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EXPLANATION OF PLATE VII.*

Abbreviations.

<i>A.</i> Anterior pole.	<i>P.</i> Posterior pole.
<i>c.v.</i> Contractile vacuole.	<i>p.</i> Outer pellicle of protoplasm.
<i>f.</i> Flagellum.	<i>pr.</i> Knob-shaped mass of protoplasm.
<i>m.</i> Matrix.	<i>pyr.</i> Pyrenoid.
<i>n.</i> Nucleus.	<i>s.sh.</i> Secondary sheath.
<i>ncl.</i> Nucleolus.	<i>st.</i> Stigma.
<i>p.sh.</i> Outer or primary sheath.	

Fig. 1. *Platydorina caudata*, face view of 32-cell colony, $\times 550$.

Fig. 2. Face view of 16-cell colony, $\times 628$.

Fig. 3. Edge view of 32-cell colony, $\times 350$.

Fig. 4. Lateral view of one of the marginal cells, $\times 1400$.

Fig. 5, a-e. Outline of the posterior ends of several deformed colonies, $\times 280$.

LXXII.—*On the Luminous Organs of Selachian Fishes.* By
RUD. BURCKHARDT, Nat. Hist. Mus., S. Kensington.

IN the 'Zeitschrift für wissenschaftliche Zoologie,' vol. lxvi. 1899, Johann, at the instigation and under the guidance of Prof. Blochmann, of Tübingen, published a paper entitled "Ueber eigenthümliche epitheliale Gebilde (Leuchtorgane) bei *Spinax niger*," in which are given the results of some researches he made in this subject.

In this paper he describes some very minute organs with

* Figures drawn by C. A. Kofoid and inked by Miss L. M. Hart.

which the skin of *Spinax niger* is covered in great numbers, more particularly so on its black-coloured parts. In addition to describing their distribution upon the surface of the body and their histological structure, which in the main points corresponds with those of *Phyllirhoë* and the Pennatulidæ, he also compares them with other luminous organs.

He moreover refers to a previous observation on phosphorescence made in another Spinacide species, *Isistius brasiliensis*, by Bennett as early as 1840 during a whale voyage, in which he states expressly that, with the exception of a ring on the throat remaining dark, the whole of the ventral surface of this fish was aglow for about three hours. It struck Johann as being remarkable, when he discovered on the throat in *Spinax* two regions extending towards the median line which were devoid of these structures. From this fact alone, and quite apart from purely structural characters, he was right in his surmise, that in all likelihood they would have to be regarded as organs of luminosity.

The accuracy of his notions as regards their functions was moreover fully borne out in a note from Th. Beer, dated Jan. 31, 1899, which reached Johann in time to find a place at the end of his paper.

In his note Beer says that, whilst engaged in ophthalmoscopic observations on *Spinax* in a room darkened for this purpose, its phosphorescence was vivid enough to enable him to see it at a distance of from 3-4 metres. "The whole of the ventral surface of the animal," he continues, "from the snout to the root of the tail, was glowing with a feebly shining greenish lustre, as if it were impregnated with phosphorus or had been coated with a luminous paint, with this difference, however, that luminosity appeared and disappeared at short intervals, but invariably increased in intensity just before its disappearance."

In this wise Johann's interpretation was indisputably confirmed. He further, too, more fully entered into those questions of their physiology which are so closely connected with these remarkable structures; and he finally endeavoured to supply proof of their presence in other Selachians which he examined for this purpose, without, however, being able to do so.

The genera investigated by him with the aforesaid object were:—*Stegostoma*, *Carcharias*, *Scyllium*, *Pristiurus*, *Mustelus*, *Crossorhinus*, *Zygæna*, *Chimæra*, *Centrophorus* (*granulosus*), *Læmargus* (*borealis*), and *Scymnus*.

At the time when Johann published his work I had already noticed some peculiar structures in *Læmargus rostratus*, a

rare shark from the Mediterranean. These I had put aside for the purpose of future microscopical use, pending the completion of other anatomical research; I then concerned myself with this shark. Unquestionably they were organs of luminosity, of the correctness of which opinion I became more firmly convinced, since a splendid specimen of *Spinax niger* afforded me an opportunity for confirming Johann's observations.

When, in the spring of 1898, I was working at the Zoological Station in Naples, Dr. Salvatore Lobianco, with his wonted kindness, seized upon the first opportunity that presented itself to procure for me half a dozen living specimens of this species, which, however, arriving one evening, died the next morning. I was greatly struck at the time by the splendour of the spectral colours which these fishes exhibited, and of which, so far as I am aware, no mention anywhere in literature seems to have been made. This latter circumstance induced me therefore to prepare a coloured sketch of this phenomenon from these fishes.

A later scrutiny of this sketch convinced me of the fact that I had been able to observe the phosphorescence of these organs by daylight, so strong was their luminous power*.

It is not my intention here to enter into details relating to the purely histological modifications of these organs amongst other Selachians, feeling sure that they all share more or less the type of form which Johann has ascribed to them for *Spinax*.

A few figures, however, which I made of *Læmargus rostratus* may well find a suitable place here—firstly, because they will prove that the organs observed by myself are really identical with those of Johann; and, secondly, they go to show, as before stated, that the organs pertain to that form whose morphological structure is so much affected by the scales, as is the case with many of the Teleostean fishes.

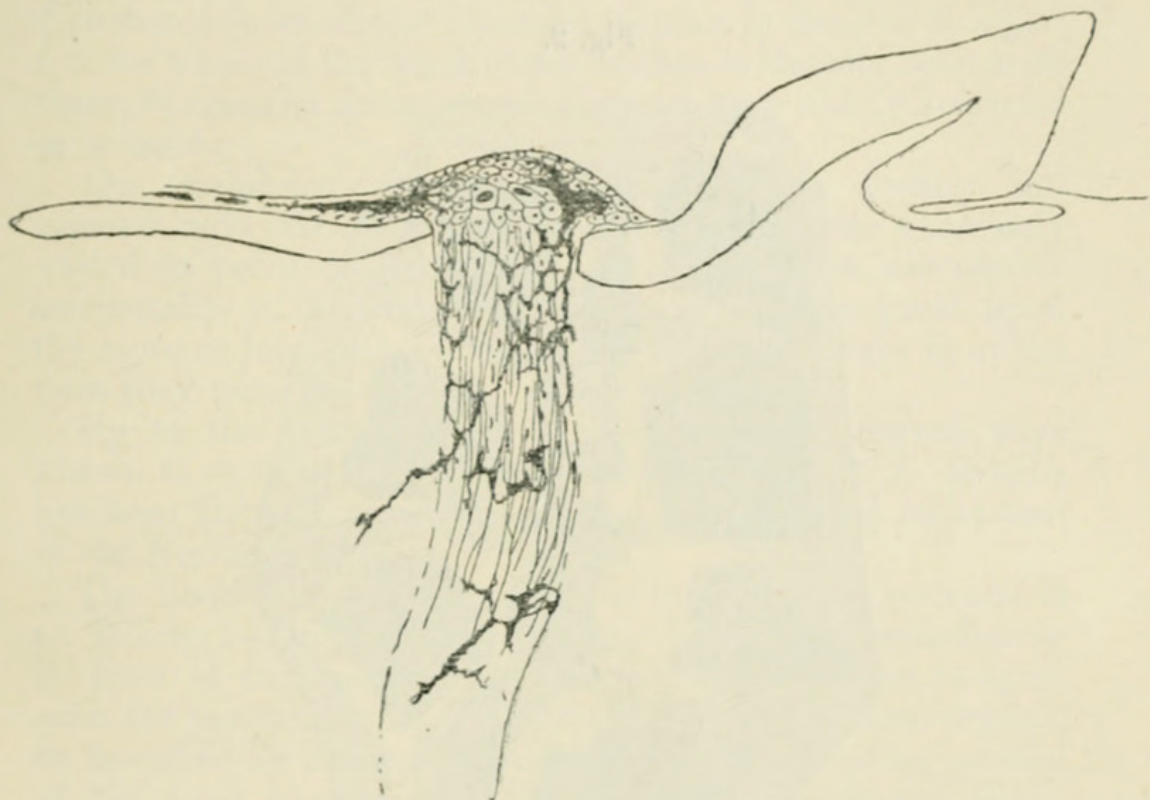
The transverse section made through the luminous organ of *Læmargus rostratus* (fig. 1) shows an epidermal swelling, projecting crater-like above the ordinary level of the epidermis. Beneath a few layers of epidermal cells of normal texture are some which contain a prismatic corpuscle. The actual limit

* It should be stated here that with regard to its outer appearance *Spinax* has repeatedly been the victim of misrepresentation, *f. v.* :—

1. In the figure which Rafinesque gives of it, by having three gill-openings only.
2. Its natural colours were quite unknown to all iconographers of fishes, from Bonaparte to Fries.
3. In being represented with its abdomen turned upwards in Moreau's drawing, without any reasons given for so doing.

between the epidermis and the cutis could not be established with precision on material which had been preserved in a solution of formalin. Certain it is that here, too, an incursion of large pigment-cells into this prominence took place by means of the strand leading to it, and which itself is enveloped

Fig. 1.



Microscopical section of the luminous organ of *L. rostratus*.

by them. This strand seems to consist of a fibrous tissue admitting a nerve of considerable size. On comparing it with the luminous organ described by Johann, it appears to me in process of atrophy, and may possibly be met with only in a state of perfect development in the fully gestated embryo, afterwards becoming resorbed.

Fig. 2 shows the luminous organ in correlation with the surrounding scales. From a bulbous centre, which latter represents the swelling seen in fig. 1, extend on two sides some epithelial strands which are covered by pigment.

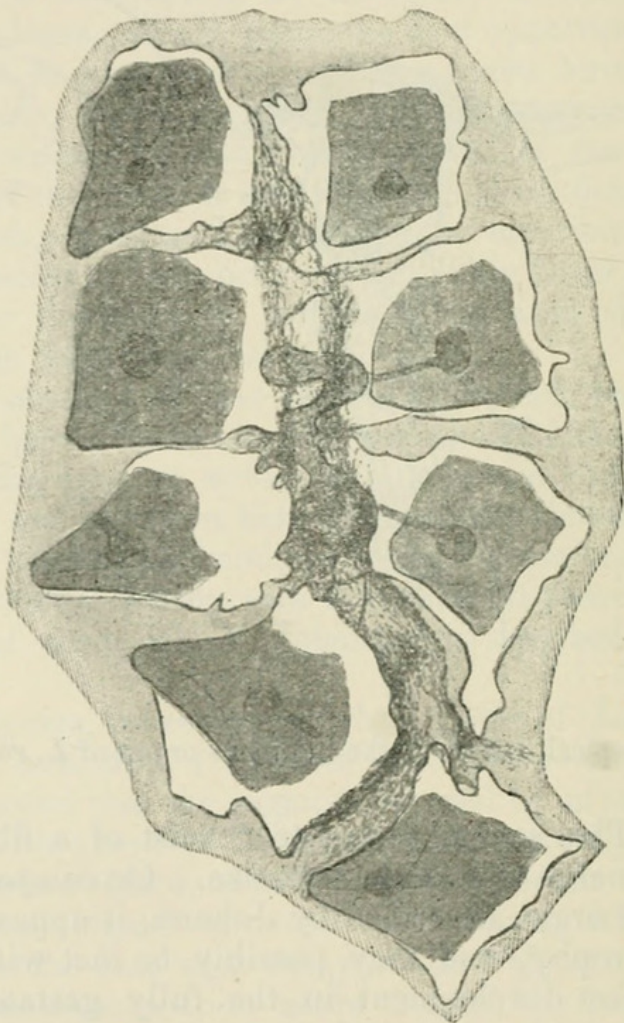
These scales differ from the normal ones in the following points:—

(1) By having a more abundant pigmentation of their pulpa, thus making the parts which these organs occupy, and which are already prominent under ordinary macroscopical observation, more conspicuous.

(2) By having their apices blunter than is the case with the normally constituted scales, in particular those rows of scales which are situated orally with respect to the luminous organs.

(3) By their base not terminating in a simple rhomboidal edge, but possessing finger-shaped projections which secure for these organs a firmer hold.

Fig. 2.



Scale-bases and pigment of the luminous organ of *L. rostratus*.

In *Lamargus borealis* the luminous organ appears to have arrived at a stage of further reduction because its histological structure is more vestigial still than is the case with that described by Johann.

Besides this, the scales which surround the luminous organs of this species differ from the normal ones in their stronger pigmentation only and in being more crowded, but not in variety of form.

I will now proceed to the description of the topographical distribution of these photogenic organs, concerning which it should be said that it differs in every species.

In the genus *Spinax* these organs were discernible, besides in *S. niger*, in *S. pusillus* and *S. granulatus*, of which latter the type is preserved in the British Museum. In *pusillus* they are distributed in an almost identical manner to those in *S. niger*, i. e. the whole of the black under surface is densely beset with them, whereas on the upperside they are very widely dispersed or isolated.

On examining several specimens I was greatly impressed with the fact that these organs appear extremely varied in point of distinctness, variations which are clearly attributable to the amount of pigmentation consequent upon the more or less fresh condition the specimens were in at the time they were preserved.

Up to the present time no phosphorescent organs were known to exist in the genus *Læmargus*, although *L. borealis* has been known for many years and is a common inhabitant of the Northern Seas.

The distribution of these organs in *Læmargus rostratus* is as follows:—On both sides of the head and immediately in front of the opercles are two bands which seem to agree with the posterior crura of a circlet consisting of these organs, as described by Johann to exist on the corresponding portion of the head in *Spinax*. The remaining bands are distributed in irregular swarms, resembling small stripes, which are placed transversely. Accumulations of this kind are situated on the occipital region and also on the base of the anterior dorsal fin orally. Moreover, an irregular row of these organs runs along the body, beginning at the back of the head and ending at the root of the caudal fin a short distance from and above the lateral line. Lastly, there is a short row, composed of seven of these organs, situated below the hindmost gill opening, which converges, together with the one on the other side, towards the ventral median line. Excepting these latter, I have not discovered any more of these structures below the lateral line.

Their distribution in *Læmargus borealis* is similar; but whereas 125 of these structures can be counted on one side of *L. rostratus*, in *L. borealis* their number is 95 only. On comparing their distribution in the two species the following are the principal differences in *borealis*:—

The number of occipital organs is fewer. The prædorsal

Fig. 3.

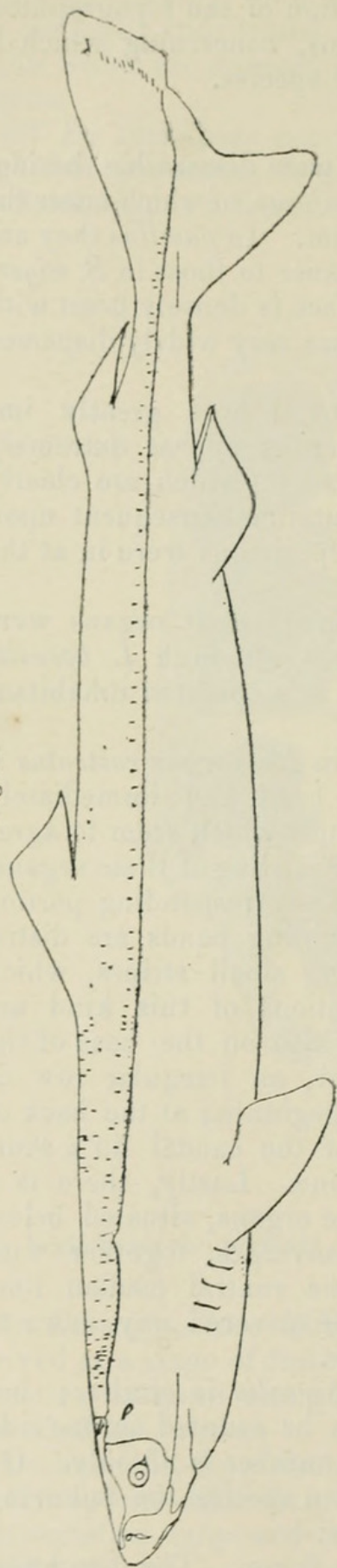
*Læmargus rostratus.* $\frac{1}{4}$ nat. size.

Fig. 4.

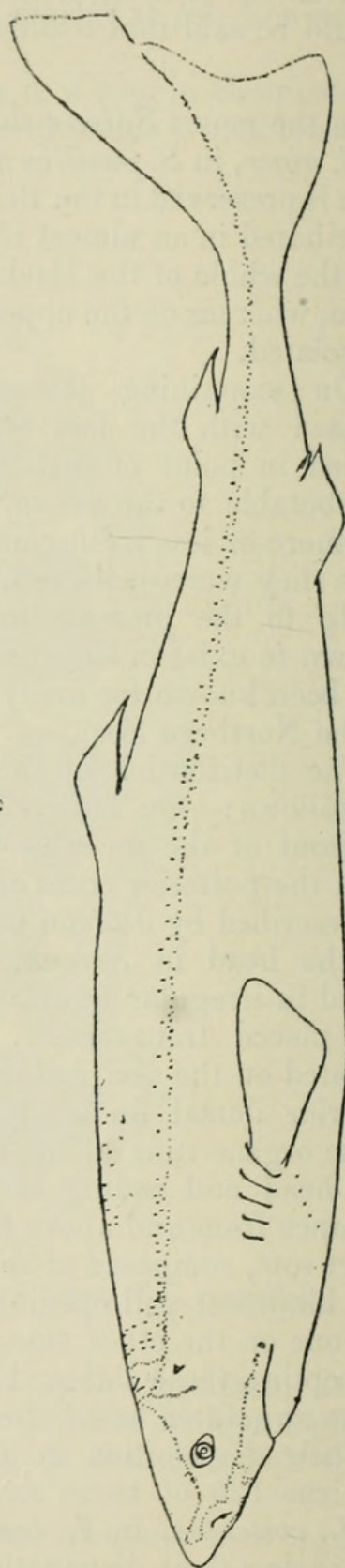
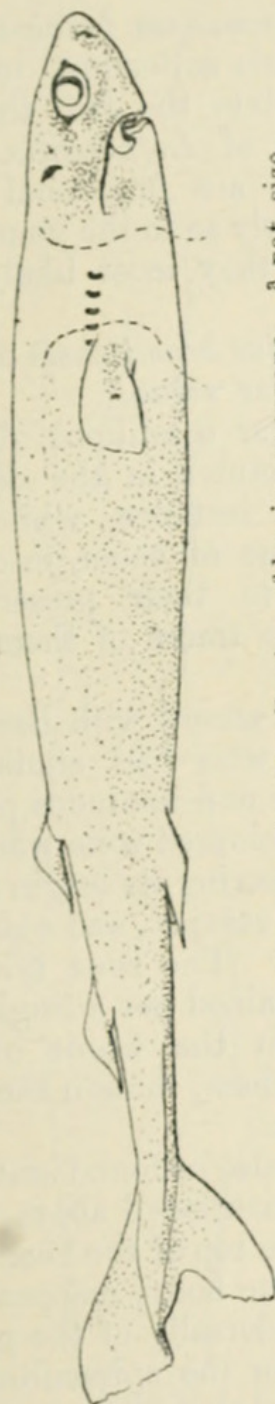
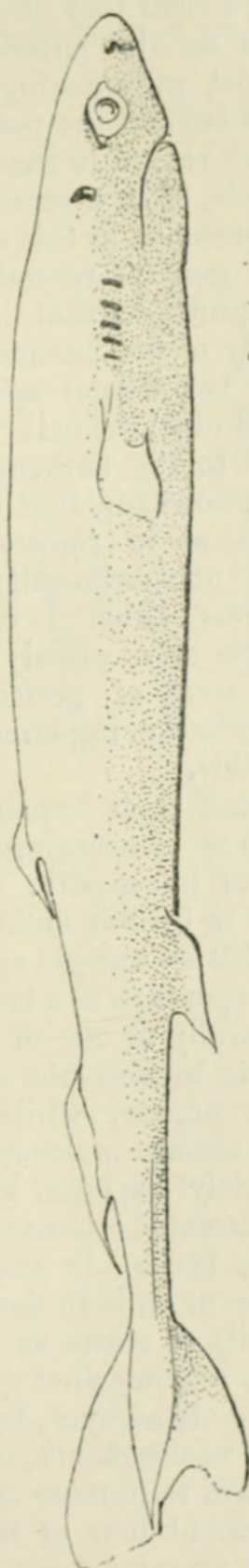
*Læmargus borealis.* $\frac{1}{2}$ nat. size.

Fig. 5.



Isistius brasiliensis. Showing the distribution of luminous organs. $\frac{2}{3}$ nat. size.

Fig. 6.



Euprotomicrus Labordii. Showing the distribution of luminous organs. $\frac{2}{3}$ nat. size.

cluster is slightly removed towards the snout and more reduced than that of *L. rostratus*. I met with some scattered organs on the anterior dorsal fin itself and also above the foremost gill-opening, while the supralateral row does not extend beyond the posterior dorsal.

With regard to these organs in *Læmargus brevipennis*, I was able, from a specimen in the Paris collection, to prove their presence in this species, and to state the fact that they have a general resemblance to those of *L. borealis*. It is quite probable that luminous organs are functional in the majority of the Læmargidæ, but possibly so in the young only of the two larger species, in which they most likely have escaped observation.

It is to the authentication in *Isistius brasiliensis* of these organs, however, that I attach particular value.

Here, as in *Spinax pusillus*, similar conditions obtained for the non-uniformity of these structures in the different specimens which I consulted. For instance, while they could be seen plainly enough in some of them, in others, whose state of perfection previous to their preservation was probably impaired, absolutely no traces of them were perceptible.

I found their expansion in perfect accord with Bennett's statements concerning this species, who had studied its sphere of luminosity. In place of the non-luminous portion referred to by this author a yellowish-coloured zone was even yet visible on the old spirit-specimen, having its origin above the gill-openings in a breadth of about 1 centim., and widening out ventrally to one of about 2 centim. The zone lying in our figure between the dotted lines contained not a single one of these organs, whilst just behind it the whole of the ventral surface is densely beset with them, though they are more widely dispersed towards the back.

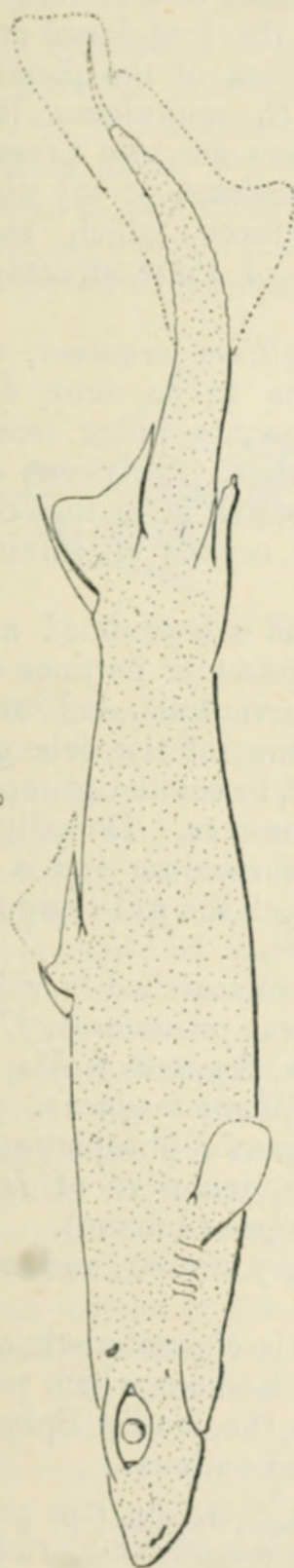
Some isolated organs can nevertheless also be found scattered along the back. In addition to those mentioned above, they further occur on both dorsal fins. On the top of the head they are equally as scarce as on the back of the body, reappearing, however, in somewhat greater numbers dorsally of the posterior angle of the eyes, below the eyes, on the spiraculum, in the angle of the mouth, on the cheeks, and also on the rostrum.

In regard to number these organs stand to the scales in the ratio of about four of the former to one of the latter on the abdomen, as against one to every ten scales on the upperside.

Euprotomiscrus Labordii is only slightly longer than *Isistius*, but considerably darker in colour. Its luminous organs are more strongly pigmented and recall to mind rather those of *Spinax*—though present only on the ventral side, where they are densely massed and quite equally distributed,

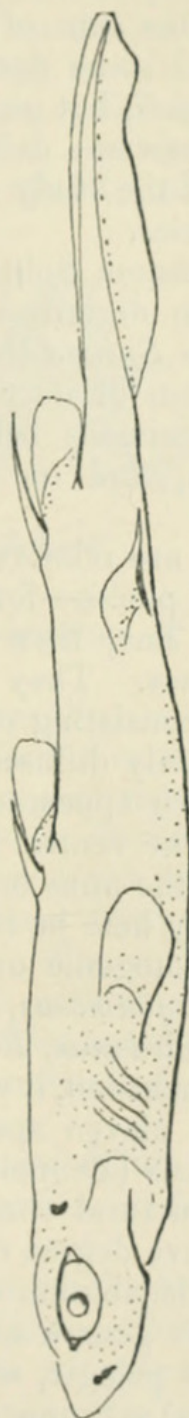
without any interruption on the throat at all. There are no fewer than twelve to every scale, and in some places they accumulate behind each scale in angle-shaped groups.

Fig. 7.



Centroscyllium granulosum, Günth. $\frac{1}{2}$ nat. size.

Fig. 8.



Luminous organs of *Paracentroscyllium ornatum*, Alcock, n. gen. Nat. size.

Dorsally they scarcely reach to the lateral line, which they certainly do not cross.

Centroscyllium granulosum was first described by Dr. Günther. On the type specimen I found the luminous organs

rather evenly distributed over the entire specimen, though somewhat sparser perhaps when compared with forms previously mentioned.

In fig. 7 I was obliged to have recourse to a restoration in part after *Centroscyllium Fabricii* for the first dorsal and the caudal fin, as well as for the distribution of the photogenic organs, the skin of the specimen of *C. granulosum* having sustained some damage. These organs are also present in *C. Fabricii*, but unfortunately the specimen at my disposal was likewise defective, a circumstance which entirely hindered the study of the distribution of these structures in this species.

An oceanic Spinacid, *Paracentroscyllium ornatum*, which has been described by Alcock, seems to be more closely allied to *Spinax* than to *Centroscyllium*, to judge from the description of its colours by this author. Only one of the three specimens belonging to this species is in the British Museum, and on this I found the organs of luminosity present.

They are relatively large in size, and are confined merely to a few places—for instance, on the muscular portions of the pectoral fins, then again on the two ventrals, and on both dorsal ones. They further occur on the inferior lobe of the caudal, consisting of a single row only, in smaller groups and more widely diffused over and below the eyes. Dorsally they make their appearance between the spiraculum and a little beyond the ventral fin, over the whole of the gill-region, and towards the anus on the ventral surface.

It may here be remarked that I have searched in vain for these photogenic organs in *Centrophorus granulosus*, *C. calceus*, *C. squamosus*, *Scymnodon ringens*, *Scymnus lichia*, *Centrina*, *Notidanus*, *Echinorhinus*, and *Chlamydoselache*.

In conclusion, it will be seen that organs of phosphorescence exist in eleven species of Selachians, inclusive of *Isistius brasiliensis* (Bennett) and of *Spinax niger* (Johann).

In structural characters they are very similar, and exhibit a primitive degree of development*.

The distribution of luminous bodies is characteristic of the respective genera and species. All Selachians which possess them are pelagic, and they belong to the family Spinacidæ (Günther) = Spinacidæ + Læmargidæ of authors.

* Luminous organs of a similar form have been described in a Teleostean fish ("The Phosphorescent Organs in the Toad-fish, *Porichthys notatus*, Girard," by Ch. Wilson Green, Journ. of Morphol. vol. xv. 1899). With reference to this I may mention that I have also noticed their existence in the occipital region of the haddock.



Burckhardt, Rudolf. 1900. "LXXII.—On the luminous organs of Selachian fishes." *The Annals and magazine of natural history; zoology, botany, and geology* 6, 558–568. <https://doi.org/10.1080/00222930008678424>.

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