowness of the palate in the female is quite as important a feature of the Tibetan race as is the small size of the cheek-teeth and the relative narrowness of the third large molar in the male. In both sexes the palate is distinctly vaulted, whereas in the typical Himalayan race it is nearly flat.

Text-fig. 187.

A.

B.

C.



Palatal aspect of the lower jaws of the same three skulls. About $\frac{1}{4}$ nat. size.

Letters as in text-fig. 186.

These features seem to justify the recognition of a distinct Tibetan race of *U. torquatus*, for which the designation *U. t. macneilli* will be appropriate, the male skull forming the subject of the present paper being the type.

Now that the Himalayan Black Bear has been shown to occur in Tibet and Sze-chuen, it might be argued that the time has come for the re-instatement of the name *tibetanus*; but since the typical

race is Himalayan, it appears to me that it will be best to follow Dr. Blanford's usage and retain the name *U. torquatus*. As I have on a previous occasion shown that the Bruang (*U. malayanus*) ranges into Sze-chuen *, we have now evidence of the occurrence in that province of two species of Black Bears.

Before concluding, I may refer to the type skull of *U. formosanus* of Swinhoe †, which is contained in the British Museum Collection (No. 70.2.10.9). That this skull indicates a bear specifically identical with *U. torquatus* appears to me indisputable—in the sense in which I regard species. At the same time, it is so much wider and shorter than the skull of *U. torquatus typicus* that it must, without hesitation, be regarded as representing a distinct race, with the designation *U. t. formosanus*. This will be apparent from the following measurements:—

	<i>typicus.</i>	<i>formosanus.</i>
Basal length of skull	10.15 ins.	9.1 ins.
Maximum zygomatic width of do. ...	6.5	6.95
Length of last 3 upper cheek-teeth ...	2.6	2.25

The Formosan skull (text-fig. 186, C) is distinguished, moreover, by the absence of any distinct bevelling away of the outer side of the talon of the last cheek-tooth, which in consequence has nearly parallel sides. The last lower molar (text-fig. 187, C) is broad and short, so that it appears more rounded than the corresponding tooth of *typicus*, and thus very different from that of *macneilli*. In its shortened and wider form the skull of *U. t. formosanus* makes a slight approximation to that of *U. malayanus*, which, however, is broadly distinguished by its still greater expansion, the excessive size of the palate, and the smaller cheek-teeth, more especially the last.

3. The Anatomy of the Olfactory Organ of Teleostean Fishes.

By R. H. BURNE, M.A., F.Z.S.

[Received May 10, 1909.]

(Text-figures 188–213.)

The coarse anatomy of the olfactory organ in the Teleostean Fishes seems to have received too little attention. Reference to the leading old and modern text-books (Milne-Edwards, Owen, Günther, Cambridge Natural History, Parker and Haswell, Wiedersheim, Gegenbaur, &c.) leaves the general impression that apart from a few isolated cases, the organ is remarkably constant and consists of a pair of simple concavities upon the fore-part of the face opening to the exterior by a pair of nostrils and each containing a group of olfactory laminae arranged rosette-wise

* *Vide* P. Z. S. 1906, p. 907.

† *Ibid.* 1864, p. 380.

above the termination of the olfactory nerve, such variation as occurs being mainly confined to details of the nostrils.

Although this impression is no doubt in part due to the natural tendency of text-books to lay too great stress upon the condition found in the usual teaching type which in this case is generally a Gadid, a study of the original papers dealing with this particular organ shows that the work done upon it has been neither large in amount nor particularly extensive in scope.

The following is, I think, a fair statement of the present state of our knowledge of the coarse anatomy of the Teleostean Nose, and of the chief sources from which it is derived:—

Owen* and Milne-Edwards† mention that in the Mackerel and *Anarrhichas* there are certain accessory nasal sacs in connection with the true olfactory chamber which act as compressible reservoirs by means of which, as in the case of the pituitary cæcum of the Lamprey, a current of water is driven through the olfactory chamber by the movements of the jaws and opercula in respiration.

1876. Sophie Pereyaslawzeff‡ published a preliminary paper on the olfactory organ of Fishes, and in it described in detail the coarse and fine anatomy of *Solea impar* and *Lophius piscatorius*. The full paper seems never to have appeared—a matter for regret, for from the list of genera and species mentioned in the preliminary paper as the material upon which the work was done, it would evidently have been a valuable contribution to the subject.

1884. Blaue§ in a most important paper on the olfactory membrane in Fishes and Amphibia gives short descriptions of the coarse anatomy of the olfactory pit and rosette in several species of Teleostei. The descriptions so far as they go are good, but as they are incidental to the true subject of the paper and only deal with the anatomy so far as it is necessary for the purpose in hand, they are naturally imperfect. However, in this paper there is a certain amount of information upon the form of the olfactory chamber and rosette in *Belone*, *Exocætus*, *Trigla*, *Esox*, *Umbra*, *Cottus*, *Gobius*, *Gadus*.

1887. Wiedersheim|| writes a full and interesting account of a series of stages in the degeneration of the olfactory organ of Plectognaths, tracing its transformation from a simple concavity of the normal type to the condition of a split tentacle in which the olfactory membrane is fully exposed. The species described are *Tetrodon*

* Anat. Vertebrates, vol. i. p. 329.

† Leçons sur la Physiol. T. xi. 1874, p. 475.

‡ Inaug.-dissert. Zürich. 1876.

§ Arch. f. Anat. 1884, p. 241.

|| Festschrift v. Kölliker, 1887, p. 73.

nigropunctatus, *T. immaculatus*, *T. papua*, *T. pardalis*, and *Diodon maculatus*.

The same subject has been treated by Tate Regan (Proc. Zool. Soc. 1902, vol. ii. p. 292).

1889. Bateson* in a paper on the sense-organs and senses of Fishes, besides some highly interesting physiological notes which will be referred to more fully later on, gives details of the structure of the nostrils and olfactory rosette in various common species of Fishes, pointing out (1) the tubular character of the anterior nostril in the few fishes that hunt their food by scent (*Motella*, *Cobitis*, *Solea*, *Conger*, *Anguilla*, *Lepidogaster*), (2) the valvular mechanism of the posterior nostril in certain Flat-fishes, (3) the main types of structure of the rosette—elongated (Eels), oval (the majority of Fishes), or circular (*Cottus*), and an exceptional type in which the leaflets are arranged in parallel series in a single row (*Pleuronectes*, *Hippoglossus*).

1894. Solger† briefly describes the olfactory chamber of the Stickleback, stating that the nostril (as in many Pharyngognaths) is single and that the olfactory chamber proper is extended downwards to the buccal membrane by an accessory sac lined with indifferent epithelium and by its alternate expansion and contraction synchronously with the respiratory movements causing water to flow in and out of the true olfactory part of the cavity.

1899. Kyle‡ describes in several species of Pleuronectids (*Hippoglossus*, *Pleuronectes*, *Rhombus*, *Solea*, *Cynoglossus*) accessory nasal sacs in connection with the true olfactory chamber and lays stress on the fact that in these Fishes, with the exception of *Solea* and *Cynoglossus*, the sacs secrete mucus and are not simple reservoirs for producing water-currents by their alternate expansion and contraction. He mentions, however, (but without description) that such simple reservoir sacs do occur in several other families (Blenniidae, one sac; Labridae, one sac; Scorpaenidae, two sacs), and concludes generally that accessory sacs are confined to semi-sedentary as opposed to migratory Fishes.

He further describes, and this forms an important part of the paper, a direct and apparently normal connection between the accessory sacs and the mouth in a single specimen of *Cynoglossus*.

In addition to the above papers which deal entirely or mainly with the nose, descriptions of this organ in isolated genera are

* Journ. Marine Biol. Ass. vol. i. 1889, p. 229.

† Zeits. Wiss. Zool. Bd. lvii. 1894, p. 186.

‡ Journ. Linn. Soc. vol. xxvii, 1899, p. 541

probably to be found scattered about in monographs, dealing with special genera. The only one, however, to which I am able to refer is the detailed description of the olfactory organ of the Plaice by Cole and Johnston *.

Some few years ago when a Catalogue of the Sense-organs in the Museum of the College of Surgeons was in preparation, my attention was directed to this subject of the anatomy of the Fish nose, and from the few dissections then made it soon became apparent that variations upon the fundamental ground plan are far more numerous and general than the ordinary sources of information would lead one to suppose. Since then I have collected notes upon this subject, as occasion offered, and in doing so have kept four main objects in view:—

- (1) To see how far the fundamental part of the olfactory organ (a concavity in the face, containing an olfactory rosette) is constant in its form and in its position relative to the bones of the skull.
- (2) To see how far the variations observed accord in their occurrence with authoritative systems of classification and so are to be regarded as of taxonomic importance.
- (3) To explain so far as possible the action of such variations of structure as appear to be of functional importance.
- (4) To see if any connection can be traced between variations in the nose and the general habits of the Fish.

The Fishes dissected belong to 32 families and 51 genera, representing to some degree most of the larger divisions of the order. They are mostly the common Fishes of the market, supplemented by some exotic forms from the College stores, for the identification of which I am much indebted to Mr. Boulenger, F.R.S. In the following descriptions the Fishes have been arranged in order according to Boulenger's system in the Cambridge Natural History, with the exception of the Anacanthini which have been taken first, out of their proper place in order that the simple unspecialised nose of the Haddock may serve as a standard of comparison for the rest.

ANACANTHINI.

GADIDÆ.

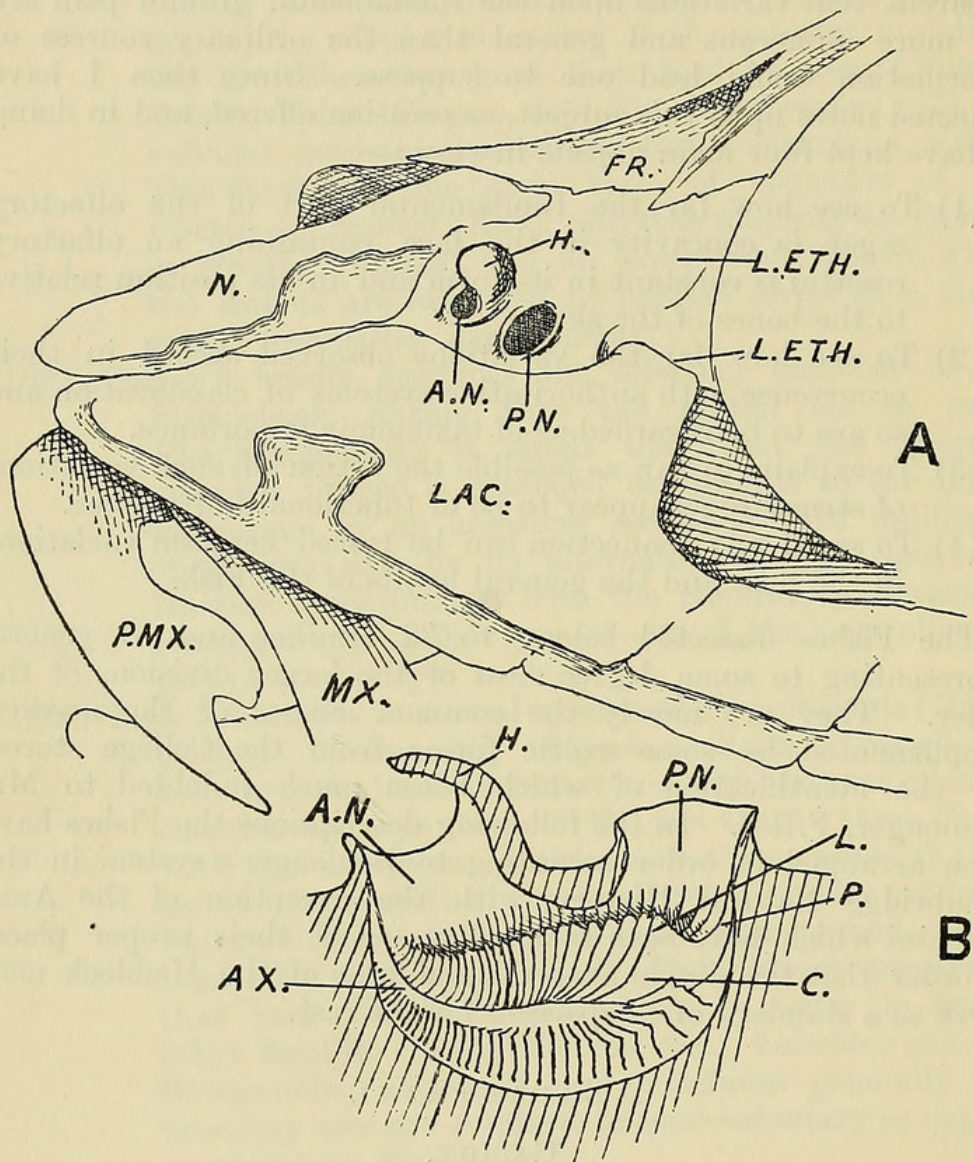
Gadus aeglefinus (text-figs. 188 & 189).

The nostrils (text-fig. 188, A, p. 614) lie in front of the orbit in an area of soft skin bounded above by the nasal and frontal bones and below by the lachrymal. A line passing through both slopes from in front downwards and backwards at an angle of about 45° to the horizontal. The anterior nostril is circular and bordered by a low tubular lip elevated posteriorly to form a hood-like flap, by which in forward progression water would be deflected

* L. M. B. C. Memoirs, No. viii. Pleuronectes. 1901.

into the nostril. The posterior nostril is larger than the anterior and of more oval shape; it is bordered by a low lip. Between the two is a narrow bridge of skin. The nostrils open into either end of a pit (olfactory chamber) which is oval in surface-view but semicircular in vertical section (text-fig. 188, B). The cavity of the pit is almost completely filled by a series of leaflets (the

Text-fig. 188*.

*Gadus aeglefinus.*

A. The relation of the nostrils to the superficial bones of the face.

B. Diagram of olfactory chamber in longitudinal section.

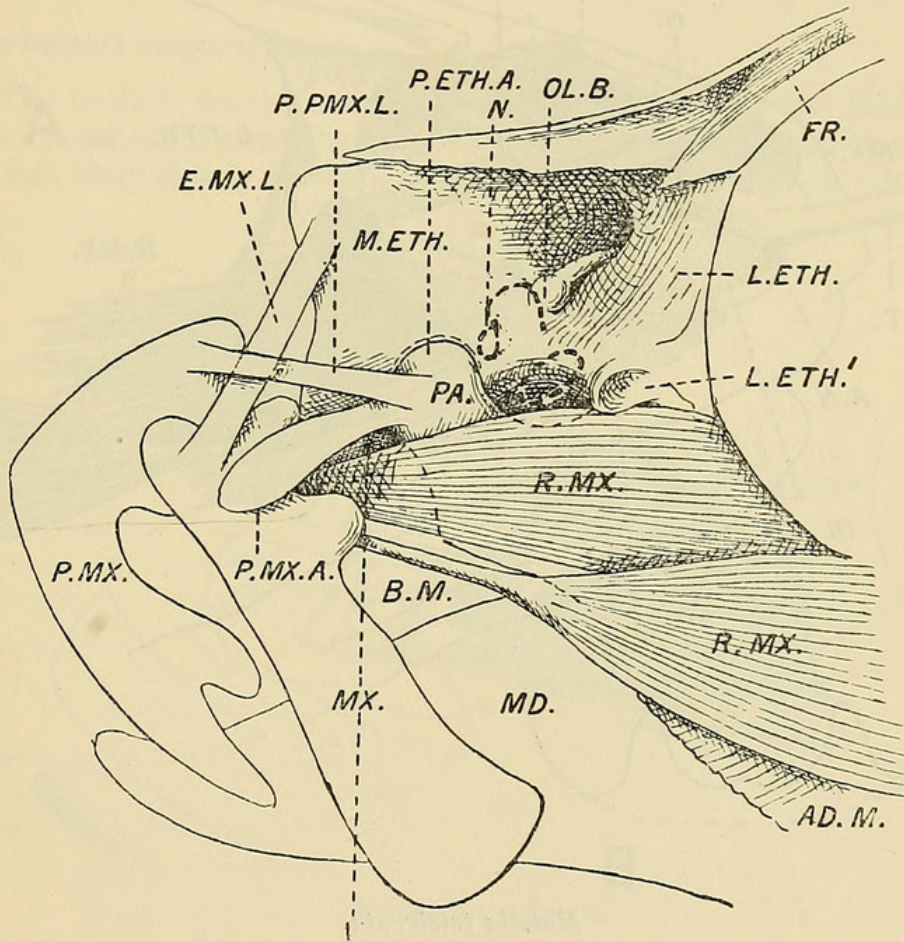
olfactory laminæ) arranged radially along the sides and posterior end of a linear axis which in front is attached to the anterior lip of the anterior nostril. The laminæ are attached to the axis and to the floor and a considerable extent of the side walls of the olfactory

* For explanation of abbreviations in the text-figures see p. 663.

chamber. The free edge of each is produced in the middle (as in Elasmobranchs) to form a "linguiform process" and can thus be conveniently divided into mesial, central, and peripheral segments.

Beyond the area covered by the rosette the lining membrane of the chamber is smooth. The epithelial wall of the olfactory chamber is separated by a layer of loose connective tissue from an outer dense fibrous capsule continuous with the general subdermal tissue of the head, the whole being to a considerable extent surrounded by lymph spaces. The entire organ lies in a hollow in the ethmoid (text-fig. 189) just above and behind the ethmo-palatine articulation and is in no direct relation with either the buccal membrane, jaws, or jaw muscles.

Text-fig. 189.



Gadus aeglefinus.

The relation of the nostrils to the deeper bones of the face.

The olfactory tract passes through the skull by a foramen in the lateral ethmoid below the anterior end of the frontal scute and at once joins the olfactory bulb which is connected to the deep surface of the rosette by short nerves.

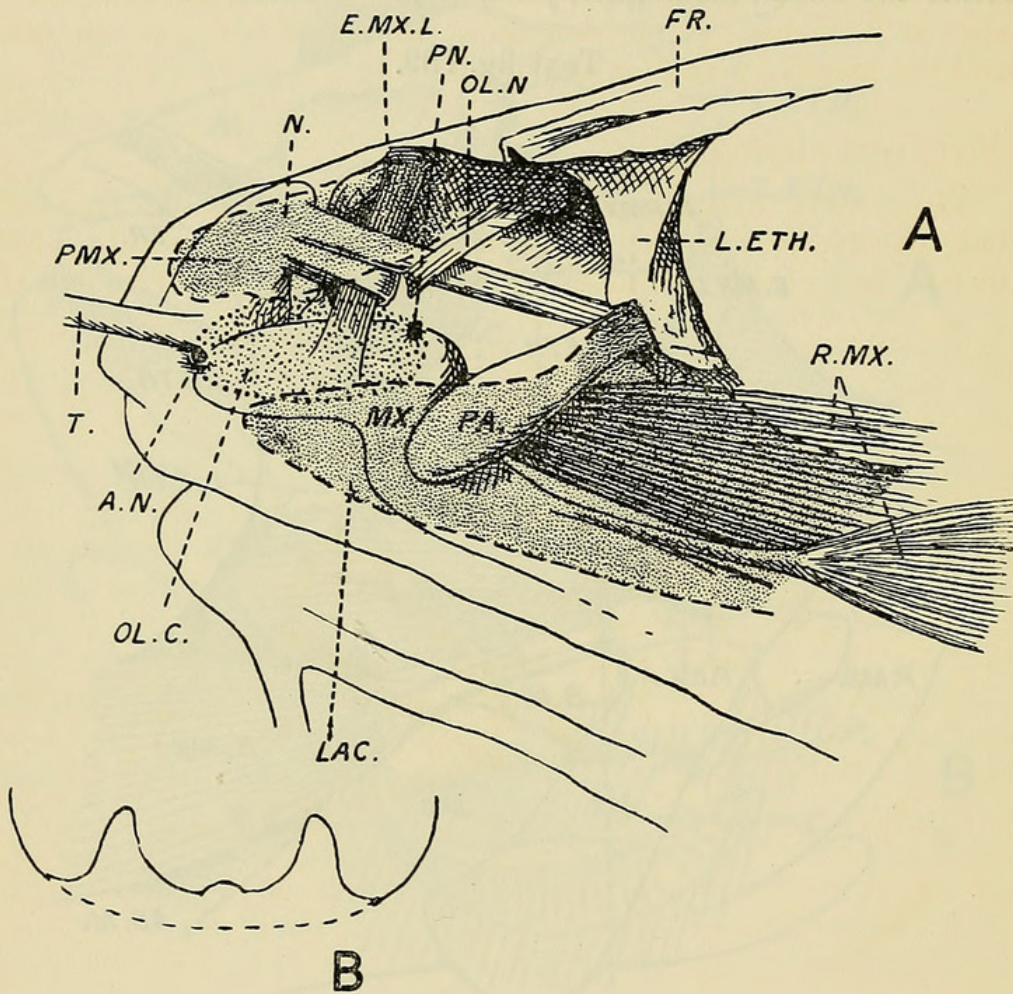
In the Cod (*Gadus morrhua*), Bib (*G. luscus*), and Whiting

(*G. merlangus*), the olfactory organ differs only in minute details from that of the Haddock. For instance, in the Whiting the nostrils are relatively further apart and smaller, and the flap upon the hinder edge of the anterior nostril is not quite so high.

Motella tricirrata.

The olfactory organ, though formed upon the same plan as in the above described Gadids, differs in the following particulars:—The nostrils are relatively smaller, more widely separated and situated nearer the extremity of the snout, the anterior being not

Text-fig. 190.



Motella tricirrata.

- A. Shape and position of the olfactory chamber.
B. Diagram of cross section of the rosette.

far removed from the upper lip. The valvular posterior border of the anterior nostril is modified to form a long tentacle, a circumstance that no doubt partly explains the forward position of the nostril. The olfactory chamber and rosette have a long oval form in agreement with the greater distance between the nostrils. The peripheral segments of the leaflets of the rosette

are but slightly developed, leaving smooth an appreciable area of the floor of the olfactory chamber around the rosette.

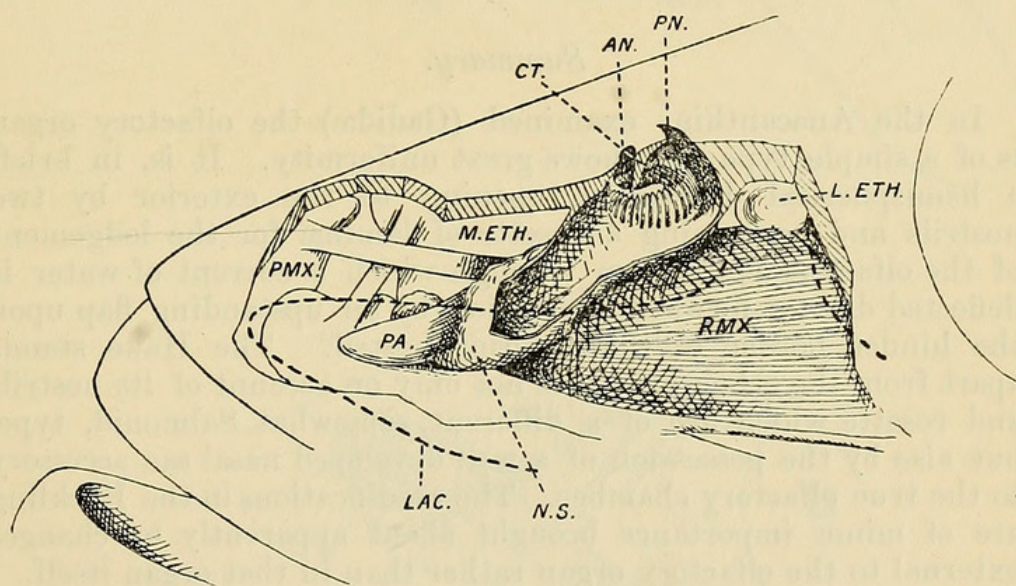
The relations of the olfactory chamber to the skull are also peculiar (text-fig. 190). It lies above the head of the maxilla, and is thus far in advance of its usual position in the hollow of the ethmoid, although the foramen in which the olfactory bulb lies perforates the lateral ethmoid at the usual spot. An olfactory nerve of unusual length is in consequence interposed between the bulb and the rosette*.

The abnormal position of the olfactory chamber may be partly explained, as suggested above, by the fact that the tentacle developed in connection with the anterior nostril would be most advantageously placed near the extremity of the snout, but it is also in part due to a shortening of the skull between the orbit and the maxillary process of the palatine.

Merluccius vulgaris.

The nostrils occupy much the same position as in the Haddock, but are set quite close together, like those of the Salmonidæ, which in fact they closely resemble. The anterior nostril is circular, the

Text-fig. 191.



Merluccius vulgaris.

Position of olfactory chamber and nasal sac.

posterior nostril crescentic and embracing the anterior with its concavity; both are wide open. There is no upstanding flap upon the hinder margin of the anterior nostril, but the integument between the two is prolonged into the cavity of the olfactory chamber, forming a curtain (as in the Salmonidæ) to conduct water

* It may be noted that here, and in all other cases observed, the olfactory nerve is very considerably larger than the tract by which the bulb is connected to the brain.

entering through the anterior nostril into the heart of the rosette.

The olfactory chamber occupies a similar position relative to the bones of the skull, as in the Haddock, but slightly lower down, so that its lower border rests upon the retractor of the maxilla (text-fig. 191, p. 617). Its anterior part, ventral to the rosette, is produced forward to form an accessory sac that passing forward deep to the dorsal parts of the lachrymal bone dips beneath the maxillary process of the palatine into the space included between this bone, the head of the maxilla, and the vomer.

The cavity of the olfactory chamber and accessory nasal sac was filled with an unusually large amount of mucus. Apart from a mucus-secreting function, it seems highly probable from its position that this nasal sac would act as an aspirator bulb, being compressed both by the movements of the head of the maxilla and by the swelling of the jaw muscles upon and near which it lies. This action must, however, be slight at the best, for no bubbles escaped from the nostrils when the jaws were forcibly closed under water.

The rosette is circular and is composed of about 28 laminae, each of which is transversely pleated and has a claw-like outline due apparently to an exaggeration of the linguiform process and the almost complete suppression of the peripheral segment.

Summary.

In the Anacanthini examined (Gadidæ) the olfactory organ is of a simple type and shows great uniformity. It is, in brief, a hemispherical depression, opening to the exterior by two nostrils and containing a rosette of laminae for the lodgement of the olfactory epithelium through which a current of water is deflected during forward locomotion by an upstanding flap upon the hinder border of the anterior nostril. The Hake stands apart from the other examples not only on account of its nostrils and rosette which are of a different, somewhat Salmonid, type, but also by the possession of a well developed nasal sac accessory to the true olfactory chamber. The modifications in the Rockling are of minor importance brought about apparently by changes external to the olfactory organ rather than in that organ itself.

MALACOPTERYGII.

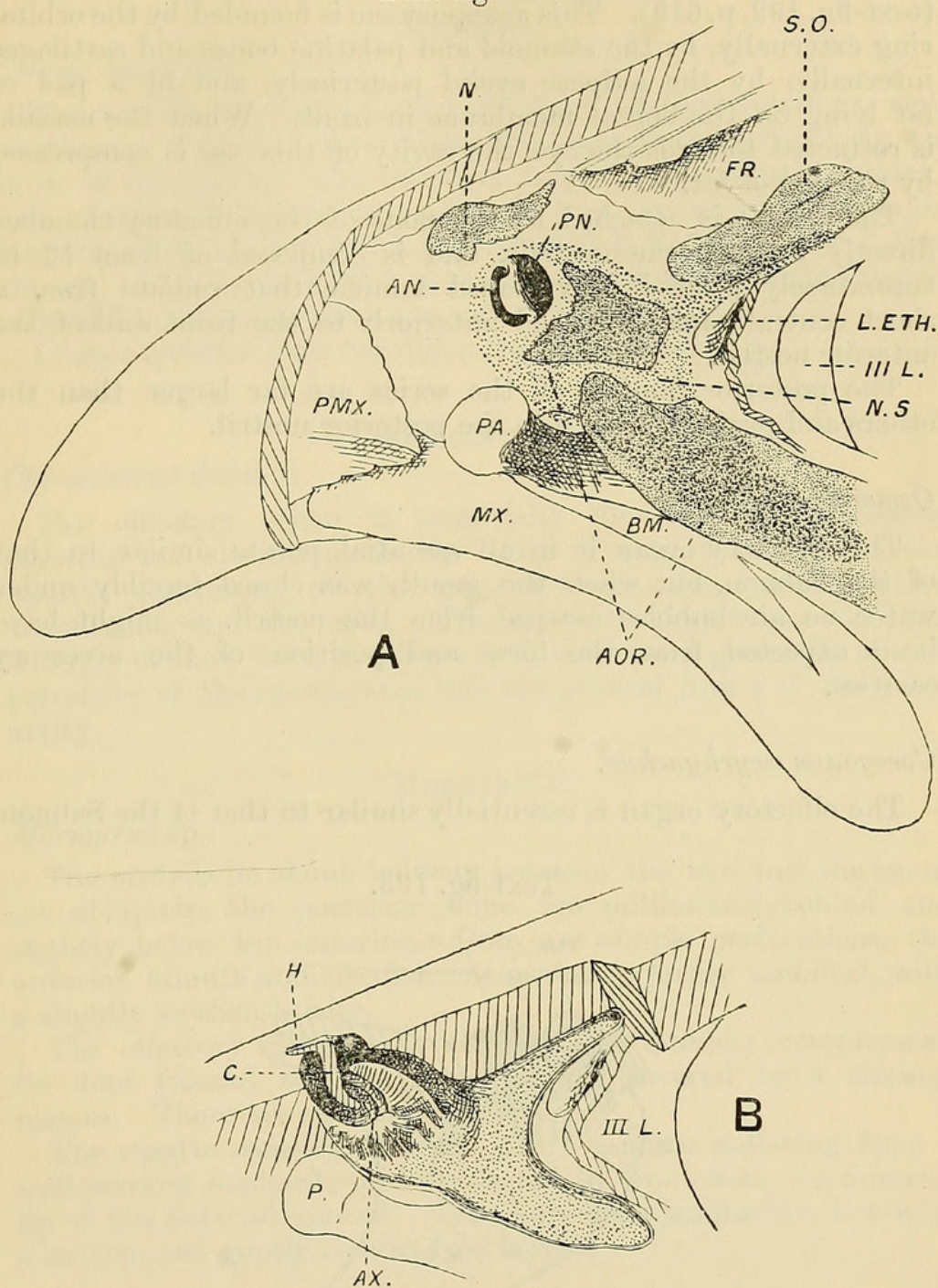
SALMONIDÆ.

Salmo salar.

The nostrils lie close together (text-fig. 192, A) upon a level with the top of the eye and about halfway between it and the snout—the posterior in close connection with the central of the three anterior circum-orbital scutes. Both are elongated dorso-ventrally, the anterior being a narrow slit, the posterior more oval. The

bridge of skin between the two is raised to form an upstanding flap and is also prolonged into the nose cavity nearly to its floor

Text-fig. 192.



Salmo salar.

A. Position and form of nostrils, olfactory cavity, and nasal sac.

B. Diagram of nostrils, olfactory chamber, and nasal sac in longitudinal section.

(text-fig. 192, B), forming a pliant curtain to conduct water entering by the anterior nostril through the laminae of the rosette.

The olfactory chamber occupies the usual position in a hollow

in the ethmoid cartilage, but its parts posterior to the rosette are extended beneath the three anterior scutes of the circum-orbital ring, forming a laterally flattened accessory nasal sac prolonged above and below along the anterior contour of the orbit (text-fig. 192, p. 619). This accessory sac is bounded by the orbital ring externally, by the ethmoid and palatine bones and cartilages internally, by the adipose eyelid posteriorly, and by a pad of fat lying on the buccal membrane in front. When the maxilla is retracted towards the eye the cavity of this sac is compressed by the pad of fat.

The rosette is attached to the floor of the olfactory chamber directly beneath the nostrils, and is composed of from 12-14 transversely pleated claw-shaped laminae that radiate from a short central raphé attached anteriorly to the front wall of the anterior nostril.

The posterior laminae of the series are far larger than the others and project freely into the posterior nostril.

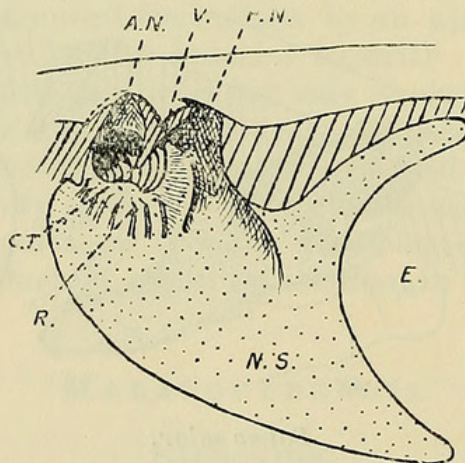
Osmerus eperlanus.

The olfactory organ is in all essential points similar to that of the Salmon, but when the mouth was closed forcibly under water no air bubbles escaped from the nostril, as might have been expected from the form and position of the accessory cavities.

Coregonus oxyrhynchus.

The olfactory organ is essentially similar to that of the Salmon.

Text-fig. 193.



Coregonus oxyrhynchus.

Diagram of nostrils, olfactory chamber, and nasal sac in longitudinal section.

V., valve.

The anterior nostril is, however, surrounded by an upstanding

conical lip and is separated by a deep gutter from the front edge of the posterior nostril, which is raised to form a valve-like flap that probably covers the posterior nostril in inspiration (text-fig. 193).

CLUPEIDÆ.

Clupea harengus.

The nostrils are very similar in form, mutual relations, and position to those of the Salmonidæ examined, particularly to those of *Coregonus*. The olfactory cavity is also closely similar, being produced towards the orbit to form an extensive though laterally flattened sac, which is prolonged both above and below the eye. The lower border of the sac is compressed by the upper edge of the mandible when the mouth is closed.

Clupea sprattus does not differ from the Herring.

CHIROCENTRIDÆ.

Chirocentrus dorab *.

The olfactory organ is essentially the same as in *Clupea* allowing for alterations in the form of the cavity due to the relative shortening of the space between the ethmo-palatine articulation and the orbit. The olfactory laminae are also less strongly defined than in *Clupea* and sink more gradually at the periphery of the rosette area into the general lining of the nasal cavity.

MORMYRIDÆ.

Mormyrus sp.

The nostrils lie about halfway between the eye and the snout set obliquely, the posterior some few millimetres behind and slightly below the anterior. Both are simple perforations, the anterior minute and circular, the posterior larger and oval, with a slightly swollen border.

The olfactory chamber is circular and laterally compressed; its floor (mesial surface) is completely covered by a circular rosette. There are no accessory sacs.

The rosette consists of from 12-16 laminae radiating from a well-marked median raphé connected in front with the anterior lip of the anterior nostril. The individual laminae are low with a swollen and gently convex free border.

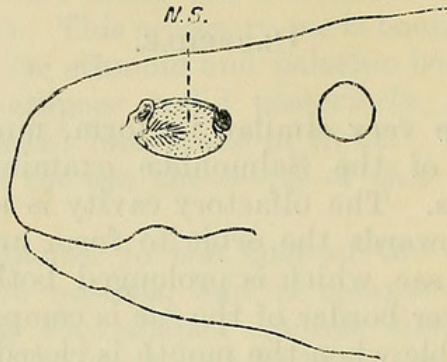
Gymnarchus niloticus.

The olfactory organ is much the same as in *Mormyrus* though its cavity is more elongated and has a considerable empty space between the rosette and the posterior nostril (text-fig. 194). The anterior nostril also is surrounded by a short tubular lip elevated

* For this specimen I am indebted to Col. C. E. Shepherd.

behind to form a small valvular flap similar to that of the Gadids and Carps.

Text-fig. 194.



Gymnarchus niloticus.

Olfactory organ, from the side.

Summary.

In the Malacopterygii examined, a distinction can be drawn between the Mormyridæ and the other families. In the former the olfactory organ is of a peculiarly simple type as regards nostrils, cavity and rosette. In the latter (Salmonidæ, Clupeidæ, Chirocentridæ) there is great uniformity and a relatively high degree of complexity. The nostrils are similar in form, position, and detailed relation to the bones of the circum-orbital ring and are modified, though imperfectly, to direct a current of water through the leaves of the rosette. There is, however (except possibly in *Coregonus*), no means of confining the inflow to the anterior nostril. The olfactory chamber is extended by an accessory sac with a similar form and position in all the genera examined and directly affected by the movements of the jaws. The laminae of the rosette though few in number are large and of characteristic claw-like shape.

OSTARIOPHYSI.

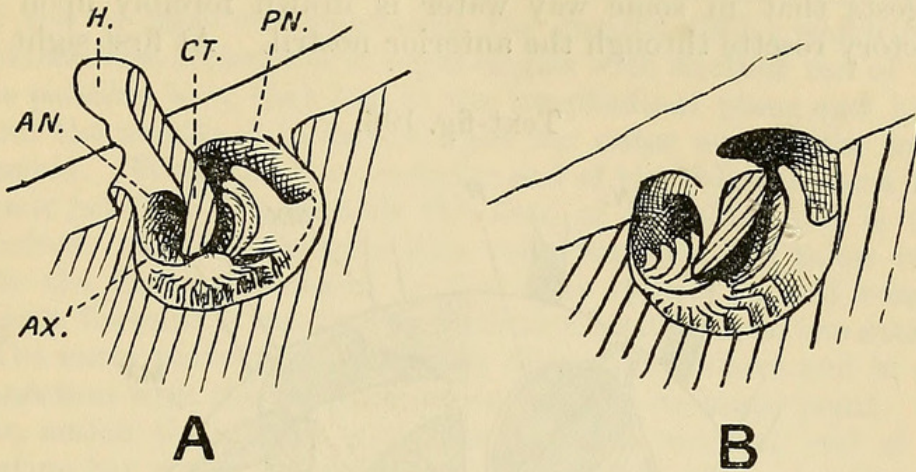
CYPRINIDÆ.

Tinca vulgaris (text-fig. 195, A).

The nostrils lie close together near the mid-dorsal line of the face about midway between the eye and the snout. In their general characters they somewhat recall those of the Salmonidæ. Both are circular and wide open. The anterior is bordered by a tubular lip, the hinder parts of which, including the whole area between the nostrils, are prolonged upwards to form a projecting hood and also inwards within the olfactory chamber as a curtain that divides this cavity transversely into two. By this combination of an external hood and an internal curtain water would be

deflected, during the forward progression of the fish, through the anterior nostril down amongst the laminae of the rosette.

Text-fig. 195.



A. Diagram of nostrils and olfactory chamber of *Tinca vulgaris* in longitudinal section.

B. A similar diagram of the olfactory organ of *Abramis brama*.

The olfactory chamber occupies the usual position with regard to the bones of the face, and lodges a rosette of 30 or so laminae radiating in the usual way from a linear raphé. The linguiform process upon the free border of each lamina is peculiarly long and narrow, especially in the hinder parts of the rosette where they form a tuft projecting freely into the posterior nostril.

An essentially similar condition of the olfactory organ was found in *Misgurnus fossilis* and in *Labeo zoneus*.

Abramis brama (text-fig. 195, B).

In this genus also the olfactory organ is essentially similar to that of *Tinca* with, however, the rather important absence of a hood-like extension of the posterior lip of the anterior nostril.

SILURIDÆ.

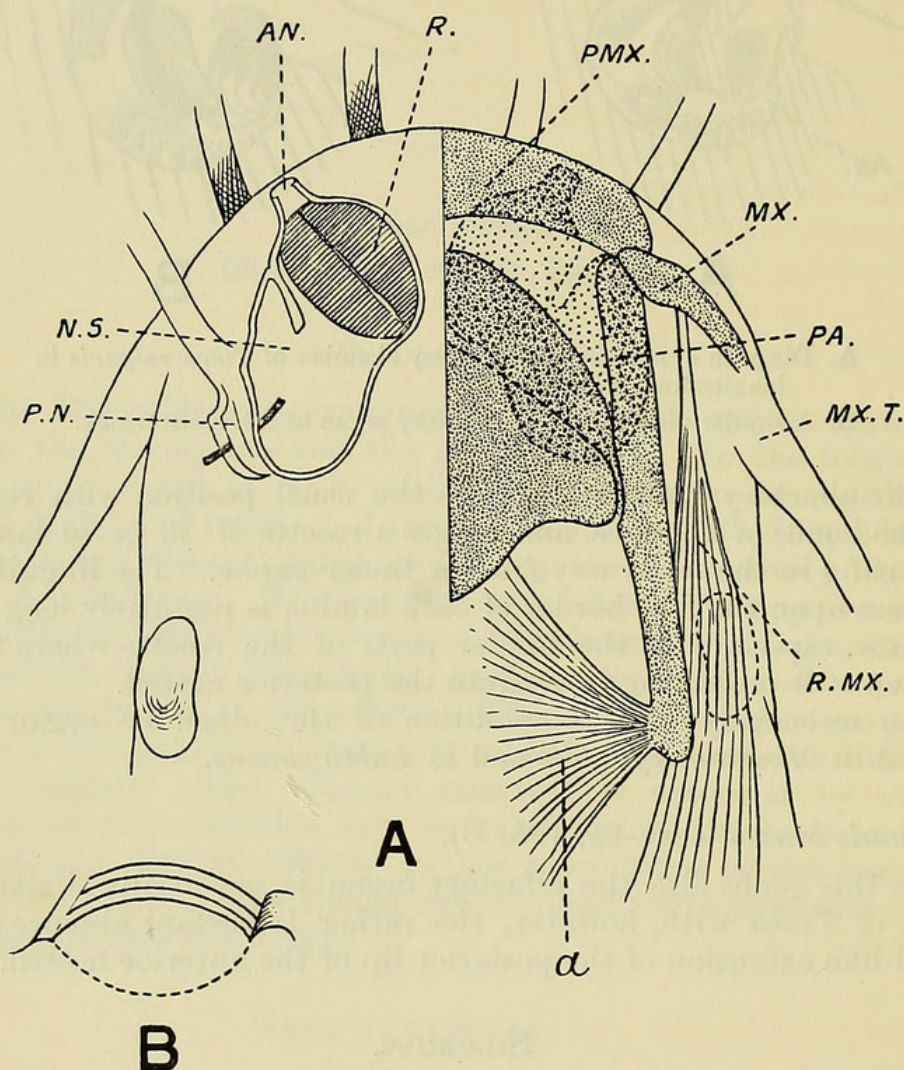
Clarias lazera (text-fig. 196, p. 624).

The nostrils lie upon the dorsal surface of the face, the anterior at the end of a short tube overhanging the upper lip, the posterior at some distance (about twice the diameter of the eye) further back. The upper and under margins of the posterior nostril are produced to form thin membranous lips, that would act as valves to prevent inflow of water by this nostril to the olfactory cavity. At its anterior corner is a long nasal tentacle.

The olfactory cavity extends from nostril to nostril but is separable into two distinct segments—(1) an oval chamber in which lies the olfactory rosette, with its long axis directed from the anterior nostril backwards and to the mid-line, and (2) a

smooth vacant cavity leading from the outer and hinder part of the first segment to the posterior nostril. The addition of this empty accessory sac to the olfactory chamber proper, in which lies the rosette and the possession of valvular lips by the posterior nostril, suggests that in some way water is drawn forcibly upon the olfactory rosette through the anterior nostril. At first sight the

Text-fig. 196.

*Clarias lazera.*

- A.** The olfactory organs from above:—On the left the nasal cavity opened; on the right the relation of the olfactory organ to the skeleton.
a. The muscle connecting the hinder end of the palatine bar to the cranium.
B. Diagram of the laminae of the rosette.

mechanism by which this is effected is not apparent, the jaws which in Fishes are the usual agents in such actions being evidently not so in this case. An examination of the rest of the skull in relation to the nasal cavity makes it clear, however, that an intermittent current of water could be, and probably is, produced automatically by the movements that take place between

certain bones when the maxillary tentacles are swung forward. This can best be explained by reference to text-fig. 196 (right side).

The root of the maxillary tentacle is supported and stiffened by the rod of bone that represents the maxilla (MX) which at its proximal end articulates at right-angles with another rod of bone (the palatine bar), that lies in the longitudinal plane and hinges about the middle of its length upon the outer end of the lateral ethmoid. From the free posterior end of the palatine bar a large muscle (α) fans out towards the floor of the skull and is there attached. Another muscle (the retractor maxillæ) takes origin from the floor of the skull to the outer side of α , and running directly forward is inserted by a slender tendon upon the maxilla.

The outer parts of the accessory nasal sac lie above and in close connection with the palatine bar in front of its hinge point.

In action the muscle α swings out the anterior end of the palatine bar which in turn rotates the maxilla into a longitudinal position shooting the point of the tentacle forwards. The reverse movements to bring the tentacle to rest result from the action of the retractor maxillæ. It will be apparent that owing to its close connection with the palatine bar the outer part of the nasal sac will follow its movements. When this bone swings outwards the sac will be dilated, and when it returns to rest, compressed, causing a stream of water alternately to enter the anterior nostril and to be expelled from the posterior or more probably from both nostrils.

Thus upon structural grounds alone it seems quite clear that when the fish is on the alert it is enabled to bristle its tentacles and sniff by means of one and the same mechanism.

In general appearance the rosette is very similar to that found in the Eels, being of considerable length and composed of a large number of laminae set at right-angles to a median raphe. Each lamina (text-fig. 196) has a simple convex free border without a linguiform process.

Malapterurus electricus (text-fig. 197, p. 626).

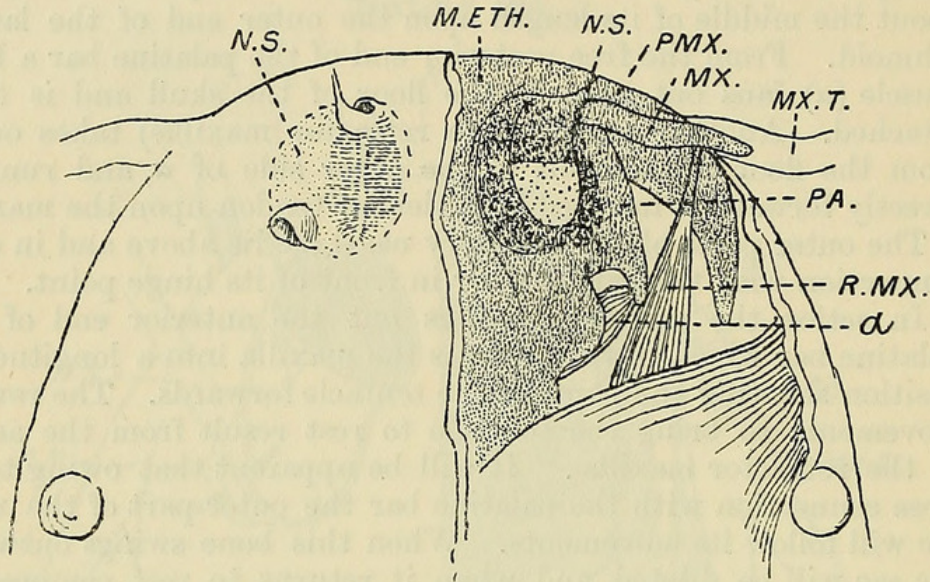
The nostrils are situated in much the same position as in *Clarias*, though relatively closer together. The anterior lies at the end of a short tube the posterior wall of which is prolonged to form a short pointed tentacular process. In a similar way the posterior nostril is guarded in front and at the sides by an upstanding hood-shaped lip.

The olfactory chamber is a simple flattened circular cavity. The rosette is oval and occupies only the inner half of the chamber leaving the outer half vacant.

The cavity is thus separable as in *Clarias*, but to a less degree, into an olfactory chamber lodging the rosette and an accessory sac between the rosette and the posterior nostril. The relations of the vacant part of the cavity to the supporting bones of the

maxillary tentacle are similar to those observed in *Clarias*, and there is little doubt that in a similar way it follows the movements of the palatine bar and acts as an aspirator bulb, though probably in a feeble way, to produce water currents through the leaves of the olfactory rosette.

Text-fig. 197.

*Malapterurus electricus.*

The olfactory organs shown as in text-fig. 196.

MX.T., maxillary tentacle.

Pimelodus sebæ.

The nostrils are very similar to those of *Clarias* though the posterior is smaller, not so distinctly valved, and not connected with a tentacle.

The olfactory chamber is a narrow oval cavity stretching from nostril to nostril and is completely occupied by a long oval rosette fastened to its floor. Its outer wall lies parallel to, but not in any connection with, the palatine bar, and although the movements of the tentacle are effected by a mechanism similar to that in *Clarias* and *Malapterurus*, there can be little or no movement communicated to the walls of the olfactory chamber.

Silurus glanis.

The nostrils are essentially similar to those of the other Siluroids examined. The anterior lies at the end of a short tube the hinder margin of which is produced as in *Malapterurus* to form a short tentacular process. The posterior lies some considerable distance (at least twice the diameter of the eye) further back and is a longitudinal slit bordered by valvular folds.

The nasal cavity occupies the space between the nostrils and is separable into an anterior half, lodging the rosette, and a vacant posterior half.

So far as could be seen the passage of water through the nose is quite independent of the movements of the bones of the skull and is probably due to the action of cilia, though this leaves unexplained the use or meaning of the vacant prolongation of the nasal cavity and the valvular borders of the posterior nostril.

The rosette is similar in form to that of *Clarias* but the laminae have well pronounced linguiform processes.

GYMNOTIDÆ.

Gymnotus electricus.

The nostrils lie towards the point of the snout upon the upper surface of the face, the anterior at some distance (rather more than the diameter of the eye) in front of and below the posterior. Both are small round apertures, the posterior flush with the surface, the anterior with a swollen border scarcely prominent enough to be called a tube.

The olfactory chamber is a simple flattened cavity of oval or diamond shape in surface view and so placed that its short axis forms the line connecting the nostrils. It is completely filled by a rosette of some 20 claw-shaped laminae arranged around a central axis, and lies directly upon the premaxilla in such a position that its walls could be little if at all affected by the movements of the neighbouring bones of the skull.

Summary.

In the Ostariophysi examined the olfactory organ of the Carps is entirely different from that of the Siluroids.

In the Carps the organ is of a simple character and very constant in structure so far as observed, differing only in unimportant details. In no instance were there sacs accessory to the olfactory chamber, and when there was any mechanism for the production of water currents in the nose it had the form of a flap of skin standing up behind the anterior nostril to deflect water into it in forward progression.

The Siluridæ on the other hand show a distinct leaning towards the Eels in the structure of the olfactory organ. The anterior nostril tends to be strongly tubular and the posterior is frequently valved. The rosette is more or less elongated and consists of a relatively large number of parallel laminae.

A tendency is also observable in this family towards the development of an accessory sac in extension of the true olfactory chamber which in some instances by movements of certain bones of the face can be contracted and expanded, thus giving rise to water-currents within the nasal cavity.

In the Gymnotidæ the olfactory organ, although peculiar, more nearly resembles that of Siluroids and Eels than that of the Carps.

APODES.

ANGUILLIDÆ.

Anguilla vulgaris.

The anterior nostril lies at the end of a short tube upon the upper lip not far from the mid-line; the posterior is a simple circular perforation situated close in front of the eye.

The olfactory chamber occupies the area between the nostrils, broadening gradually behind and terminating in a rounded end to the mesial side of the posterior nostril. Its floor and mesial side are covered by an olfactory rosette in which the laminae lie at right-angles to a linear raphé that runs from the anterior nostril to the hinder end of the olfactory chamber. The individual laminae are triangular in outline.

Conger vulgaris.

The Conger agrees in all essential particulars with the Eel as regards the structure of its nose.

The olfactory nerves are of enormous size, which accords with Bateson's observation that the Conger is one of the few Fishes that hunt by scent. He also states that the water current in the nose is due to the movement of cilia in the tubular nostril.

MURÆNIDÆ.

Muraena tigrina.

The olfactory organ is very similar to that of an Eel or even more to that of a Siluroid (e. g. *Pimelodus*). Both nostrils are situated at the extremity of a short tube, one projecting forwards above the snout, the other backwards above the eye.

The olfactory chamber is a simple oval cavity lying between the two nostrils and occupied by an elongated oval rosette.

Muraena zebra had an olfactory organ of precisely the same character, except that the cavity and rosette were shorter and rounder.

Summary.

In this group the examples seen show a very strong similarity in the structure of the nose and a close resemblance also (through the Murænidæ) with that of Siluroids. The anterior nostril (and sometimes the posterior) is strongly tubular and the cavity and rosette are elongated.

HAPLOMI.

ESOCIDÆ.

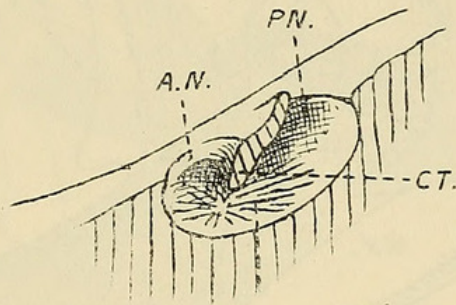
Esox lucius (text-fig. 198).

The nostrils lie close together upon the slope of the forehead about one quarter the distance from the eye to the snout facing upwards and forwards. The anterior is circular, of relatively large size (about a quarter the diameter of the eye) and flush with the surface. The posterior is crescentic, with the concavity

directed forward. The anterior border of the narrow bridge of skin between the two is sharply deflected into the nasal cavity.

The olfactory chamber occupies the normal position with regard to the bones of the skull, and is a shallow oval cavity corresponding to the area covered by the nostrils. Its floor is covered by a peculiarly insignificant circular rosette in which the laminae are low folds of the mucus membrane differing amongst themselves in importance and radiating from a central boss situated directly below the anterior nostril and without any connection with its anterior lip.

Text-fig. 198.



Esox lucius.

Diagram of olfactory organ in longitudinal section.

A description of this cavity is given by Blaue.

The organ lies well above the range of any pressure that might be caused by the swelling of the adductor mandibulæ, but probably currents of water are deflected into the cavity of the chamber during forward progression by the tilt of the nostrils towards the front and by the downward bend of the bridge between the two nostrils.

SCOPELIDÆ.

Scopelus crocodilus.

The nostrils are simple circular perforations in a smooth area of skin lying as usual between the lachrymal and nasal scutes. The posterior is four times as large as the anterior and is separated from it by a narrow bridge of integument.

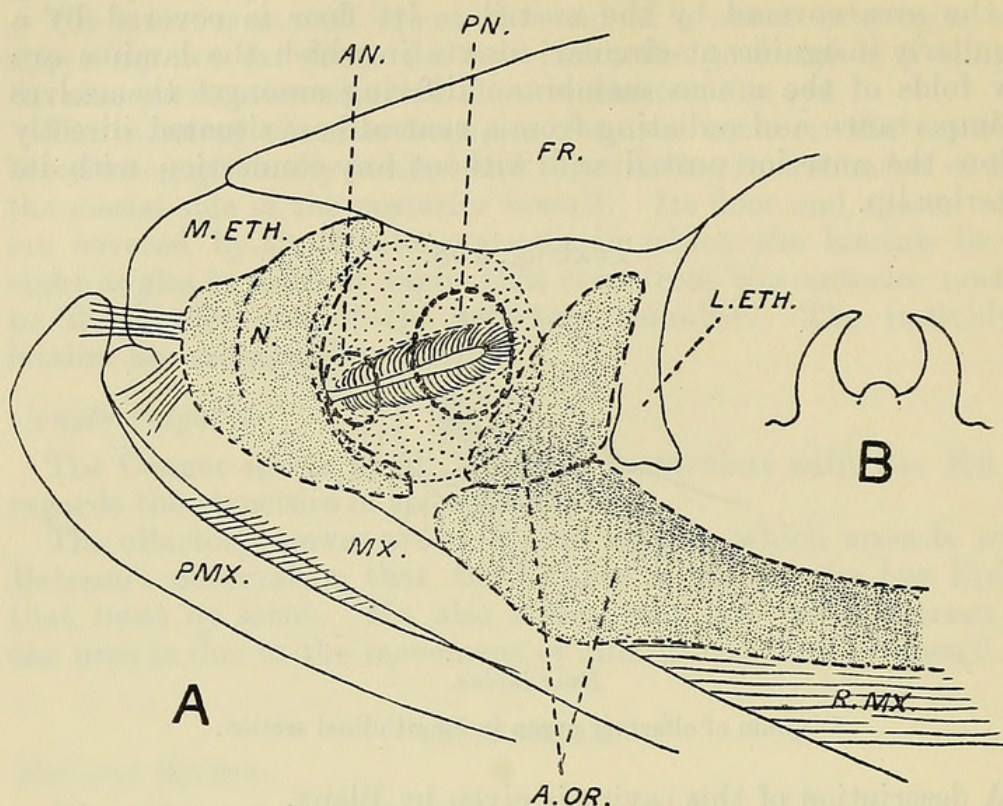
The olfactory chamber is globular and lies partly within the usual hollow in the ethmoid cartilage, but extends also over the maxillary process of the palatine and the head of the maxilla. This somewhat abnormal position is due to the extreme antero-posterior compression of the front part of the face.

The lining membrane of the chamber is deeply pigmented except upon the rosette, which is brilliantly white in contrast.

The rosette is of very unusual form (text-fig. 199, A), being linear with its axis lying in the plane of the two nostrils. It is, however, composed as usual of a series of laminae arranged along the sides and around the posterior end of an elongated central

raphé. The individual laminæ (text-fig. 199, B) are very small, especially in the length of their attached base, and are acutely pointed.

Text-fig. 199.

*Scopelus crocodilus.*

- A.** Position and form of nostrils and olfactory chamber.
B. Diagram of the laminæ of the rosette.

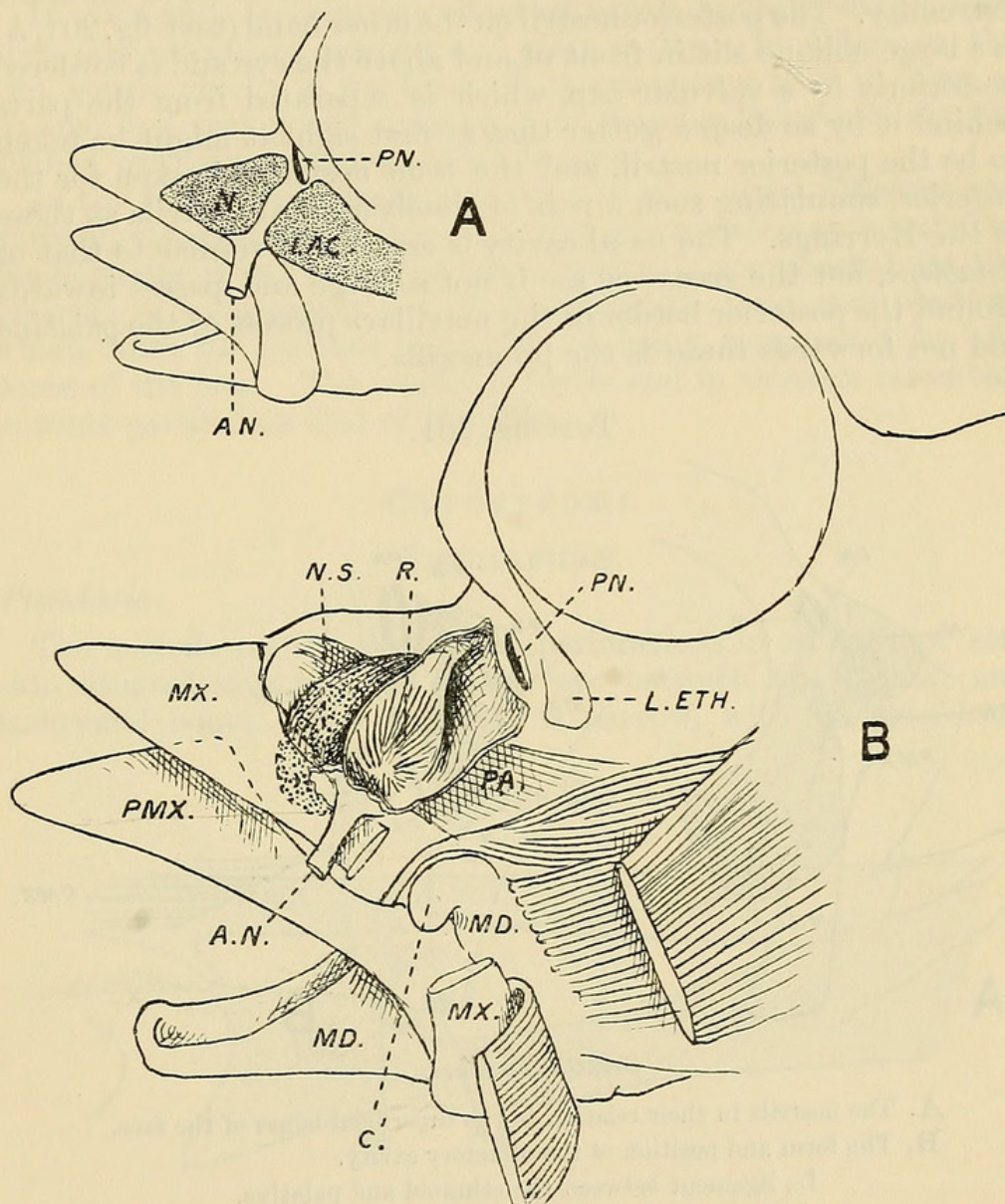
CYPRINODONTIDÆ.

Anableps microlepis.

The posterior nostril lies just in front of the lower part of the eye. It is a vertical slit, and is apparently valved against ingress by the thinness and flexibility of its posterior lip. The anterior nostril lies at the end of a short tube overhanging the edge of the maxilla about its centre (text-fig. 200, A). Forcible closure of the mouth under water caused air within the nose-cavity to bubble from the posterior nostril, indicating the presence of accessory sacs in connection with the olfactory chamber. Dissection shows that the nasal cavity is in fact separable into two parts—one just within the anterior nostril occupied by a simple oval rosette, and thus the olfactory chamber proper, and another between this and the posterior nostril lined by smooth membrane and extending forward deep to the rosette across the maxillary process of the palatine and beneath the maxilla to the hinder edge of the premaxilla. This second portion of the cavity is an accessory nasal sac whose state of compression depends upon the movements of the premaxilla, and acts as an aspirating mechanism for the production of water currents in the nose-cavity. The action of the jaws when

the mouth is opened and closed is peculiar. When the lower jaw is depressed by the action of the gular muscles the premaxilla is strongly protruded by the forward pressure of a hooked process of the coronoid border of the mandible (text-fig. 200, B, c') upon the hinder margin of the premaxilla. By this movement of the premaxilla the membranes between it and the palatine are stretched

Text-fig. 200.



Anableps microlepis.

- A.** Position of the nostrils.
B. The nasal cavity in its relation to the neighbouring bones of the face.
 C', hooked process on the coronoid border of the mandible that protrudes the premaxilla.

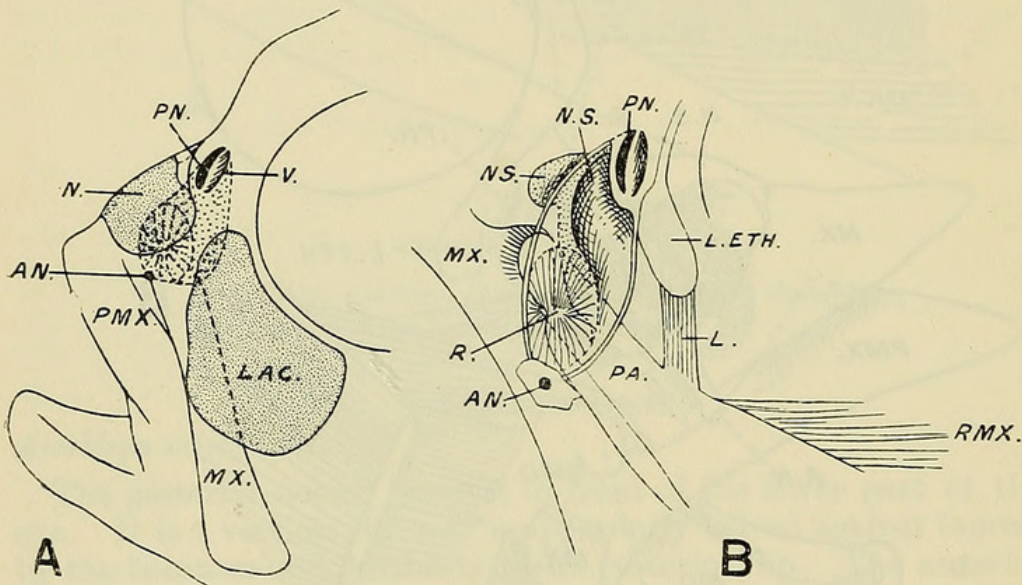
and the nasal sac distended. Closure of the jaws by the contraction of retractor muscles inserted upon the premaxilla and the coronoid process of the mandible is accompanied by a retraction of the premaxilla and the compression of the nasal sac. In this mechanism

the maxilla is comparatively fixed, its lower end forming the fulcrum upon which the premaxilla swings backwards and forwards.

Orestias lesueurii.

In this species the olfactory organ is of the same type as in *Anableps*, though differing from it in detail. The anterior nostril is not tubular but is a simple hole, minute and easily overlooked, lying near the anterior margin of the maxilla towards its upper extremity. The posterior nostril on the other hand (text-fig. 201, A) is a large oblique slit in front of and above the eye and is bordered posteriorly by a valvular flap, which is separated from the parts behind it by so deep a gutter that at first sight it might be taken to be the posterior nostril, and the true nostril mistaken for the anterior, simulating such a pair of closely applied nostrils as those of the Herrings. The nasal cavity is essentially similar to that of *Anableps*, but the accessory sac is not so large and passes inwards around the posterior border of the maxillary process of the palatine and not forwards towards the premaxilla.

Text-fig. 201.



Orestias lesueurii.

- A. The nostrils in their relation to the superficial bones of the face.
 - B. The form and position of the olfactory cavity.
- L., ligament between the ethmoid and palatine.

Movements of the jaws had but little effect apparently upon the contents of the nose-cavity, but when the operculum was raised and lowered air-bubbles could readily be expelled from the posterior nostril. This effect seems to be due to the movements of the maxillary process of the palatine. This bone is attached in front in the usual way (though loosely) to the maxilla and at the root of its maxillary process by a long ligament to the lateral ethmoid. As the gill-cover is opened the maxillary process of the palatine rotates inwards and backwards around this ligament as a

pivot, compressing the accessory nasal sac that rests upon its posterior and inner surfaces. The jaw movements may possibly also be of some little assistance in the compression of this sac, but those of the gill-cover appear to be by far the more important.

The rosette is very feeble and consists of a series of low pleats radiating from a central boss.

Summary.

In *Esox* and *Scopelus* the olfactory organ is quite simple with open non-specialized nostrils and plain cavity. It differs in the two genera chiefly in the form of the rosette, which in *Esox* is circular and very poorly developed, in *Scopelus* linear and sharply defined with strong though small laminae.

In the two Cyprinodonts the organ is of a quite different and more highly specialized type. The anterior nostril may be tubular, the posterior is valved. The nasal cavity is complicated by the presence of an accessory sac of characteristic form and position, which from its position is capable of being compressed by the bones of the face. The rosette is feeble and in *Orestias* resembles in some particulars that of the Pike.

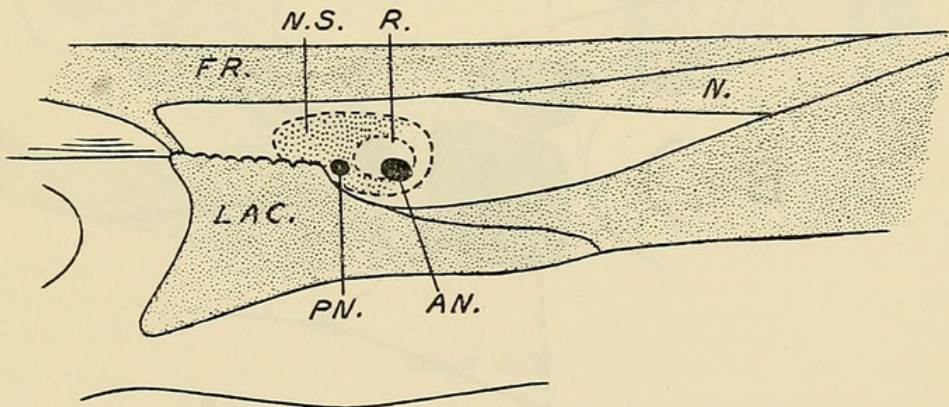
CATOSTEOMI.

FISTULARIIDÆ.

Fistularia.

The nostrils are two plain oval perforations in an area of soft skin situated close in front of the eye between the frontal and lachrymal bones. The posterior is narrow, with its chief axis

Text-fig. 202.



Fistularia sp.

Right olfactory organ showing relative proportions of olfactory (R.) and indifferent (N.S.) areas of the nasal cavity.

longitudinal, the anterior about three times as large. The bridge of skin between the two is about equal in breadth to the long axis of the anterior nostril. The olfactory chamber is oval but very shallow. It lies upon the bones of the skull (lateral ethmoid) and extends backwards some distance beyond the posterior nostril,

its front half only being occupied by the rosette. The laminae of the rosette are very feeble and resemble those of the Pike.

GASTROSTEIDÆ.

The olfactory organ of *Gastrosteus* has been described by Solger. He states that it has in connection with the lower part of the olfactory chamber an accessory nasal sac. One nostril only is present. It has the form of a short tube, situated in the normal position between the nasal and lachrymal scutes.

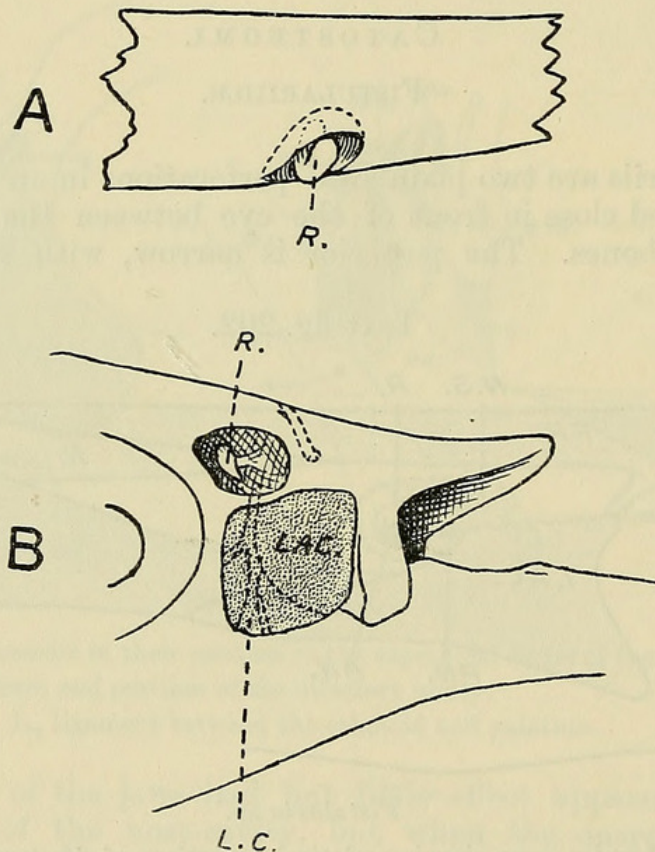
PERCESOCES.

SCOMBRESOCIDÆ (see Blaue).

Belone vulgaris (text-fig. 203, A).

The olfactory organ of this species has been described by Blaue. The chief peculiarity in it is that the olfactory chamber is a simple open pit, from the centre of which protrudes a solid mushroom-shaped boss, representing the usual laminate rosette.

Text-fig. 203.



- A.** The right olfactory organ of *Belone vulgaris*, from above.
B. The right olfactory organ of *Hemirhamphus*, from the side.
 L.C., lateral-line canals in the lachrymal.

Hemirhamphus (text-fig. 203, B).

The olfactory organ is very similar to that of *Belone*, but the central boss is relatively smaller.

Exocætus volitans.

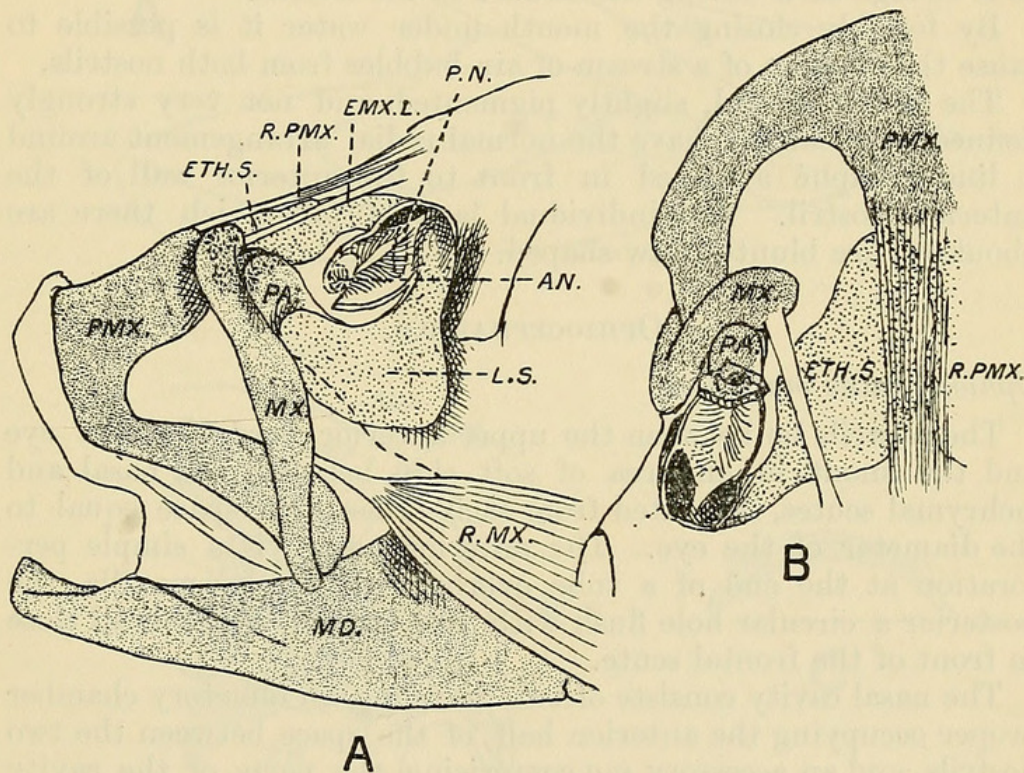
The olfactory organ is similar to that of *Hemirhamphus*. It is worthy of notice that in *Hemirhamphus* and *Exocætus* the tubules of the lateral line that traverse the lachrymal bone open directly into the lower part of the olfactory chamber. This probably indicates that the single opening of the olfactory pit is not primitive, but a secondary modification, the original openings having spread to include within the pit what at one time was the external surface of the face.

MUGILIDÆ.

Mugil chelo.

The nostrils lie about halfway between the eye and the snout, bounded as usual by the lachrymal and nasal bones. The anterior nostril is circular, with a short tubular lip higher behind than in front. It is separated by a bridge of skin about twice its

Text-fig. 204.

*Mugil chelo.*

- A.** The olfactory organ, in position, from the side.
B. The same, from above.

diameter in breadth from the posterior nostril, which is a vertical slit protected from ingress by a thin, transparent valvular extension of its anterior border.

The olfactory chamber is oval and of the same length as the space between the nostrils. It lies in the usual hollow in the ethmoid behind the maxillary process of the palatine. Its hinder parts, which are unoccupied by the rosette, extend for some little

distance beyond the posterior nostril, and here are dilated above and below the ridge that carries the olfactory nerve to the rosette to form two large accessory sacs. The upper sac (ethmoidal) bends forward beneath the ethmo-maxillary ligament parallel to the upper margin of the olfactory chamber, and fills in all the space available between the mesethmoid and the backward process of the premaxilla. The lower (lachrymal) sac, after passing down upon the lateral ethmoid, expands in the space between the lachrymal bone, the palatine arcade and buccal membrane, and the maxilla.

It will be apparent from the close relations of these sacs to the bones of the mouth that their expansion or contraction will depend upon the movements of these bones. This is particularly the case with regard to the ethmoidal sac, which is greatly expanded as the premaxilla shoots forward in the protrusion of the jaws and compressed as it is retracted. The effect of the movements of the maxilla upon the lachrymal sac is less apparent, although the sac is visibly compressed by the hinder margin of this bone as it swings back during the closure of the mouth.

By forcibly closing the mouth under water it is possible to cause the ejection of a stream of air-bubbles from both nostrils.

The rosette is oval, slightly pigmented, and not very strongly defined. Its laminae have the normal radial arrangement around a linear raphé attached in front to the anterior wall of the anterior nostril. The individual laminae (of which there are about 30) are bluntly claw-shaped.

OPHIOCEPHALIDÆ.

Ophiocephalus marulius.

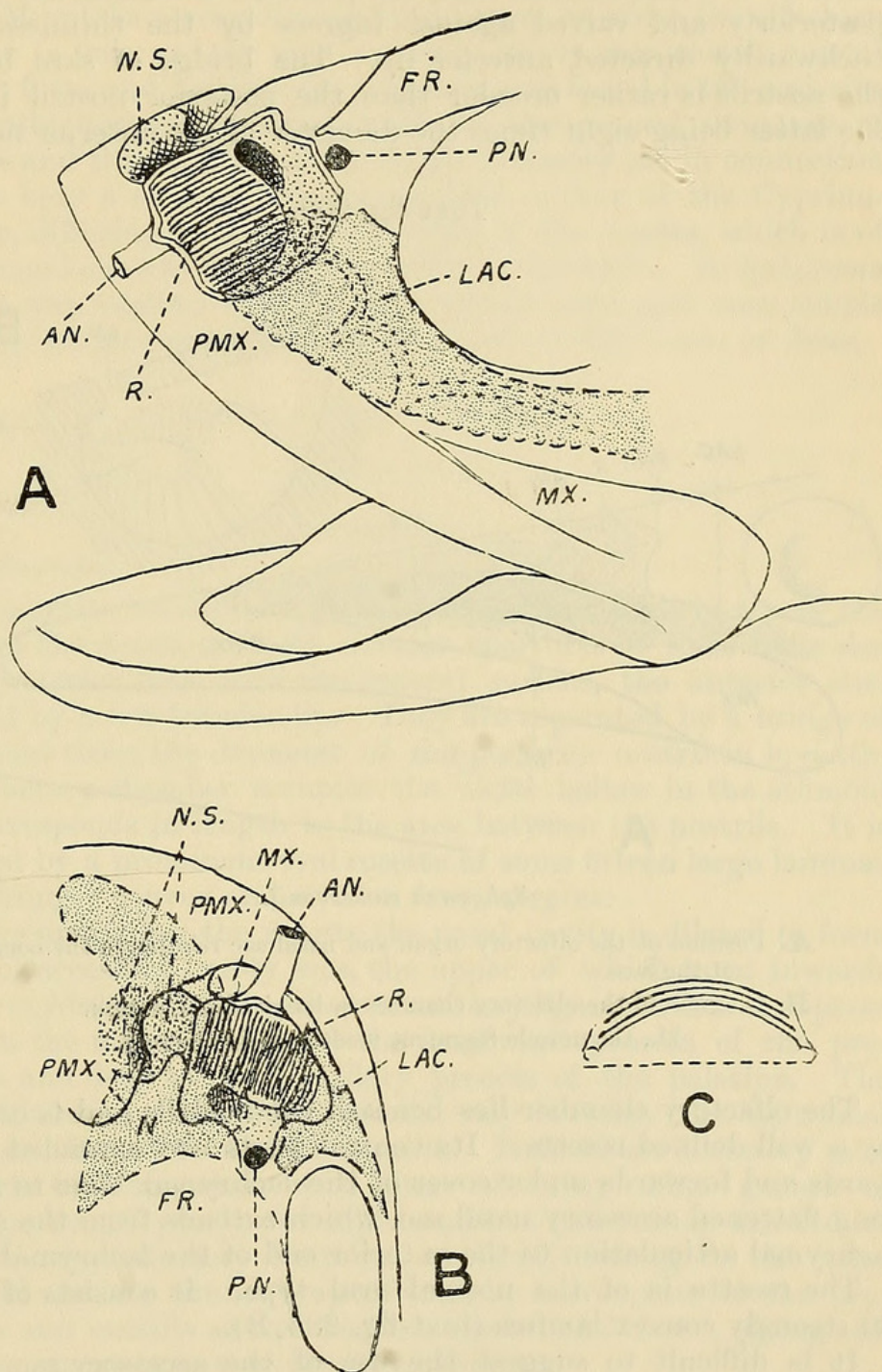
The nostrils lie between the upper anterior border of the eye and the snout in an area of soft skin between the nasal and lachrymal scutes, separated from each other by a space equal to the diameter of the eye. The anterior nostril is a simple perforation at the end of a tube overhanging the premaxilla, the posterior a circular hole flush with the surface of the head close in front of the frontal scute.

The nasal cavity consists of two divisions, an olfactory chamber proper occupying the anterior half of the space between the two nostrils, and an accessory sac comprising the parts of the cavity between the rosette and the posterior nostril, and extending forward deep to the true olfactory chamber to the backward process of the premaxilla.

The rosette is quadrangular in shape and consists of a series of laminae set parallel to one another in the longitudinal plane. Each lamina (text-fig. 205, C) has a gently curved free margin without linguiform process. The accessory sac is so closely applied to a considerable part of the backward process of the premaxilla that it necessarily shares in the movements of this bone, being compressed when it is retracted, expanded when it protrudes. It

thus no doubt acts as an aspirator bulb to produce water currents through the leaves of the olfactory rosette.

Text-fig. 205.



Ophiocephalus marulius.

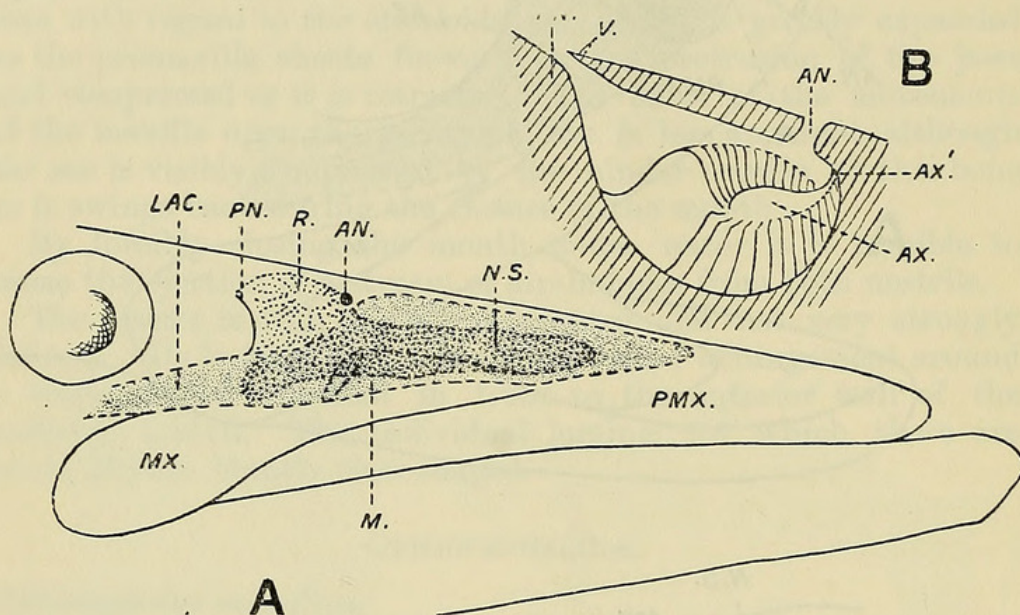
- A. The left olfactory organ, from the side.
- B. The same, from above.
- C. Diagram of the olfactory laminae.

SPHYRÆNIDÆ.

Sphyræna cameroonii.

The nostrils lie in an area of soft skin above the lachrymal bone at a quarter the distance from the eye to the snout. The anterior is a small round hole, the posterior a vertical slit concave posteriorly and valved against ingress by the thinness of its backwardly directed anterior lip. The bridge of skin between the nostrils is rather broader than the posterior nostril is long, the latter being eight times the diameter of the anterior nostril.

Text-fig. 206.

*Sphyræna cameroonii*.

- A. Position of the olfactory organ and nasal sac relative to the bones of the face.
 B. Diagram of the olfactory chamber in longitudinal section.
 M., the muscle fragment mentioned in the text.

The olfactory chamber lies beneath the nostrils and is occupied by a well-defined rosette. Its ventral parts are extended downwards and forwards under cover of the lachrymal bone to form a long flattened accessory nasal sac, which extends from the ethmo-lachrymal articulation to the anterior end of the lachrymal bone.

The rosette is of the normal oval type. It consists of about 30 strongly convex laminae (text-fig. 206, B).

It is difficult to suggest the use of the accessory sac, as the specimen observed was in a fragmentary condition; but the presence of a piece of muscle and tendon (probably the retractor maxillæ) upon the lower border of the lachrymal and underlying the accessory sac, suggests that it may very likely be used as an aspirator bulb, compressed either by the swelling of this muscle or by the upward swing of the maxilla when the mouth is closed.

Summary.

In the Percosoces the olfactory organs show a wide range of variation in the above examples of the different families observed. In the Scombresocidæ they are of a quite peculiar and characteristic form, unlike that seen in any other group of Teleostei. In the Mugilidæ a very distinct type occurs in which the olfactory chamber is enlarged by two accessory empty sacs, closely resembling in form and position the accessory sacs found in the majority of Acanthopterygii. In *Ophiocephalus* the general structure of the nose and the position of the single accessory sac in connection with it bear a considerable resemblance to that of the Cyprinodontidæ, differing however in the form of the rosette, which is of a type found elsewhere only in certain Pleuronectids. In *Sphyræna* there is yet another type of nose, with a large and very simple accessory sac stretching forward like that of *Merluccius* or *Zeus*.

ACANTHOPTERYGII.

PERCIFORMES.

PERCIDÆ.

Perca fluviatilis.

The nostrils, which lie high up on the face slightly nearer the eye than the snout, are both circular apertures of some little size—the posterior flush with the general surface, the anterior surrounded by a low tubular lip. They are separated by a bridge of skin about twice the diameter of the posterior nostril in breadth. The olfactory chamber occupies the usual hollow in the ethmoid and corresponds in length to the area between the nostrils. It is occupied by a prominent oval rosette of some fifteen large laminae, with strongly convex and swollen free margins.

Above and below the rosette the nasal cavity is dilated to form a pair of accessory empty sacs, the upper of which runs inwards and forwards beneath the ethmo-maxillary ligament into the spaces between the mesethmoid and the backward process of the premaxilla and deep to the maxillary process of the palatine. The lower dilatation extends in a similar way between the lachrymal scute and the palate to the maxilla. Both these accessory sacs, although in comparison with those of many other genera of Acanthopterygii poorly developed and but indefinitely marked off from the true olfactory chamber, evidently belong to the same type and are in a similar way affected by movements of the premaxilla and maxilla as the mouth is opened and closed, giving rise to water currents in the olfactory chamber.

LATRIDÆ.

Latris ciliaris *.

The olfactory organ closely resembles that of the Perch, although

* This specimen was obtained through the kindness of Col. Nicholson.

smaller and with less strongly developed accessory sacs, the upper (ethmoidal) one being represented by a mere recess above the hinder part of the rosette, and the lower (lachrymal) extending forward only as far as the root of the maxillary process of the palatine.

Neither of the sacs seems to be within reach of the direct effects of the movements of the jaws.

The rosette is not so strong and definite as in the Perch. It is of the usual oval type and consists of about 30 laminae, each with a well-formed, almost claw-shaped linguiform process.

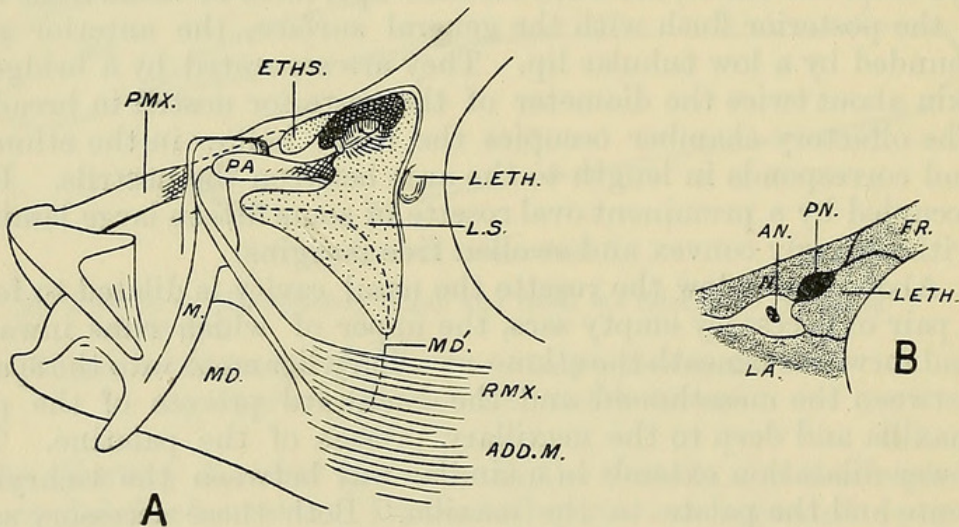
CAPROIDÆ.

Capros aper.

The nostrils lie in a similar position to those of the Perch, the anterior within an area of smooth skin, the posterior closely surrounded by scutes (text-fig. 207, B).

The anterior nostril is a small and simple oval aperture, with its long axis vertical; the posterior, which is four or five times as large as the anterior, is pear-shaped, with its swollen end directed forwards. The bridge between the two is less than the length of the posterior nostril in breadth.

Text-fig. 207.



Capros aper.

A. Left olfactory organ, from the side.

MD. position of the coronary border of the mandible when the mouth is shut.

B. Surface-view of the nostrils.

The nasal cavity is disposed much as in the Perch, but the rosette is relatively smaller and the lachrymal accessory sac larger and far more dilated ventrally towards both the head of the maxilla and the hinder end of the lachrymal scute.

The ethmoidal accessory sac is comparatively small, being a small forward extension of a general dilatation of the olfactory chamber above the rosette. It probably is not of much service as

an aspirator, although it can undoubtedly be compressed by the retraction of the premaxilla.

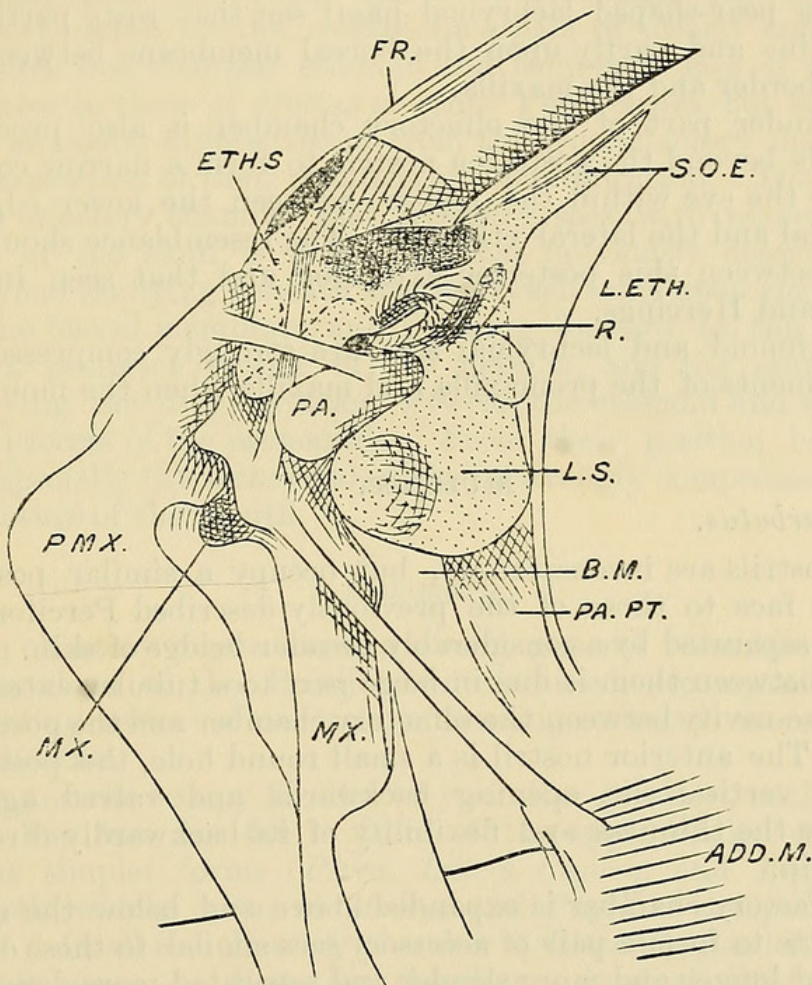
The lachrymal sac, on the other hand, is evidently most effective in producing water currents in the nose, for its lower border is extensively indented by the coronoid border of the mandible when the mouth is closed.

BERYCIDÆ.

Beryx delphinus.

The nostrils lie about halfway between the eye and the snout towards the dorsal line of the head, surrounded by the nasal, lachrymal and frontal bones. Both are large, oval, and widely

Text-fig. 208.



Beryx delphinus.

Left olfactory organ, from the side.

PA.PT., palato-ptyergoid arcade.

S.O.E., supraorbital extension of the nasal cavity.

open, the anterior about half the size of the posterior. The bridge of skin between the two is relatively narrow and is produced as a transverse curtain into the cavity of the olfactory chamber.

The rosette which covers the floor of the olfactory chamber is sharply defined and very prominent, like that of the Perch. It is composed of about thirty claw-shaped transversely pleated laminae arranged in the usual way radially around the hinder parts of a linear raphé.

The whole of the olfactory chamber above the rosette is dilated to form a peculiarly capacious ethmoid accessory sac, that extends backwards into two hollows beneath the anterior end of the frontal, inwards between the backward process of the premaxilla and the mesethmoid, and forwards between the palato-premaxillary and ethmo-maxillary ligaments and the greatly elongated head of the maxilla.

In a similar way the wall of the olfactory chamber below the hinder end of the rosette is expanded beneath the lachrymal bone, forming a pear-shaped lachrymal nasal sac that rests partly on the palatine and partly upon the buccal membrane between its anterior border and the maxilla.

The hinder part of the olfactory chamber is also produced backwards beyond the posterior nostril to form a narrow conical sac above the eye within the hollow between the lower edge of the frontal and the lateral ethmoid. The resemblance should be noticed between this posterior extension and that seen in the Salmon and Herrings.

The ethmoid and lachrymal sacs are strongly compressed by the movements of the premaxilla and maxilla when the mouth is closed.

MULLIDÆ.

Mullus barbatus.

The nostrils are inconspicuous, but occupy a similar position upon the face to those of the previously described Perciformes, although separated by a considerably broader bridge of skin. The distance between them is due in large part to a tubular extension of the nose-cavity between the olfactory chamber and the posterior nostril. The anterior nostril is a small round hole, the posterior a narrow vertical slit, opening backwards and valved against ingress by the thinness and flexibility of its backwardly directed anterior lip.

The olfactory chamber is expanded above and below the olfactory rosette to form a pair of accessory sacs similar to those of the Perch, but longer and more slender and separated more definitely from the olfactory chamber itself. Although occupying the normal positions between the premaxilla and ethmoid and near the hinder border of the maxilla, these sacs, owing probably to their small capacity, do not seem to be greatly compressed by the movements of these bones—at least, no air-bubbles could be driven from the nostrils by forcibly closing the mouth under water.

The rosette, as in the other Perciformes, is oval and very prominent. The laminae are few in number and, like those of the Perch, have a sharply convex free border.

SPARIDÆ.

Pagellus centronotus.

The olfactory organ is comparable to that of the Perciformes previously described, particularly to that of *Mullus*, but is in every way better developed.

The nostrils have a similar position and form, differing only in the fact that they are relatively closer together and that the posterior is protected from ingress by a special valvular fold (text-fig. 209, C, p. 644) attached to the inner surface of its posterior lip.

The olfactory chamber is almost completely filled by a very prominent oval rosette of the normal type, in which the individual laminae have a sharply convex free margin. The cavity is not prolonged between the hinder margin of the rosette and the posterior nostril, but above and below the ridge that carries the olfactory nerve to the rosette are a pair of clearly defined oval apertures that lead into ethmoid and lachrymal sacs of a similar character to those of *Mullus* or other Perciformes, but larger and more markedly differentiated from the true olfactory chamber by the narrowness of their channels of communication. The position of the olfactory chamber and accessory sacs with regard to the bones of the skull is similar to that previously described, the lachrymal sac lying beneath the lachrymal bone upon the palatine and the buccal membrane and reaching forward to the strongly convex posterior border of the maxilla, and the ethmoid sac occupying the usual position between the ethmoid and the backward process of the premaxilla. From their position both sacs, and especially the lachrymal, must be strongly compressed during the closure of the mouth.

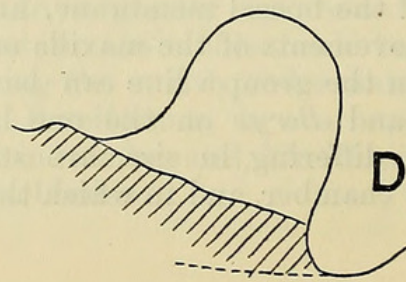
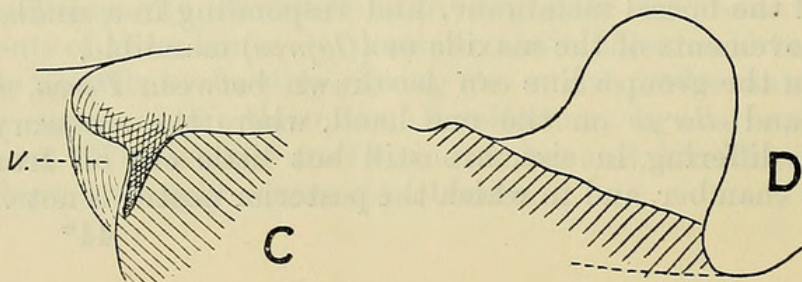
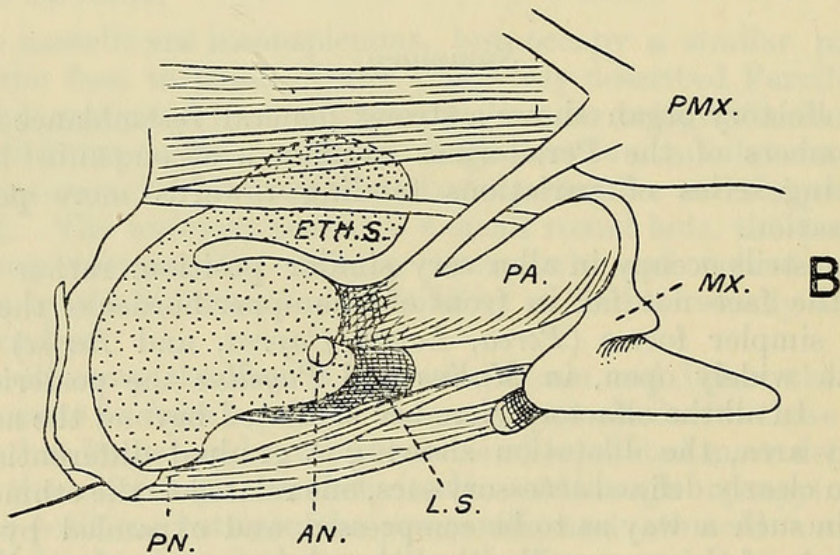
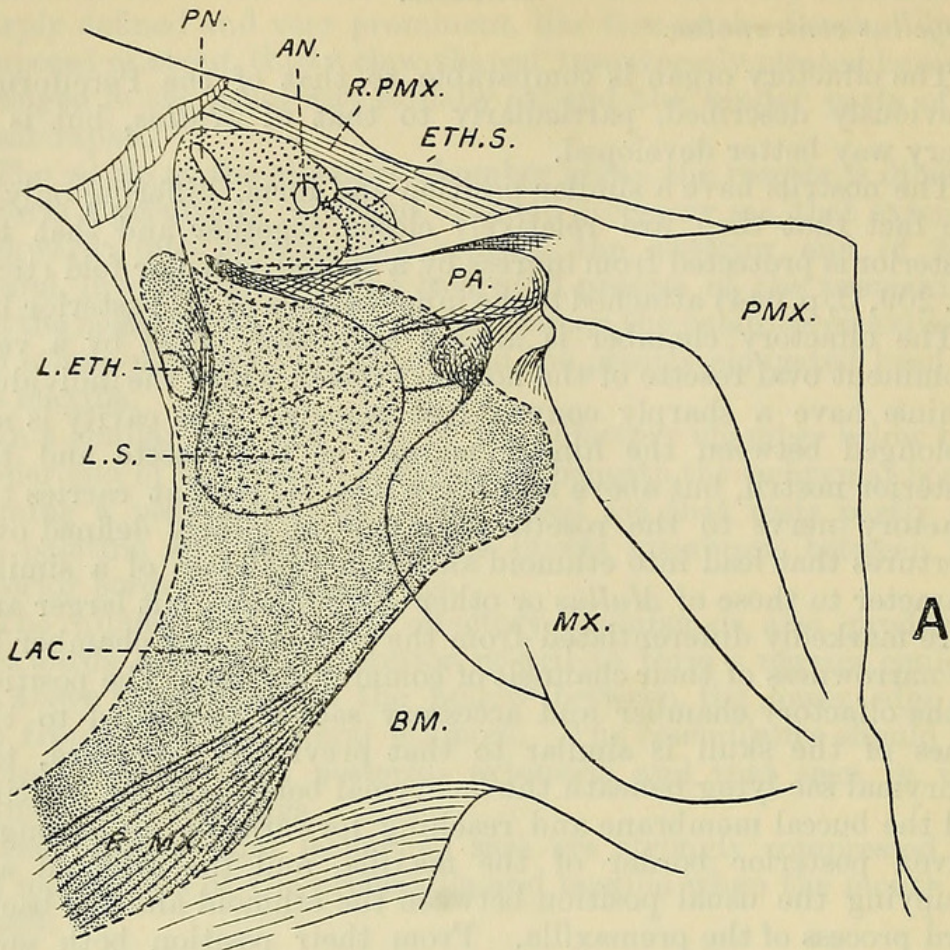
Summary.

The olfactory organ shows a strong general resemblance in all the members of the Perciformes examined, accompanied by an interesting series of variations tending towards more perfect specialization.

The nostrils occupy in all a very similar position, rather high up on the face not far in front of the upper border of the eye. In the simpler forms (*Perca*, *Latris*, *Capros*, and *Beryx*) they are both widely open, in *Mullus* and *Pagellus* the posterior is valved. In all the olfactory chamber is dilated beyond the actual olfactory area, the dilatation showing a gradual differentiation into two clearly defined accessory sacs, one related to the ethmoidal region in such a way as to be compressed and expanded by the movements of the premaxilla, the other lying upon the palatine bone and the buccal membrane, and responding in a similar way to the movements of the maxilla or (*Capros*) mandible.

Within the group a line can be drawn between *Perca*, *Latris*, *Capros*, and *Beryx* on the one hand, where the accessory sacs, although differing in size, are still but little cut off from the olfactory chamber, and in which the posterior nostril is not valved,

Text-fig. 209.



and *Mullus* and *Pagellus* on the other, in which the posterior nostril is valved and the sacs open into a definite part of the olfactory chamber by restricted orifices.

A parallel specialization is also observable in the differentiation of the jaw-muscles in these two groups.

SCOMBRIFORMES.

SCOMBRIDÆ.

Scomber scombrus.

The nostrils lie in the posterior half of the distance from the eye to the snout separated by a bridge of skin 8 mm. or so in breadth. The anterior nostril is a small and quite simple circular hole, the posterior a vertical slit about 4 mm. long, and valved against ingress by the thinness and flexibility of its backwardly directed anterior lip.

The olfactory rosette is prominent and sharply defined, and lies as usual directly beneath the anterior nostril. It consists of about 30 claw-shaped laminae arranged as usual radially around the hinder parts of a linear raphé.

The olfactory chamber is dilated posteriorly and below to form an extensive though very shallow accessory sac, which is divided into upper and lower parts by the ethmo-lachrymal articulation, the upper part passing beyond the posterior nostril to the anterior and upper edge of the orbit, the lower extending downwards and forwards upon the palatine bone and buccal membrane to the upper border of the maxilla, by which it is compressed when the mouth is closed.

ZEORHOMBI.

ZEIDÆ.

Zeus faber.

The nostrils lie close in front of the eye, near the dorsal mid-line of the face. Both are wide open and of large size, the anterior being a circular aperture about 3 mm. in diameter, with a thick but low tubular lip higher behind than in front, and the posterior a large bean-shaped opening (7 mm. \times 4 mm.) lying close behind the anterior, and partly embracing it with its concave border.

The rosette, which is plainly visible through the posterior nostril, is prominent and sharply defined. It consists of a

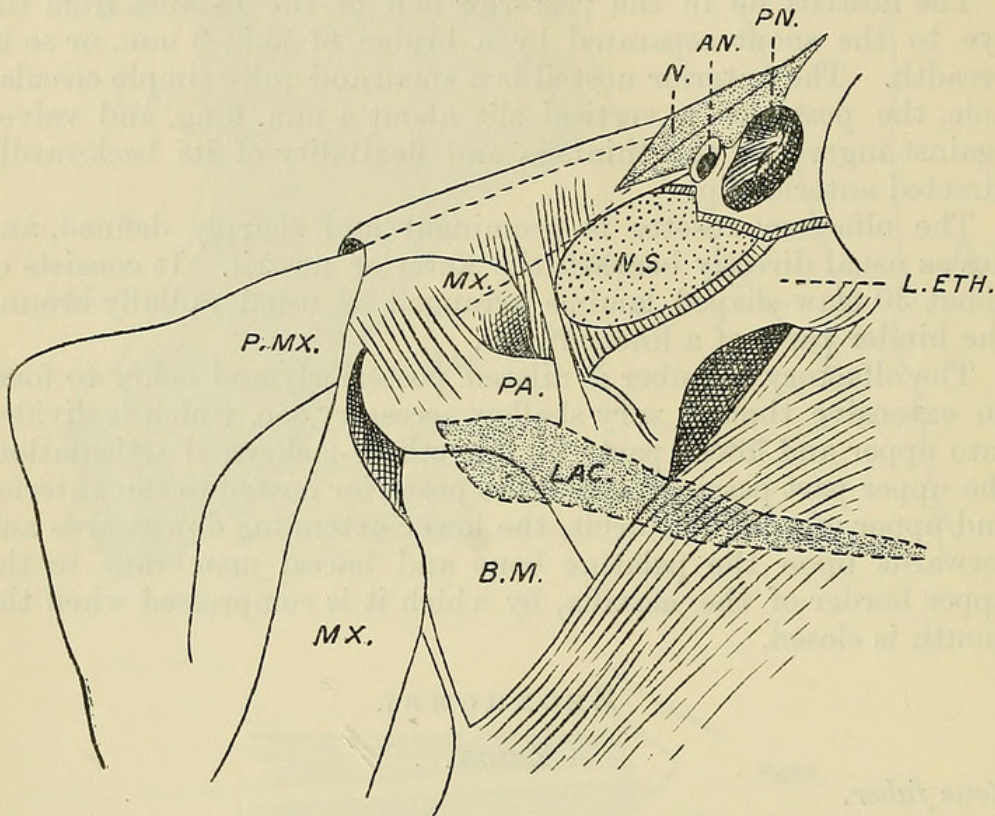
Explanation of Text fig. 209 (see opposite).

Pagellus centrodontus.

- A. Olfactory organ in position, from the side.
 - B. The same, from above.
 - C. The valve (V) upon the hinder lip of the posterior nostril, in section.
 - D. Diagram of a lamina of the rosette.
- BM., buccal membrane. R.PMX., retractor premaxilla.

swollen cushion-like base, from the surface of which protrude the apices of about thirty sharp-pointed laminae attached to a linear central raphé in the usual way. Owing to the abnormal structure of the face the olfactory chamber does not occupy the usual hollow in the ethmoid, but lies higher up in a cavity between the backward process of the premaxilla and the upper part of the ethmoid, separated by a prominent ridge from the cavity of the ethmoid, within which it would normally be lodged.

Text-fig. 210.

*Zeus faber.*

Left olfactory organ, from the side, showing abnormal position.

The anterior parts of the cavity below the rosette are produced forward above the same ridge of bone towards the expanded head of the maxilla, forming a large finger-shaped accessory sac, filled with mucus and separated by a large lymph-space from the deeper parts of the skull.

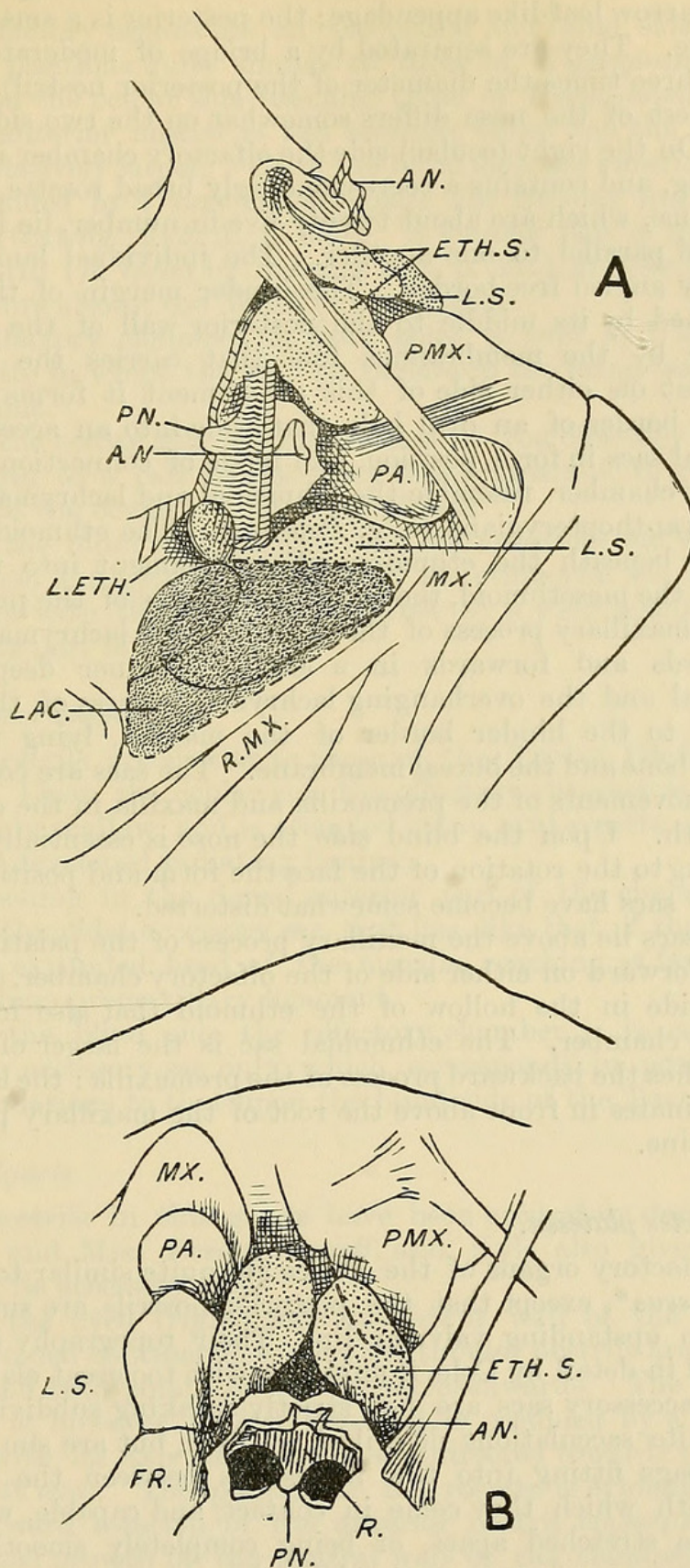
This accessory sac, except for its position with regard to the facial bones, is in many ways very similar to that of *Merluccius*, and it should be noted that both were filled with mucus.

PLEURONECTIDÆ.

Hippoglossus vulgaris.

The olfactory organs are situated on either side of the head, that of the right in front of the interorbital ridge, that of the left just to the left of the dorsal line of the body.

Text-fig. 211.

*Hippoglossus vulgaris.*

- A. Position of both olfactory organs, from the ocular side.
 B. Left olfactory organ, from above,

The anterior nostril is tubular with the hinder lip raised to form a narrow leaf-like appendage; the posterior is a small circular open hole. They are separated by a bridge of moderate breadth (about three times the diameter of the posterior nostril).

The rest of the nose differs somewhat on the two sides of the head. On the right (ocular) side the olfactory chamber is broader than long, and contains a correspondingly broad rosette, in which the laminae, which are about twenty-five in number, lie longitudinally and parallel to one another. The individual laminae have a sharply angled free border. The hinder margin of the rosette is attached by its middle to the posterior wall of the olfactory chamber by the membranous fold that carries the olfactory nerve, but on either side of this attachment it forms the free anterior border of an oval hole that leads into an accessory sac. The nasal sacs in form, position, and mode of connection with the olfactory chamber resemble the ethmoidal and lachrymal sacs of other Acanthopterygians (e. g. *Pagellus*). The ethmoidal passes upwards beneath the ethmo-maxillary ligament into the space between the mesethmoid, the backward process of the premaxilla, and the maxillary process of the palatine; the lachrymal extends downwards and forwards in a similar manner deep to the lachrymal and the overhanging lachrymal process of the lateral ethmoid to the hinder border of the maxilla, lying upon the palatine bone and the buccal membrane. The sacs are compressed by the movements of the premaxilla and maxilla in the closure of the mouth. Upon the blind side the nose is essentially similar, but owing to the rotation of the face the form and position of the accessory sacs have become somewhat distorted.

Both sacs lie above the maxillary process of the palatine, being rotated forward on either side of the olfactory chamber, and lying side by side in the hollow of the ethmoid that also lodges the olfactory chamber. The ethmoidal sac is the larger of the two and reaches the backward process of the premaxilla; the lachrymal sac terminates in front above the root of the maxillary process of the palatine.

Pleuronectes platessa.

The olfactory organs of the Plaice are quite similar to those of *Hippoglossus**, except that the posterior nostrils are surrounded by a thin upstanding valvular lip. Their topography has been described in detail by Cole, if anything with too great elaboration, for the accessory sacs are not strictly speaking subdivided into the definite sacculations described by Cole, but are simple pear-shaped bags fitting into the interstices between the different bones with which they come in contact, and capable, when the bones are stretched apart, of being completely smoothed out, leaving no trace of permanent subdivision.

* A rosette with longitudinally arranged laminae has been recorded (Bateson) for three species of *Pleuronectes* besides *P. platessa*.

Rhombus maximus.

The olfactory organs lie on the ocular and blind sides of the head in positions quite similar to those of *Hippoglossus*. The nostrils on the ocular side resemble those of *Hippoglossus*, except that the anterior nostril is less strongly tubed and the posterior nostril relatively larger. Upon the blind side the anterior nostril is surrounded by a very characteristic flat circular leaf-like expansion (text-fig. 212, A, p. 650). A similar flap is mentioned for the Brill (*R. levis*) by Bateson (*l. c.* p. 231), and, as described later, occurs also in the Whiff (*Arnoglossus*).

The olfactory chamber, on both sides, is oval and lodges an oval rosette in which the laminae radiate in the usual way from a linear raphé.

Upon the ocular side the hinder end of the olfactory chamber gives origin to a pair of accessory sacs comparable in every way to those of the ocular side of *Hippoglossus*.

Upon the blind side there is only one accessory sac which has the position and general relations of an ethmoidal sac, and communicates with the olfactory chamber by a wide opening above the hinder part of the rosette.

Arnoglossus megastoma.

The nostrils are similar to those of the Turbot (Bateson, *l. c.* p. 231). Upon the ocular side the olfactory chamber is oval and exceedingly shallow, and is occupied by an oval rosette consisting of poorly developed radiating laminae.

An opening in the dorsal anterior part of the chamber leads into an ethmoidal accessory sac that lies, like that of the Turbot, upon the expanded head of the maxilla, reaching as far forward as the ethmo-premaxillary ligament.

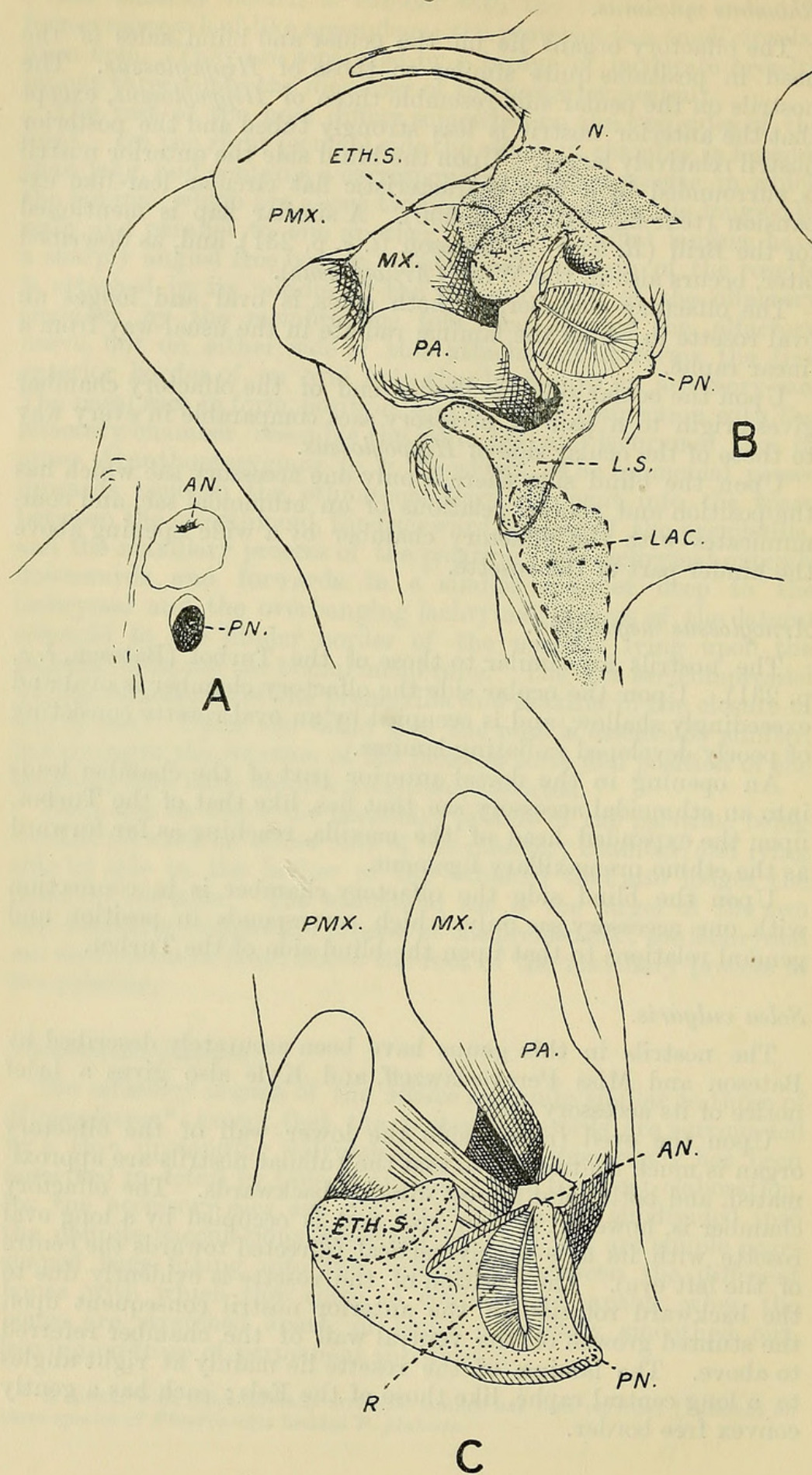
Upon the blind side the olfactory chamber is in connection with one accessory sac only, which corresponds in position and general relations to that upon the blind side of the Turbot.

Solea vulgaris.

The nostrils in this genus have been accurately described by Bateson and Miss Pereyaslawzeff, and Kyle also gives a brief notice of its accessory sacs.

Upon the eyed (right) side the lower wall of the olfactory organ is much contracted, so that the tubular nostrils are approximated, and both point almost directly backwards. The olfactory chamber is, however, of fair size, and is occupied by a long oval rosette with its axis nearly vertical (directed towards the centre of the left eye). The position of the rosette is evidently due to the backward rotation of the anterior nostril consequent upon the stunted growth of the ventral wall of the chamber referred to above. The laminae of the rosette lie mainly at right angles to a long central raphé, like those of the Eels; each has a gently convex free border.

Text-fig. 212.



Posterior to the rosette, just above the posterior nostril, is a clearly defined oval hole that leads into a two-lobed accessory sac. The lower and larger lobe runs backwards parallel to the margin of the mouth, swelling slightly towards its distal end. The upper lobe lies beneath the upper end of the rosette. These two lobes obviously represent the ethmoidal and lachrymal sacs of more normal genera.

Upon the blind (left) side, the nostrils are separated by a very considerable distance, due almost entirely to a tubular elongation of the nasal cavity between the rosette and the posterior nostril (cf. *Mullus*). Both nostrils are tubular, the anterior stout and bluntly conical, the posterior smaller and protected against ingress by the thinness of its converging lip. This nostril opens and shuts with a jerk synchronously with the respiratory movements (Bateson).

The rosette is similar in form to that of the right side, but lies with its length parallel to the internarial axis. It occupies only the anterior part of the nasal cavity; behind it a long tubular empty passage leads to the posterior nostril. The lower wall of this passage is dilated between the hinder limit of the rosette and the ethmo-lachrymal articulation to form a long accessory sac, that runs backwards and downwards with the adductor mandibulæ and palatine arcade superficial to it, giving off a small secondary diverticulum forward towards the lower end of the maxilla.

Summary.

In considering the Zeorhombi, *Zeus* can be at once set aside as differing completely from the Pleuronectidæ in all the details of its nose structure.

The Pleuronectidæ examined can be separated into three groups.

1. *Hippoglossus* and *Pleuronectes*, in which the laminae of the rosette are disposed longitudinally.

2. *Rhombus* and *Arnoglossus*, with a flat, leaf-like lobe to the left anterior nostril.

3. *Solea*, with tubular nostrils and elongated Eel-like rosette.

In all the genera there are accessory sacs in connection with the olfactory chamber, which are comparable to the ethmoidal and lachrymal sacs found in other Acanthopterygians, although they differ in number according to the genus and the side of the face, and except in the Sole are more strongly developed on the ocular than on the blind side.

Explanation of Text-fig. 212 (see opposite).

Rhombus maximus.

- A. Nostrils of the blind (right) side.
- B. Olfactory organ of the ocular (left) side, in position.
- C. Olfactory organ of the blind side, in position, from above.

In *Hippoglossus* and *Pleuronectes* both sacs are present and well developed on both sides of the face. In *Rhombus* the lachrymal sac is absent on the blind side, and in *Arnoglossus* on both sides. In the Sole the lachrymal sac is more developed than the ethmoidal, and is present on both sides, being particularly large on the blind side, the ethmoidal sac, or rather an indication of it, occurring only on the ocular side.

SCLEROPAREI.

TRIGLIDÆ.

Trigla hirundo.

The nostrils lie in an area of soft skin surrounded by scutes, high up on the face, slightly more than halfway from the eye to the point of the snout. The anterior nostril is a small round aperture surrounded by a low tubular lip. The posterior is separated from it by a bridge some few millimetres in breadth, and has the form of a vertical slit valved against inflow by special membranous flaps attached to the inner surface of each of its lips.

The olfactory chamber occupies the usual position with regard to the bones of the face, being lodged in a hollow between the maxillary process of the palatine in front and the ethmo-lachrymal articulation. It contains a clearly defined oval rosette consisting of from thirty to forty laminae with gently convex free borders arranged as usual around a linear axis.

Above and below the rosette the nasal cavity is extended to form a pair of accessory sacs, which have the position and arrangement common to the lachrymal and ethmoid sacs of other Acanthopterygians. The lachrymal sac spreads out into the hatchet-shape presented by that of *Capros*, reaching in front to the maxilla, and backwards upon the jaw muscles. Both sacs are compressed by the bones of the jaws as the mouth is closed.

CYCLOPTERIDÆ.

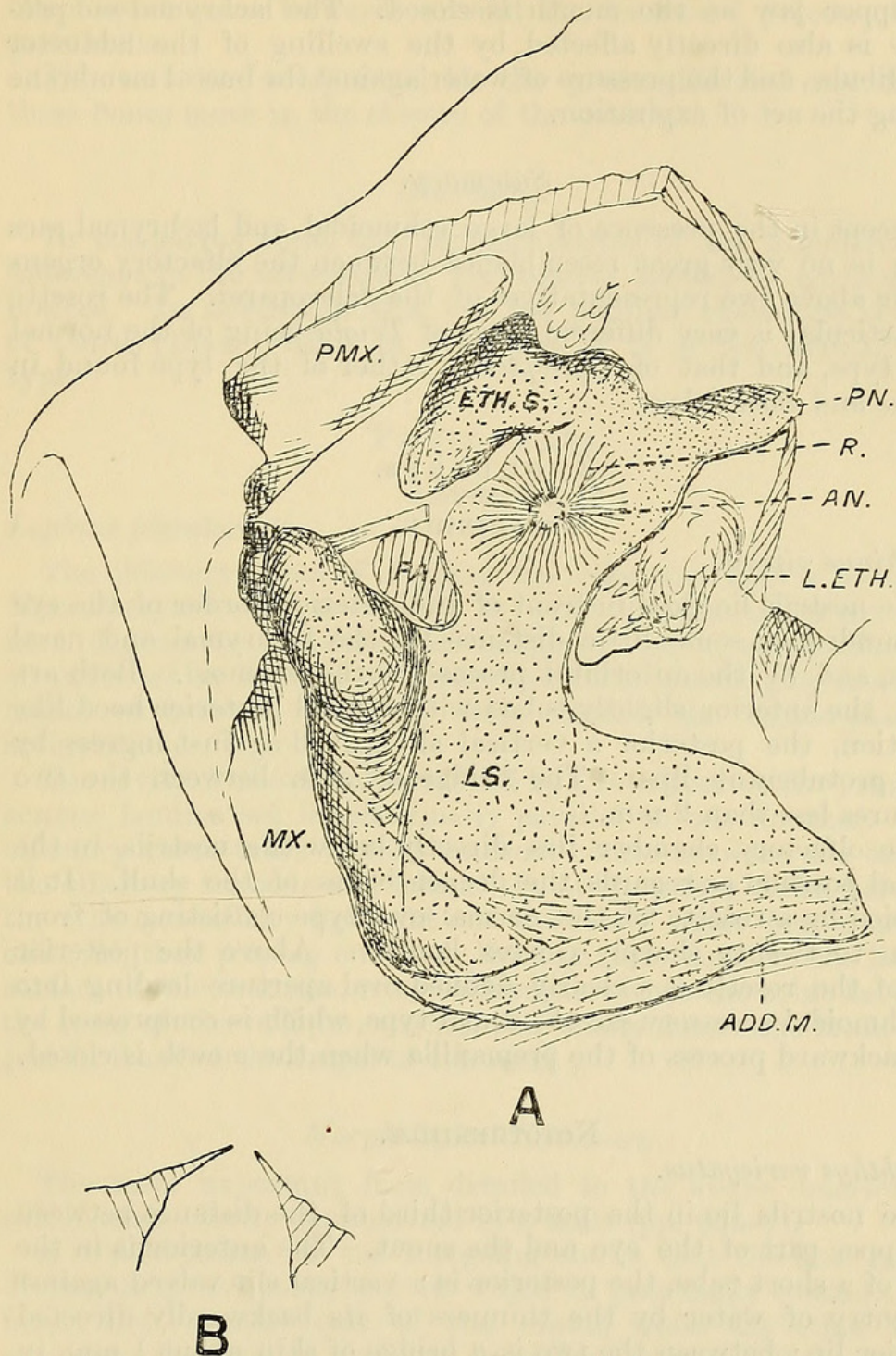
Cyclopterus lumpus.

The olfactory organ is in every way more extensive than that of *Trigla*. The nostrils lie very high up on the head, the anterior slightly in front of the eye above the level of its upper border, the posterior some considerable distance further back about halfway between the anterior border of the eye and the dorsal mid-line of the head. Both nostrils are circular, the anterior slightly the larger of the two, and situated at the end of a short conical tube; the posterior a mere pin-hole, valved against ingress by the thinness of its slightly protuberant lips.

The olfactory cavity is occupied by a circular rosette, consisting of about fifteen feeble laminae radiating from a central boss, which lies directly below the anterior nostril. The hinder part of the chamber is prolonged backwards as a smooth tubular passage to the posterior nostril (cf. *Mullus*, *Solea*), and above and below

the rosette is dilated to form two remarkably extensive accessory sacs similar to those of *Trigla* except in size. The lachrymal sac

Text-fig. 213.



Cyclopterus lumpus.

- A. Left olfactory organ, in position.
B. Diagram of valvular posterior nostril.

in particular is of enormous size, extending forward beneath the head of the maxilla in front of the palatine, and backward along

the border of the maxilla and upon the adductor mandibulæ to a point below the eye.

It rests partly upon the palatine, but mainly upon the buccal membrane. Both sacs are strongly compressed by the bones of the upper jaw as the mouth is closed. The lachrymal sac probably is also directly affected by the swelling of the adductor mandibulæ, and the pressure of water against the buccal membrane during the act of expiration.

Summary.

Except in the presence of large ethmoidal and lachrymal sacs there is no very great resemblance between the olfactory organs of the above two representatives of the Scleroparei. The rosette in particular is very different, that of *Trigla* being of the normal oval type, and that of *Cyclopterus* rather of the type found in *Cottus* and *Bovichthys*.

JUGULARES.

TRACHINIDÆ.

Trachinus vipera.

The nostrils lie close in front of the anterior border of the eye surrounded at some little distance by the lachrymal and nasal bones, and by the antorbital process of the ethmoid. Both are small, the anterior slightly tubed with a small posterior hood-like elevation, the posterior a vertical slit valved against ingress by thin protuberant lips. The bridge of skin between the two measures less than 2 mm.

The olfactory chamber lies directly below the nostrils, in the normal position as regards the deeper bones of the skull. It is occupied by a rosette of the normal oval type consisting of from fifteen to twenty sharply convex laminae. Above the posterior end of the rosette is a clearly defined oval aperture leading into an ethmoidal accessory sac of normal type, which is compressed by the backward process of the premaxilla when the mouth is closed.

NOTOTHENIIDÆ.

Bovichthys variegatus.

The nostrils lie in the posterior third of the distance between the upper part of the eye and the snout. The anterior is in the form of a short tube, the posterior is a vertical slit valved against the entry of water by the thinness of its backwardly directed anterior lip: between the two is a bridge of skin about 1 mm. in breadth. The rosette is circular and composed of nine swollen laminae radiating from a central circular boss, which has no connection with the anterior nostril, as in most Fishes.

The olfactory chamber is expanded below and in front to form an extensive though shallow accessory sac which lies under cover of the lachrymal scute, and to a slight extent beneath the adductor

mandibulæ. It reaches in front into the angle between the maxillary process of the palatine and the maxilla, and is bounded internally by the buccal membrane. A small ethmoidal sac is also present, formed by an extension of the upper part of the olfactory chamber forwards around the backward process of the premaxilla.

The sacs are compressed by the premaxilla and maxilla as these bones move in the closure of the mouth.

Summary.

In comparing these two representatives of the Jugulares the difference in the structure of the rosette should be particularly noticed. In *Bovichthys* this has the peculiar characters of that of *Cottus* (Blaue), while in *Trachinus* it is of the normal oval type.

PEDICULATI.

LOPHIIDÆ.

Lophius piscatorius.

The olfactory organ of *Lophius* has been described in detail by Miss Pereyaslawzeff, so that it is sufficient to mention that it is in a degenerate condition, consisting of only a small olfactory chamber set on the end of a short tentacle standing up from the dorsal surface of the face close behind the ethmo-palatine articulation.

The cavity of the chamber is filled by a few (four or five) sharply convex laminae set longitudinally parallel to one another. The olfactory nerve takes a most unusual course between the base of the olfactory tentacle and brain. It at first dips down between the ethmo-maxillary ligament and the raised outer border of the ethmoid, then passing outwards through this bone to the lateral surface of the cranium, runs backwards within the orbit between the roots of the oblique muscles, and finally enters the brain-case just in front of the origin of the recti.

Morphological Summary.

The most important facts detailed in the above descriptions can be most clearly summarized in a table (pp. 656-7).

A consideration of the foregoing shows that the nose can be divided into two parts, one of which is practically constant and forms the essential part of the organ, while the other is of secondary importance, and may be present or not. These are the olfactory chamber with its rosette and the accessory nasal sacs.

The olfactory chamber differs comparatively little in shape and relative size, and in nearly every case occupies a constant and fixed position with regard to the bones of the skull, being lodged in a hollow in the ethmoid between its points of articulation with the palatine and the lachrymal bones. In nearly all cases it

	NOSTRILS.						ROSETTE.						NASAL SACS.					
	ANTERIOR.				Pos- TERIOR.		GENERAL FORM.				LAMINÆ.							
	Simple perforation.	Tubular.	With posterior hood.	With internal curtain.	Valved.	Open.	Oval with linear raphe.	Elongated.	Circular with central boss.	With laminae longitudinal.	With central linguiform process.	Linguiform process predominant.	Linguiform process absent.	Slight indefinite extension.	Posterior sac.	Ventral sac.	Dorsal sac.	Dorsal and ventral sacs
Malacopterygii.																		
Salmo	N	...	N	N	...	N	R	...	...	...	...	L	...	...	S			
Osmerus	N	...	N	N	...	N	R	...	...	...	...	L	...	...	S			
Coregonus .....	...	N	...	N	N	...	R	...	...	...	...	L	...	...	S			
Clupea .....	...	N	...	N	...	N	R	...	...	...	...	L	...	...	S			
Chirocentrus	N	...	...	N	...	N	R	...	...	...	...	L	...	...		
Mormyrus	N	...	...	...	...	N	R	...	...	...	...	...	L	...				
Gymnarchus .....	...	N	N	...	...	N	R	...	...	...	...	...	...	...
Ostariophysi.																		
Tinca .....	...	N	N	N	...	N	R	...	...	...	L	...	...	...	
Abramis .....	...	N	...	N	...	N	R	...	...	...	L	...	...	...	
Cobitis .....	...	N	N	N	...	N	R	...	...	...	L	...	...	...	
Labeo .....	...	N	N	N	...	...	R	...	...	...	L	...	...	...	
Clarias .....	...	N	...	...	N	...	R	R	...	...	L	...	...	...	S	...	S	
Malopterurus .....	...	N	N	...	N	...	R	...	...	...	...	...	...	...	S			
Pimelodus .....	...	N	...	...	...	N	...	R	...	...	...	...	...	...	S			
Silurus .....	...	N	...	...	N	...	...	R	...	...	...	...	...	...	S			
Gymnotus .....	...	N	...	...	...	N	R	...	...	...	...	L	...	...		
Apodes.																		
Anguilla .....	...	N	...	...	N	...	...	R	...	...	...	...	...	...
Conger .....	...	N	...	...	N	...	...	R	...	...	...	...	...	...
Muræna .....	...	N	...	...	N	...	...	R	...	...	...	...	...	...
Haplomi.																		
Esox	N	...	...	N	...	N	...	...	R	...	...	...	L	...				
Scopelus .....	...	...	...	...	...	...	R	...	...	...	...	L	...	...		
Anableps .....	...	N	...	...	N	...	...	...	...	...	...	...	...	...	...	...	S	
Orestias	N	...	...	...	N	...	...	...	...	...	...	...	...	...	...	...	S	
Catosteomi.																		
Gastrosteus (Solger) ...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	S		
Fistularia	N	...	...	...	...	...	R	...	...	...	...	...	L	...	S	...	S	
Percesoces.																		
Belone .....	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Hemirhamphus .....	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Exocoetus .....	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Mugil .....	...	N	N	...	N	...	R	...	...	...	...	...	...	...	...	...	...	S
Ophiocephalus .....	...	N	...	...	...	N	...	...	...	R	...	...	L	...	...	...	...	...
Sphyræna	N	...	...	...	N	...	R	...	...	...	...	L	...	...	...	S		...
Anacanthini.																		
Gadus .....	...	N	N	...	...	N	R	...	...	...	L	...	...	...	S			
Motella .....	...	N	...	...	...	N	R	...	...	...	L	...	...	...	...	...	...	...
Merluccius	N	...	...	...	...	N	R	...	...	...	...	L	...	...	...	S		...

	NOSTRILS.						ROSETTE.						NASAL SACS.					
	ANTERIOR.				Pos- TERIOR.		GENERAL FORM.				LAMINÆ.							
	Simple perforation.	Tubular.	With posterior hood.	With internal curtain.	Valved.	Open.	Oval with linear raphe.	Elongated.	Circular with central boss.	With laminae longitudinal.	With central linguiform process.	Linguiform process predominant.	Linguiform process absent.	Slight indefinite extension.	Posterior sac.	Ventral sac.	Dorsal sac.	Dorsal and ventral sacs.
Acanthopterygii.																		
Perciformes.																		
Perca .....	...	N			...	N	R	...	...	...		L	...	...	...	...	...	S
Latris .....	...	N	N		...	N	R	...	...	...	L	...	...	...	...	...	...	S
Beryx	N	...			...	N	R	...	...	...	...	L	...	...	...	...	...	S
Capros	N	...			...	N	R	...	...	...	...	L	...	...	...	...	...	S
Mullus	N	...			N	...	R	...	...	...	...	L	...	...	...	...	...	S
Pagellus	N	...			N	...	R	...	...	...	...	L	...	...	...	...	...	S
Scombriformes.																		
Scomber	N	...			...	N	R	...	...	...	...	L	...	...	S	...	...
Zeorhombi.																		
Zeus .....	...	N			...	N	R	...	...	...	...	L	...	...	...	S	...	
Hippoglossus .....	...	N	N		...	N	...	...	R	...	L	...	...	...	...	...	...	S
Pleuronectes .....	...	N	N		N	...	...	...	R	...	...	...	...	...	...	...	...	S
Rhombus .....	...	N	N		...	N	R	...	...	...	...	...	...	...	...	S	...	S
Arnoglossus .....	...	N			...	N	R	...	...	...	...	...	...	...	...	...	S	S
Solea .....	...	N			N	...	...	R	...	...	...	...	...	...	S	...	...	S
Scleroparei.																		
Trigla .....	...	N			N	...	R	...	...	...	...	L	...	...	...	...	...	S
Cyclopterus .....	...	N			N	...	...	R	...	...	...	L	...	...	...	...	...	S
Jugulares.																		
Trachinus .....	...	N	N		N	...	R	...	...	...	L	...	...	...	...	...	S	
Bovichthys .....	...	N	N		N	...	...	R	...	...	L	...	...	...	...	...	...	S
Pediculati.																		
Lophius																		

opens to the exterior by two nostrils, and contains a rosette in which the component laminae are as a rule set radially around the sides and hinder end of an axis which is attached in front to the anterior wall of the anterior nostril (Rosette, Column 1).

An olfactory organ of this description occurs in most of the lower Teleosteans, and is well represented in a generalized condition in the Haddock, which, therefore, serves as a good central type with which to compare the rest.

Minor variations occur to different degrees in all parts—in the details of the nostrils, of the rosette, and of the cavity, some of

which appear to be characteristic of families or even larger groups.

The nostrils are perhaps the most variable part, and also that in which variation is correlated least with natural affinities.

The position of the anterior nostril directly above the rosette is almost universal, no doubt in order that the incurrent water may play directly upon the olfactory membrane. This position is also probably due in part to the close connection that there is in almost every instance between the axis of the rosette and the front lip of the nostril, which indicates that the rosette belongs essentially to the anterior part of the olfactory chamber. When the rosette is elongated, as in the Eels, Siluroids, and some Pleuronectids (Rosette, Column II.) the nostril opens in front of and not above it.

The anterior nostril is very frequently, especially in the lower Teleostei, more or less tubular (Nostrils, Column II.). The tube is particularly well marked in the Eels, some Siluroids, *Anableps*, and *Ophiocephalus*, but the tendency towards tube-formation is so widely distributed and variable in its occurrence and extent that it probably has little to do with natural affinity.

In certain groups, notably the Cyprinidæ and Gadidæ, the hinder wall of the tube is elevated to form a valvular flap (Nostrils, Column III.), and in other groups or separate genera (*Merluccius*, *Esox*, Salmonidæ, Clupeidæ) this may be augmented or replaced by a similar downward prolongation or curtain that dips into the olfactory cavity above the centre of the rosette (Nostrils, Column IV.). Both these developments of the bridge of skin between the nostrils are without doubt mainly of physiological importance, although in restricted groups (*e. g.* Cyprinidæ) they are also constant enough in their occurrence to be of systematic importance.

Variations in the form of the posterior nostril seem also to depend little upon affinity.

Broadly speaking this nostril is either a simple open perforation flush with the surface of the skin (Nostrils, Column VI.), which may show considerable differences in size, but commonly is either circular, oval, or crescentic in shape; or it is a slit or pin-hole closed by valves.

The crescentic type is highly characteristic of the Salmons, Herrings, and Carps, though found also in *Merluccius*, *Esox*, and (in a bean-shape) in *Zeus*. It always more or less closely embraces the hinder margin of the anterior nostril.

The oval or circular form occurs in many groups, but can hardly be regarded as characteristic of any.

A valved condition (Nostrils, Column V.) is found chiefly though not solely (some Siluroids) in fishes provided with accessory nasal sacs, and forms part of a general mechanism for drawing water forcibly into the olfactory chamber through the anterior nostril. In their simplest condition the valves are merely the thin converging lips of a minute perforation at the end of a short

conical tube (*Solea*, *Cyclopterus*, *Trachinus*), or the thin backwardly directed anterior lip of a slit-like orifice (*Mugil*, *Sphyræna*, *Scomber*, *Bovichthys*), but when fully developed they are special folds of membrane attached to the inner surface of one or both lips of the nostril and directed outwards (*Trigla*, *Pagellus*, *Anableps*, *Orestias*, *Clarias*).

Finally, there are cases in which there is one nostril only present [*Gastrosteus* (Solger); Chromidæ, Labridæ (Milne-Edwards)]. Or the nose may assume (apparently as a secondary modification) the condition of a widely open pit without defined nostrils at all (Scombresocidæ); or by the elevation of its floor and the subsequent rupture of the bridge between the nostrils, the cavity may be everted and the organ transformed to a bifoliate tentacle (Tetrodons, Wiedersheim and Tate Regan).

Turning now to the rosette, it is noticeable that the axis is most frequently linear and continued to the front lip of the anterior nostril, as in the Haddock, the rosette being usually of an oval form (Bateson's type 3) (Rosette, Column I.).

In *Cyclopterus*, *Bovichthys*, *Cottus*, *Esox*, *Orestias*, it is a central circular boss from which the laminae radiate in all directions, the rosette being circular (Bateson's type 3) (Rosette, Column III.).

In the Eels, and to a less extent in the Siluroids and the Sole, the axis is lengthened and the laminae are set in parallel series at right angles to it (Bateson's type 2) (Rosette, Column II.); and finally in *Ophiocephalus*, *Hippoglossus*, and *Pleuronectes*, the axis lies transverse to the internarial line and the laminae are attached to its posterior border in parallel series (Bateson's type 4).

In the degenerate nose of *Lophius* the few laminae left are also arranged parallel to one another and to the narial axis, and in the *Percesoces* laminae are entirely wanting.

Considerable differences are apparent in the shape of the individual laminae of the rosette. Starting from the type presented by *Gadus* as a centre (Rosette, Column V.), one line of variation leads by the suppression of the peripheral part of the lamina and the exaggeration of the linguiform process (Rosette, Column VI.) to the claw-like shape which is particularly characteristic of the rosette of the Salmonidæ and Clupeidæ. A similar though less pronounced modification is shown by the sharply convex laminae of *Mugil*, *Perca*, *Pagellus*, or *Sphyræna*, and probably the triangular laminae of the Eels should be included in the same series. On the other hand, suppression of the linguiform process (Rosette, Column VII.) gives rise to a gently curved or straight free border such as that seen in *Mormyrus*, *Clarias*, *Esox*, *Orestias*, some *Pleuronectids*, *Ophiocephalus*, *Bovichthys*, *Trigla*, and *Cyclopterus*. Except in the case of the Salmons and Herrings the form of the laminae has apparently little dependence on natural affinity, except in quite closely related forms.

Variations in the position of the olfactory chamber relative to the framework of the face are very exceptional, being found only in *Motella*, *Zeus*, and *Lophius*. Its shape also is very constant,

and corresponds roughly to that of the rosette. In some genera the cavity is extended to an appreciable extent beyond the rosette (especially posteriorly) forming an empty space (Nasal sacs, Column I.), which in many genera undergoes further development to form a definite sac or sacs accessory to the true olfactory chamber.

The accessory sacs can be separated for convenience into three series. (1) A single sac directed anteriorly from either above or below the rosette (Nasal sacs, Columns III. & IV.). (2) A single sac directed posteriorly towards the orbit (Nasal sacs, Column II.). (3) Two sacs (ethmoidal and lachrymal nasal sacs) with very definite relations to the ethmoidal and lachrymal regions of the face, and constant also in their point of entry into the olfactory chamber above and below the hinder end of the rosette (Nasal sacs, Column V.). With regard to the two sacs of the third group there is not much doubt that they are homologous in the different genera in which they occur, but in the case of the sacs grouped in Series I. it is very difficult to determine how far they are homologous among themselves or to either of the sacs in Series III. In some cases (*Orestias*, *Anableps*, *Ophiocephalus*, *Trachinus*) the sac is possibly homologous with the ethmoidal sac, in others (*Gastrosteus* (Solger), *Solea*) with the lachrymal, having regard to its position, and especially to its mode and point of connection with the olfactory chamber; but in other cases (*Merluccius*, *Zeus*, *Sphyræna*, *Clarias*) the protrusion is of too general a character to render the homology anything more than very doubtful.

The backwardly directed sacs of the Salmons, Herrings, and the Mackerel (Series II.) being little more than a general protrusion of the hinder part of the olfactory chamber, should probably not in any way be regarded as homologous with either of the sacs of Series III. Their distribution is interesting, being restricted to fishes in which there is a great development of mucoid tissue about the eye and face, giving rise to a third eyelid against the base of which the sac abuts.

The two sacs in Series III. are found in their typical form, with one exception, in the Acanthopterygii. The exception is *Mugil*, which it should be noticed is in Günther's system of classification included among the Acanthopterygii. Upon the other hand, the presence of these sacs in the Pleuronectidæ appears to lend further justification for the removal of these Fishes from close proximity to the Gadids (Günther) to the Acanthopterygii (Boulenger).

The least specialized form of the olfactory organ is undoubtedly the rosette-filled hollow found in most of the non-Acanthopterygian fishes (Physostomi, Günther). From this as a starting point we may justly assume that the development of accessory sacs commenced with a general expansion of the parts of the olfactory chamber around the rosette, such as we find in *Motella*, and in a slightly more accentuated form in *Gymnarchus*, the Siluroids, and *Fistularia*.

Further specialization can be seen in the Salmon and Herrings, where the sac, though still a general extension of a great part of the olfactory chamber, is definite in shape, and enters into functional relations with the skeleton of the jaws. The next stage is shown by *Orestias*, *Ophiocephalus*, *Anableps*, *Bovichthys*, the opening of the sac becoming restricted to a definite circumscribed hole in a fairly definite and constant position in the wall of the olfactory chamber. Finally, the position and number of the sacs and their mode of connection with the olfactory chamber became crystallized in the Acanthopterygii, resulting in the definite ethmoidal and lachrymal sacs more or less characteristic of this group.

In certain fishes the accessory sacs have apparently been further specialized for the production of mucus. This point has been specially dealt with by Kyle in the case of Pleuronectids. To the fishes mentioned by him should be added *Merluccius* and *Zeus*, in both of which the accessory sac and olfactory chamber were filled with an abundance of coagulated mucus.

Physiological Summary.

From our knowledge of the structure of the olfactory organ, it may be concluded that there are at least three means by which a current of water may be brought to play upon the laminae of the rosette. The first is by the action of cilia within the anterior nostril and upon the lining membrane of the olfactory chamber (Bateson, p. 230). This seems to be the only way in the Eels, which are among the few fishes shown by Bateson to hunt their food by smell, and is probably also in many other cases one of the agents, though not the most important, in ensuring a constant gentle flow of water over the rosette.

The second method is by the deflection of water into the nose-cavity during forward progression. This may be effected by the position and slope of wide-open nostrils to the horizontal, as in *Esox*, but more frequently it is brought about by a hood or screen upstanding behind the anterior nostril (Gadids, Carps). In this case the force of the current is under the control of the fish, and varies directly with the pace at which it is moving. In noses of this type a further refinement is frequently met with in the form of an internal flap that conducts the water-current right down into the centre of the rosette.

The third method is by the alternate dilatation and compression of accessory sacs connected usually with the hinder part of the olfactory chamber.

In the majority of cases these are acted upon by the movements of the premaxilla and maxilla, occasionally (*Capros*, *Clupea*) by those of the mandible, or (Siluroids) of the palatine bar, and in several cases (where the lachrymal sac extends upon the buccal membrane) by the general pressure of the water in the mouth during expiration.

The currents produced normally by these sacs are rhythmical *, flowing in and out of the nose as the fish gently opens and closes its mouth in breathing, and may be compared to the air-currents in the Mammalian nose during ordinary respiration. The strength of the current must, however, be quite under the control of the fish, for sudden and energetic movements of the jaws would naturally produce corresponding sudden and strong currents in the nose, comparable to a sniff. In noses of this class it is generally arranged by means of valves that the water shall enter by the anterior nostril and leave by the posterior.

A study of the anatomy of these parts leaves little doubt that their action is somewhat as stated above, but the facts detailed by Bateson from direct observation of the living fish make it difficult to account for the presence of these different and often elaborate mechanical devices. He states, and his experiments are quite conclusive, that practically all Teleostei seek their food by sight, and apparently have no appreciation whatever of what we term smells, so that it still remains an open question what their olfactory organ is sensitive to, and what part in their economy it fills.

Apart from the essential structural identity of the fish olfactory organ with that of higher Vertebrates, the mechanisms by which the surrounding medium is brought to play upon their sensitive membranes gently or violently at will are so closely analogous that one would be almost compelled to regard their functions as also essentially the same, did not Bateson's observations prove beyond question that the sense of smell in the ordinary sense of the word is absent in the vast majority of fishes, and it is to be noticed that it is just in those cases where it is absent that the mechanisms for regulating the water-currents within the nose are the most efficient.

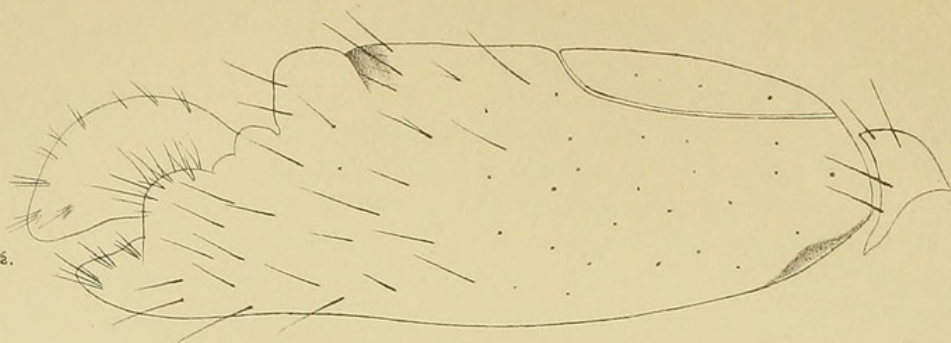
It should, on the other hand, be observed that in a large number of the more highly specialized fishes there is a close connection between the nasal water-currents and the respiratory movements of the jaws, a fact that suggests that the nose may have more to do with respiration than with the discrimination of food, and possibly may be of some use in testing the water used for respiration.

The Relation between the Structure of the Nose and General Habit.

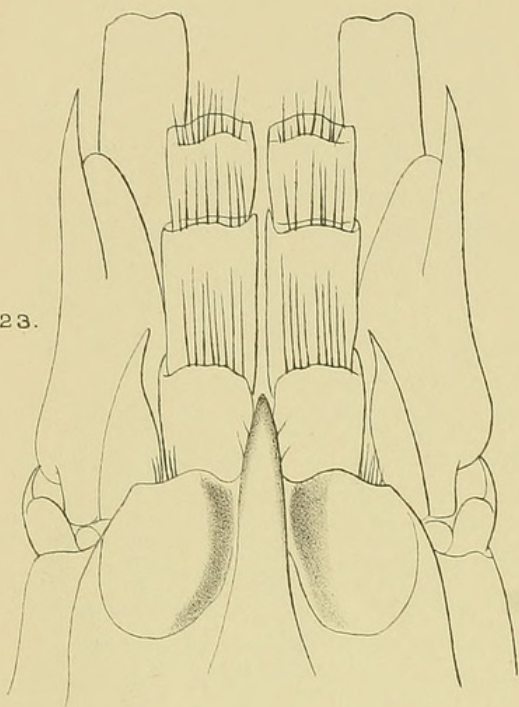
Although it is difficult to obtain accurate information concerning the habits of sea-fishes, enough can be ascertained (Day's 'British Fishes,' Cunningham's 'Marketable Fishes,' &c.) to roughly group

* In many fishes (Bateson, *l. c.* p. 230) oscillating currents keeping time with the movements of the jaws in respiration have been directly observed, but they are not a necessary result of these movements, for although under normal conditions the two go together, the current may stop while the respiratory movements continue. Whether this depends upon a voluntary closure of the nostrils or what its explanation may be there is at present no evidence to show.

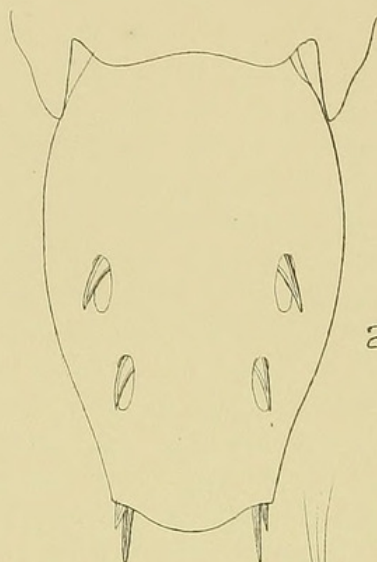
3. x 8½.



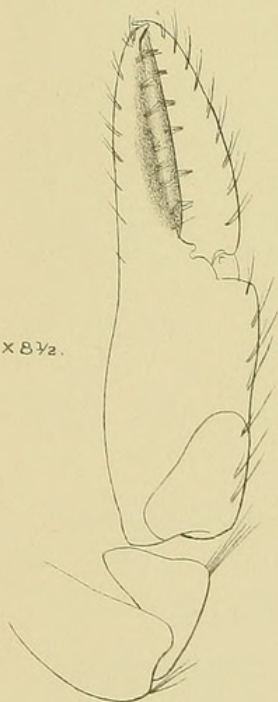
1. x 23.



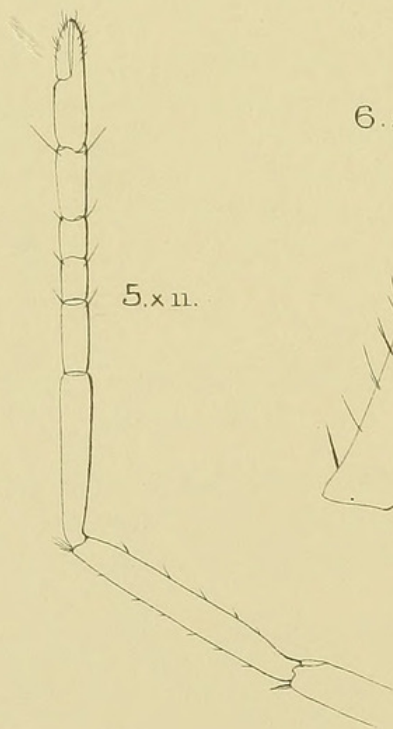
2. x 23.



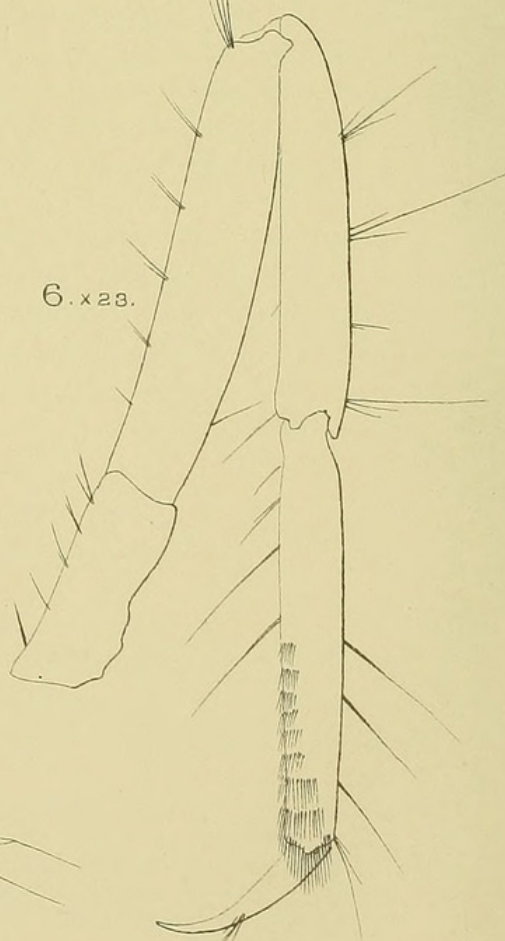
4. x 8½.



5. x 11.



6. x 23.



the fishes dealt with in this paper into Bottom Fishes, Sluggish Shallow-water Fishes, and Free-swimming Open-water Fishes.

When tabulated thus there is seen to be practically no connection between the structure of the nose, particularly as regards the presence or absence of accessory sacs, and the general life-habit. Thus fishes of all habits may have accessory sacs (*Mullus*, Pleuronectids, *Scomber*, Herrings, Perch), or not (Eels, some Siluroids, Carps, Pike, *Scopelus*, *Gadus*, *Exocoetus*). This is a conclusion somewhat at variance with Kyle's generalization, that accessory sacs are characteristic of bottom or sluggish fishes as opposed to free-swimming forms and are in the main adaptive structures determined by habit.

On the contrary, it would appear from the above that they are rather part of a general advance in structure, and belong, at least in their most characteristic development, to families that have reached the highest all-round development.

EXPLANATION OF ABBREVIATIONS IN THE TEXT-FIGURES.

A.N., anterior nostril. ADD.M., adductor mandibulæ. AOR., antorbital scutes. AX., axis of rosette; AX.', its connection with lip of anterior nostril. B.M., buccal membrane. C., central segment of lamina. CT., curtain-like extension of bridge between nostrils. E., eye. E.MX.L., ethmo-maxillary ligament. ETH.P.A., ethmo-palatine articulation. ETH.S., ethmoidal nasal sac. FR., frontal. H., hood-like process of posterior lip of anterior nostril. L., linguiform process of lamina. LAC., lachrymal scute. L.ETH., lateral ethmoid; L.ETH.', its articular process for the lachrymal. LM., lamina. L.S., lachrymal nasal sac. MD., mandible. METH., mesethmoid. MX., maxilla. N., nasal. N.S., nasal sac. OL.B., olfactory bulb. OL.C., olfactory cavity. OL.N., olfactory nerve. P., peripheral segment of lamina. PA., palatine. PMX., premaxilla; P.MX.A., palato-maxillary articulation. P.PMX.L., palato-premaxillary ligament. P.N., posterior nares. R., rosette. R.MX., retractor maxillæ. R.PMX., retractor premaxillæ. T., tentacle.

4. Description of a new Species of the Genus *Alpheus* Fabr. from the Bay of Batavia. By J. G. DE MAN *.

[Received April 30, 1909.]

(Plate LXX. †)

ALPHEUS EHLERSII, sp. n.

Syn.: *Alpheus macrochirus* de Man, in Archiv für Naturg. 53 Jahrg. (Berlin, 1888), p. 519.

A re-examination of the two specimens of *Alpheus* from the island of Edam, Bay of Batavia, described by me (*l. c.*) under the name of *A. macrochirus* Richters, not only proved that they had been wrongly referred to that species, but also that they are the representatives of a hitherto unknown form. This new species, which I have the pleasure to dedicate to Professor Ehlers of

* Communicated by R. I. Pocock, F.L.S., F.Z.S.

† For explanation of the Plate see p. 666.

Göttingen, who kindly enabled me to study the two specimens, apparently belongs to the group "*insignis*" of Coutière and is most closely related to *A. paracrinitus* Miers, to *A. paracrinitus* Miers, var. *bengalensis* Cout., and to *A. lanceoloti* Cout., three species inhabiting the Maldive and Laccadive Archipelagoes, though the first of them was originally discovered at Goree Island, Senegambia.

The larger specimen is 16.5 mm. long, the other 15 mm.

Rostrum acute, reaching to the distal fourth of the visible part of basal antennular article; rostral carina obtuse, extending backward to the base of the rounded, unarmed, orbital hoods, from which it is separated by rather deep, though narrow grooves. On each side of the rostrum, the frontal margin (Pl. LXX. fig. 1) bears a rounded prominence, nearly as in *A. superciliaris*, but glabrous and with the outer margin more oblique. Antennal and antennular peduncles with spines and appendages nearly as in *A. paracrinitus bengalensis* (Coutière, *Alpheidæ Mald. and Laccad. Archip.* 1905, pl. lxxxii. fig. 37). Second antennular article once and a half longer than wide distally, a little longer than the visible part of the 1st and of the 3rd, which are of equal length; stylocerite acuminate, reaching to the second fourth part of median article. Carpocerite surpassing the antennule almost by the whole length of 3rd article; the terminal spine of the scaphocerite, the outer margin of which is slightly concave, is slightly curved inward and reaches almost to midway between the extremities of both peduncles; the terminal spine exceeds by a little more than one third of its length the tip of the scale, which is a little shorter than the inner peduncle. Basicerite with a small spine on the lower side, not visible from above. Telson (Pl. LXX. fig. 2) nearly as in *A. paracrinitus* var. *bengalensis*, but the outer angles of the slightly prominent posterior margin obtuse. The length of the telson equals in both specimens 3.1 times the width of the posterior margin; the greatest width anteriorly is, in the larger specimen, 1.93 times, in the other just twice the width of posterior margin; in both specimens the spinules of the upper surface, which are 0.2 mm. long, are situated as in the var. *bengalensis* of *A. paracrinitus*, the anterior pair anterior to the middle, the proportion between the length of the telson and the distance of that pair from the posterior margin being, in the larger specimen, 1.73, in the other 1.85; the proportion between the distances of both pairs of spinules from the posterior margin is, in the larger specimen, 1.6, in the other 1.7.

Meropodite of larger chelipede twice as long as wide; upper margin unarmed at its extremity, infero-internal margin with a small acute tooth at the apex and with seven small movable spinules, 0.117 mm. long, inserted from the proximal extremity to the distal third. Chela 8.4 mm. long, one third longer than the carapace, 2.8 times longer than high, and somewhat compressed, its thickness being in proportion to the height as 2.3; upper and lower borders of the palm (Pl. LXX. fig. 3) nearly parallel, lower border



Harmer, S. F. 1909. "May 25, 1909." *Proceedings of the Zoological Society of London* 1909, 597–666. <https://doi.org/10.1111/j.1469-7998.1909.tb00598.x>.

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