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MUSEUM OF COMPARATIVE ZOÖLOGY

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Vol. XXXII. No. 1.

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Communicated by Alexander Agassiz.

No. XLI.

ON DACTYLOMETRA.

By Alexander Agassiz and Alfred Goldsborough Mayer.

With Thirteen Plates.

CAMBRIDGE, MASS., U. S. A.
PRINTED FOR THE MUSEUM.
April, 1898.

No. 1. — *Studies from the Newport Marine Laboratory.* Communicated by ALEXANDER AGASSIZ.

XLI.

On Dactylometra.

By ALEXANDER AGASSIZ AND ALFRED GOLDSBOROUGH MAYER.

THE genus Dactylometra belongs to the Pelagidæ. At the present time there are four genera of this family known, and they may be distinguished as follows: —

(1)	*Pelagia,*	8 tentacles,	16 marginal lappets.
(2)	*Chrysaora,*	24 tentacles,	32 marginal lappets.
(3)	*Dactylometra,*	40 tentacles,	48 marginal lappets.
(4)	*Melanaster,*	24 tentacles,	48 marginal lappets.

Thirteen species of Pelagia and eight of Chrysaora are known, and they are found distributed among all of the great oceans of the world. There are only two species of Dactylometra, and they are found along the Atlantic coasts of North and South America. The genus Melanaster is represented by but one species, M. Mertensii (L. Agassiz, Cont. Nat. Hist. U. S., 1862, Vol. IV. pp. 126, 166). It was described and figured by Brandt,[1] and is found in the North Pacific.

The genus Dactylometra consists of Pelagidæ with 40 tentacles (3 large and 2 small ones between each successive pair of marginal sense organs), and with 48 marginal lappets (6 between each successive pair of sense organs).

In *Dactylometra quinquecirra* the bell is high, being almost hemispherical in shape. In mature medusæ there are five tentacles between each successive pair of marginal sense organs (Figs. 2–4, 6). Three of these tentacles, the primary and secondary (I, II, II, Fig. 6), arise from the clefts between the lappets, and the other two, which we will call tertiary tentacles (III, III, Fig. 6), are generally seen arising from the

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[1] Brandt, J. F., 1838; Mem. Acad. d. St. Pétersbourg, 6 Série, Tom. IV. p. 385, Pls. XVI. and XVII.

sub-umbrella floor of the ocular lappets; for even in very large medusæ the ocular lappets exhibit only a slight notch, as is seen in *oc*, *oc*, Figure 6, and in Figure 26, Plate X., and only in a very few of the largest and most mature medusæ do we find the ocular lappets divided so that the tertiary tentacles arise from the cleft. This latter condition is shown in Figure 19, Plate IX. It is interesting to notice that these tertiary tentacles do not make their appearance until the medusa is almost mature, when the bell has attained a diameter of 130 mm., and even then many of them fail to develop into anything more than mere filaments of very short length, such as are shown in Figure 4, Plate IV., and Figure 27, Plate IX. Indeed they never grow to a greater length than is seen in Figure 6, which represents their condition in a medusa measuring 190 mm. across the disk. These rudimentary tentacles stand in striking contrast with the primary and secondary ones, which, when fully extended, attain a length of from three to four times the diameter of the disk.

In common with all other Pelagidæ, there are eight marginal sense organs in Dactylometra; four of these occupy the primary, and four the secondary radii. They are set into little niches in the edge of the bell, and project downwards from the oral surface. Figure 7, Plate VII., represents the sense organ as seen from the oral side, and Figure 8 is a somewhat diagrammatic longitudinal section, showing the so called "olfactory pit" (*opt*), which projects downwards from the upper surface of the bell just above the region of the sense organ. As was long ago pointed out by L. Agassiz, these sense organs are morphologically nothing more than little hollow tentacles, the entoderm of which contains a mass of otolythic concretions (*con*, Figs. 7, 8, and 9).

The mouth opening (*M*, Figs. 6, 31, Plates VI., IX.) is cruciform, and occupies the centre of the oral surface of the disk. It is surrounded by four oral fringes, or palps, which occupy the secondary radii, and when fully expanded attain a length of about three or four times the diameter of the disk itself. Fewkes[1] is mistaken in stating that the oral appendages are "of *two* kinds, four of which are quite long, floating gracefully along after the medusa as it swims in the water. The remaining oral appendages being shorter, more ruffled, and confined to the immediate vicinity of the mouth." He was evidently deceived by observing a peculiar state of contraction of the oral fringes, for their shape is constantly changing. Sometimes one sees them as beautifully

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[1] Fewkes, J. W., 1881; Studies of the Jelly Fishes of Narragansett Bay, p. 173 Bull. Mus. Comp. Zoöl., Vol. VIII. pp. 142–182, 10 Plates

fimbricated pennants trailing in long graceful curves far behind the medusa, and at other times they are drawn up into a shapeless mass about the medusa's mouth. A view of the free extremity of one of the oral fringes is given in Figure 30, Plate XI.; and a good idea of their general structure and appearance may be obtained from Figures 1, 2, and 4. Small wart-like protuberances (Fig. 29, Plate XI.) are found scattered thickly over the outer surface of the oral fringes; they consist of clusters of nematocysts and red colored pigment granules.

The plan of the stomach is represented in Figure 15, Plate VIII. It occupies a large space in the midst of the umbrella, and consists of a wide central cavity from which radiate outwards sixteen simple pockets (r, r', r, r', etc.). These pockets are separated from one another by sixteen radiating partitions or septæ (*rp*, Figs. 6, 15, and 33), which join the upper and lower walls of the umbrella together. These radial partitions contain numerous muscle fibres, by the contraction of which the rhythmical movements of the bell are produced. From an inspection of Figure 15 it will be seen that eight of the pockets (r, r, r) of the stomach lead out into the sense organs, and that the eight others (r', r', r') lead out into the tentacles; indeed, the tentacles are hollow throughout almost their entire length, and their entoderm is ciliated exactly as is that of the stomach itself.

The genital products are contained in four radially situated infoldings of the oral wall of the stomach, and their position is marked upon the oral floor of the disk itself by the four deeply sunken sub-genital pits (*gpt*, Figs. 6, 14, 17, 18, 23, and 25). Figures 14 and 23 are somewhat diagrammatic sections of the medusa, intended to show the manner in which the genital organs fold inwards into the cavity of the stomach. Figure 14, Plate VIII., represents a section through the centre of the sub-genital pit and the pocket of the stomach; while the section represented in Figure 23, Plate X., passes through the edge of the sub-genital pit, and through the centre of one of the septal partitions. A view looking down upon one of the genital organs, the exumbrella being removed, is given in Figure 17, Plate IX. In this figure part of the genital epithelium is represented as torn away in order to show the opening of the sub-genital pit (*gpt*) lying below. It will be seen from an inspection of Figures 14, 16, 17, and 23 that the genital organs are furnished with numerous gastric cirri (*gc*) which project inwards into the cavity of the stomach. A view looking down upon the surface of the ovary is given in Figure 34, Plate XI., where we see the immature eggs of various sizes attached by peduncles to the ovarian wall. A section of one of these immature eggs, drawn from a specimen killed in Flemming's fluid and stained in Kleinenberg's hæmatoxylin, is given in Figure 11, Plate VII. The protoplasm is finely granular, the nucleus large and vesicular, and the nucleolus contains about half a dozen deeply staining highly refractive granules. Figures 12 and 13, Plate VII., represent young scyphostomæ, one of which possesses two and the other four tentacles. The older one is 1.5 mm. in height.

The medusa is provided with two well differentiated sets of radially arranged muscle fibres. The principal set is found in the septæ of the oral surface of the disk (*mso*, Figs. 6 and 33, Plates VI. and XI.), and the other set is found in the exumbrella *me*, *me'*, Fig. 6, and also Figs. 2–4), and alternates in position with the set in the oral septæ; so that there are sixteen radial strands of muscle fibres in the sub-umbrella alternating with sixteen strands in the exumbrella. It will be seen that of the sixteen exumbrella muscle strands, eight (*me*, Fig. 6) go to the sense organs, and eight (*me'*) to the primary tentacles.

Clusters of nematocysts are found in the numerous wart-like protuberances (Figs. 24 and 29, Plates X. and XI.) which are thickly scattered over the exumbrella surface of the disk, the palps, and the tentacles. These protuberances are thickly clustered near the centre of the disk, where they appear as little hemispherical projections above the general surface; near the outer edges of the disk, however, they are elongate in shape, and at the extreme edge they are again hemispherical (see Figs. 19, 26, 28, and 32). If a weak solution of picric acid in 50% alcohol is allowed to permeate the sea water in which the medusa is living the nematocysts are exploded with great energy. Ordinarily they then present the appearance shown in Figure 21, Plate IX., but occasionally one finds one resembling that shown in Figure 22, where the main shaft of the thread is tightly coiled in a right-handed helix, and a small ellipsoidal mass of protoplasm (*p*) is borne upon the free extremity. It is very difficult to imagine how such a thread could be turned outward in the ordinary manner, and it is probable that the extreme stimulation caused by the picric acid produced an abnormal discharge of the nematocysts. The nematocysts which exhibited this peculiar structure were invariably immature in development, and were only about one tenth as numerous as the ordinary normal ones.

An idea of the color of the medusa may be obtained from Plates II. and III. In some individuals the general color of the disk is yellowish with a bluish opalescence, while in others it is decidedly pinkish; and it is interesting to notice that when the pinkish ones have been confined in an aquarium for a few days they lose their bright color and fade into a dull yellow. Indeed, if the medusa be kept in an aquarium without food for about six weeks, its disk shrinks to about one eighth of its former diameter, and all color fades away until it becomes transparent. The aboral surface of the disk is thickly sprinkled over with light ochre-yellow spots, caused by protuberances bearing masses of nettling cells; and in addition to these there are sixteen radially arranged regions of reddish brown spots, lying just above the radial septæ of the stomach (see Figs. 2, 3, and 5). These reddish regions usually extend for about half way from the periphery of the disk towards the centre, and a closer examination shows that they are caused by highly refractive rosin colored pigment granules which are contained in the protoplasm of the epithelial cells of the disk (see Fig. 20, Plate IX.). In this respect indeed, according to McKendrick,[1] they are similar to the red pigment spots of Chrysaora. The male genital organs are usually decidedly pink in color, while the ovaries are often yellowish, or ashy gray. The bands of muscles in the radial septæ are of a glistening white. The ectoderm of the tentacles is ochre-yellow, and the entoderm is often pink. The oral fringes are often yellowish, with a delicate shade of opalescent blue in certain lights. In other individuals, however, they are of a delicate shade of pink, and they are always sprinkled over with red colored pigment spots similar to those of the aboral surface of the disk. The marginal sense organs are usually white in color.

The habits of this medusa have already been described by A. Agassiz,[2] who says: "It is somewhat strange that almost all of the Medusæ which have been observed were found in the brightest sunshine only, or in very dark nights. Early in the morning, and until about ten o'clock, even on clear days, medusæ do not make their appearance, while from eleven until one or two o'clock they can be caught in abundance. After this time they disappear gradually, and late in the afternoon it is rare to see a single jelly-fish. Between nine and ten o'clock they come to the surface again; and that hour, in fact, is one of the most favorable for collecting, in spite of the darkness." When the medusæ are confined in the stale water of an aquarium they often assume the position shown in Plate V., where the disk is flattened out to an extreme degree, the palps are spread out over the floor of the aquarium, and the tentacles droop listlessly downward. In this position the medusa often remains

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[1] McKendrick, J. G.: Coloring Matter of Medusæ. Journ. of Anat. and Physiol., 1881, Vol. XV. pp. 261–264.

[2] North Am. Acal., 1865, p. 49.

motionless for a long time, and one is almost forced to compare it with a round flat table supported upon numerous legs.

This medusa makes its appearance on the southern coast of New England at about the first of August. The diameter of the disk is then about 50 mm., and there are only three tentacles between each successive pair of eye spots, so that it might well be mistaken for a Chrysaora, were one unacquainted with its future development. The medusæ increase both in size and numbers until about the middle of September, after which time they begin to disappear, although a few may still be found as late as the middle of October. The diameter of the disk of the full grown medusæ is often as great as 250 mm. In common with many other Discophoræ this species seems to prefer the relatively impure water of bays and narrow estuaries. It is very common in the upper reaches of Narragansett Bay near Tiverton, while in the relatively purer water of the lower bay it is generally rarer.

The medusa has also been found at Nantucket (Desor); Naushon (A. Agassiz); Bermudas (A. S. Bickmore); between the Bermudas and the Azores (J. Drayton); and a well marked southern variety from Beaufort, North Carolina (W. K. Brooks).

Two species of fish have been found to accompany this medusa; one of these is a Clupeoid, and the other is the young of the common Butterfish (Stromateus triacanthus). These fish constantly crowd about the medusa, and so persistent are they in following the jelly-fish that they often allow themselves to be dipped up in the net along with their companion.

The relations between the fish and the medusa, however, are far from symbiotic, for the fish gorge themselves with fragments of the tentacles and oral fringes, which they tear off from time to time. The medusa, on the other hand, is not wholly unavenged, for every now and then it succeeds in stinging to death and devouring one of its persecutors. The fish which possess this curious habit are rarely more than an inch in length.

An interesting abnormal specimen of Dactylometra quinquecirra was found at Tiverton, Rhode Island, in September, 1896. In this individual there were three oral fringes, six genital organs and sub-genital pits, twelve marginal sense organs, forty-eight marginal lappets, and thirty-six tentacles (three between each successive pair of marginal sense organs).

Dactylometra lactea L. Agassiz.

Plates XII. and XIII., and Fig. 10, Plate VII.

Chrysaora lactea F. Eschscholtz, 1829; Syst. der Acal., p. 81, Taf. VII. Fig. 3.
Dactylometra lactea L. Agassiz, 1862; Cont. Nat. Hist. of U. S., Vol. IV. pp. 125, 126, and 166.
Dactylometra lactea E. Haeckel, 1879; Das Syst. der Medusen, p. 517.
Dactylometra lactea R. von Lendenfeld, 1884; Proc. Linnean Soc. New South Wales, Vol. IX. p. 271.

Dactylometra lactea is the type species of the genus Dactylometra, which was established by L. Agassiz.[1]

We shall confine ourselves to describing the differences which exist between this species and its near ally D. quinquecirra. Figure 35, Plate XII., shows a young Dactylometra lactea in the stage where there are but *four* lappets, and five tentacles between each successive pair of sense organs. In the mature individual (Fig. 36, Plate XIII.), on the other hand, there are *six* lappets and five tentacles between each two sense organs. The tentacles of the mature individuals arise from the notches between the lappets. The primary tentacles when expanded may stretch out to a length of from two to three times the diameter of the bell. The secondary tentacles, however, are only about one half, and the tertiary about one quarter, as long as the primary ones.

The general color of the medusa is a milky white; and the bell is sprinkled over with light ochre-yellow spots, which are clustered thickly about the aboral pole. The genital organs are slightly yellowish, and a faint purplish iridescence is seen playing over the palps. The sense organs are of a brilliant white. A view of one of these sense organs as seen from the under side of the bell is given in Figure 10, Plate VII.

Our figures were drawn from life, from specimens obtained in Havana harbor, Cuba, on February 22, 1893, while on the expedition to the Bahamas in the yacht "Wild Duck."

It is probable that this medusa is the species found by Eschscholtz in the Bay of Rio Janeiro, Brazil.

The habits of this medusa are remarkable for their extreme regularity; during the morning hours not one of them is to be found, while at about four o'clock in the afternoon they suddenly appear in large numbers, and remain swimming near the surface until long after nightfall. One

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[1] Cont. Nat. Hist. of U. S., 1862, Vol. IV. p. 125.

cannot but wonder how these creatures can live, and thrive, in the disgustingly impure water of Havana harbor. It is, however, well known that the Discophoræ in general seem to prefer the relatively impure waters of bays to that of the open ocean. Dactylometra lactea is much smaller than its northern ally, D. quinquecirra. Fully developed specimens measure only 65 mm. across the disk, while the young individual figured upon Plate IX. was only 40 mm. in diameter.

EXPLANATION OF PLATES.

PLATE I.

Fig. 1. Dactylometra quinquecirra, from a photograph.

PLATE II.

Fig. 2. Side view of Dactylometra quinquecirra, ½ natural size. Specimen found at Tiverton, Rhode Island.

PLATE III.

Fig. 3. Aboral view of a mature male Dactylometra quinquecirra, measuring 190 mm. in diameter. Tiverton, Rhode Island.

PLATE IV.

Fig. 4. Oral view of Dactylometra quinquecirra. One of the oral fringes is cut away in order to expose to view one of the sub-genital pits (see *gpt*, Figs. 5, 13, 16, 17, 22, and 24). From a specimen found at Tiverton, Rhode Island, measuring 130 mm. in diameter.

PLATE V.

Fig. 5. Side view of a Dactylometra quinquecirra which has been confined for a considerable length of time in the stale water of an aquarium. The bell is greatly flattened and expanded, and the oral fringes and tentacles lie spread out over the aquarium floor. The specimen here represented is in the "Chrysaora" stage of development; i. e. there are only three tentacles, and four lappets between each successive pair of sense organs.

PLATE VI.

Fig. 6. Oral view of an octant of the disk of a mature Dactylometra quinquecirra: natural size. The oral fringes are cut off in order to show the shape of the mouth opening (*M*); *gen*, genital organs; *gpt*, sub-genital pit; *me* and *me′*, muscles of exumbrella; *mso*, muscles of sub-umbrella; *rp*, radial partitions of stomach; *oc*, ocular lappets; *t*, tentacular lappets; I, II, III, primary, secondary, and tertiary tentacles respectively.

PLATE VII.

Fig. 7. Sense organ of Dactylometra quinquecirra, as seen from the oral side of the disk.

Fig. 8. Longitudinal section of the sense organ. *opt*, "olfactory" pit; *con*, otolythic concretions; *ect*, ectoderm; *ent*, entoderm.

Fig. 9. Otolythic concretions from the sense organ of Dactylometra quinquecirra.

Fig. 10. Oral view of sense organ of Dactylometra lactea.

Fig. 11. Section of immature egg from ovary of Dactylometra quinquecirra.

Figs. 12 and 13. Young scyphostomæ of Dactylometra quinquecirra, with two and four tentacles respectively.

PLATE VIII.

Fig. 14. Longitudinal section of Dactylometra quinquecirra through the centre of two of the sub-genital pits. *gc*, gastric cirri; *gpt*, sub-genital pit.

Fig. 15. Plan of the stomach of Dactylometra quinquecirra. *r*, *r′*, *r*, *r′*, pockets of the stomach; *rp*, *rp*, radial partitions of stomach.

PLATE IX.

Dactylometra quinquecirra.

Fig. 16. View looking down upon a small portion of the genital organs to show gastric cirri (*gc*).

Fig. 17. View looking down upon one of the genital organs, the exumbrella being removed, and part of the genital epithelium being torn away in order to expose the opening of the sub-genital pit (*gpt*).

Fig. 18. Side view of oral fringes facing a primary radius.

Fig. 19. Aboral view of ocular lappets and tertiary tentacles. Showing the tentacle arising from a cleft in the lappet.

Fig. 20. Section 6.6μ thick, through one of the red pigment spots of the exumbrella surface of the disk. The pigment appears as small highly refractive rosin colored granules in the protoplasm of the epithelial cells. Nematocystic capsules of various sizes are situated between the epithelial cells.

Fig. 21. An exploded nematocyst.

Fig. 22. A young and probably immature nematocyst exploded under the stimulus of picric acid.

PLATE X.

Dactylometra quinquecirra.

Fig. 23. Longitudinal section through edge of sub-genital pit and centre of one of the radial septæ of the stomach.

Fig. 24. One of the wart-like protuberances of the exumbrella surface of the disk, showing pigment granules and clusters of nematocysts.

Fig. 25. Side view of oral fringes seen facing a secondary radius.

Fig. 26. View of ocular lappet and tertiary tentacle, showing a slight cleft in the lappet.

Fig. 27. Enlarged view of the tertiary tentacle shown in Figure 26.

Fig. 28. Oral view of primary tentacle. The tentacle is hollow.

PLATE XI.

Dactylometra quinquecirra.

Fig. 29. One of the wart-like protuberances, consisting of nematocystic capsules and pigment cells, found upon the oral fringes.

Fig. 30. Free extremity of one of the oral fringes.

Fig. 31. Oral fringes cut off to show shape of mouth opening (*M*).

Fig. 32. Aboral view of primary tentacle showing also dark-red pigment spots on disk.

Fig. 33. Oral view of radial septum (*rp*) of the stomach. *mso*, muscles in radial septum.

Fig. 34. View looking down upon genital epithelium of ovary showing mode of attachment of eggs of various sizes.

PLATE XII.

Fig. 35. Side view of a young Dactylometra lactea. There are only 4 lappets between each successive pair of sense organs, instead of 6, as in the mature medusa. $\frac{1.5}{1}$, natural size.

PLATE XIII.

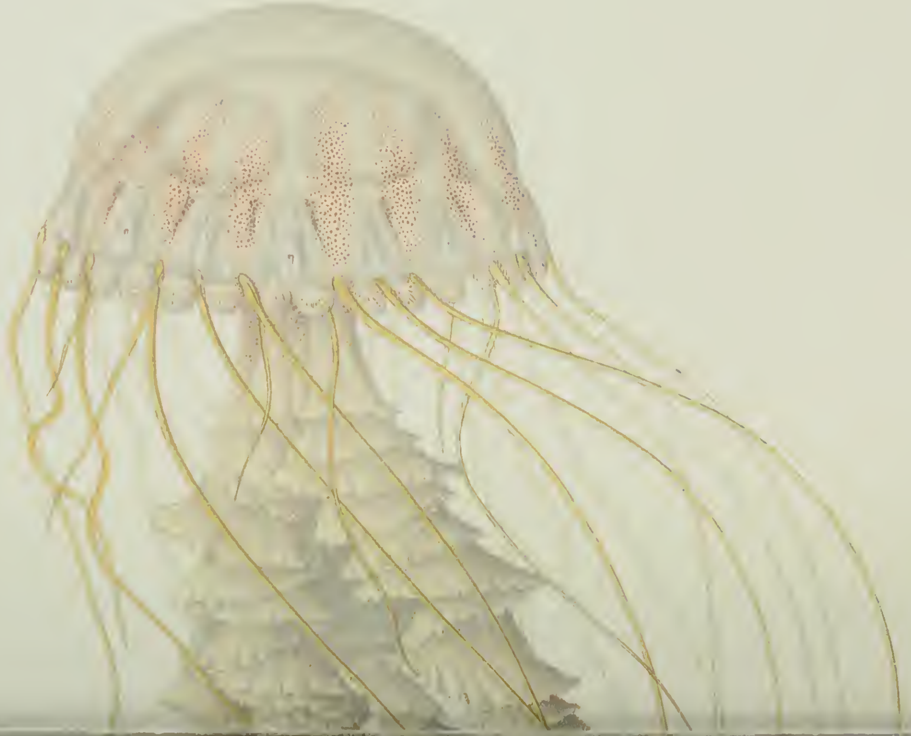
Fig. 36. Oral view of a mature Dactylometra lactea. Natural size.

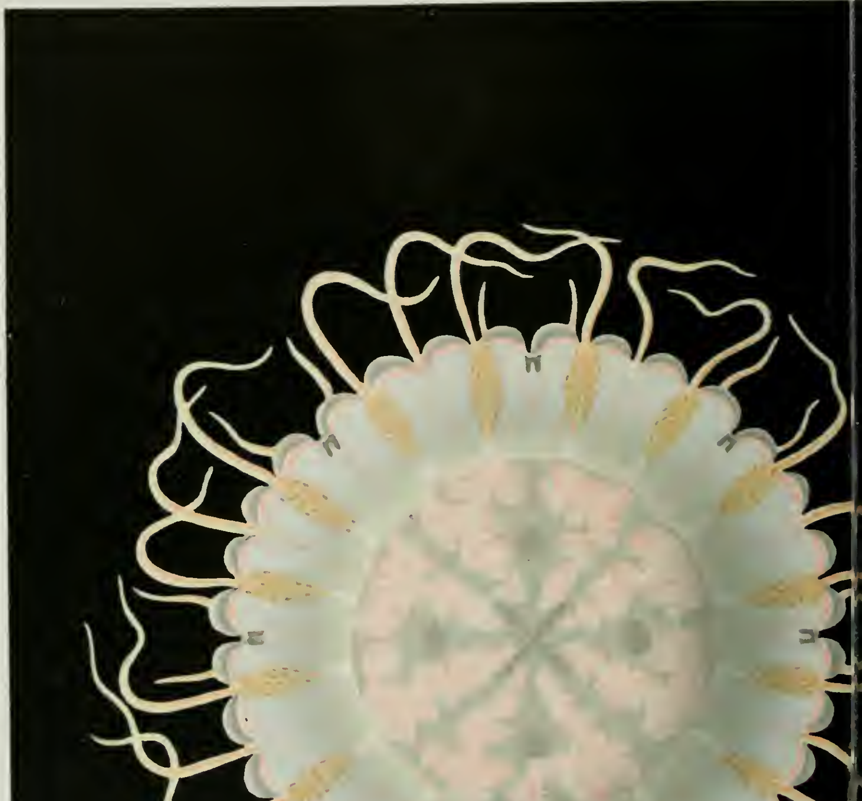
CHILD, PHOTO

ARTOTYPE E. BIERSTADT, N. Y.

DACTYLOMETRA

PL. II

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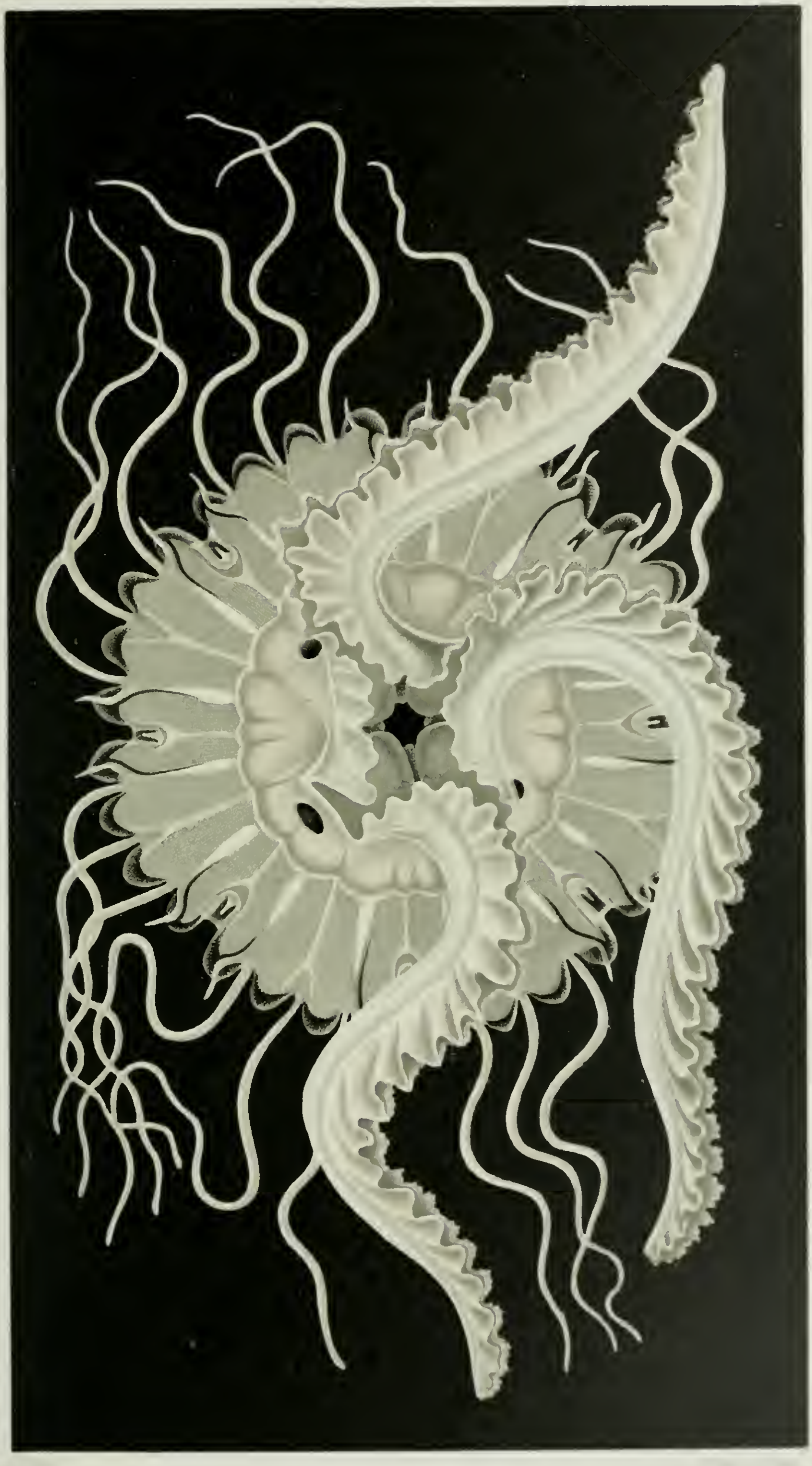
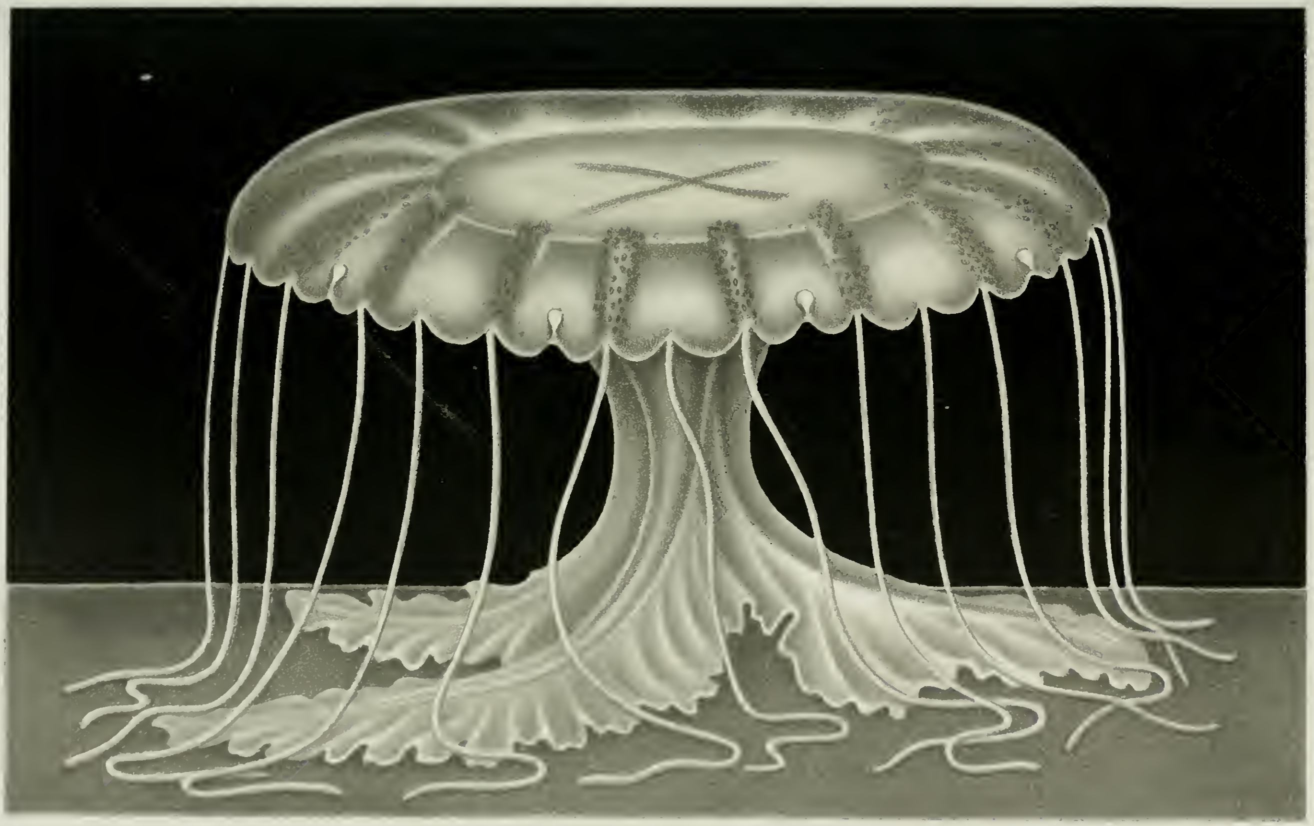


DACTYLOMETRA

PL.V

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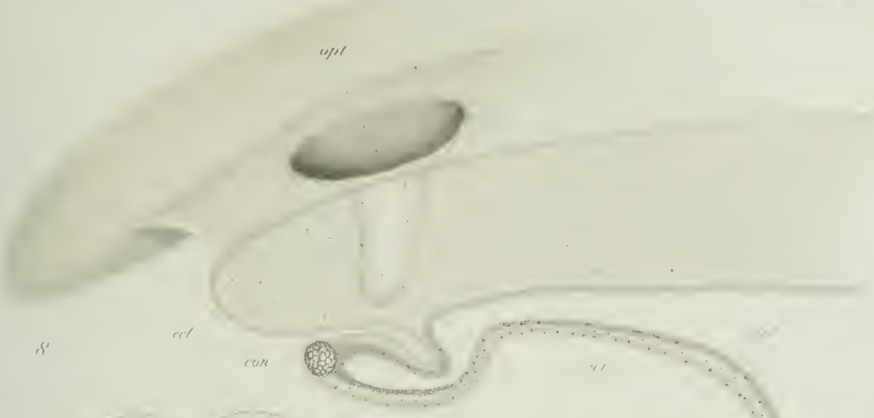

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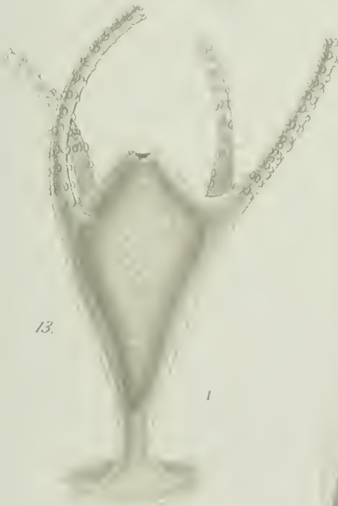

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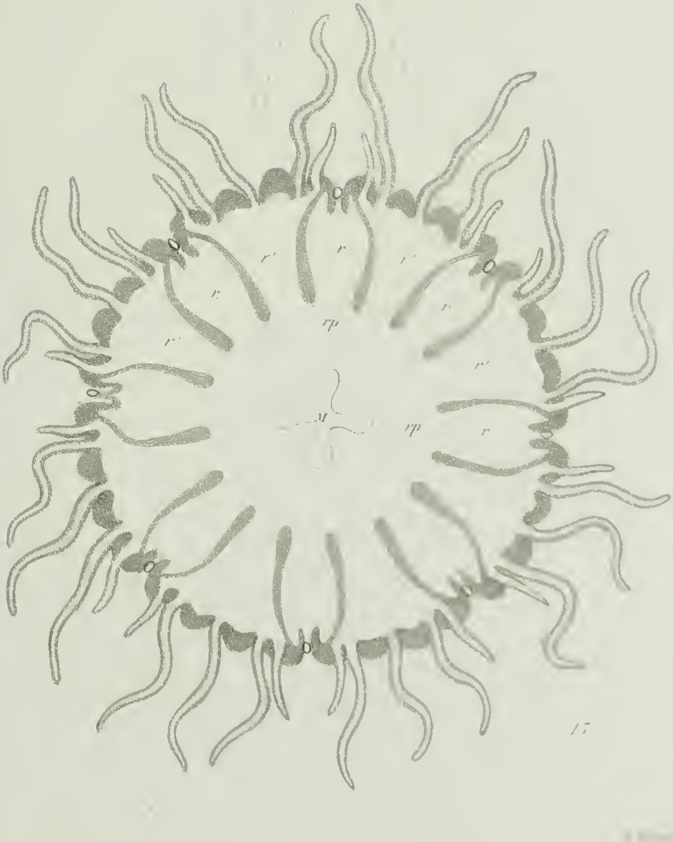

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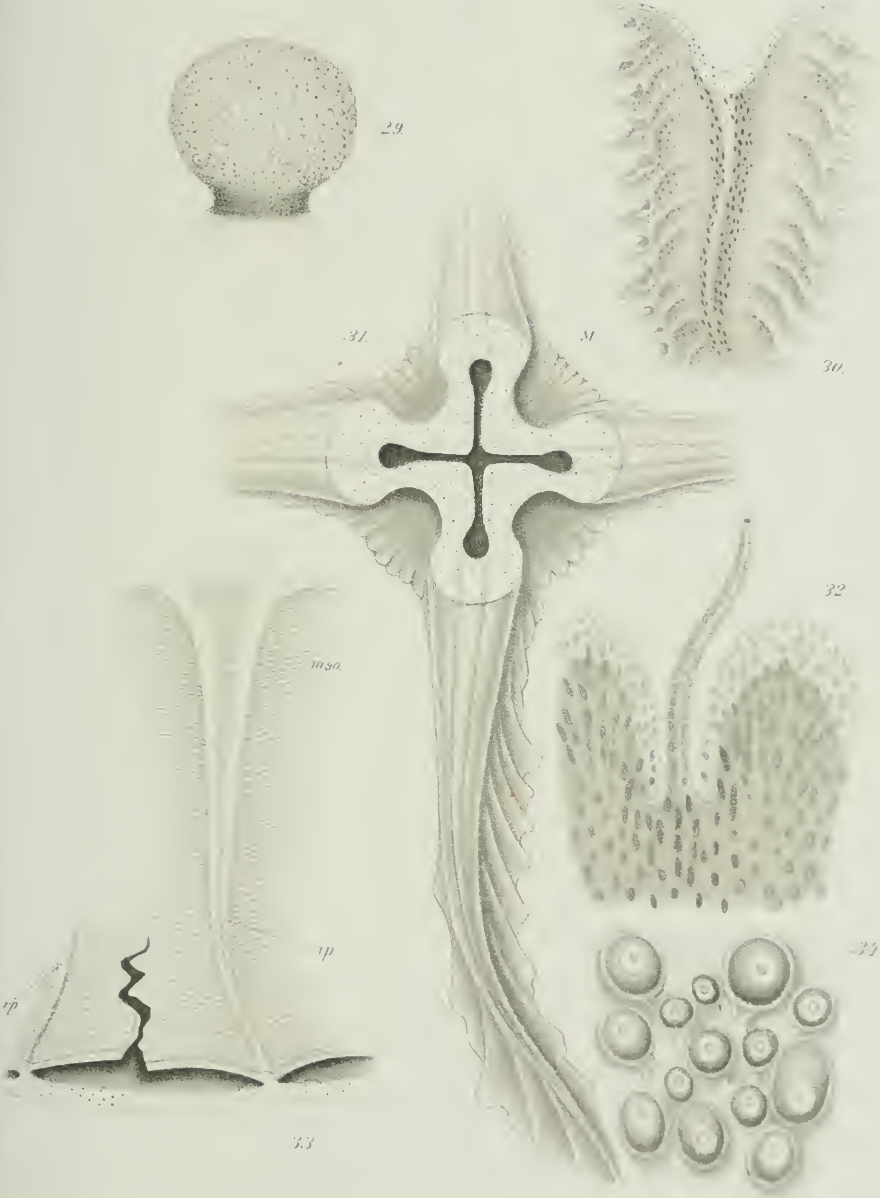
DACTYLOMETRA

Pl. X.



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Vol. XXXII. No. 2.

ON SOME MEDUSÆ FROM AUSTRALIA.

By Alexander Agassiz and Alfred Goldsborough Mayer.

With Three Plates.

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No. 2. — *On some Medusæ from Australia.* By Alexander Agassiz and Alfred Goldsborough Mayer.

The medusæ described in the following paper were obtained while accompanying Mr. Agassiz during his recent visit to the Great Barrier Reef of Australia in April and May, 1896. Our course lay along the Queensland coast between the Great Barrier Reef and the mainland as far north as Lizard Island. Unfortunately, the season of the south-east Monsoon is far from favorable for collecting pelagic animals, as the winds blow a brisk gale almost incessantly and the water is much disturbed.

The few hauls of the surface net were all very similar, and brought to light large numbers of Sagittæ and Copepods, and a few Appendicularia, Doliolum, and Decapod larvæ. The only Cœlenterates found were several specimens of a Rhegmatodes, and a Mertensia. Two Discophoræ were found during our cruise. One of these is a new species, for which we propose the name Desmonema rosea, and the other is Crambessa mosaica Haeckel.

Desmonema rosea, nov. sp.

Plate I. Fig. 1.

The genus Desmonema was established by L. Agassiz.[1] It contains Cyaneidæ with eight sense organs, and numerous tentacles which are arranged in eight bunches arising from the sub-umbrella. The tentacles of each of these bunches are arranged, one after the other, in a single row. The margin of the bell possesses eight principal lappets and sixteen to thirty-two secondary lappets.

An oral view of Desmonema rosea is given in Plate I. Figure 1. The bell is rather flat, being about twice as broad as it is high. The eight primary lappets are separated from one another by deep clefts, which extend inwards for about a quarter of the distance from the margin of the bell towards the centre. There are thirty-two small, smoothly rounded, secondary lappets.

The eight marginal sense organs are sunken in long narrow niches lying in the oral floor of the sub-umbrella.

The tentacles are arranged in eight crescent-shaped rows, lying between and alternating with the eight primary lappets of the disk. There is but a single row of tentacles in each of these crescents.

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[1] Agassiz, L., 1862; Contrib. to Nat. Hist. of U. S., Vol. IV. p. 166.

The muscles of the oral surface of the disk are very conspicuous, and are arranged in sixteen bi-forked bundles, containing both circular and radial muscle fibres. The bundles lying adjacent to the tentacles are about twice as broad as those that lie near the sense organs.

The genital organs protrude from the oral surface of the disk as four complexly fimbricated sacs. The four oral fringes are very wide, and their free edges are sharply folded.

The general color of the substance of the disk is a delicate opalescent yellow, reminding one of the mediæval glass of Venice. The muscle system of the oral wall of the bell is of a delicate pink, as are also the genital organs. The oral fringes are of a most exquisite and delicate rose-color, and the entoderm of the tentacles is port-wine colored. The sense organs bear an intense orange pigment. The diameter of the disk is 180 mm. The medusa was found swimming in great numbers in Largs Bay, near Adelaide, South Australia, on May 29, 1896.

This species is similar in some respects to Cyanea Muellerianthe, that was described by Haacke[1] from the Gulf of St. Vincent. C. Muellerianthe is, however, smaller than Desomnema rosea ; the shape of the marginal lappets and muscle bands is different, and, above all, there are several rows of tentacles in each crescent, instead of a single row, as is characteristic of the genus Desmonema. It also bears some resemblance to Cyanea annaskala, von Lendenfeld.[2]

Crambessa mosaica Haeckel.

Plates II. and III.

Cephea mosaica Quoy et Gaimard, 1824 ; Voyage de l'Uranie, Zoologie, p. 569, Plate 85, Fig. 3.

Rhizostoma mosaica F. Eschscholtz, 1829; System der Acalephen, p. 53. T. H. Huxley, 1849; Phil. Trans. Roy. Soc., pp. 422, 432, Plate 38 (Figs. 26, 27), Plate 39 (Figs. 28–34).

Catostylus mosaicus L. Agassiz, 1862 ; Contrib. to Nat. Hist. of U. S., Vol. IV. p. 152. Grenacher und Noll, 1876 ; Abhandl. Senckenberg. Ges., Bd. X. p. 38.

Catostylus Wilkesii L. Agassiz, 1862 ; Contrib. to Nat. Hist. of U. S., Vol. IV. p. 152.

Crambessa mosaica E. Haeckel, 1879 ; Das System der Medusen, p. 622. R. von Lendenfeld, 1883 ; Zeitschrift für Wissen. Zool., Bd. XXXVIII. p. 635. R. von Lendenfeld, 1884 ; Proc. Linn. Soc. New South Wales, Vol. IX. Part II. p. 299. R. von Lendenfeld, 1884 ; Proc. Linn. Soc. New South Wales, Vol. IX. p. 926 ; Medusæ of the Australian Seas, Part I. p. 30, Sydney, 1887. Zeit. für Wissen. Zool., 1888, Bd. XLVII. Heft 2, pp. 213, 231–242, Pls. 19, 21, 23–27.

Although so much has been written concerning the anatomy and histology of this medusa, no figure of it has as yet been given, if we except the sketch by Quoy and Gaimard in the Voyage de l'Uranie, Plate 85, Fig. 3. We there-

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[1] Haacke, W., 1887 ; Jenaische Zeitschrift, Bd. XX. pp. 605–614, Plate 36.

[2] R. von Lendenfeld, 1882 ; Zeit. Wiss. Zool., Bd. 37, p. 465, Pl. 27–33.

fore give a figure on Plate II., and a few details of its structure on Plate III., and also a brief description of the Medusa.

When fully expanded the bell is rather flat, being five or six times as broad as it is high. The aboral surface is thickly covered with small granular papillæ, which give it a roughened appearance. The marginal lappets are very numerous, and their number is not very constant, but there are usually 16 between each pair of sense organs, and as there are 8 sense organs, it would seem that the normal number of lappets is 128.

An aboral view of one of the marginal sense organs is given in Figure 3, Plate III. An excellent figure of a longitudinal section has been given by von Lendenfeld ('88, p. 269, Fig. 66).

Four thick pillars extend downwards from the ventral surface of the bell, and support the brachial disk, or subgenital porticus, as it is often called. The brachial disk, in turn, bears the eight mouth-arms (von Lendenfeld, '88, p. 239, Taf. 19, Fig. 10). A drawing of one of these mouth-arms is given in Figure 5, Plate III.; and it is lettered to correspond with von Lendenfeld's Figure 36, Plate 23. The short, simple, upper portion of the arm is indicated by *e*, and *a*, *b*, and *d* show the three wings of the lower arm; *a* being ventral, and *b* and *d* dorsal. A cross section of the lower portion of the arm taken at niveau *ss*, Figure 5, is given in Figure 6. Its lettering is similar to that of Figure 5. A view of the terminal portion of one of the mouth-arms showing the suctorial mouths, surrounded by double rows of small tentacles, is given in Figure 4. In life these tentacles keep in incessant motion, and by this means small particles of food are swept into the numerous suctorial mouths which open at intervals between the rows of tentacles. Good descriptions of the mouth-arms will be found in the papers of Grenacher and Noll ('76),[1] and of Hamann ('82).[2]

The color of this medusa is normally cobalt-blue, but, as was discovered by von Lendenfeld ('84, p. 925), a species of Zoöxanthella commonly infests it, forming dense clusters throughout the jelly; and when this is the case the blue color is lost, and the medusa changes to a brown color, varying from that of white bread to that of coffee. Our figure (Plate II.) shows one of these infested medusæ, and it will be seen that the only trace of the normal color is found in a faint blue line marking the uppermost regions of the suctorial mouths of the mouth-arms. In the estuary of the Brisbane River on May 21 we saw a great number of these medusæ nearly every one of which was of a deep cobalt-blue, while now and then one was seen almost white in color, and still others showed intermediate stages between the deep blue and the white. We found the white or slightly brownish medusæ in the Hawkesbury River near Sydney on April 4; in the harbor of Cairns, Queensland, April 27; and in the Brisbane River, May 21. We also found a small dark brown or coffee-colored

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[1] H. Grenacher und F. C. Noll, 1876; Abhand. d. Senckenberg. Naturf. Gesell., Vol. X. p. 146, Plates I., III.–VII.

[2] O. Hamann, 1882; Jen. Zeit. für Naturwis., Vol. XV. pp. 243–285, 3 Plates.

specimen at Lark Opening, near Cooktown, Queensland, on May 4. The medusa has been found by von Lendenfeld in the harbors of Sydney and Melbourne. In Melbourne Harbor the specimens are blue, while in Sydney they are universally brown or coffee-colored (von Lendenfeld, '88, p. 241). The medusa is evidently common all along the eastern coast of Australia, where it congregates in large numbers in the harbors and brackish estuaries.

Von Lendenfeld found a small species of fish, Trichiurus declivis Jenyns, in "symbiosis" with the medusa in Sydney Harbor. We found the same species accompanying the medusæ collected in Cairns Harbor, Queensland.

The diameter of the disk of full grown medusæ is about 250 mm.

EXPLANATION OF THE PLATES.

PLATE I.

Fig. 1. Desmonema rosea; oral view; $\frac{4}{7}$ natural size.

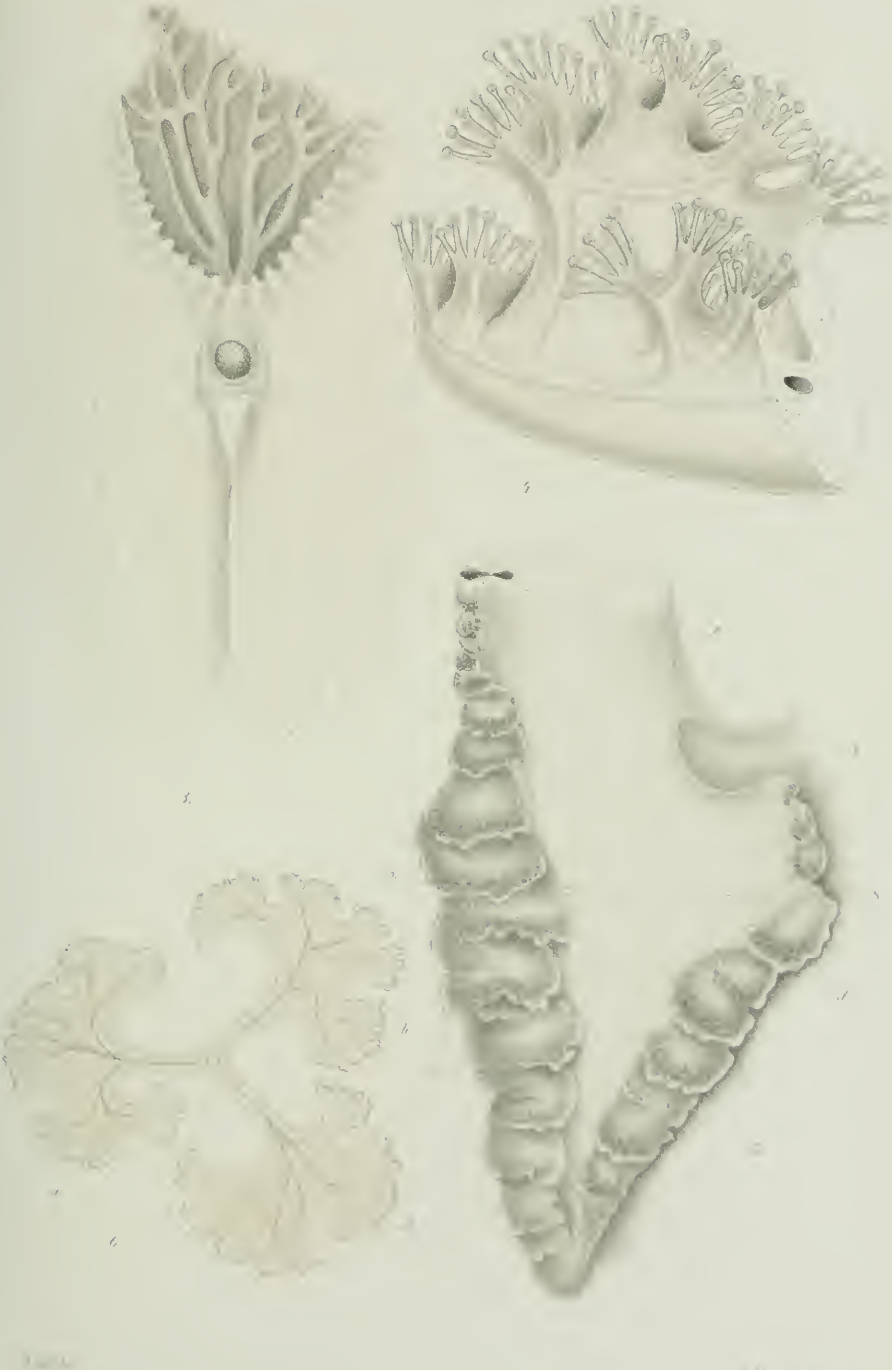
PLATE II.

Fig. 2. Side view of Crambessa mosaica; $\frac{2}{5}$ natural size.

PLATE III.

Crambessa mosaica.

Fig. 3. Aboral view of marginal sense organ.
Fig. 4. Side view of the terminal portion of one of the mouth-arms, highly magnified, showing the suctorial mouths and the furrows bordered by rows of tentacles.
Fig. 5. Side view of a mouth-arm.
Fig. 6. Cross section of one of the mouth-arms.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THE GORDIACEA OF CERTAIN AMERICAN COLLECTIONS.

WITH PARTICULAR REFERENCE TO THE NORTH AMERICAN FAUNA.

BY THOMAS H. MONTGOMERY, JR.

WITH FIFTEEN PLATES.

CAMBRIDGE, MASS., U. S. A.:
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No. 3.— *The Gordiacea of certain American Collections with particular Reference to the North American Fauna.* By Thomas H. Montgomery, Jr.

It has been the intention of the author to pursue certain anatomical studies on *Gordius* and its allies, but this object could not be immediately carried out owing to lack of material, and also to the difficulty encountered in determining the American species. Accordingly it seemed advisable to describe the American species systematically before entering upon an anatomical study of them. It is very apparent that the North American Fauna is very rich in species of *Gordiacea*, and yet the investigation of these interesting forms has been almost wholly neglected by American zoölogists, Joseph Leidy being thus far almost our only writer upon them; and more species are known from South than from North America.

The material for this study was mainly derived from three collections. The Leidy collection, which is the property of the University of Pennsylvania, is the richest of these, and contains some of Leidy's types; my thanks are due to Dr. Charles W. Stiles of the Smithsonian Institution for having kindly forwarded this collection. I would express my obligations to Dr. Alexander Agassiz for permission to examine the excellent collection of the Museum of Comparative Zoölogy at Harvard; and to Dr. W. M. Woodworth for his trouble in sending me this collection. My thanks are further due to Dr. Stiles for specimens from his own and from the Smithsonian collection; and for other specimens to the following gentlemen: Prof. E. G. Conklin, University of Pennsylvania; Prof. Thos. H. Morgan, Bryn Mawr College; Mr. E. G. Vanatta, Academy of Natural Sciences, Philadelphia; and to Mr. Satterthwaite of Westtown, Pa. Further, I would express my thanks to the curators of the Academy of Natural Sciences, Philadelphia, for the opportunity to examine the specimens in this collection. In a previous paper, to appear in April, 1898, in Spengel's "Zool. Jahrbücher," I described two new exotic species from American collections.

Certain of the new species here described were based upon the examination of a single specimen, but of most of them several individuals were studied. It is, in my opinion, less adducive to confusion of nomenclature to preliminarily separate aberrant forms, even though only single specimens are known, than to class them all under one name. This group of worms is difficult of study, the external specific characters are few, and it appears that it is a group in which many of the species are in process of transformation, judging from their amount of variability. Then there are sometimes sexual differences, as well as differences at various times of life. Bearing these points in view, I have laid particular stress upon the following systematic characters: the superficial markings of the cuticle, which have been shown by Villot to present exceedingly valuable and reliable characters, though even the surface of the cuticle is in many forms subject to individual variation; the form of the posterior end in both sexes; and, though this is not as reliable as the preceding character, the form of the anterior end. The presence of median dorsal or ventral grooves along the surface of the body is a less reliable character, and still less so is the coloration. The males are more easily determined than the females; the form of the tail lobes in *Gordius* and the presence or absence of hairs or spines in their neighborhood are of much importance; but in the genius *Chordodes* the form of the posterior end of the male is much more uniform than in the males of the former genus.

A historical review of the previous researches upon the American species will be followed by the descriptions of the species examined.

A. HISTORICAL REVIEW.

1847. Creplin described *Chordodes parasitus*, n. sp., from a Brazilian *Acanthoditis*, but his brief description is altogether insufficient for purposes of identification.

1849. Gay described from Valparaiso, Chile, a *Gordius* (*G. chilensis*) as follows: "Gordius gracilis, cinereo-fuscus, obscurus; capite nigro . . . es de color pardo morenusco oscuro, con la estremidad anterior del cuerpo ó la region cefálica negra; en los manchos la porcion posterior se bifurca mucho." I agree with Camerano ('90) that this diagnosis is wholly insufficient.

1850. Leidy briefly refers a *Gordius* seen by him to the European *G. aquaticus*.

1851. Leidy describes *G. varius,* n. sp., which is distinguished from *G. aquaticus* in that "the caudal extremity of the female is trifurcated, while that of the European species is blunt. The length is from 4 to 12 inches. Of this species there are several varieties from different localities, which may upon further examination prove to be distinct species. . . . A second species of Gordius was obtained by Professor Baird from a spring in Essex County, New York. It is much more delicate than the former, and from 5 to 7 inches long. The female caudal extremity is blunt. The male caudal extremity is bifurcate and fringed with peculiar epidermoid appendages. For this second species the name Gordius lineatus was proposed." In the same year Diesing writes of *G. chordodes,* n. sp.: "Corpus longissimum teretinsculum crassum rigidum, fusco-brunneum. Caput apice rotundatum. . . . Habitaculum. Acanthodis glabrata: in cavo abdominis, in Brasilia (Beschke). Specimen identicum femineum ex aqua in Brasilia hausit (Natterer)." Diesing's species is not sufficiently characterized.

1853. Baird mentions two new species from North America, of which the first is a good species: *G. platyura,* n. sp.: "Body of a uniform dull white color, quite smooth, with a depressed line on one side throughout its whole length, obscurely ringed at unequal distances, narrower at the anterior extremity and terminating in a broad, flattish tail, which is slightly bifid. Length of animal 32 inches, breadth of middle of body about ½ a line; tail 1 line broad. Jamaica?" *G. fasciatus,* n. sp.: "Epidermis granulated. . . . Body smooth, skin prettily shagreened with very fine lines crossing each other in opposite directions, of a light color banded with broad patches of dark brown. Anterior extremity smaller than posterior, and roughened with raised circular ridges, which extend for about three lines, and as well as posterior extremity of a very dark color, almost black. Length 11½ inches, breadth about 1 millimeter." This was a female from North America. I regard this description of *G. fasciatus* as wholly inadequate for purposes of identification, and on this account judge that Römer ('96) is in error in placing it as a synonyme of *G. aquaticus* Linn. Leidy ('53) mentions *Gordii* of a milk-white color as very common in grasshoppers in the vicinity of Philadelphia.

1855. Möbius gives a good description of *Chordodes pilosus,* n. sp. from Venezuela; though he confused the head end with the posterior extremity: length 212 mm., "er . . . nahm aber während neun Tagen, die er noch im Wasser, sich träge bewegend, lebte, um 259 mm. zu, so dass seine Länge, als er todt war, 471 mm. betrug"; tail end swollen, cloacal opening large, circular. Head laterally compressed, somewhat pointed; cuticle with irregular prominences, which are figured. Or, in the words of his own diagnosis: "Corpus nigrum verrucosum, medio cylindricum, utrinque attenuatum depressumque, linea ventrali et dorsali, quarum parti caudali fasciculi pilorum insiti. Caput ellipsoideum, concavitate frontali. Extremitas caudalis trigona, apice rotundata." This is a good species.

1856. Leidy gives a much fuller description of his *G. varius.* He also describes *G. robustus*, n. sp., and places synonymous with it *G. seta* Müll., and *G. lineatus* Leidy.

1857. The same author mentions a collection of 48 *Gordii*, 525 miles west of Fort Riley, Kansas.

1858. Leidy notes the occurrence of an embryo of *G. varius* in *Lumbriculus limosus.*

1861. Diesing regards *G. platyurus* and *fasciatus* Baird as good species; as also *G. varius* Leidy, with which he considers synonymous the "*G. aquaticus*" of Leidy, '51. He considers Leidy's *lineatus* and *robustus* as doubtful synonymes of *G. seta* Müll. (*aquaticus* Linn.). Diesing also describes *G. subspiralis*, n. sp.: "Corpus maris brunneum, feminæ antrorsum attenuatum, læte brunneum, nitidum, iridescens. Caput annulo obscure brunneo cinctum. Extremitas caudalis maris subspiralis crucibus furcæ terminalis divergentibus, incurvatis, lævibus, plica membranacea semilunari ad basin junctis, feminæ obtusa, subcompressa. . . . In palude cum Siredonibus, copiose, in territorio Kansas (Hammond)."

1866. Schneider regards *G. varius* Leidy as a possible synonyme of *G. gratianopolensis* Charvet (*G. tricuspidatus* Meissn.).

1874. Villot regards the following as good species: *G. lineatus, robustus*, and *varius* of Leidy; *G. subspiralis* and *G. chordodes* of Diesing; and *G. chilensis* Blanchard. He describes the following new species from America: — *G. æneus*, n. sp.: "Extrémité antérieure tronquée, légèrement renflée. Ouverture ano-génitale du mâle entourée d'un anneau brun. Lobes bien développés, séparés par un assez large intervalle. Brun bronzé. (Les jeunes individus sont d'un blanc jaunâtre uniforme.) Epiderme divisé en losanges par un réseau de lignes saillantes obliquement croisées"; from Cumana, Venezuela. *G. reticulatus*, n. sp.: "Extrémité antérieure terminée en pointe aiguë. Diamêtre du corps allant en grossissant de l'extrémité antérieure à l'extrémité postérieure, qui se termine en point tronqúee. Ouverture ano-génitale large. Brun marron. Une bande dorsale et une bande ventrale d'un brun plus foncé. Epiderme aréolé. Aréoles formant un réseau à mailles irrégulières et inégales, ayant en moyenne 10 millièmes de millimètre. Une bordure simple de petites papilles autour des aréoles. . . . Californie." *G. prismaticus*, n. sp.: "Grêle et aplati. Extrémité postérieure bilobée. Brun pâle. Epiderme aréolé. Aréoles prismatiques et hexagonales, ayant environ 10 millièmes de millimètre de haut sur 6 millièmes de millimètre de large. Quelques papilles très-petites et très-espacées. . . . Nouvelle-Grenade. Prairie du plateau de Bogota, par 2,600 mètres d'altitude." He also describes *G. deshayesi*, n. sp. from Venezuela.

1879. Weyenbergh gives inadequate descriptions of the following new species from South America: *G. tenuis, dubius*, and *acridiorum*. In the same year Leidy gives a good description of his *G. robustus*, based on specimens from Maryland.

1881. Oerley regards the following American forms as good species: *G. fasciatus* and *platyurus* Baird, *G. æneus* and *trilobus* of Villot.

1885. Jeffrey-Bell mentions *G. verrucosus* Baird, from Vera Paz, Guatemala, and from Costa Rica.

1887. Villot considers *G. subspiralis* Dies. as a synonyme of *G. aquaticus* Duj.; and adds: "Il se peut aussi que le *Gordius robustus* de Leidy et mon *Gordius reticulatus*, établis sur des échantillons recueillis en Amérique, ne soient que des synonymes du *Gordius violaceus* de Baird.

1890. Camerano considers as doubtful species *G. chilensis* Gay, *tenuis* and *dubius* Weyenbergh, and *parasitus* (Creplin), and considers that *G. acridiorum* Weyenbergh is either a *Mermis* or *Filaria*. According to him Villot's three species, *G. æneus, deshayesi*, and *prismaticus*, are tenable, and he gives a description of a female specimen of *G. æneus*.

1892. Camerano describes a male of *G. paranensis*, n. sp. from Palmeira (Parana).

1893. The same writer says of the occurrence of *G. verrucosus* Baird in North America, as reported by Jeffrey-Bell, "Je crois qu'il serait nécessaire de faire une révision des spécimens américains rapportées a cette espèce." He also mentions a specimen of *G. varius* Leidy, from Monterey, Mexico, and states "mais on peut douter . . . que ces caractères soient suffisants pour distinguer le *G. varius* du *G. tricuspidatus* L. Dufour (*G. gratianopolensis* Diesing, Villot)." Janda describes a male of *Chordodes brasiliensis*, n. sp. from Brazil.

1894. Goeldi mentions the occurrence of the preceding species in Brazil. Camerano describes the following new species from Paraguay and the Argentine Republic: *G. alfredi, danielis,* and *peraccæ;* and also describes female specimens of *prismaticus* Villot and *paranensis* Camer.

1895. Camerano describes males of *G. latastei,* n. sp. from Santiago, Chile. Römer describes *Chordodes variopapillatus,* n. sp. from Brazil; a female of *G. violaceus* Baird from Arizona, a male of *G. aquaticus* Linn. from Brazil, and a female of the same species from Chili.

1896. Römer, in his excellent revision of the *Gordiacea,* regards the following American species as tenable: *G. platyurus* Baird, *æneus* Villot, *paranensis* Camer., *Chordodes brasiliensis* Janda, *Chordodes pilosus* Möbius, and *C. variopapillatus* Römer; the following as synonymes of *G. aquaticus* Linn.: *robustus* and *lineatus* Leidy, *fasciatus* Baird, *subspiralis* Diesing; *G. reticulatus* Villot as a synonyme of *G. violaceus* Baird; and the following species as untenable: *G. chilensis* Blanchard, *prismaticus* Villot, *Chordodes parasitus* Creplin, *G. parasitus* Diesing, *G. deshayesi* Villot, and *G. verrucosus* Baird. According to Römer, *Gordius varius* Leidy becomes *Chordodes varius* Leidy. In this year Camerano describes *Chordodes balzani,* n. sp. from Bolivia.

1897. Camerano ('97^a) mentions specimens of *G. obesus* Camer. from Santiago and Gualaquiza, and of *Chordodes bouvieri* Villot from Gualaquiza; and also describes males of *C. festæ,* n. sp. from Cuenca. In a second paper ('97^b) he describes *C. talensis,* n. sp. from Bolivia; he notes *G. alfredi* Camer. from Tala, *G. varius* Leidy from Bolivia, and *C. peraccæ* from Tucuman; and he further describes male and female specimens of *C. brasiliensis* Janda from S. Lorenzo and Tala.

CRITIQUE.

There is considerable confusion in regard to the tenability of certain of the preceding American species, mainly due to insufficient diagnoses, so that it is necessary to relinquish some of them. Those species which are insufficiently described, and hence untenable, are in my opinion the following: *Chordodes parasitus* Creplin ('47), *Gordius chilensis* Gay (Blanchard) ('49), *G. aquaticus* Leidy ('50), *G. chordodes* Diesing ('51), *G. tenuis, dubius,* and *acridiorum* of Weyenbergh ('79). *G. fasciatus* Baird ('53) seems also inadequately described. The description of *G. subspiralis* Diesing is sufficient for identification, though in the descriptive part of this paper we shall find it to be possibly synonymous with *G. aquaticus robustus* (Leidy). Leidy's description ('51) of his *G. lineatus* is really insufficient; but this species is nevertheless tenable, since I had opportunity to examine the type specimens, and have found them to differ from any other species of *Gordius*. *G. reticulatus* Villot ('74) seems to be also untenable, though it may correspond to *G. violaceus* Baird, as is supposed by Villot ('87) and by Römer ('96); Villot's *G. deshayesi*, *æneus*, and *prismaticus* seem to me to be also doubtful, though the last two may be preliminarily retained, since Camerano has found further specimens which appear to agree with them. Römer has given good reasons to show that *G. verrucosus* Baird is too poorly described to be tenable; and there is the greater reason for relinquishing this species, since Camerano ('93) has described under the same name a form which appears to be a *Chordodes;* hence this name must be dropped from the American fauna, if not altogether from the nomenclature of the *Gordiacea.* Leidy's ('56, '79) descriptions of his *G. robustus* are sufficient for purposes of identification, though in the descriptive part of our paper I shall rank this form as a subspecies of the European *G. aquaticus* Linn.

There remain then the following species from the American continents which appear tenable: *Gordius varius* Leidy, *G. robustus* Leidy, *G. lineatus* Leidy, *G. platyurus* Baird, *G. æneus* Villot, *G. paranensis* Camer., *G. alfredi* Camer., *G. danielis* Camer., *G. latastei* Camer., *G. obesus* Camer.; *Chordodes pilosus* Möbius, *C. brasiliensis* Janda, *C. peraccæ* Camer., *C. variopapillatus* Römer, *C. balzani* Camer., *C. bouvieri* Villot, *C. festæ* Camer., and *C. talensis* Camer. Thus all of the species described by Camerano appear tenable, but since most of his descriptions are unaccompanied by figures the reidentification of them is rendered very difficult. The following species are to be regarded as doubtful, if not even needing elimination: *G. fasciatus* Baird, *G. prismaticus* Villot, *G. deshayesi* Villot, and *G. verrucosus* Baird.

It seems to be questionable whether the specimens of *G. violaceus* Baird and *G. aquaticus* Linn., described by Römer from Arizona and South America respectively, really belong to these species; but this point will be more fully criticised in our description of *G. aquaticus robustus* (Leidy), and of the two new species, *G. platycephalus* and *G. densareolatus.*

In the following descriptions, unless otherwise specified, it will be understood that the cuticle has been examined on surface preparations and sections in Canada balsam.

B. DESCRIPTIONS OF THE SPECIES EXAMINED.

1. Gordius aquaticus robustus (Leidy).

Plates 1, 2, and Figs. 13, 16-19 of Plate 3.

G. robustus Leidy, '56, '79.
G. subspiralis Diesing, '61.
G. robustus Leidy, Villot, '74.
? *G. violaceus* Baird, Villot, '87.
? *G. aquaticus* Linn., Römer, '95, '96.

(Leidy's '79, *types;* Leidy coll. no. 5056, Coningo, Maryland.)

Form. The male more slender than the female, in both sexes the body of approximately the same diameter in its whole extent. Head end (Figs. 2, 6, 9, 10, 11, 17) usually obtuse, especially in the male (Figs. 2, 6, 10), sometimes somewhat conical in the female (Fig. 17). Occasionally a slight neck constriction is present. Usually no median longitudinal grooves are to be seen. In some of the larger specimens, especially the females, the whole body is very much flattened, and these are apparently individuals which have discharged their ova. The posterior end of the female is obtusely truncated (Figs. 7, 8), with a faint vertical groove on the terminal aspect; the cloacal aperture is terminal, and lies in this groove. Figures 9, 10, show depression on the terminal face of the head.

The posterior end of the male is spirally inrolled (a character of the males of all the *Gordiacea* examined), and is furcate. The tail lobes (Figs. 1, 3–5, 19) are short, nearly cylindrical on cross section except that they are somewhat concave on their medio-ventral surface, and divergent. The cloacal opening is round and situated anterior to the point of bifurcation of the lobes. On the ventral side of the anterior ends of the tail lobes is situated a more or less crescent-shaped transverse cuticular ridge, with posteriorly directed concave edge. This sharp cuticular ridge is postcloacal. Short branching hairs occur on the surface of the tail lobes as elsewhere on the surface of the body, but no spicules; and there is no particular arrangement of the hairs in the vicinity of the cloacal aperture.

Cuticle (Figs. 12, 13, 16). True areoles are absent. In most of the specimens, and especially well marked in the males, the surface of the cuticle is marked by very fine intersecting lines, and, at greater distances apart, by broader intersecting raised ridges, which are strictly parallel to the finer lines which lie in the rhombic spaces demarcated by them, and which themselves are formed of bundles of fine lines. These larger ridges are seen with low powers of magnification, but higher powers are necessary in order to detect the system of finer lines which lie between them. On the cuticle, especially abundant at the ends of the body, are also seen short, thick, and branching hairs.

Color. Variable according to age, and apparently also according to locality. The body varies from a yellowish white to a yellowish brown, or a light chocolate-brown ; the males are usually darker than the females. The tip of the head is white, and behind it a broad reddish brown ring is to be seen in most specimens (not present in some females from Kansas). In all the females a more or less intense reddish brown ring immediately encircles the cloacal aperture ; and in some specimens there is a narrower, lighter ring outside of and separated from the former. In the male a similar dark ring encircles the cloacal opening, at a little distance from it ; and a spot of deep brown may lie at the posterior edge of this ring : the postcloacal cuticular ridge is brown, its posterior edge a much darker reddish brown.

Dimensions. Largest male, 655 mm. ; greatest diameter, 1.3 mm. Largest female, length 705 mm. ; greatest diameter, 1.9 mm. The males are more slender and usually somewhat shorter than the females. The individuals from the western United States (Montana, Kansas) averaged considerably longer than any eastern specimens examined.

Comparison. This species has been placed by me as a subspecies of *G. aquaticus* Linn., since the differences do not warrant ranking it as a separate species. It differs from the true European *aquaticus* in these points : the presence of a dark ring around the female cloacal aperture, the absence of a row of hairs around the male cloacal aperture, and the absence of white spots ("helle Flecken") on the cuticle.

Especial Diagnostic Characters. The approximately equal diameter of the whole body, with the obtuse truncation of the two ends ; the absence of true areoles, and the presence of short hairs on the cuticle ; the presence of a transverse postcloacal cuticular ridge in the male, the posterior edge of which is darkest in color, and the absence of a line of hairs around the cloacal aperture.

Geographical Distribution. I have seen specimens from Maryland, Massachusetts, District of Columbia, New York, Maine, Pennsylvania, Montana, and Kansas ; and Leidy mentions its occurrence at the Bay of Fundy. The specimens of "*G. aquaticus*" mentioned by Römer ('95), from South America, are probably specimens of our subspecies.

2. G. aquaticus difficilis, n. subsp.

Figs. 14, 15, Plate 3.

(*Type:* 1 male, Leidy coll. 5100, Roan Mt., N. Carolina.)

Form. General form as in the preceding subspecies, cylindrical with the greatest diameter posteriorly, head (Fig. 14) rounded. Posterior end (Fig. 15) as in the preceding, but a parabolic line of hairs curves around the cloacal aperture, the posterior ends of this line of hairs situated upon the latero-ventral surfaces of the tail lobes, at about the plane of anterior bifurcation of the latter.

Cuticle. At the tip of the head there are small, round or polygonal prominences or areolæ, of slight elevation, and of a deeper brown color than the surrounding portions of the cuticle. These are densely massed together at the tip of the head, and a few isolated areolæ occur along the sides of the body near the head. Similar areolæ, but of larger size, are found also on the dorso-lateral surfaces of the tail lobes. The cuticle is elsewhere marked by minute intersecting lines, much as in the preceding species; when studied in alcohol the cuticle appears to be areolated in its whole extent, but sections show that the apparent areolæ are nothing but slight elevations between the bundles of intersecting lines, the supposed areolæ themselves being striated by fine lines.

Color. Remarkably iridescent. Whole body a light chocolate-brown color, the tip of the head the same. There is a dark ring immediately around the cloacal aperture. The whole surface of the postcloacal cuticular ridge is of a uniform brown color, without darker posterior edge.

Dimensions. Length, 70 mm.; greatest diameter, .5 mm.

Comparison. This form resembles, but seems to be distinct from *G. aquaticus robustus.* It differs from the latter as follows: in the presence of areolæ on the head and tail lobes; in the circumcloacal line of hairs; in the uniform dark brown color of the postcloacal cuticular ridge; in the absence of a dark ring around the neck, and of a white tip to the head. These characters seem to warrant placing it, preliminarily at least, as a new subspecies.

3. G. lineatus Leidy.

Figs. 20–31, Plate 4.

G. lineatus Leidy, '51.
G. robustus Leidy, '56.
? *G. seta* Müll., Diesing, '61.
G. lineatus Leidy, Villot, '74.
G. aquaticus Linn., Römer, '96.

(*Types:* Leidy coll. 5008, Essex County, New York, 1851.)

Form. Head end (Figs. 20, 21) rounded, not constricted from the body; body cylindrical, somewhat narrowed anteriorly. Median grooves absent. Posterior end (Figs. 22, 23, 28) not swollen, obtusely truncated in the female.

Males somewhat more slender than the female, and somewhat flattened. Tail lobes (Figs. 24–26) rather long and divergent, their distal ends curved inwards (ventrad). Cloacal opening elongate, above the lobes. Cuticular spicules of an elongate conical form on the median surfaces of the tail lobes, though not on the distal ends of the lobes. Two rows of rather long branching hairs on the ventral surface of the body; one row on each side of the median line, each row extending from a little in front of the cloacal opening to a little behind the point of bifurcation of the tail lobes; the hairs are longest in the middle of each line. Tail lobes concave on their medio-ventral surfaces.

Cuticle (Figs. 29–31). Areolated, areolæ closely opposed without intervening spaces; rectangular or polygonal in outline, frequently elongated in the direction of the body axis, and with a tendency to group themselves into longitudinal rows which form ridges on the body surface. The areolæ vary considerably in form and size.

Color. A pale transparent yellowish white, the female of a deeper buff color. In the female the cloacal opening is immediately surrounded by a narrow, reddish brown ring.

Dimensions. Length of largest male, 278 mm.; greatest diameter, .6 mm. Length of largest female, 283 mm.; greatest diameter, .8 mm. The females are a little longer and broader than the males, but both sexes are very slender.

Comparison. This species stands closest to *G. violaceus* Baird, but differs from it in the form of the tail lobes, and in the arrangement of the spicules on them, as well as by its very slender form.

Particular Diagnostic Characters. Very slender and short, of a pale yellowish or buff color. Areolæ small, close together, with a tendency to form longitudinal ridges. A line of long hairs to each side of the cloacal aperture in the male, and spicules on the tail lobes.

Geographical Distribution. New York, Maryland, and one specimen secured by me in a spring in Chester County, Pennsylvania. Leidy's type specimens were also found in a spring.

4. G. densareolatus, n. sp.

Figs. 32-33, Plate 4; Plate 5.

(*Types*: Leidy coll. 5063, Fort Bridger, Wyoming.)

Form of Female. Head end (Figs. 34, 35) conical, terminally rounded, the terminal portion slightly constricted off; mouth opening terminal. Anterior portion of the body narrower than the middle and posterior portions. With more or less pronounced dorsal and ventral median lines. Posterior end (Figs. 38, 39) slightly widened horizontally, obtusely truncated, with a shallow vertical groove on its posterior aspect, in the middle of which the cloacal opening lies.

Form of Male. Generally similar to but more slender than the female. The tail lobes (Figs. 36, 37) are short, thick, asymmetrical, and divergent. The cloacal aperture is small, circular, and immediately enveloped by a dark ring; it is situated anterior to the tail lobes, on the ventral surface of the body. On the antero-ventral surface of the tail lobes is an integumentary (not purely cuticular) ridge of slight elevation, the two arms of this ridge converging and joining just behind the cloacal aperture. The ventro-median surfaces of the tail lobes are concave. From the cloacal aperture, and embracing it, there extends cephalad, for a distance about equal to the length of the shorter tail lobe, a comparatively wide groove on the ventral surface of the body; at each antero-lateral edge of this groove lies a rounded prominence or ridge. The ventro-median surfaces of the tail lobes and the postcloacal integumentary ridge are covered with short conical cuticular spicules, which extend cephalad to each side of the cloacal aperture.

Cuticle (Figs. 32, 33). Areolated; the areolæ variable in size and form, usually elongate-oval or irregularly pentagonal in outline. Their longitudinal axis is usually nearly perpendicular to that of the body, and they tend to produce transverse rows or chains, in each of which rows some of the areolæ are confluent. Narrow, shallow grooves separate neighboring parallel rows of areolæ; and beneath the areolæ a system of fine intersecting lines is seen. No interareolar bristles or hairs are present.

Color. In the female (three specimens examined) the extreme tip of the head is white, this is followed by a light buff ring, and immediately behind the latter a broad transverse reddish brown ring. The cloacal aperture is immediately surrounded by a thin black ring, and around the latter is a much broader circular area of a reddish brown color. The rest of the body is a deep yellowish brown in one specimen; a light chocolate color in the other specimen. Color of the male (a single specimen) similar to that of the female, but darker, a deep chocolate color; a nearly black ring surrounds the cloacal opening, while the postcloacal integumentary ridge is slightly lighter than the surrounding parts.

Dimensions. Male, length, 290 mm.; greatest diameter, 1.1 mm. Female, length of largest specimen, 395 mm.; greatest diameter, 1.7 mm.

Comparison. This species is quite similar to the European *G. tatrensis* Janda, but differs from it in that all the areolæ are of a dark color and there are no groups of areoles forming white spots; and in the male the tail lobes are shorter and thicker, and there is no "knorriges, glattes, dreiwandiges Höfchen" around the cloacal aperture, such as is described by Janda ('93). It also differs from *G. violaceus* Baird in the manner of distribution of the spicules on the tail lobes, and in the confluence of the areolæ. It is however most closely allied to *G. platycephalus*, n. sp.; these resemblances will be discussed under the heading of that species.

Especial Diagnostic Characters. The dense arrangement of the irregular areolæ, which have a tendency to produce transverse rows, and the tendency to confluence of the areoles; the comparatively robust form of the body; the short, thick tail lobes in the male, with the conical spines on their ventral surface, the obscure postcloacal integumentary ridge, and the ventral depression within which the cloacal aperture lies.

Geographical Distribution. The type specimens (2 males, 1 female) are from Fort Bridger, Wyoming; and another female from South Montana (coll. Acad. Nat. Sci. Philadelphia).

5. G. platycephalus, n. sp.

Plate 6; Figs. 46-49, Plate 7.

(*Type* of female: coll. Acad. Nat. Sci. Phila., Guatemala. *Type* of male: coll. Acad. Nat. Sci. Phila., South Montana.)

Form of Female. Anterior portion of the body attenuated and flattened in all specimens, and the head constricted from the body. The head (Figs. 42, *b*, *c*, 45) is of slightly greater diameter than the part of the body immediately preceding, tip of the head rounded or truncated; in one specimen a groove on the ventral surface of the head. Body either flattened or cylindrical, with deep dorsal and ventral median grooves. In all females except one the posterior end (Figs. 42 *a*, 43, 44) of the body is somewhat constricted for a distance of about 6 mm., but the extreme posterior end is usually swollen, somewhat knob-shaped; on lateral view this end appears obliquely truncated, the posterior end of the body has a vertical groove on its terminal aspect, and the cloacal aperture is not exactly terminal, but somewhat ventral.

In the male the anterior portion (Fig. 40) of the body is not attenuated, though it is slightly flattened horizontally; the head is elongate-oval in outline, of greater diameter than the part immediately preceding, and is terminally rounded. The body like that of the female, but more slender. Tail lobes (Fig. 41) rather slender and long, asymmetrical, their distal ends curved ventro-mediad; they are nearly cylindrical, flattened only on the median surface. The large, elongate cloacal aperture is situated on the ventral surface of the body, and separated from the anterior point of bifurcation of the tail lobes by a distance equal to half the length of the tail lobes. This aperture does not lie in a groove; nor do spicules nor long hairs occur near it or on the tail lobes, but only minute, short hairs.

Cuticle (Figs. 46–49). Areolated; the areolæ slightly smaller than those of *G. densareolatus*, more or less of the same size, and either irregularly polygonal or somewhat elongate in outline, and then usually elongated in the direction of the transverse axis of the body. The areolæ are usually well separated from one another, except in the median line, and show no tendency to produce confluent rows. Small interareolar groups of small bristles occur in most of the individuals, these bristles varying in number and form.

Color. Brown, varying in shade, but never very intense; tip of head lighter, and a more or less pronounced dark ring around the neck. In the male an obscure brown ring immediately surrounds the cloacal aperture.

Dimensions. Length of male, 216 mm.; greatest diameter, 1 mm. Length of largest female, 335 mm.; greatest diameter, 1.4 mm.

Comparison. In the configuration of the cuticle this species is most closely allied to *G. violaceus* Baird, and to *G. densareolatus* mihi. The males of these three species are very different, however, in regard to the arrangement of the spicules on the posterior end, such spicules being absent in *platycephalus*. This character does not serve to distinguish the females of these species however, though the flattening of the anterior portion of the body is diagnostic of *platycephalus*. But I am wholly at a loss to classify one female from Montana in the collection of the Acad. Nat. Sci.: it has the flattened head of *platycephalus*, with the confluent areolæ of *densareolatus;* its color is a deep buff, with a narrow black ring immediately around the mouth, but with no dark ring around the neck; the shape of the posterior end and the deep median grooves of the body resemble *platycephalus*, so that on the whole I should be inclined to consider it as *platycephalus*. But might not this specimen be a hybrid between these two species? Though the females of *violaceus*, *densareolatus*, and *platycephalus* are so similar, the males are nevertheless very different in regard to the form of their posterior ends, so that these species may be regarded as genetically related, and we must consider that the course of modification which they have undergone has influenced the males more than the females. This view of the question cannot be regarded as bizarre, since in other groups of animals also the males are in some cases far more dissimilar than the females.

Especial Diagnostic Characters. The flattening of the anterior end, and the constriction of the head from the body; the slight enlargement of the posterior end in the female; the absence of spicules on the tail lobes in the male; the presence of small, rounded-polygonal cuticular areoles, which are as a rule well separated from one another.

Geographical Distribution. Guatemala, South Montana, Pennsylvania, Bridger Basin, Fort Laramie. 1 male and 7 females examined.

6. G. platyurus Baird.

Figs. 50–52, Plate 7.

G. platyura Baird, '53.
G. platyurus Baird, Diesing, '61.
G. platyurus Baird, Villot, '74.
G. platyurus Baird, Oerley, '81.
G. platyurus Baird, Römer, '96.

(1 female examined: Leidy coll. 5096.)

Form. Very massive, flattened dorso-ventrally, with broad dorsal and ventral grooves, which do not extend quite to the posterior end. Head end (Fig. 52) conical. Largest diameter posteriorly. The posterior end (Fig. 51) is dorso-ventrally flattened, expanded, wider than the preceding portion of the body, spatulate in form, with shallow dorsal and ventral depressions. The cloacal aperture is terminal.

Cuticle (Fig. 50). With fine intersecting lines, much as in *G. aquaticus* Linn. Here and there bundles of elevated lines are demarcated from the finer lines, and these bundles, which are parallel to the finer lines, deliminate rhomboid-shaped spaces.

Color. A light yellowish buff, somewhat iridescent. Extreme tip of head white, behind which is a faint brownish ring. Posterior tip of the body a light yellowish white.

Dimensions. Length, 540 mm.; greatest diameter of body, 2.4 mm.; greatest transverse diameter of tail, 2.3 mm.

No locality is marked for this specimen; the only other specimen known, the type in the British Museum, is labelled "Jamaica?" so that it is not yet proved that this species is American. It seems to me probable that it does not come from the North American continent, since otherwise there would probably be numerous examples of this large species extant. Its massive form and the spatulate shape of the posterior end are good diagnostic characters.

7. G. leidyi, n. sp.

Figs. 53-55, Plate 7; Figs. 56-59, Plate 8.

(1 female, type: Leidy coll. 5089, no data.)

Form. Head (Fig. 53) conically pointed, obtusely rounded at the tip, where the mouth opening is terminal and forms a slight projection. Body cylindrical, with deep dorsal and ventral grooves, the ventral one not quite in the median plane. Posterior portions of the body for a distance of about 12 mm. slightly flattened horizontally, and of slightly less diameter than the middle of the body. The dorsal groove of the head extends nearly from the head to the posterior end of the body; the ventral groove ends about 5 mm. in front of the posterior end. Posterior end (Figs. 56–58) truncated, almost vertically. Cloacal aperture (Fig. 57) terminal, nearly in the centre of the disk which forms the distal face of the posterior end. This aperture is placed upon a round, elevated papilla, the latter sunk in a depression of the distal face of the body. To each side of the cloacal papilla is a short vertical, elevated integumentary ridge, while below the depression in which the cloacal papilla lies is a transverse ridge. On the dorsal side of the posterior end (Fig. 56) is a nearly U-shaped integumentary fold, to each side of which is an elongated pit or depression. The latter pits lie respectively on the dorso-lateral sides of the posterior end of the body, and extend posteriorly as far as the vertical tegumentary ridges which form the lateral boundaries of the depression in which the cloacal papilla is situated. The distal end of the dorsal U-shaped fold forms a transverse ridge bounding dorsally the depression in which the cloacal papilla lies. The dorso-median groove of the body extends on the surface of this fold to the posterior end of the latter, the groove being broadest at this point. Thus the posterior end of the body is vertically truncated, with a concave distal face; in the centre of this depression, situated on the summit of a slightly elevated papilla, lies the cloacal aperture; the outlines of this terminal concavity of the body form nearly a square, its boundary being two short vertical ridges, a transverse ventral ridge, and a transverse dorsal ridge which is the distal end of a U-shaped fold of the integument situated on the dorsal side of the end of the body. These relations are somewhat complicated, and may be best understood by reference to the Figures 56–58.

Cuticle. Areolated; areolæ (Figs. 54, 55) only slightly elevated, on cross section they show no hyaline summit, irregularly polygonal in outline; they are usually elongated in the line of the transverse axis of the body, and show a tendency to form short and interrupted rows or chains, contiguous areoles in such rows being confluent. The areolæ are separated only by narrow spaces. The cuticle is also marked by intersecting elevated lines (Fig. 59) placed at considerable but varying distances apart, these lines being easily visible on the alcoholic specimen. Interareolar bristles are absent.

Color. Head end light yellowish brown, the rest of the body a deep yellowish brown color, with an obscure dusky brown ring on the head. In the median line of the dorsal groove of the body are two narrow, parallel stripes of an intense reddish brown color, which are in contact with one another in the median line. In the ventral median groove of the body are two parallel stripes of about the same color as those in the dorsal groove, but with this difference, that they are separated from one another by a distance about equal to the diameter of either of the lines, and that the two ventral stripes are of not quite the same diameter. Both the dorsal and ventral stripes of color disappear near the two ends of the body.

Dimensions. Length, 295 mm.; greatest diameter, 1.5 mm.

This species is sharply distinguished from all other species of the genus known to me by the peculiar form of the posterior end, and by the colored stripes lying within the median grooves of the body. Unfortunately the locality is not given for the specimen. I have named it in honor of the pioneer student of the American *Gordiacea*, Joseph Leidy.

3. G. agassizi, n. sp.

Figs. 63-66, Plate 9.

(Type, 1 male: Harvard collection no. 296, Sandwich Isl.)

Form. Body much flattened dorso-ventrally, without well marked median grooves; the body is flattened in such a way that the dorsal side is rounded, the ventral side concave, so that a cross section would show the body to be somewhat sickle-shaped. Head end likewise dorso-ventrally flattened. The particular characteristic of this species, however, is that the broad plane of the neck does not coincide with the broad plane of the head, but is nearly vertical to it (Fig. 63). Thus the flattening of the head and of the body lies in approximately the same plane, while the neck region (for a distance of about .9 mm.) is twisted around through an angle of nearly 180 degrees, and hence the broad plane of the neck is nearly vertical to that of the head and to that of the body. Hence in viewing the head end either from the dorsal (Fig. 63) or the ventral aspect, the neck appears like a short slender thread. This relation has probably been produced by a torsion of the neck region through an angle of nearly 180 degrees. The outline of the head, viewed from the flattened surface, has somewhat the shape of an unbarbed arrow-head, broadest posteriorly and with rounded tip; the mouth opening is large, transversely elongated, and situated at the termino-ventral margin of the head. The neck inserts itself along an elevated ridge which circumscribes the posterior portion of the head. On the dorsal surface of the head (Fig. 63), to each side of the median line, are found just behind this elevated ridge a number of small ridges which are parallel to one another (i. e. those on the same side of the ridge are parallel), and these are obliquely disposed to the large ridge. These relations are difficult to describe, but may be understood by comparing the figure.

The tail lobes (Figs. 65, 66) are bent ventrad, nearly at right angles to the posterior end of the body region proper. Each tail lobe is much flattened laterally, and is very short; it is somewhat rounded on the lateral, and correspondingly concave on the median side. Viewed from the side (Fig. 65) each shows a more or less conical outline, broadest at the proximal end, rounded at the distal end. The dorso-median margin is slightly thickened. The flattened planes of the two lobes are not parallel, their dorso-median margins being much closer together than the ventro-median; the proximal ends of their dorso-median margins are in contact, while the ventro-median margins are farthest apart proximately (Fig. 66). The median plane between the two lobes is vertical to the flattened plane of the posterior end of the body proper. The tail lobes may well be termed leaf-shaped.

Cuticle (examined in alcohol only, since it seemed inadvisable to section the single specimen at hand). The surface (Fig. 64) viewed with low powers of the microscope, shows very plainly a system of deep intersecting lines, between which lie slightly elevated areolæ of rhombic or rhomboid outline. There are necessarily two systems of parallel lines; and in one of these two systems the lines tend to occur in pairs.

Color. The body is a uniform rufous-brown color, the tail lobes somewhat lighter. The mouth region of the head is yellowish, behind which follows a zone of a nearly black color; the posterior portion of the head is but little darker in color than the body.

Dimensions. Length, 158 mm.; greatest diameter of head, 1 mm.; greatest diameter of body, 1.5 mm.

Comparison. This species may be very sharply distinguished from any other Gordiacean yet described, by the torsion of the neck through an angle of nearly half a circle, and by the extreme flattening of the tail lobes. It is the only species known from the Sandwich Islands.

9. G. capitosulcatus, n. sp.

Figs. 67–69, Plate 9; Fig. 70, Plate 10.

(*Type,* 1 male: Harvard coll. 1466 a, Cuba.)

Form. The body is dorso-ventrally slightly flattened, with slight dorsal and ventral median grooves. The head (Figs. 67, 69) is flattened laterally, higher than broad, and is separated from the body by a slight constriction (neck). The head has the greatest diameter at the anterior end, where it is obliquely truncated, the dorsal margin projecting slightly farther forwards than the ventral. The terminal aspect (Fig. 67) of the head is concave, the large mouth opening situated in the median line, nearer the ventral than the dorsal margin of the head. At each anterior dorso-lateral margin of the head is a ring-shaped prominence (Fig. 69), which surrounds a pit-like depression. It would be impossible to determine the structural significance of these pits without sectioning the head, but this was not permitted on the single specimen examined.

The tail lobes (Fig. 70) are slightly divergent; each is terminally rounded, nearly cylindrical on cross section, but concave on the median surface. The lobes are long and slender, and apparently bear no hairs or spicules. The cloacal aperture is situated on the ventral surface of the body, a short distance in front of the point of union of the two lobes.

Cuticle (Fig. 68). With small elevated areoles, situated close together. The areoles are somewhat variable in size and form, but are mostly rounded-polygonal in outline. Their surface is not smooth, as in the other species of the genus examined by me, but with irregular short tubercles. Interareolar bristles are apparently absent.

Color. Pitch-black to the naked eye, but with a brownish tinge when viewed with the microscope. The margins of the ring-shaped prominences of the head are of a whitish color.

Dimensions. Length, 165 mm.; greatest diameter, 9 mm.

Especial Diagnostic Characters. The presence of depressions on the anterior dorso-lateral margins of the head; the roughened surface of the areoles; the intense black color.

Comparison. This form differs from *G. violaceus, densareolatus,* and *platycephalus* by the roughened surface of the areoles, the coloration, and the presence of the pits on the head. It has no close resemblance to any of the species described by Camerano from South America, and on the whole appears to be a well defined species.

10. G. paranensis Camer.

Figs. 71–74, Plate 10.

G. paranensis Camerano, '92, '94.
G. paranensis Camer., Römer, '96.

(1 female, 5 males: Harvard coll. no. 1478, Casabianca, Chile.)

Form of Female. Body somewhat flattened dorso-ventrally, without well marked median grooves. Head conical, concave on the terminal aspect, mouth terminal; head not constricted from the body. Posterior end (Fig. 71) truncated, with a circular depression on its terminal aspect, in which the cloacal opening lies; this posterior end of the body is round on cross section, while the immediately preceding portion of the body is much flattened dorso-ventrally.

Form of Male. Body more slender than in the female, and with more or less well marked median grooves. In one male (Fig. 74) the head end is conical with rounded tip; in the others it is separated from the body by a slight constriction, and is terminally truncated, the terminal face concave (Fig. 73); on this terminal aspect of the head in one specimen is a vertical, median ridge, to each side of which is a depression. A conical and a truncate form of head being found in different specimens of this species would lead to the conclusion that the truncate form, in which the anterior aspect of the head is concave, is probably due to a muscular contraction of the tip of the head. The tail lobes (Fig. 72, *a*, *b*) are comparatively short and thick, flattened on their proximo-median surfaces as well as on their dorso-lateral surfaces.

Apparently neither hairs nor spicules occur in the vicinity of the lobes. At the anterior point of union of the tail lobes, on the ventral surface of the body, is situated a V-shaped ridge, each arm of which is placed on the ventro-median margin of the corresponding tail lobe, the two arms of the V converging, and joining at an angle cephalad at the anterior point of union of the tail lobes. Anterior to this ridge is situated a broad and deep depression. At the deepest part of this depression, i. e. in the medio-ventral line just anterior to the ridge described, is situated the cloacal aperture; this aperture lies on the summit of a slightly elevated papilla. The anterior margin of the depression which surrounds the cloacal papilla forms a sharp ledge, irregularly semicircular in outline (the opening of the semicircle directed caudad); this sharp ledge, forming the anterior and lateral margin of the cloacal depression, is not elevated above the level of that portion of the ventral surface of the body which lies anterior to the depression. Along this ledge are arranged a row of short, thick hairs. Accordingly, we find on the ventral surface of the posterior end of the male a narrow V-shaped ridge at the base of the tail lobes; anterior to this a large and deep depression, in the centre of the posterior part of which the cloacal papilla is situated; and the anterior and lateral boundary of this depression, formed by a nearly semicircular sharp ledge.

Cuticle. There are no areoles, but a system of broad intersecting, oblique lines, between which are much finer intersecting lines. Short hairs also occur here and there, but sparsely. The cuticle is thus very similar to that of *G. aquaticus robustus* (Leidy).

Color. Body of a dull olive-brown color. Tip of the head yellowish white, the remainder of the head reddish brown, varying in shade. The posterior end of the female is yellowish ; the pit in which the cloacal aperture lies is of a deep reddish brown color, there being thus a disk of this color immediately around the aperture. In the male the postcloacal cuticular ridge is reddish brown, its posterior edge black.

Dimensions. Length of female, 470 mm.; greatest diameter, 1.8 mm. Length of largest male, 340 mm. ; greatest diameter, 1.3 mm.

Especial Diagnostic Characters. The presence of a postcloacal ridge in the male, and the presence of a sharp precloacal ledge which bounds the cloacal depression; the intersecting lines of the cuticle.

Comparison. These specimens seem to agree wholly with Camerano's description of the species. This form is most closely allied to *G. aquaticus robustus* (Leidy).

Geographical Distribution. Asuncion, Paraguay; Palmeira (Parana); Casabianca, Chile.

11. G. violaceus Baird.

Figs. 60-62, Plate 8; Figs. 75-77, Plate 11.

G. violaceus Baird, '53. (For the synonymy of descriptions of specimens from other localities than America, cf. Römer, '96.)
? *G. reticulatus* Villot, '74 (from California).
? *G. violaceus* Baird, Villot, '87.
? *G. violaceus* Baird, Römer, '95 (from Arizona).
? *G. violaceus* Baird, Römer, '96.

(1 female, Harvard coll. no. 1465, California; 1 female, Harvard coll. no. 1666 c, Cuba.)

Description of the Californian Specimen. *Body* cylindrical without median lines. Posterior and especially the anterior portions of the body somewhat narrower than the middle; head (Fig. 61) of a rounded conical form, not constricted from the body, mouth terminal. Posterior end (Fig. 60) of the same diameter as the immediately preceding portion of the body, obtusely rounded terminally; the small, round cloacal aperture is terminal. *Cuticle* (Fig. 62) areolated: the brownish areolæ vary somewhat in size, are irregularly polygonal, and do not form rows but are well separated from one another; a few small interareolar bristles are present. *Color:* a clear chocolate-brown, head paler, a deep reddish brown ring around the mouth. *Length,* 130 mm.; *greatest diameter,* 9 mm.

Description of the Cuban Specimen. *Body* nearly cyclindrical, with dorsal and ventral median grooves. Head cyclindrical, narrower than the portion of the body immediately preceding, terminally truncated (Fig. 76); this plane of truncation is slightly convex, the mouth situated in its centre. The anterior portion of the body is gradually attenuated, of less diameter than the middle portion. Posterior end of the body (Fig. 75) obliquely truncated, in that the dorsal margin projects farther caudad than does the ventral margin; the posterior end of the body is flattened on its ventral surface. In the medio-ventral line is a shallow narrow groove, which passes dorsad on the terminal aspect of the body, this groove being deepest at the dorso-terminal margin of the body. Within this groove lies the terminal cloacal aperture. *Cuticle* (Fig. 77) areolated: areolæ low, irregularly rounded in outline, smooth superficially, close together; the areolæ are very little darker than the inter-areolar spaces; between them lie thick, conical hairs, which are higher than the areolæ. *Color* a uniform grayish brown, head lighter; the mouth is surrounded by a narrow reddish brown ring, and the vertical groove at the posterior end of the body is also of this color. *Length,* 112 mm.; *greatest diameter,* 1 mm.

Comparison. There is some doubt in my mind whether these specimens should be attributed to *G. violaceus* Baird, but they certainly come closer to this species than to any other, and until further specimens are examined from these localities may best be placed under this species. But we know that *platycephalus* and *densareolatus* come very close to *violaceus* in the structure of the cuticle, but differ markedly in the form and armature of the posterior end of the male; and so it may be that the males of these two specimens, when discovered, may also be found to differ from the males of *violaceus*. But it would be inadvisable to classify these two females as a new species until the males are known.

The Californian form agrees very closely with the *G. reticulatus* of Villot ('74), also from California, but the male of the latter is likewise unknown, so that *reticulatus* must still be regarded as a doubtful species. Villot ('87) and Römer ('95, '96) hold the view that *reticulatus* may be synonymous with *violaceus*. The males of specimens from all these localities must first be examined before we can decide whether the true *violaceus* really occurs in America, or whether a subspecies or different species, distinct also from *platycephalus* and *densareolatus* does not take its place. Hence these two doubtful female specimens from Cuba and California, may only preliminarily be placed under *violaceus*.

PARAGORDIUS, n. gen. (cf. the Appendix).

(Type of the genus: *Gordius varius* Leidy, '51, '56.)

Generic Characters. The cloaca in the adult female is remarkably long (Fig. 86), nearly half an inch in length, and the caudal ganglion (Fig. 79, *N. Gl.*) is in direct connection with the cloacal epithelium, and at no point with the epidermis. The male is characterized by the absence of a cloacal musculature (Fig. 78). The trilobation of the posterior end of the female (Figs. 88–90) possibly also furnishes a true generic character.

Thus *Paragordius* differs anatomically more widely from *Gordius* and *Chordodes*, than the last two do from each other; for in both of the last two the female cloaca is very short, usually a fraction of a millimeter, and the caudal ganglion is never in contact with the cloacal epithelium, and in these also the male always possesses a cloacal musculature (Fig. 18). I am inclined to suppose that the European *Gordius tricuspidatus* (Dufour) (*G. gratianopolensis* Dies.) should be placed in this new genus, since its female has also a trilobation of the posterior end. But unless the latter species be found to show also the anatomical generic characters given above, it must be kept separate from *Paragordius*, since it is doubtful whether the mere trilobation of the posterior end constitutes a good generic character, for we find in the female of *G. tolosanus* Duj. a tendency to bilobation of the posterior end of the body. I have had no opportunity to examine *G. tricuspidatus*, and find no description of the anatomical structures at issue, so that the generic position of this European species must still remain doubtful, though it certainly should not be placed under *Chordodes*, as Römer ('96) has done, since the male has the typical bilobation of the posterior end shown by all true *Gordii*. I quite agree with Janda ('93) that the shallow ventral groove on the posterior end of the males of *Chordodes* is one of the important characters of the genus, since I have found this typical form of the posterior end in all male *Chordodes* examined by me, and it has been found characteristic for all the males of *Chordodes* which have been heretofore described. The characters of these three genera of *Gordiacea* may be compared as follows.

Gordius. Posterior end of the male bilobed, a cloacal musculature present; posterior end of the female rarely much swollen, never cleft (except in *G. tolosanus*, where it is deeply grooved rather than cleft); the caudal ganglion in the female not in contact with the cloacal epithelium, the cloaca very short; cuticula marked with intersecting lines or with low areolæ, never with high tubercles or papillæ, though frequently with short hairs or conical processes (spicules).

Chordodes. Posterior end of the male not bilobed, but only with a comparatively shallow groove on the ventral surface; posterior end of the female usually swollen, never cleft; the caudal ganglion in the female not in contact with the cloacal epithelium, the cloaca very short; the male with a special cloacal musculature; cuticle usually marked with high tubercles or papillæ, and apparently always with hyaline club-shaped processes, which are very different from the interareolar hairs of *Gordius.*

Paragordius. Posterior end of the male bilobed, no cloacal musculature; posterior end of the female trilobed; the caudal ganglion in the female is in contact with the cloacal epithelium, and the cloaca is long; cuticle as in *Gordius*, except that the papillæ are enveloped in a hyaline layer, which forms the external layer of the cuticle (Fig. 91, *a*).

These three genera appear to be very natural groups, and each is to be distinguished by the union of certain characters, rather than by the presence of any single character. Of the three, *Gordius* occupies an intermediate position, with relations on the one hand to *Chordodes*, on the other to *Paragordius*, though it shows the greater affinity to *Chordodes;* while there are no good characters in common between *Chordodes* and *Paragordius.* Thus *Gordius* might be regarded as the more primitive parent form, from which the others have differentiated; but I reserve a discussion of this point for a subsequent contribution.

The following preliminary note on the caudal ganglion of *Paragordius* (in the female) may be of anatomical interest. This ganglion lies in contact with the cloacal epithelium at the anterior point of bifurcation of the two lateral tail lobes (Fig. 79). The posterior margin of this ganglion forms a thin vertical lamina, which may be in contact with that portion of the epidermis lying between the two lateral lobes, but it certainly does not terminate in contact with the epidermis of the ventral surface of the body. The ventral nerve chord anterior to the caudal ganglion lies in the ventro-median line between the intestine and the longitudinal musculature of the body wall, as in both *Gordius* and *Chordodes*, as far as the latter genera have been examined. But there are certain small nerves which take their origin from the antero-dorsal margin of the caudal ganglion, and these nerves lie directly beneath the cloacal epithelium. These relations were studied on sections of two females; and anterior and posterior nerves may be distinguished with reference to the course which they pursue. The anterior nerves, which are of greater diameter than the posterior ones, varied in number in the two specimens sectioned. In the one, two nerves arise from the dorso-lateral margin of the ganglion, and may be traced cephalad for a number of sections; they diverge only slightly; in the other specimen there is, in addition to the two lateral anterior nerves, also an unpaired median nerve of greater diameter than the other two, which bifurcates at its anterior end. The posterior nerves arise a couple of sections behind the anterior ones, and are two in number (one on each side of the median line), though in one of the specimens there appeared to be two on one side and one on the other; these posterior nerves pass caudad, diverging in their course, and may be traced into the lateral tail lobes, where they divide into still smaller nerves.

In one male sectioned an elongated cuticular penis was present in the cloaca, this being only the second case of a penis being observed in a Gordiid, the other case having been observed by Vejdovsky. But the description of these interesting anatomical details must be postponed to a later paper.

12. Paragordius varius (Leidy).

Figs. 78-85, Plate 11; Figs. 86-93, Plate 12.

Gordius varius Leidy, '51, '56, '58.
G. varius Leidy, Diesing, 1861.
G. gratianopolensis Charvet, Schneider, '66.
G. varius Leidy, Villot, '74.
G. trilobus Villot, Oerley, '81.
G. varius Leidy, Camerano, '93.
Chordodes varius Leidy, Römer, '96.

(Leidy's original type specimens have apparently not been preserved.)

Form of the Female. The anterior and posterior portions of the body are narrower than the middle, the decrease in diameter being very gradual; the anterior is narrower than the posterior end. The head end (Figs. 83–85) is obliquely truncated in such a way that the antero-ventral margin projects farther forward than does the antero-dorsal; this truncated plane, which forms the terminal aspect of the head, is very nearly flat. The mouth lies near the ventral edge of the truncated plane. The posterior end (Figs. 88–90) is trilobed, there being one dorso-median and two latero-ventral lobes; these lobes have no cuticular spines on their surface, and in the great majority of the numerous specimens examined are of equal length. Two specimens in the Harvard collection were exceptions to this equality in length: in one the dorsal lobe was slightly longer than the others, in the other slightly shorter. But the dorsal lobe is narrower than the others, and further differs from the latter in having an elevated median ridge on its ventral surface, so that on cross section it appears triradiate (Figs. 80, 81). The lateral lobes are crescent-shaped on cross section. The cloacal aperture, wholly hidden by these lobes, lies at their base and between them, so that the cuticle and epidermis of the inner surface of the lobes are directly continuous with the cuticle and epithelium of the cloaca (Fig. 86). The lobes may be either parallel or divergent, and hence are probably movable.

Form of the Male. The anterior end (Fig. 82) as in the female, but the body more slender. The tail lobes (Fig. 87) are comparatively long and slender, cylindrical in shape, and obtusely rounded terminally. Small conical spicules occur on the medio-ventral surfaces of the anterior half of the lobes, and short hairs on their anterior surfaces. The elongate cloacal aperture lies in the medio-ventral line of the body, anterior to the tail lobes.

Cuticle. On cross section (Fig. 91, *a*) an outer thin hyaline layer is seen, and an inner, much thicker fibrous layer. Embedded in the hyaline layer are small lozenge-shaped bodies, which stain more deeply than any other portion of the cuticle, and which correspond to the areolæ seen on surface views. The external surface of the hyaline layer of the cuticle is marked by short conoidal processes of the same structure as the hyaline matrix; these are not seen on surface views. On surface view (Figs. 91, *b*–93) the cuticle appears areolated: the areolæ are small, variable in size and form, and irregularly arranged. Sometimes they occur in groups, sometimes in interrupted longitudinal rows; their arrangement varies both in different individuals as well as on different portions of the same individual. The areoles are irregularly polygonal in outline. In one female larger brown-colored areoles were present in addition to the smaller, lightly colored ones; the former were mainly arranged in the form of longitudinal ridges, and were irregularly star-shaped in outline.

Color. Color usually lighter in the females than in the males, varying from a light brown or yellowish to a dark brown (the larger individuals usually darker). The tip of the head is white or a pale brownish; just behind there is a dark ring of color, usually rusty brown or even black, rarely pale; this ring is darkest at its anterior edge, and darker on the dorsal than on the ventral side of the body. At least a trace of this ring is to be seen on all specimens when mature, though the intensity of its coloration is very variable.

Dimensions. Length of largest male seen, 350 mm.; greatest diameter, .9 mm. Length of largest female, 290 mm.; greatest diameter (of a flattened individual), 2 mm. The males are more slender and average considerably shorter than the females.

Especial Diagnostic Characters. The trilobation of the posterior end of the female, the long and cylindrical tail lobes of the male, the oblique truncation of the head end, and the usually very dark colored ring around the head, render this species very easy of identification.

Comparisons. This species has the greatest affinity to *Gordius* (*Paragordius ?*) *tricuspidatus* (Dufour); but it differs from it in that there are no spicules or spines upon the tail lobes of the female, and in that the dorsal is narrower than the lateral lobes; further, in *varius* the areoles of the cuticle are frequently arranged into rows or groups.

Geographical Distribution. I have examined specimens from the following localities: New York, Maine, Massachusetts, New Jersey, Pennsylvania, Virginia, Kansas, California, and Guatemala; and it has been observed by others in Mexico, Peru, and Bolivia. It appears to have a very extensive range, and it and *G. aquaticus robustus* are the most abundant forms in the northeastern portion of the United States.

Genus CHORDODES (Creplin) Möbius.

13. C. morgani, n. sp.

Fig. 94, Plate 12; Figs. 95-100, Plate 13.

(1 female, type, in my possession, from Maryland; a second female from Iowa in the Harvard coll. no. 1470.)

Description of the Type Specimen. Form: Perfectly cylindrical without median lines. Anterior end gradually attenuated, head (Fig. 98) much narrower than the posterior end, rounded. Tail end (Fig. 97) swollen, obtuse posteriorly, the swelling most pronounced on the ventral aspect. *Cuticle:* With three kinds of prominences (Figs. 99, 100): (1) Larger tubercles which are about twice as high as broad, nearly circular on cross section, and rounded apically; these bear no hairs, and are distributed at nearly equal distances on the surface of the cuticle, with only a slight tendency to arrange themselves into disjointed groups. (2) Smaller tubercles, which are pointed at the apex and more or less conical in form; these vary considerably in height, but are never more than a quarter the height of the preceding kind. Each bears on its summit a single delicate hair. These tubercles are arranged quite densely on the surface of the cuticle, and the larger ones among them are grouped closely around the tubercles of the 1st order; in the median line of the body they are more numerous, especially the larger ones of them, which form groups between as well as around the tubercles of the 1st order. (3) Delicate slender hyaline processes, frequently club-shaped, which occur only sparsely, and are a little higher than the first kind of tubercles. *Color*: A uniform yellowish brown. *Dimensions*: length, 222 mm.; greatest diameter of body, 1.1 mm.

Description of the Second Specimen. Form: Anterior end pointed, and head tip (Fig. 94) rounded as in the preceding, but on the ventral surface of the head, to each side of the median line, is a short longitudinal groove. Body nearly cylindrical, with narrow but deep median grooves; on a portion of the surface there are likewise irregular longitudinal grooves. Posterior end (Figs. 95, 96) swollen, though of less diameter than the body at its middle point; this distal swelling is of greater diameter than the dorso-ventrally flattened portion of the body which immediately precedes it. The posterior end is truncated terminally, and near the centre of this terminal aspect (Fig. 96) is situated the cloacal aperture at the middle point of a vertical ridge, to each side of which is a groove. On the dorso-lateral sides of the posterior end larger and deeper grooves are situated. *Color*: A uniform dull chocolate-brown, the terminal aspect of the head somewhat lighter in color.

Cuticle: as in the preceding specimen. *Dimensions*: length, 158 mm.; greatest diameter of body, 9 mm.

Especial Diagnostic Characters. The peculiarities of the cuticular tubercles, and the uniform coloration.

Comparisons. The papillæ of the cuticle have some resemblance to those of *C. hamatus* Römer, from West Africa. But the arrangement and form of the papillæ of the latter form is not quite the same, judging from Römer's ('96) description of them: "Die Haut ist mit Papillen bedeckt von der Form kleiner Hügel und spitzer Zacken. Sie sind ganz niedrig; ihre Form ist nicht gleichmässig, auch ihre Entfernung von einander nicht die gleiche, aber sie haben im allgemeinen denselben Habitus. . . . Kopfende des Weibchens stark zugespitzt."

Thus far only two specimens observed, from Iowa and Maryland, respectively.

I have the pleasure of naming this species in honor of my friend Dr. Thos. H. Morgan, of Bryn Mawr College, who kindly gave me the first specimen seen.

14. C. puerilis, n. sp.

Figs. 101-105, *b*, Plate 13.

(*Type*, 1 male: Leidy coll. no. 5071, from a cockroach. A second male secured by me in Chester County, Pennsylvania.)

Form. Anterior portion of the body more slender than the posterior. Head end (Figs. 101, 102) dorso-ventrally flattened, obliquely truncated terminally, mouth opening terminal. Middle and posterior portions of the body horizontally flattened in the larger specimen, cylindrical in the smaller. Posterior end of the body (Fig. 103) narrower than the preceding part, almost cylindrical, terminally rounded; a median groove is present on its ventro-terminal end, and to each side of this groove the integument forms a slightly elevated ridge.

Cuticle. With four kinds of prominences (Fig. 105, *b*): (1) the largest tubercles, usually of a rounded-conical shape, but vary somewhat in length (the length is usually one third greater than the largest diameter, which is at the base). On the rounded apex occur short, rather thick hairs, terminally pointed, from 5 to 10 hairs to each tubercle. (2) Long hyaline, slender processes, which vary considerably in form, but are usually either finger-shaped or club-shaped; these are the highest and least abundant of all cuticular prominences, and are devoid of hairs. (3) These most abundant tubercles are usually conical in shape, and from one fourth to one half the length of the first kind; each bears on its summit a single strong hair, which is slightly longer than the hairs of the 1st kind of tubercles. (4) The smallest tubercles are not quite as high as the preceding kind, are hemispherical, and without hairs. On surface views of the cuticle (Figs. 104, 105, *a*) the various kind of tubercles are seen to be closely arranged together, without any regular distribution into groups. All these tubercles are very small, and may be distinguished clearly only on thin sections studied with the $\frac{1}{12}$ immersion lens of Zeiss.

Color. A more or less deep chocolate-brown, somewhat lighter on the anterior end; head (not merely its terminal tip) almost white.

Dimensions. Length of the larger individual, 212 mm.; greatest diameter of body, 1 mm.

Especial Diagnostic Characters. The three kinds of minute papillæ, which are not arranged into particular groups, furnish the chief diagnostic character.

Comparisons. This species differs in the characters of its cuticle from all foreign species of the genus. These characters appear to resemble those described by Camerano ('97, *b*) for *C. talensis;* but the description of this author is difficult to understand, and is without figures, so that it seems justifiable to class our species as new, at least until further descriptions and figures of *talensis* are published.

15. C. gordioides, n. sp.

Figs. 106, 107, Plate 13; Figs. 108-110, Plate 14.

(*Types*, males and 1 female: coll. Acad. Nat. Sci. Phila., Hayden's Survey, S. Montana.)

Form of Male. Anterior end slender, cylindrical, attenuated, head (Fig. 108) somewhat conical with obtusely truncated tip; mouth terminal. Body for the most part cylindrical, without well marked median grooves; thickest in the posterior fourth. Posterior end, for the distance of 10 mm., considerably narrower than the immediately preceding portion, and slightly flattened dorso-ventrally. Cloacal aperture on the ventral surface (Fig. 110), anterior to the posterior tip of the body; just anterior to this aperture is a slightly elevated semilunar ridge. In the medio-ventral line of the body, behind the cloacal aperture, is a shallow groove, to each side of which is a longitudinal prominence. The posterior end of the body is rounded terminally.

Form of Female. General form as in the male, the body thickest in the middle, narrowed anteriorly, more or less flattened posteriorly. Posterior end (Fig. 109, *a*, *b*) enlarged, somewhat spherical, constricted off from the immediately preceding portion of the body; cloacal aperture terminal, nearer the dorsal than the ventral side.

Cuticle. With low flattened tubercles, but little higher than the areolæ of *Gordius densareolatus.* On surface views (Fig. 107) these appear small, ovoid or rounded-polygonal in outline, but they vary considerably in shape and somewhat in size, and are often much elongated. They have a tendency to arrange themselves into parallel rows, contiguous rows being well separated from one another; the direction of these rows is slightly oblique to the transverse axis of the body, and their component tubercles are more or less confluent. Light colored lines also are seen on the surface of the cuticle, the distances which separate these lines being variable; these lines, the optical representations of shallow grooves, demarcate rhomb-shaped portions of the cuticle. On cross sections (Fig. 106) the tubercles are seen to be low, and usually flattened apically, with rounded margins; occurring at intervals, but sparsely, are club-shaped slender hyaline processes such as are characteristic of the genus, and these are about double the height of the tubercles; and also small inter-tubercular groups of short, spiniform hairs.

Color. In the males the head is yellowish white, with a narrow black ring (appearing like a spot) immediately around the mouth; the rest of the body a deep chocolate-color, or rufous-brown, with evidences of lighter brown bands and spots on the posterior end, though these spots were absent in one individual; in the smallest male the body color was a clear yellowish brown. In the single female specimen a black ring immediately surrounded the mouth opening; but the rest of the body is a clear yellow, the head and posterior tip of the body somewhat lighter.

Dimensions. Length of largest male, 215 mm.; greatest diameter, 1.3 mm. Length of female, 150 mm.; greatest diameter, .8 mm.

Diagnostic Characters. The presence of flattened tubercles, resembling the cuticular areoles of the genus *Gordius*, none of which have a light spot on the surface, and which tend to arrange themselves into irregular oblique rows, and the presence of inter-tubercular groups of small hairs, serve to distinguish this species.

Comparisons. This species resembles most closely *C. occidentalis*, n. sp. (*q. v.*). It also bears some resemblance to *C. moluccanus* Römer ('96), but differs from the latter in the form and more especially the arrangement of the tubercles of the cuticle, and in the swelling of the posterior end of the female.

The cuticle of this species resembles that of a *Gordius* rather than that of a *Chordodes*, except that it shows the typical hyaline processes of the latter genus; and since its cuticle thus unites characters of these two genera, the specific name *gordioides* is suggested.

16. C. occidentalis, n. sp.

Figs. 111-114, Plate 14; Figs. 115-117, Plate 15.

(*Type* 1 male: Harvard coll. no. 1469, San Francisco, Cal. A second male: Harvard coll. no. 1481, Rio Gila, Arizona.)

Form. Whole body much flattened dorso-ventrally, with the exception of the posterior end, in the type without, in the second specimen with, shallow median grooves; anterior and posterior ends narrower than the middle portion of the body, though the anterior end is attenuated only for a distance of about 1 cm. Head (Figs. 111, *a*, *b*) flattened, conical, the tip rounded or else obtusely truncated, and then the dorsal margin projects farther forward than does the ventral. Mouth terminal. In the second specimen (Figs. 114, *a*, *b*) a Y-shaped ridge is situated on the terminal aspect of the head, the mouth placed at the point of union of the three arms of the Y; the unpaired arm of this Y-shaped ridge runs from the mouth mediad and dorsal, the paired arms latero-ventrad.

Posterior end of the body is nearly cylindrical, somewhat flattened ventrally, and terminally either rounded or obliquely truncated. On the medio-ventral surface of the posterior end (Figs. 112, 113, *a*, *b*) is a shallow groove, which extends from the cloacal aperture caudad to the distal end of the body, and to each side of this groove is a longitudinal ridge of slight elevation.

Cuticle. On surface view (in Canada balsam) two kinds of low, flattened tubercles or areoles are to be seen (Figs. 115, 117): (1) The larger (those of greater diameter) are darker in color, and either elongate (in one specimen) or rounded-polygonal in outline. In the median line of the body they are smaller and more densely arranged than elsewhere. In one specimen (the type, Fig. 115) these areoles were non-confluent; but in the other they show a tendency to group themselves in interrupted, transverse rows, and consequently are more elongate in form than in the former (type) specimen. On the surface of some of the larger areoles is seen a small, circular clear spot, in the centre of which appears a small granule; sections show that this spot is a pit on the surface of the tubercle, which is nearly filled with a small rounded-conical process; those tubercles on the lateral surfaces of the body which contain such clear spots, and they are few in number, are usually dumbbell-shaped in outline, and their clear spots are smaller than those of the median tubercles, in which they occur more frequently. (2) Smaller, lighter colored tubercles, much more variable in form and size than the preceding, and which are irregularly arranged between the former kind. In one of the specimens a system of oblique lines is seen on the surface of the cuticle, and these lines are peculiar in that they do not lie between rows of areoles, but appear to run right across their surface (Fig. 117).

On transverse section of the cuticle two kinds of tubercles are seen, corresponding to the two kinds seen on surface views (Fig. 116): (1) Low tubercles of greater diameter, which are flattened apically, and have no projections. (2) Tubercles of smaller diameter, very irregular in form, and usually of slightly less elevation than the preceding; these correspond to the smaller, lighter tubercles seen on surface views. The apex of these is not flattened, but more or less irregularly rounded; from the summit project upwards short conical or spiniform processes, which are exceedingly variable in form, sometimes cleft or pectinate terminally, though most of them are largest at the base and pointed at the apex. Rarely is there only a single process to a tubercle: as a rule there are a number, and on the tubercles of the dorso-median line of the body they are more numerous than elsewhere. In addition to these two kinds of tubercles are seen on sections, though only sparsely, hyaline club-shaped processes.

Color of type specimen: black, at the anterior end of the body with a reddish tinge; the tip of the head yellowish white. The second specimen was of a deep rufous-brown color, lighter at the anterior tip of the body, and blackish at the posterior end.

Dimensions. Length of larger individual (type), 255 mm.; greatest diameter, 1.5 mm.

Especial Diagnostic Characters. The presence of two kinds of slightly elevated tubercles on the cuticle: tubercles of greater diameter with smooth summit, a few of which have an apical clear spot; and tubercles of smaller diameter and usually less elevation, the surface of which is not smooth, but with more or less numerous conical or spiniform short processes.

Comparisons. This species is more closely allied to *C. gordioides* than to any other, but differs from it in the following points: the presence of tubercles whose surface bears short processes, the presence of clear spots on the surface of some of the smooth tubercles, and the absence of groups of inter-tubercular hairs; there are also differences in coloration, such as the absence of a black ring around the mouth aperture, and the much darker color of the body.

17. C. cubanensis, n. sp.

Figs. 118-123, Plate 15.

(*Type of Female*: Harvard coll. 1466, Cuba. *Type of Male*: Harvard coll. 1466 d, Cuba.)

Form of Male. Body nearly cylindrical, without well marked median grooves; anterior end slightly attenuated. Head (Fig. 123) very narrow, truncated apically, slightly concave on the terminal aspect; on the ventral surface alone is there a constriction separating the head from the body. Posterior end (Fig. 122) flattened on the ventral surface, with a median groove behind the cloacal aperture; this groove is broadest and deepest at the ventro-terminal point of the body; just behind the cloacal aperture is a transverse semilunar ridge.

Form of Female. Larger and more robust than the male, the shape of the anterior portion of the body otherwise similar. Head (Fig. 120) rounded at the apex, mouth nearer the ventral than the dorsal margin of the head. Posterior portion of the body (Fig. 121) narrower than the middle, but the extreme distal end is swollen, and of greater diameter than the part immediately preceding. This posterior end is obliquely truncated, the dorso-terminal margin projecting farther caudad than the ventro-terminal; the swelling is most pronounced on the ventral side.

Cuticle (Fig. 119). With papillæ of three kinds, besides hyaline processes; though it is difficult to distinguish sharply between these kinds since they seem to intergrade. The hyaline processes have the same form as in most other species of the genus, and are slender club-shaped processes, slightly swollen and rounded at the apex; they are about the height of the highest papillæ. *1st Kind of Papillæ:* The smallest, least elevated, and most numerous of all occur close together between the groups of larger papillæ, and also in the latter groups. They are pyramidal or somewhat elongate-conical on lateral view, pointed at the apex which bears a single (rarely two) long, delicate, usually curved spine; this spine is thickest at the base and sometimes recurved at the tip. A modification of these tubercles attains nearly the height of the largest papillæ. *2d Kind of Papillæ:* These, the second in point of numerical abundance, occur usually in groups close together. They are much larger than the preceding, round on cross section, usually considerably longer than broad, slightly thickened at the base but with nearly parallel sides, and with rounded summit. In a few cases the sides of these papillæ may be somewhat denticulate. On the margin of the rounded or flattened apex occur from three to six short thick spines, which are broadest at the base and pointed at the tip; these spines curve upwards and outwards, and are shorter and thicker than those of the preceding category of papillæ. These papillæ vary considerably in form, and sometimes are nearly square in lateral outline. *3d Kind of Papillæ:* These are of the same form and size as the preceding, but are less numerous (the groups which they compose are smaller), and differ from them in the absence of spines on their summits; the apex of most of them is elliptically rounded, rarely flattened, and then somewhat denticulate with short conical processes; some of these papillæ are expanded at the summit.

On surface views (Fig. 118) of the cuticle, seen with a low power of magnification, only the second and third kinds of papillæ are seen, and they appear as small brown disks with a clearer central point. The cuticle of the male differs from that of the female only in that the larger kinds of papillæ are less abundant, and the groups formed by them smaller.

Color. The males are uniform pitch-black, the head somewhat lighter; in the female the whole body is deep black.

Dimensions. Length of largest male, 165 mm.; greatest diameter, 1 mm. Length of female, 280 mm.; greatest diameter of body, 1.6 mm.; greatest diameter of tail swelling, 1 mm.

Especial Diagnostic Characters. The dense arrangement of the usually pencil-shaped papillæ, and the union of the larger of them into large and irregular groups, together with the black color of the body, serve to distinguish this form.

Comparisons. In color this species resembles *C. brasiliensis* Janda, and *C. festæ* Camer.; but it differs from the former as well as from *C. morgani*, n. sp., in the form and arrangement of the papillæ. In the structure of the cuticular papillæ it also differs from *festæ*, judging from Camerano's description: but unfortunately most of the South American *Gordiacea* described by this author have not been figured, and for a clear understanding of the form and arrangement of areoles and papillæ figures are absolutely necessary.

Postscript. — The preceding descriptions of body form, color, and dimensions have been based entirely upon a study of alcoholic specimens, with the consequence that the particulars in regard to coloration and dimensions could be only approximately ascertained, since the action of the alcohol would probably produce shrinkage, and certainly obscures the brightness of the coloration. Formaline would probably be a superior fluid for the preservation of museum specimens. For purposes of histological fixation rapidly penetrating fluids are necessary, such as picro-formaline or picro-nitric acid.

APPENDIX.

Since the preceding was sent to press (on the 16th August, 1897) I have received from Professor Camerano the following important contribution by him: "Monografia dei Gordii" (Accademia Reale delle Scienze di Torino, 1897). This paper furnishes descriptions and revisions of all known species of Gordiacea, with illustrations of all those described by Camerano, and is especially valuable on this account from the systematic standpoint. To the already known genera *Gordius* and *Chordodes*, this author adds two others, namely, *Paragordius* and *Parachordodes*. *Paragordius* embraces, according to Camerano, *G. tricuspidatus* (Dufour), *G. emeryi* Cam., *G. stylosus* Linstow, and *G. varius* Leidy. He characterizes it as follows: "L' estremità posteriore del ♂ è biforcata al di là dell' apertura postcloacale con lobi profondamente separati fra loro: non vi è lamina cutanea postcloacale. L' estremità posteriore della ♀ è divisa in tre lobi postcloacali profondamente separati fra loro i quali circondano l' apertura cloacale. Lo strato cuticolare esterno presenta delle formazioni areolari di una sola seria e pochissimo sporgenti, irregolarmente disposte: non vi sono granuli o tubercoli rifrangenti interareolari." By an unusual coincidence, I had in the preceding pages proposed the same name, *Paragordius*, to include Leidy's species *Gordius varius*, so that independently of one another Camerano and I have founded a new genus, and given it the same name for the same species. By the rules of priority in nomenclature, however, Camerano's publication having appeared first, the genus must stand Paragordius Camerano, not Montgomery. But the diagnostic given by Camerano for this new species is not very well chosen, for in it the only character of possible genetic value mentioned is the trilobation of the posterior end in the female; this character is of doubtful generic value, since in *Gordius tolosanus* Duj. the posterior end of the female is somewhat lobed, though in this case the lobation is generally regarded as only a specific character! I think the characters described above by me as diagnostic of the new genus, — namely, the structure of the cloaca in the female and the absence of a cloacal musculature in the male, — are of higher value, and accordingly should constitute the diagnostic of the genus. The second new genus of Camerano is characterized thus (*Parachordodes*): "Estremità posteriore del ♂ biforcata al di là apertura cloacale, con lobi profondamente separati fra loro: nessuna lamina-cutanea postcloacale. L' estremità posteriore della ♀ è intiera coll' apertura cloacale mediana collocata in un solco dorso ventrale più o meno profondo. Strato cuticolare esterno meno complicato che nel genere Chordodes: ora con una sola sorta di formazioni areolari, ora con formazioni areolari di due sorta: le une più basse e chiare: e le altre un po' più elevate e scure che stanno intorno allo sbocco dei canaletti che attraversano gli strati cuticolari: fra le areole spesso vi sono granuli o tubercoli rifrangenti." *Parachordodes* thus differs from *Gordius* merely in regard to cuticular structures, and I cannot consider that such differences warrant the separation of a new genus. For in the Gordiacea the cuticular differences have little more than specific value, as is well shown by the fact that the cuticle may show marked differences in different individuals of the same species. If more important differences than these be subsequently determined, then, and not until then, does it seem justifiable to me to recognize *Parachordodes* as a well defined genus; and hence it should for the present be retracted into *Gordius*. (A preliminary to this monograph was published by Camerano in the Zool. Anzeiger for August, 1897, with the title "Nuova classificazione dei Gordii.") In this paper are given figures of the cuticle of *Chordodes talensis* Cam., which represent its structure as quite different from that of my new species, *C. puerilis*.

Here may also be mentioned certain papers on American Gordiacea which had been omitted in the preceding pages.

Girard (1851, "Historical Sketch of Gordiacea," Proc. Acad. Nat. Sci. Philadelphia, 5) mentions a specimen caught at Richmond, Virginia, and several collected in Oregon by the U. S. Exploring Expedition.

Sanford (1853, "On some Points in the History of Gordius," Proc. Amer. Assoc. Sci.) collected some specimens from crickets (Gryllidæ).

Thompson (1853, "History of Vermont," Burlington) states that Gordii are very common in still waters and mud in that State.

White (1859, "Gordius trifurcatus, n. sp.," Proc. Boston Soc. Nat. Hist., 7) gives the following description of this species, which may possibly be referable to the ♀ of *Paragordius varius* (Leidy): "Male. Length, 5 inches; diameter, ⅛ line; shape uniformly cylindrical; head obtusely conical; posterior end divided into two long and narrow lobes, and one shorter and broader lobe, incurved and fringed with short thick hairs. At base of larger lobe is the genital opening, from which the spermatozoa are seen escaping with extremely long tails. Color uniformly light brown. . . . It does not answer to either of the two described by Dr. Leidy."

Clementi (1869, "Hair Snakes," Canadian Entomologist) found Gordii (?) in a large spider.

Leidy (1870, "The Gordius, or Hair-worm," Amer. Entomol. and Botanist, 2) gives a good description and some figures (the only figures published by him of members of this group) of his *G. varius*. He considers the males of this form, as previously described by him, to be really of two different species: in the one (*varius*) the forks of the tail are thick, with a crescentic fold above the genital pore. In the other males (*G. longilobatus*, n. sp.) "the forks of the tail are two or three times the length of the thickness of the body, and the forks do not include at their base a crescentic fold as in the former." (The male here termed "*varius*" is really *G. aquaticus robustus*, while "*longilobatus*" is the true *Paragordius varius*.)

Leidy (1871, "Notice of some Worms," Proc. Acad. Nat. Sci. Philadelphia) describes as "*Gordius lacustris*" several specimens from Kansas; but "*lacustris*" is certainly a misprint for "*robustus*," since the papers to which he refers for the preceding name make no mention of it.

Garman (1886, "Amblystoma and Gordius," Science Observer, Boston Sci. Soc., cited by Camerano) mentions a *Gordius* found in *Amblystoma*.

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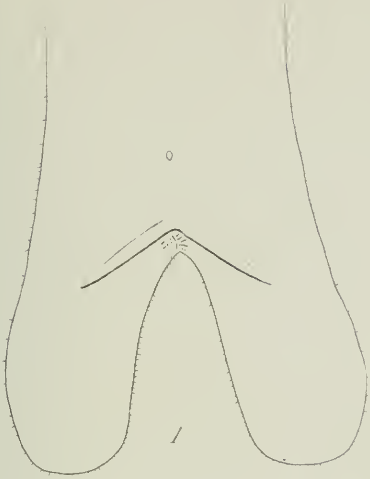
EXPLANATION OF THE PLATES.

All the figures have been drawn with the aid of the camera lucida, unless otherwise specified. The microscope and lenses of Zeiss were used; almost all the contour figures of the body have been drawn with oc. 2, obj. A; and the majority of the surface figures of the cuticle with oc. 4, obj. C.

PLATE 1.

Gordius aquaticus robustus.

Fig. 1. Male, ventral view of posterior end (A, 4).
Fig. 2. Idem, head end (A, 2).
Fig. 3. Male, oblique ventral view of posterior end (Harvard coll. 290, A, 2).
Fig. 4. Lateral view of the preceding, from the left side.
Fig. 5. Male, ventral view of posterior end (A, 2).
Fig. 6. Male, ventral view of head end; the transverse curved line shows the posterior extension of the white area (A, 2).



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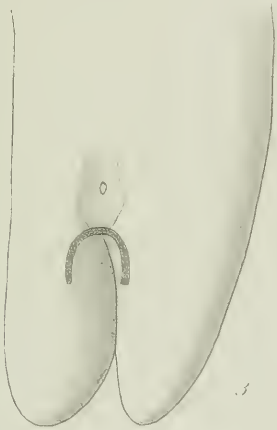

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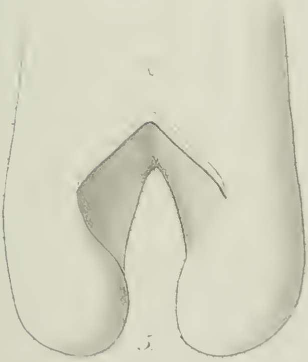

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PLATE 2.

G. aquaticus robustus.

Fig. 7. Female, ventral view of posterior end; a portion of the brown ring around the anus is to be seen (A, 2).

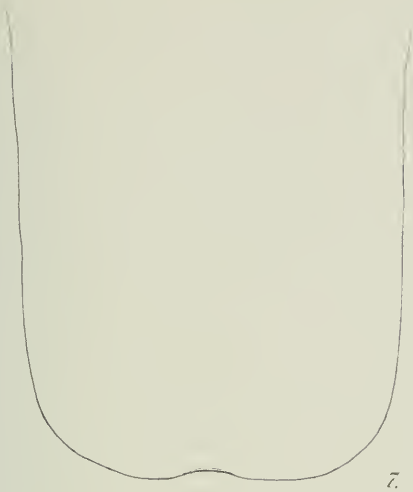
Fig. 8. Female, posterior end, showing the ring of brown color around the cloacal aperture (A, 2).

Fig. 9. Male, antero-ventral view of the head end, showing the grooves on the surface (A, 2).

Fig. 10. Idem, lateral view.

Fig. 11. Female, head end (A, 2).

Fig. 12. Surface view of the cuticle, Canada balsam, the finest lines drawn only in one portion (C, 4).



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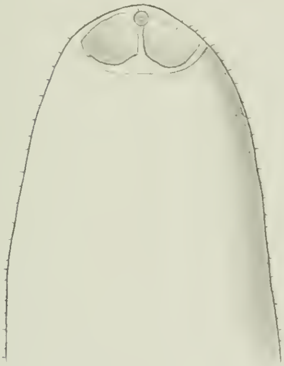

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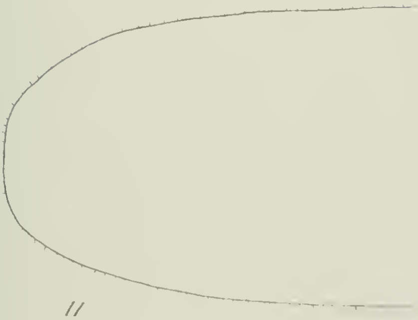

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PLATE 3.

Fig. 13. *G. aquaticus robustus.* Surface view of the cuticle of a male, the intrarhombic intersecting lines not reproduced (C, 4).

Fig. 14. *G. aquaticus difficilis*, n. subsp. Male, head end, from the type (A, 2).

Fig. 15. Idem, oblique lateral view of the posterior end (A, 2).

Figs. 16–19, *G. aquaticus robustus.*

Fig. 16. Male, surface view of the cuticle, Canada balsam (C, 4).

Fig. 17. Female, head end (A, 2).

Fig. 18. Male, cross section through the body in the plane of the cloacal aperture. *Cut.*, cuticula; *Epi.*, epidermis; *Musc.*, longitudinal musculature of the body wall; *Cl. Musc.*, cloacal musculature; *Cn. t.*, connective tissue; *N.*, branches of the ventral nerve chord; *Cl. Ap.*, cloacal aperture (C, 2).

Fig. 19. Male, ventral view of posterior end (A, 2).

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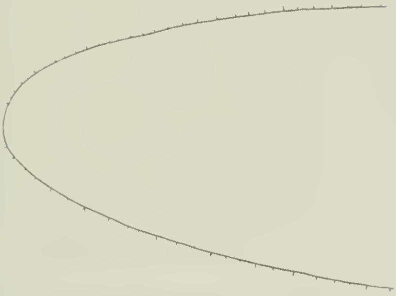

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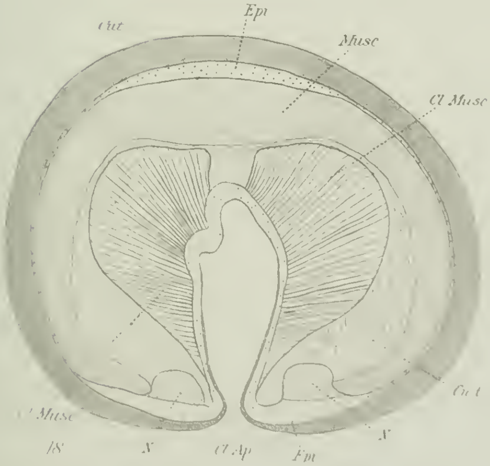

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PLATE 4.

Figs. 20–31, *Gordius lineatus* Leidy.

Fig. 20. Female, antero-ventral view of head end (A, 2).
Fig. 21. Male (type), head end (A, 2).
Fig. 22. Female (type), lateral view of posterior end (A, 2).
Fig. 23. Female, posterior end, the cloacal epithelium apparently extruded (A, 2).
Fig. 24. Male (type), lateral view of the posterior end (A, 4).
Fig. 25. Idem, ventral view (A, 2).
Fig. 26. Male, oblique lateral view of posterior end (A, 2).
Fig. 27. Male, ventral view of posterior end (A, 2).
Fig. 28. Female (type), termino-ventral view of posterior end, showing the colored ring around the cloacal aperture (A, 2).
Fig. 29^{a}. Male (type), transverse section of the cuticle (immers. $\frac{1}{12}$, 2).
Fig. 29^{b}. Idem, surface view (C, 4).
Fig. 30. Male, surface view of cuticle (C, 4).
Fig. 31. Female, transverse section of cuticle (immers. $\frac{1}{12}$, 2).

Figs. 32, 33, *G. densareolatus*, n. sp.

Fig. 32. Female, surface view of cuticle (C, 4).
Fig. 33. Transverse section of the cuticle of the same specimen (immers. $\frac{1}{12}$, 2).


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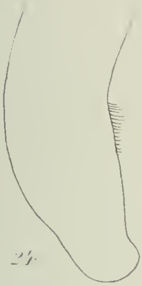
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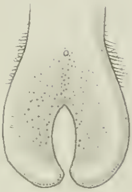
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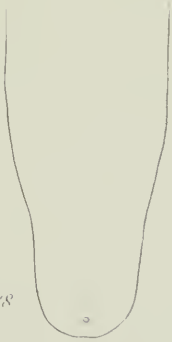
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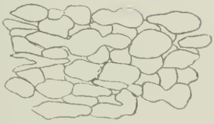
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PLATE 5.

G. densareolatus, n. sp.

Fig. 34. Female, head end (A, 2).
Fig. 35. Female (type), head end (A, 2).
Fig. 36. Male (type), oblique lateral view of posterior end (A, 2).
Fig. 37. Idem, ventral view.
Fig. 38. Female (type), posterior end (A, 2).
Fig. 39. Female, posterior end rendered transparent by cedar oil, the intestine and a portion of the atrium and oviducts are seen. The transverse line represents the edge of the extruded cloacal epithelium (A, 2).

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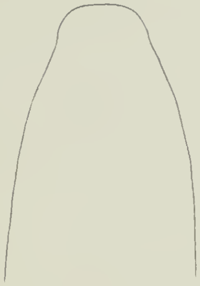

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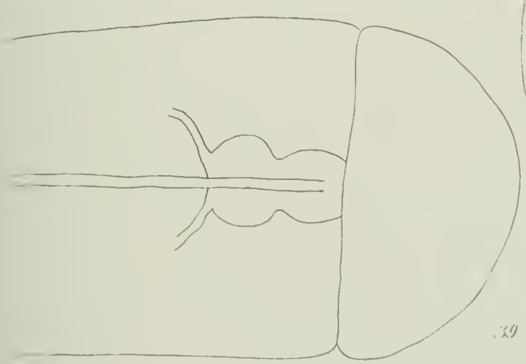

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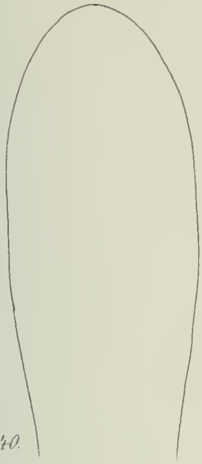
PLATE 6.

G. platycephalus, n. sp.

Fig. 40. Male (type), head end (A, 2).
Fig. 41. Idem, ventral view of posterior end (A, 2).
Fig. 42. Female: *a*, oblique ventral view of posterior end; *b*, dorsal view of head end; *c*, lateral view of head end (A, 2).
Fig. 43. Female (type), ventral view of posterior end (A, 2).
Fig. 44. Idem, lateral view.
Fig. 45. Female (type), head end seen in its broadest plane of expansion (A, 2).



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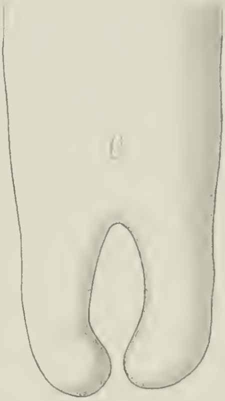

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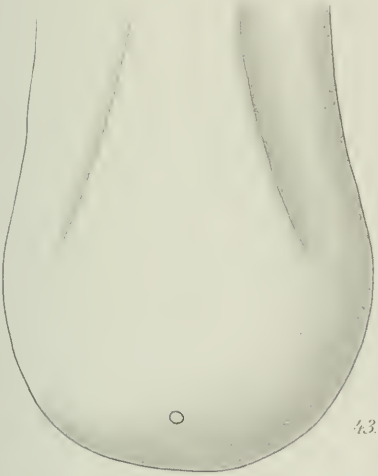

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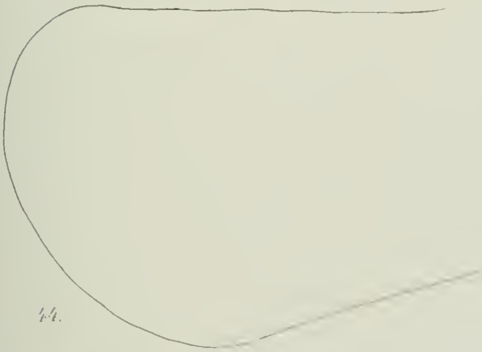

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PLATE 7.

Figs. 46–49, *G. platycephalus*, n. sp.

Fig. 46^{a}. Female, surface view of cuticle (C, 4).
Fig. 46^{b}. Transverse section of the cuticle of the same individual (immers. $\frac{1}{12}$, 2).
Fig. 47. Female (type), surface view of cuticle (C, 4).
Fig. 48. Female, transverse section of cuticle (immers. $\frac{1}{12}$, 2).
Fig. 49. Male (type), transverse section of cuticle (immers. $\frac{1}{12}$, 2).

Figs. 50–52, *G. platyurus* Baird. Female.

Fig. 50. Surface view of cuticle, the finest intersecting lines reproduced at only one place (C, 4).
Fig. 51. Posterior end, free hand drawing. × about 4.
Fig. 52. Head end (A, 2).

Figs. 53–55, *G. leidyi*, n. sp. Female.

Fig. 53. Dorsal view of the head (A, 2).
Fig. 54. Transverse section of the cuticle (immers. $\frac{1}{12}$, 2).
Fig. 55. Surface view of cuticle (C, 4).

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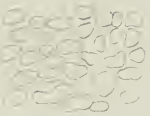

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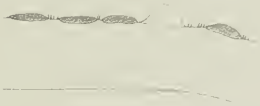

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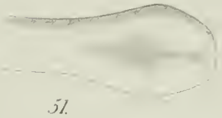

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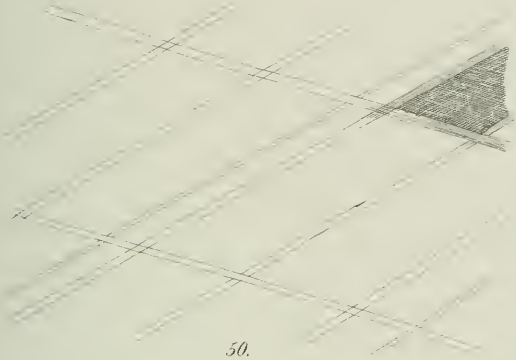

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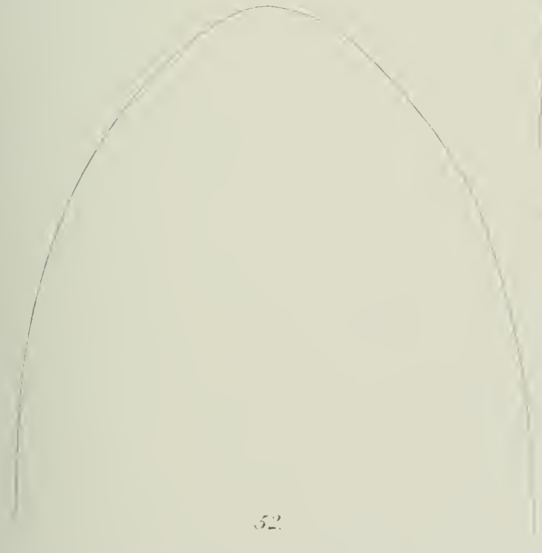

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PLATE 8.

Figs. 56–59, *G. leidyi*, n. sp. Female (type).

Fig. 56. Dorsal view of posterior end (A, 2).
Fig. 57. Idem, termino-ventral view.
Fig. 58. Idem, oblique lateral view.
Fig. 59. Surface view of cuticle (C. 4).

Figs. 60–62, *G. violaceus* Baird (?). Female (Harvard coll. no. 1465).

Fig. 60. Posterior end (A, 2).
Fig. 61. Head end (A, 2).
Fig. 62. Surface view of cuticle (C, 4).

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PLATE 9.

Figs. 63–66, *G. agassizi*, n. sp. Male (type).

Fig. 63. Dorsal view of anterior end (A, 2).

Fig. 64. Surface view of cuticle (seen in alcohol, A, 4).

Fig. 65. Posterior end of the body, the tail lobes seen from the right side, the preceding portion of the body from the latero-ventral aspect (A, 2).

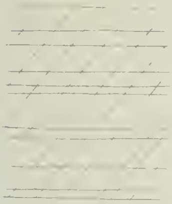
Fig. 66. Posterior end, tail lobes seen from the termino-dorsal aspect, the preceding portion of the body from the ventral (A, 2).

Figs. 67–69, *G. capitosulcatus*, n. sp. Male (type).

Fig. 67. Terminal aspect of head end, its ventral edge towards the bottom of the page (A, 2).

Fig. 68. Surface view of cuticle (C, 4).

Fig. 69. Dorsal view of head end (A, 2).



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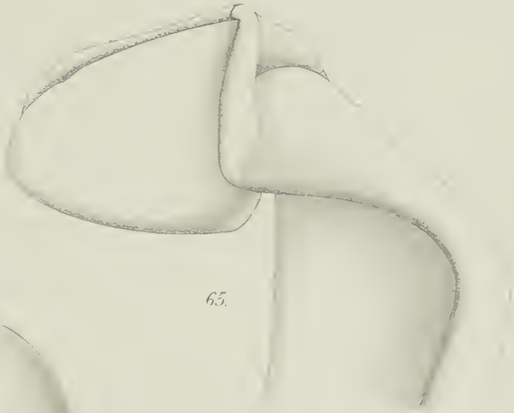

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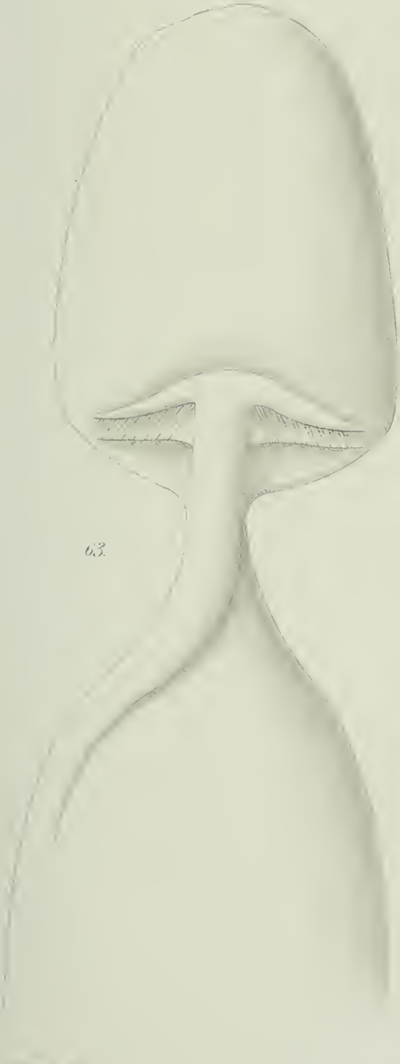

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PLATE 10.

Fig. 70. *G. capitosulcatus*, n. sp. Male (type), oblique ventral view of the posterior end (A, 2).

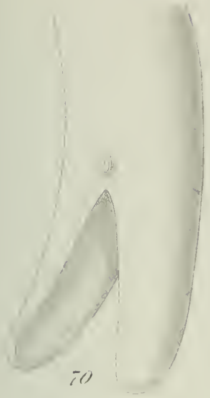
Figs. 71–74, *G. paranensis* Camer.

Fig. 71. Female, termino-ventral view of the posterior end (A, 2).

Fig. 72. Male, posterior end: *a*, oblique ventral view; *b*, oblique lateral view (A, 2).

Fig. 73. Male, head end (A, 2).

Fig. 74. Male, head end (A, 4).



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THM Jr del.

PLATE 11.

Figs. 75–77, *G. violaceus* Baird (?). Female, Harvard coll. no. 1466 c.

Fig. 75. Latero-ventral view of posterior end (A, 2).

Fig. 76. Head end (A, 2).

Fig. 77. Transverse section of cuticle (immers. $\frac{1}{12}$, 2).

Figs. 78–85, *Paragordius varius* (Leidy).

Fig. 78. Male, transverse section through the plane of the cloacal aperture. *Cut.*, cuticle; *Epi.*, epidermis; *Musc.*, longitudinal musculature of the body wall; *Par.*, parenchym; *N.*, branches of the ventral nerve chord; *Cl. Ap.*, cloacal aperture (C, 2).

Fig. 79. Female, transverse section through the body in the plane of the caudal ganglion. *Cl. Epi.*, cloacal epithelium; *N. Gl.*, ganglion of the ventral nerve chord; the other lettering as in the preceding figure (C, 2).

Fig. 80. Female, cross section through the tail lobes near their proximal ends; the median lobe is on the dorsal side (A, 2).

Fig. 81. Female, cross section of tail lobes near their distal ends (A, 2).

Fig. 82. Male, oblique dorsal view of head (A, 2).

Fig. 83. Female, head end: *a*, ventral view; *b*, dorsal view, showing two colored stripes. The colored ring around the neck is shown in these figures (A, 2).

Fig. 84. Female, ventral view of head end; the transverse line shows the posterior limit of the white area (A, 2).

Fig. 85. Female, lateral view of head end; the transverse line shows the posterior limit of the white area (A, 2).

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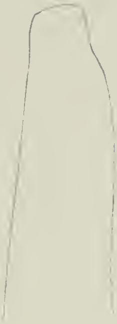

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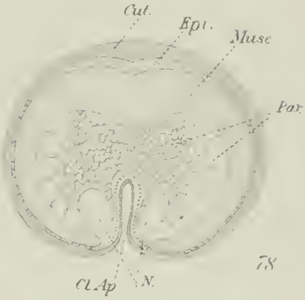

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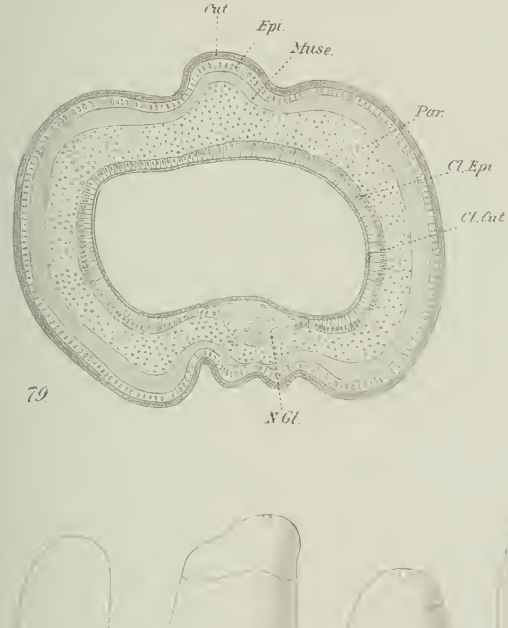

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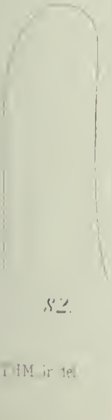

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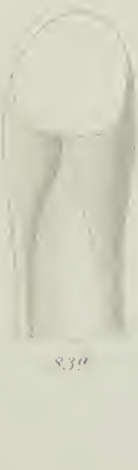


83a.

83b.

PLATE 12.

Figs. 86–93, *Paragordius varius* (Leidy).

Fig. 86. Optical median section of the posterior end of the female, from a reconstruction of sections (A, 2), to show the characteristic length of the cloaca. The omitted portion x–y has about ten times the length of the portion x–z. *T. l.*, tail lobes; *Cut.*, cuticle; *Cl.*, cloaca; *Cl. Ap.*, cloacal aperture; *Atr.*, atrium (uterus); *Ov. D.*, left oviduct; *Int.*, intestine; *Rec. S.*, receptaculum seminis.

Fig. 87. Male, oblique ventral view of posterior end (A, 2).

Fig. 88. Female, posterior end from the dorsal side (A, 2).

Fig. 89. Female, oblique dorsal view of the posterior end (A, 2).

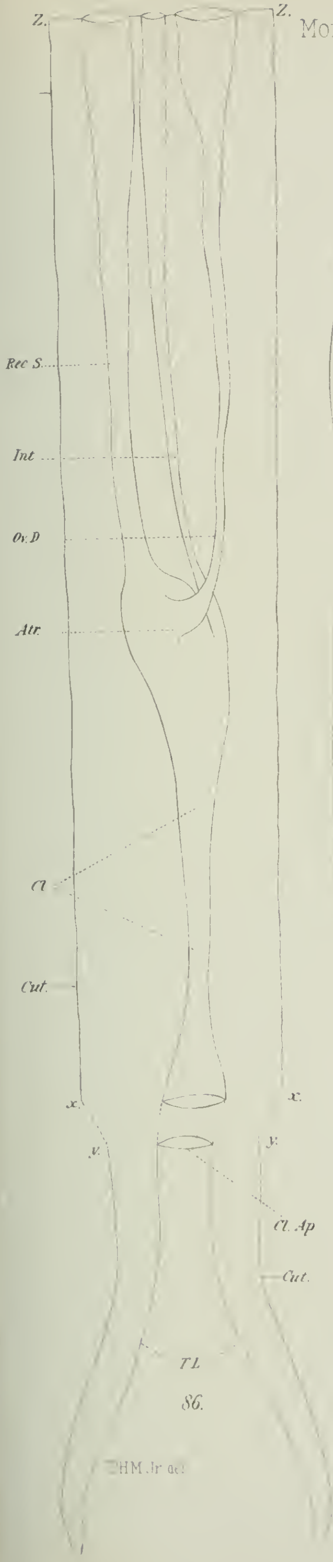
Fig. 90. Female, dorsal view of the posterior end (A, 2).

Fig. 91. Cuticle of a female: *a*, transverse section (immers. $\frac{1}{12}$, 2); *b*, surface view (C, 4).

Fig. 92. Female, surface view of cuticle (C, 4).

Fig. 93. Male, surface view of cuticle (C, 4).

Fig. 94. *Chordodes morgani*, n. sp., female (Harvard coll. 1470). Head end from the left side (A, 2).



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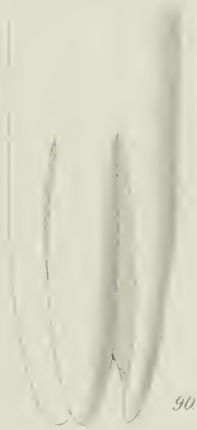

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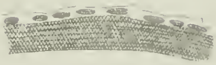

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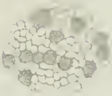

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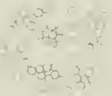

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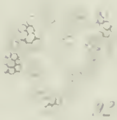

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PLATE 13.

Figs. 95–100, *Chordodes morgani*, n. sp., female; 95, 96, from Harvard coll. 1470; 97–100, from the type specimen.

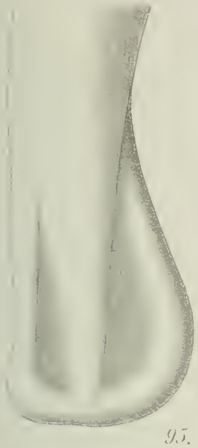
Fig. 95. Posterior end from the right side (A, 2).
Fig. 96. Termino-lateral view of the posterior end (A, 2).
Fig. 97. Lateral view of the posterior end, right side (A, 2).
Fig. 98. Head end (A, 2).
Fig. 99. Transverse section of the cuticle (immers. $\frac{1}{12}$, 2).
Fig. 100. Surface view of the cuticle, from the side of the body (C, 4).

Figs. 101–105, *b*, *C. puerilis*, n. sp., male. Figs. 101–104, from the type specimen; 105, *a* and *b*, from a specimen in my possession.

Fig. 101. Head end, dorsal view (A, 2).
Fig. 102. Idem, lateral view.
Fig. 103. Oblique ventral view of the posterior end (A, 2).
Fig. 104. Surface view of the cuticle (C, 4).
Fig. 105. Cuticle: *a*, surface view (C, 4); *b*, transverse section (immers. $\frac{1}{12}$, 2).

Figs. 106, 107, *C. gordioides*, n. sp., male (type).

Fig. 106. Transverse section of the cuticle (immers. $\frac{1}{12}$, 2).
Fig. 107. Surface view of cuticle, the areoles reproduced on only a portion of the surface (C, 4).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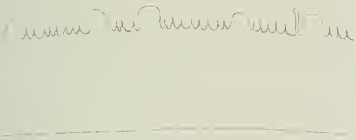
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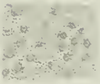
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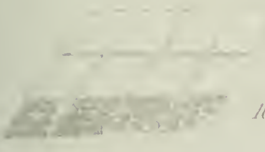
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PLATE 14.

Figs. 108–110, *C. gordioides*, n. sp. (types).

Fig. 108. Male, head end (A, 2).
Fig. 109. Female, posterior end: *a*, ventral view; *b*, lateral view (A, 2).
Fig. 110. Male, ventral view of posterior end (A, 2).

Figs. 111–114, *C. occidentalis*, n. sp., males.
Figs. 111, 112, from the type specimen.

Fig. 111. Head end: *a*, lateral view; *b*, dorsal view (A, 2).
Fig. 112. Lateral view of posterior end (A, 2).
Fig. 113. Posterior end: *a*, oblique dorsal view; *b*, from the left side (A, 2).
Fig. 114. Head end: *a*, termino-ventral view; *b*, from the left side (A, 2).

108.

109^a

109^b

110

111^a

111^b

112

113^a

113^b

114^a

114^b

T.H.M. ad del. [illegible]

PLATE 15.

Figs. 115–117, *C. occidentalis*, n. sp., males, the first two from the type specimen.

Fig. 115. Surface view of the cuticle, a line passing through x, x shows the median plane of the body (C, 4).

Fig. 116. Transverse section through the cuticle in the dorso-median plane of the body (immers. $\frac{1}{12}$, 2).

Fig. 117. Surface view of the cuticle; the arrow denotes the line of the transverse axis of the body (C, 4).

Figs. 118–123, *C. cubanensis*, n. sp. (types).

Fig. 118. Female, surface view of cuticle (C, 4).

Fig. 119. Female transverse section of cuticle (immers. $\frac{1}{12}$, 4).

Fig. 120. Female, head end (A, 2).

Fig. 121. Female, posterior end from the left side (A, 2).

Fig. 122. Male, oblique ventral view of the posterior end (A, 2).

Fig. 123. Male, head end from the right side (A, 2).

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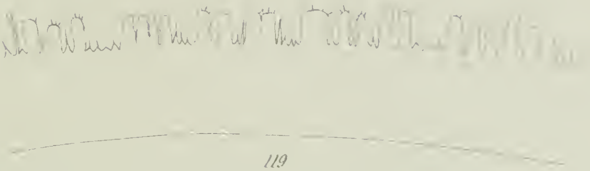

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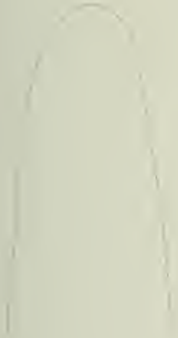

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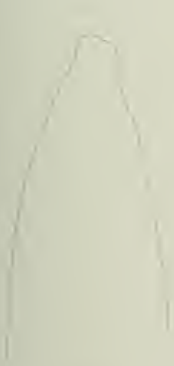

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Bulletin of the Museum of Comparative Zoölogy
AT HARVARD COLLEGE.
Vol. XXXII. No. 4.

SOME PLANARIANS FROM THE GREAT BARRIER REEF OF AUSTRALIA.

By W. McM. Woodworth.

With One Plate.

CAMBRIDGE, MASS., U. S. A.:
PRINTED FOR THE MUSEUM.
April, 1898.

No. 4. — *Some Planarians from the Great Barrier Reef of Australia.* By W. McM. Woodworth.

Pseudoceros devisii, sp. nov.

Fig. 1.

General color, bright orange-yellow, with a broad marginal band of deeper orange and a prominent median dorsal ridge along which the pigment is denser than over the general surface of the body, though not so deep in color as the marginal band. Length, 33 mm.; greatest breadth, 16 mm. From the Brisbane River near Brisbane, April, 1896.

The single specimen of this species, was given to me by Mr. C. W. de Vis, the curator of the Brisbane Museum, in whose honor it is named. The drawing for the accompanying figure (Fig. 1) was prepared by Dr. A. G. Mayer, but unfortunately the specimen was destroyed before it could be preserved, or studied in detail. The color and brilliancy of its markings, however, distinguish it from any described species.

Idioplana australiensis, gen. nov., sp. nov.

Figs. 2-5.

General color, bluish to yellowish cream when seen on black background, more reddish on white background. Small spots of dark reddish brown uniformly distributed over the dorsal surface except at extreme margin, which is free from pigment. Ventral surface without pigment, white. Slightly translucent; pharynx and male organs indistinctly visible, the vasa deferentia together with the penis forming a Y-shaped figure (Fig. 2). Expanded anteriorly, with a deep median fold or notch. Anterior or expanded portion provided with marginal eye-spots extending backwards to a distance about one third the total length of the animal from the anterior end. No marginal eye-spots in anterior median notch. Two tentacles, situated about one sixth the total length from the anterior end; anterior faces of tentacles provided with eye-spots, and a scattered group of eye-spots over the brain region extending as far forwards as a line joining the tentacles (Fig. 3). Length 50 mm.; greatest breadth 22 mm. A very sluggish form. Only one specimen, taken on the reef at Hope Island, May 12.

The genus Idioplana differs from other Planoceridæ chiefly as regards the sexual organs. The closely approximated sexual openings lie in the anterior part of the posterior third of the body, and in the preserved specimen the male gonopore was at a distance of less than 1 mm. from the female opening. There is a large muscular penis enclosing a spacious prostate gland ("Körnerdrüse"), which communicates with the ductus ejaculatorius at the tip of the organ, the two ducts opening to the exterior almost together (Fig. 5). The ciliated ductus ejaculatorius extends along the ventral wall of the penis, at the posterior end of which it divides into two vesiculæ seminales, convoluted tubes with muscular walls (not well shown in the diagram, Fig. 4). The vasa deferentia are two large convoluted canals of nearly uniform calibre which connect with the vesiculæ seminales at the root of the penis. There are also two smaller posterior seminal canals which unite with the main anterior canals immediately before these join the vesiculæ seminales (Fig. 4). As the specimen was in a late stage of sexual activity, no trace of the testes could be found, and the vasa deferentia were only partly filled with spermatozoa.

The female gonopore leads into a spacious bursa, from which the vagina, with diminishing calibre, leads upward and backward over the male organ, and receives the oviducts which open into it opposite to one another at a point above the posterior limits of the penis. The canal, which is ciliated throughout, and which from now on is reduced in diameter and uniform in calibre, passes forwards and downwards over the penis, reaching nearly to the ventral wall, and then bends upwards and backwards again, passing over the vagina and terminating a little posterior to the female gonopore in a vesicle or enlargement, "accessorische Blase" (Figs. 4 and 5).

The terminology employed in the description of the sexual organ of this species is not that which is customarily used in descriptive anatomy of Polyclads, but corresponds to the terminology applied to Triclads. The so called "accessory vesicle" I believe to be directly homologous with the uterus of Triclads, and that fertilization takes place in it. Although the single specimen of the species under consideration was far advanced sexually, there was still a packet of spermatozoa in the uterine vesicle, and Plehn[1] has figured the uterine vesicle of Latocestus atlanticus containing both ova and spermatozoa.

Diposthus corallicola, gen. nov., sp. nov.

Figs. 6-11.

Color, yellowish rose; very opaque except at margin, which is bluish and very translucent. Of the internal organs the position of the pharynx only can be seen as a lighter ragged median streak. Two closely approximated groups of eye-spots about one tenth the total length of the animal from the anterior end. Two pointed conical tentacles close to anterior margin. Length, 15–40 mm.; greatest breadth, 6–13 mm. Abundant under coral rock on reef at Hope Island, May 12. A very active form.

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[1] Plehn, M. Neue Polycladen gesammelt von Herr Kapitän Chierchia, etc. Jen. Zeitschr. f. Naturw., Bd. XXX. p. 160, Taf. XI. Fig. 10, 1896.

The peculiarities of the male sexual organs of this form have necessitated the establishment of a new family for its reception (Diposthidæ). The salient feature is the separation of the penis and prostate gland into two distinct organs, both of which are doubtless intromittent. The prostate gland ("Körnerdrüse") occupies the male genital atrium together with the penis, and lies posterior to it directly over the gonopore. It is slightly larger than the penis, and both organs are nearly pendent or perpendicular in position (Figs. 8, 9, and 11). The prostate gland is provided with a heavy layer of circular muscles, which together with the epithelial covering of the organ decrease in thickness toward the free end, and at the very tip are entirely lacking. I could not satisfy myself that there was an opening at this point, nor could I demonstrate any distinct lumen, which is explicable, possibly, by the fact that all of the specimens were in a late stage of sexual activity, all traces of testes, vasa deferentia, ovaries, and oviducts having disappeared. Two kinds of nuclei occur in the prostate gland, deeply staining nuclei which are found chiefly under the zone of circular muscles, and more lightly staining granular ones, which are accumulated at the free end of the organ (Fig. 9). The latter kind I am inclined to look upon as belonging to the glandular cells of the prostate. There are two large vesiculæ seminales the ducts of which unite to form the ductus ejaculatorius (Fig. 11). The seminal vesicles were filled with spermatozoa. The female gonopore opens into a large atrium, the walls of which are thrown into folds, and into which numerous unicellular glands, the shell glands, open. The walls of the chamber are also highly muscular, to function doubtless as a bursa copulatrix. Two of the specimens that were sectioned showed remains of uterine vesicles. One specimen exhibited two pairs of vesicles, and in the other there were three vesicles on one side of the body and two on the other side, with a third duct which ended abruptly, indicating the atrophy of the third vesicle of that side. In the specimen with but two pairs of uterine vesicles the vesiculæ seminales had also disappeared, but their ducts could be traced back for a considerable distance from the penis. The full number of uterine vesicles can only be determined from material in an earlier stage of sexual activity.

The uterine vesicles cannot be compared exactly with the uterine glands figured by Lang[1] for Oligocladus sanguinolenta, for in that species they are only indirectly connected with the uterus by means of the oviducts. They are better comparable with the uterine vesicles of Uteriporus vulgaris of Bergendal,[2] and I look on the uterine vesicles of Diposthus as different chambers of a multipartite uterus, having at least six such parts. The vesicles of each side of the body communicate with a common duct, the ducts of opposite sides uniting to enter the female genital atrium (Fig. 11). As evidence that the

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[1] Lang, A. Die Polycladen, Fauna u. Flora des Golfes v. Neapel, Monog. XI., Taf. XXIII. Fig. 3. 1884.

[2] Bergendal, D Studier öfver Turbellarier. II. Om Byggnaden af Uteriporus, etc. Lunds Univ. Års-Skrift, Fys. Sällsk. Handlingar, Bd. VII. 1896.

uterine vesicles are but separate chambers of a compound organ, is the simultaneous occurrence in these chambers of both ova and spermatozoa. Figure 10 represents a section through one of the uterine vesicles, showing an ovum surrounded by a dense mass of filaments, which in every way resemble the spermatozoa found in the seminal vesicles of the same specimen. Lang (*op. cit.*, p. 297) speaks of skeins of fine filaments resembling spermatozoa in the accessory vesicles, and of "lumps" which he doubted not were fragments of eggs that had found their way in there.

EXPLANATION OF THE PLATE.

ABBREVIATIONS.

dt. ejac.	Ductus ejaculatorius.	*ut.*	Uterine vesicles.
gl. pr.	Prostate gland.	*vag.*	Vagina.
gl. sh.	Shell gland.	*v. d.*	Vasa deferentia.
ov.	Ovum.	*ves.*	Uterine vesicles.
ov'dt.	Oviduct	*v. sem.*	Vesiculæ seminales.
pe.	Penis.	♂	Male gonopore.
sp'z.	Spermatozoa.	♀	Female gonopore.

Fig. 1. Pseudoceros devisii, sp. nov. Drawn from life by A. G. Mayer. × 2.

Fig. 2. Idioplana australiensis, gen. nov., sp. nov. From life; slightly enlarged.

Fig. 3. Idioplana australiensis. To show the arrangement of the tentacular and epi-cerebral eye-spots. × 4.

Fig. 4. Idioplana australiensis. Diagram of sexual organs. × 10.

Fig. 5. Idioplana australiensis. A drawing from five longitudinal consecutive sections to show the course of the sexual ducts. × 20.

Fig. 6. Diposthus corallicola, gen. nov., sp. nov. Drawn from life; natural size.

Fig. 7. Diposthus corallicola. Anterior end of corrosive sublimate preparation to show the arrangement of tentacular eye-spots. × 4.

Fig. 8. Diposthus corallicola. Longitudinal section through gonopores. × 47.

Fig. 9. Diposthus corallicola. Enlarged drawing of prostate gland, from same section. × 170.

Fig. 10. Diposthus corallicola. Diagram of sexual organs. × 50.

Fig. 11. Diposthus corallicola. Section through a uterine vesicle. × 160.

Barrier Reef Planarians.


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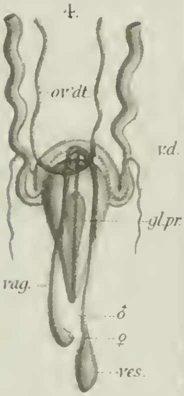
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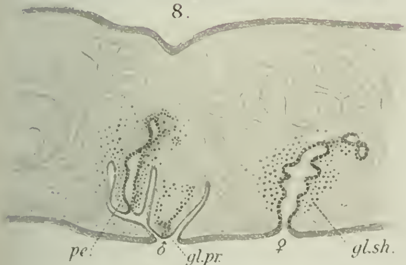
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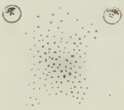
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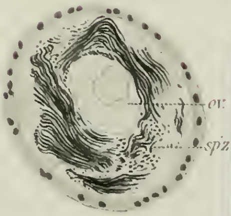
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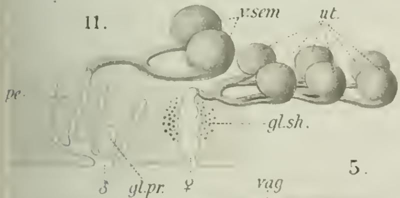
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Bulletin of the Museum of Comparative Zoölogy
AT HARVARD COLLEGE.
VOL. XXXII. No. 5.

REPORTS ON THE DREDGING OPERATIONS OFF THE WEST COAST OF CENTRAL AMERICA TO THE GALAPAGOS, TO THE WEST COAST OF MEXICO, AND IN THE GULF OF CALIFORNIA, IN CHARGE OF ALEXANDER AGASSIZ, CARRIED ON BY THE U. S. FISH COMMISSION STEAMER "ALBATROSS," DURING 1891, LIEUT. COMMANDER Z. L. TANNER, U. S. N., COMMANDING.

XXIII.

PRELIMINARY REPORT ON THE ECHINI.

BY ALEXANDER AGASSIZ.

[Published by Permission of MARSHALL McDONALD and GEORGE M. BOWERS, U. S. Fish Commissioners.]

WITH THIRTEEN PLATES,
AND A CHART OF THE ROUTE OF THE "ALBATROSS."

CAMBRIDGE, MASS., U. S. A.:
PRINTED FOR THE MUSEUM.
JUNE, 1898.

No. 5. — *Reports on the Dredging Operations off the West Coast of Central America to the Galapagos, to the West Coast of Mexico, and in the Gulf of California, in charge of* ALEXANDER AGASSIZ, *carried on by the U. S. Fish Commission Steamer "Albatross," during* 1891, LIEUT. COMMANDER Z. L. TANNER, U. S. N., Commanding.

XXIII.

Preliminary Report on the Echini. By ALEXANDER AGASSIZ.

THE following brief descriptions, accompanied with figures of the more interesting species, collected during the "Albatross" Expedition of 1891, are published to prevent possible confusion in the names adopted for the new species of sea-urchins, which will appear on the Plates preparing for the final Report.

As regards the distribution of Echini in the Pacific, we have at the present day a condition of things very similar to that which must have prevailed in the Atlantic when the species of Echini living in the Crag and in the Maltese beds had their representatives in the West Indies, having, as has been suggested, found their way from the Mediterranean along the shores of an ancient continent. Some of the species living on the west coast of Central America have a very extended geographical distribution in the Pacific, and yet no one claims that this great range has been brought about by their migration along the shores of a continent, or continental islands, existing between Panama and the Sandwich Islands or the Marquesas.

The great equatorial current gives us a cause fully efficient to effect such a wide distribution, and that in a comparatively short time. While undoubtedly many of the species of Echini have no pelagic Plutei, and are so to speak viviparous, or carry their young for a considerable period, yet we should remember that young Echini, even after they have assumed the characters of the adult, are capable of being transported long distances by currents. It is not an uncommon thing to find the young of Arbacia, of Strongylocentrotus, and of Echinarachnius on our coasts floating about, and they are not unfrequently caught in the surface townet. The same holds good for many species of Starfishes and of Ophiurans, as well as of Holothurians. In Florida I have caught in the same way the young of Cidaris and Hipponoë, and of Toxopneustes, and of many other species of Starfishes and Ophiurans. These young Echinoderms all float, and may be carried very long distances during the period in which they still have the huge embryonic tentacles characteristic of their younger stages, when the ambulacral feet are entirely out of proportion in size to the rest of the test, and the young thus possess a great floating capacity when their suckers are expanded.

They retain these suckers for a considerable period of time, during which they can be transported very great distances. There is no other explanation for the identity of the littoral marine fauna of the Bermudas than that the young and embryos of the Echinoderms and Polyps of the West Indies have been carried northward fully six hundred miles by the Gulf Stream at a rate of from one to three miles a day, and have finally settled in the Bermudas.

We can well imagine an equatorial current taking during Miocene and Eocene periods the young of the Echini flourishing in the Crag and in the Mediterranean, and in the southern extension of that fauna perhaps only from the Cape Verd Islands, and bringing them to the shores of Northern South America or into the Caribbean Sea. That stretch is but little longer than the stretch which we know is annually traversed by Acalephs, Pteropods, Fishes, and Annelids, along the course of the Gulf Stream from the Straits of Florida to Narragansett Bay, and to the southern shores of Cape Cod and the adjacent islands.

The existence of a continent or of intervening islands does not seem to me necessary to explain the similarity of the Echinid fauna of former times on both sides of the Atlantic or Pacific. The causes now at work appear to me sufficient to explain their relationship, when we take into account what is known of the efficient transporting agency of equatorial or other oceanic streams for the Pluteus or the young stages of Echini during a considerable period of their post-embryonic life.

We should also remember that, even with our imperfect knowledge of the bathymetrical range of Echini, the range in depths of many genera is known to be very great, as will be seen from an examination of the lists given in the "Challenger" Reports and from the depths obtained by this Expedition. Among these I may mention those having a great geographical distribution, as well as a wide bathymetrical range.[1] This will serve to show the extent to which many species can slowly migrate upon the bottom, even at a very considerable distance from land or continental or insular slopes, when living in the track of a great equatorial current which supplies them with a constant and abundant supply of food.

DESMOSTICHA, Haeckel.

CIDARIDÆ, Müll.

GONIOCIDARIDÆ, Haeckel.

Dorocidaris panamensis A. Ag.

Plate I.; Plate II. Fig. 1.

The test of this species is greatly flattened; the primary radioles are short, in many specimens not longer than the diameter of the test; they are comparatively slender but with a coarser granulation than in the Atlantic species (D. papillata). The abactinal system is also smaller, the anal system more pentagonal, and the genital plates more elongate than in the D. papillata, and the actinal spines are smaller than in that species.

Station No. 3367, off Cocos Island, 100 fathoms.
" " 3368, off Cocos Island, 66 fathoms.
" " 3378, off Galera Point, 112 fathoms.
" " 3397, off Galera Point, 85 fathoms.

Goniocidaris Doederleini A. Ag.

Plate III. Fig. 1.

The nearest ally of this species is G. canaliculata, from which it is readily distinguished by the greater flatness of the test and the very slender primary

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[1]

Genera.	Range in fathoms.	Genera.	Range in fathoms.
Dorocidaris	874	Hipponoë	451
Porocidaris	1444	Fibularia	950
Goniocidaris	1975	Pourtalesia	2550
Salenia	1850	Homolampas	1600
Podocidaris	1075	Maretia	800
Cœlopleurus	1323	Echinocardium	2675
Aspidodiadema	1800	Hemiaster	400
Dermatodiadema	800	Brissopsis	2435
Phormosoma	1100	Aërope	600
Temnechinus	600	Cystechinus	900
Trigonocidaris	460	Urechinus	600
Echinus	2400	Periaster	1800
Sphærechinus	400	Schizaster	1400

radioles. When alive the bare spaces of the test are of a deep brownish violet, the primary spines reddish, and the miliaries greenish with brownish longitudinal bands. The sutures of the genital and ocular plates are marked by a sharp violet line and the genital system is comparatively bare and free from miliaries.

Station No. 3369, off Cocos Island, 52 fathoms.

Two new species of Porocidaris were dredged by the "Albatross."

Porocidaris Milleri A. Ag.

Plate IV.

This species is closely allied to P. elegans collected by the "Challenger." Its radioles differ from those of the Challenger species in having finer serrations. The actinal system is marked for the prominent development of the interambulacral plates, while in P. elegans the actinal system is paved with ambulacral plates (Agassiz, Chall. Echini, Plate III. Fig. 3). The primary tubercles of this species are not crenulate as they are in the other species of the genus, but the species possesses the remarkable primary actinal radioles which are so characteristic of the genus. The median interambulacral suture is bare of miliaries, while in P. elegans the presence of the closely packed miliaries conceals the suture.

Station No. 3359, off Cape Mala, 465 fathoms.
" " 3360, off Cape Mala, 1672 fathoms.
" " 3381, off Malpelo Island, 1772 fathoms.
" " 3399, off Galera Point, 1740 fathoms.
" " 3415, off Acapulco, 1879 fathoms.

Porocidaris Cobosi A. Ag.

Plate III. Figs. 2-5.

This species is readily recognized by its comparatively small actinal and abactinal system. The primary radioles recall those of the Atlantic species P. Sharreri. In the ambulacral zone the primary miliaries are larger than those surrounding the scrobicular area of the primary tubercles in the interambulacral area. The primary mammary bosses are perforated and crenulated; the scrobicular area is narrow.

Station No. 3404, off Chatham Island, 385 fathoms.

SALENIDÆ, Agass.

Salenia miliaris A. Ag.

Plate II. Figs. 2-4.

This species can at once be distinguished from its Pacific congeners by the great size of the anal system, which is irregularly hexagonal and covered with a comparatively larger number of plates than in the other pacific species. The primary radioles are marked for the great development of the milled ring. The primary ambulacral tubercles are small and the two vertical rows are separated by a wide band crowded with minute miliaries. Some of the primary radioles are curved at the extremity and their great length is very striking. In a specimen measuring 12 mm. in diameter, the radioles were slightly over 60 mm. in length.

Station No. 3357, off Mariato Point, 782 fathoms.
" " 3360, on way to Cocos Island, 1672 fathoms.
" " 3361, on way to Cocos Island, 1471 fathoms.
" " 3362, on way to Cocos Island, 1175 fathoms.
" " 3376, South of Malpelo Island, 1132 fathoms.
" " 3380, off Malpelo Island, 899 fathoms.
" " 3407, Galapagos Islands, 885 fathoms.
" " 3411, Galapagos Islands, 1189 fathoms.
" " 3413, Galapagos Islands, 1260 fathoms.

ARBACIADÆ, Peters.

At Station 3382 in 1793 fathoms we dredged a single specimen of a species constituting a new genus (Dialithocidaris), and one which we may consider as the Pacific representative of Podocidaris of the West Indies. I am inclined to consider as also belonging to this genus Podocidaris prionigera A. Ag., which when described was referred with considerable doubt to the genus Podocidaris.

DIALITHOCIDARIS, A. Ag.

The genus is marked by the great size of the genital and ocular plates of the apical system ; by the width of the interambulacral area, by the peculiar linear arrangement of the large interambulacral miliaries along the median line parallel with the horizontal sutures of the upper interambulacral plates. The plates nearer the ambitus and on the actinal surface each carry two primary tubercles. The ambulacral plates carry one primary tubercle. The sutures of the abactinal coronal plates are somewhat sunken and bare, as in some species of Goniocidaris.

Dialithocidaris gemmifera A. Ag.

Plate V. Figs. 1, 2.

There are only four anal plates in the single specimen we dredged. The genital and ocular plates are crowded with irregularly arranged sessile spines, either globular or clubshaped. The madreporite is well developed. The actinal system is marked by ten large elliptical plates placed in the extension of the ambulacral system. The longest primary radioles are 8 mm. in length, flattened, fluted and serrated on the edges, and are comparatively smaller and more slender than in species of the allied genus Podocidaris. The diameter of the test of this specimen was 21 mm. when alive. The color of test and spines is yellowish brown.

DIADEMATIDÆ, PETERS.

DERMATODIADEMA, A. AG.

This genus holds the same relation to Aspidodiadema which Echinothrix holds to Diadema. It differs from it in having only small secondary tubercles in the ambulacral areas while in Aspidodiadema there are large primary tubercles in the actinal region, as in Hemicidaris.

Dermatodiadema globulosum A. AG.

Plate V. Figs. 3, 4.

Marked for its high test, the five large plates surrounding the anal opening, the great width of the ambulacral area, and the stout primary interambulacral radioles, and the deep furrows of the scrobicular area. The longest specimen collected measured 22 mm. in diameter, the largest primary radioles are nearly twice the length of the diameter of the test.

Station No. 3381, north of Malpelo Island, in 1772 fathoms.
" " 3398, off Galera Point, in 1573 fathoms.

Dermatodiadema horridum A. AG.

Plate V. Figs. 5-7.

This species has a comparatively large apical system. The anal system is covered by a large number of small plates, a ring of seven or eight somewhat larger plates surrounding the anal opening. The greater number of specimens were about 20 mm. in diameter, the apical system measuring 14 mm. across. It is probable that Aspidodiadema antillarum, collected by the "Blake," will have to be transferred to Dermatodiadema, the lack of material inducing me to associate it with Aspidodiadema, although it possesses the miliary primary ambulacral tubercles characteristic of the genus Dermatodiadema. Test dark claret color, primary radioles pinkish.

Station No. 3362, between Cocos Island and Mainland, in 1175 fathoms.
" " 3363, between Cocos Island and Mainland, in 978 fathoms.
" " 3364, between Cocos Island and Mainland, in 902 fathoms.
" " 3375, south of Malpelo Island, in 1201 fathoms.
" " 3376, near Malpelo Island, in 1132 fathoms.
" " 3381, north of Malpelo Island, in 1772 fathoms.
" " 3398, off Galera Point in 1573 fathoms.
" " 3400, from Galera Point to Galapagos, in 1322 fathoms.
" " 3413, northwest of Culpepper Island, Galapagos, in 1360 fathoms.

ECHINOTHURIDÆ, Wyv. Thoms.

Phormosoma panamensis A. Ag.

The specimens of this species were all in a poor condition; they are allied to Ph. tenuis, but this species is interesting in having on the actinal side the characters of Phormosoma most decidedly developed, while on the abactinal side the great elongation of the ambulacral plates and the arrangement of the coronal plates resemble the structural features of Asthenosoma. Better preserved specimens may show this species to belong to a new genus of the family intermediate between Phormosoma and Asthenosoma.

Station No. 3374, southwest of Malpelo Island, in 1825 fathoms.

Phormosoma hispidum A. Ag.

Plate VI., Plate VII.

This species is the Pacific representative of the Caribbean and Northern Atlantic Ph. uranus; it has like it an extensive geographical range, but in comparatively deeper water. The largest specimens collected measured 201 mm. in diameter. The test is marked for the great width of the ambulacral system at the ambitus, which is nearly as wide as the adjoining interambulacral system. The large primary radioles of the actinal edge are slightly curved and tipped. On the abactinal side of the ambitus the coronal plates both ambulacral and interambulacral carry only one small secondary tubercle on the distal extremity of the plate with a few irregularly scattered miliaries. The outer primary row of interambulacral tubercles extends on half the coronal plates, the inner row only on two or three of them.

PETALOSTICHA, Haeckel.

SPATANGIDÆ, Agass.

POURTALESIÆ, A. Ag.

Pourtalesia Tanneri A. Ag.

Plate VIII. Figs. 1, 2.

This species is closely allied to P. laguncula (Challenger Echini, Plate XXII.^{a} Figs. 7–15, Plate XXXI. Figs. 1–11), but differs from it in the shape of the test, which is less bottle-shaped, the greater height of the anterior extremity of the test, the concentration of the primary tubercles on the sides of the test in more or less parallel rows in a triangular space extending from the anal system to the lower angle of the ambitus, and the greater length of the primary spines on the flanks of the test. The actinal side of the test is flatter than in P. laguncula and the proboscis runs at a less angle from the plane of that surface. The color of the test is pinkish ; the radioles are white.

Station No. 3411, between Bindloe and Wenham Islands, in 1189 fathoms.
" " 3431, off Altata, Gulf of California, in 995 fathoms.

PLEXECHINUS, A. AG.

Only two specimens of this interesting genus were collected. This genus is peculiar as combining some of the features of Urechinus and Pourtalesia. It has the flush actinostome of the former genus, and at the apex the widely separated bivium and trivium of Pourtalesia, with simple ambulacral pores, a slightly developed anal proboscis, a sunken anal system, and a well developed broad subanal fasciole.

Plexechinus cinctus A. Ag.

Plate VIII. Figs. 3, 4.

Seen in profile, the test slopes very gradually from the bivium towards the rounded anterior extremity. The posterior end is truncated, deeply scooped out above the broad anal proboscis for the reception of the anal system. The anal proboscis is rounded, curved back anteriorly, and is gradually lost in the keel of the actinal plastron. The anal proboscis is banded by a wide fasciole, extending far beyond the posterior edge of the anal system to the keel of the actinal plastron. On the actinal side the posterior ambulacral areas are broad and bare. At the anterior extremity towards the ambitus the test is closely covered by primary tubercles; they become smaller as they pass beyond the ambitus and cover the abactinal area, and are quite regularly scattered over the test with somewhat distant minute miliaries in the intertubercular spaces. The anal system is transversely elliptical, strengthened by eight large trapezoidal plates surrounding the central anal opening.

Station No. 3424, off Tres Marias, Gulf of California, in 676 fathoms.

Echinocrepis setigera A. Ag.

Plate XIII.

Although a number of fragments of this species were collected, only a single fairly complete specimen was obtained from Station 3399. It measured 99 mm. in length, 51 mm. in greatest width, and 53 mm. in height. The test was of chocolate color ; the primary spines from 20 to 22 mm. long were pinkish. This species is at once distinguished from E. cuneata by the great elongation of the odd interambulacrum and the more rounded outline of the test, which is far less angular than that of E. cuneata (Challenger Echini, Plate XXVII. Figs. 1–5). The anterior ambulacral groove is but slightly depressed above the ambitus; the actinal pouch is entirely on the oral surface, and the anterior extremity does not pass, as in E. cuneata, into the anterior ambulacral groove. The actinal system is protected by five large plates.

Station No. 3398, off Galera Point, in 1573 fathoms.
" " 3399, off Galera Point, in 1740 fathoms.
" " 3415, off Acapulco, in 1879 fathoms.

Urechinus giganteus A. Ag.

Plate VIII. Figs. 7, 8.

At Station No. 3431 two specimens of Urechinus were collected, much larger than those of any of the species dredged by the "Challenger" or the "Blake," the largest specimen measuring 93 mm. in length, 80 mm. in width, and 39 mm. in height. This species is also remarkable for the great length of the primary spines, which in proportion to the length of the test are nearly as long as those of Linopneustes. Above the ambitus the test is covered by minute miliaries, scattered uniformly over the surface of the coronal plates. The primary tubercles are placed uniformly over the abactinal part of the test both in the ambulacral and interambulacral areas. They are somewhat more closely placed near the ambitus and in the interambulacral areas of the actinal surface they are closely packed, forming a distinct actinal plastron in the odd interambulacrum. The phyllodes extend to the sixth or seventh pore from the actinostome. It is interesting to note that there are quite well developed "bourrelets" separating the ambulacral areas, a feature characteristic of such genera as Conolampas, Conoclypus, Echinolampas, and the like.

Station No. 3431, off Altata, Gulf of California, in 995 fathoms.

Cystechinus Loveni A. Ag.

Plate IX.

The test of this species is comparatively stout; it is closely allied to Cystechinus Wyvillii, but can at once be distinguished from it by its transverse anal system (it is longitudinal both in C. Wyvillii and C. clypeatus), by the great size of the actinal interambulacral plate of the actinal plastron, and by the structure of the apical system which is intermediate between that of C. clypeatus and C. Wyvillii (Challenger Echini, Plate XXIX.^{b} Fig. 1, and Plate XXXV.$_b$ Fig. 10).

Station No. 3415, off Acapulco, in 1879 fathoms.

Cystechinus Rathbuni A. Ag.

Plate X.

A number of specimens in excellent condition were dredged from the two localities at which this species was procured. The test of this species is thinner than in C. Loveni, but somewhat thicker than in C. vesica. A few of the specimens came up which had preserved their shape, so we are able to give figures of the outlines of the group of Cystechinus allied to C. vesica. The specimens collected varied from a brilliant dark violet to a light claret color.

The anal system is very large, placed well above the ambitus. On the actinal side, the primary tuberculation of the test is smaller and less crowded than in C. vesica. There are four genital pores in all the specimens collected; another feature distinguishing it from C. vesica.

Station No. 3360, southwest of Mariato Point, in 1672 fathoms.
" " 3374, southwest of Malpelo Island, in 1823 fathoms.

ANANCHYTIDÆ, Alb. Gras.

PHRISSOCYSTIS, A. Ag.

This genus is allied to Palæotropus and Palæobrissus in having like them a simple ambulacral system, without even the slight trace of petaloid arrangement found in Palæobrissus. The petals are perhaps even more like those of Cystechinus, Echinocrepis, Gonicopatagus, Calymne, and the like. At the actinosome, however, the phyllodes attain an extraordinary development, recalling those of Paleopneustes and Linopneustes. The apical system is compact, similar to that of the genera last named, and the primary spines are long and curved, recalling those of the same genera.

Phrissocystis aculeata A. Ag.

Plate XII. Figs. 1-7.

Although not a single complete specimen of this species was obtained, a sufficient number of larger fragments were collected to enable us to reconstruct fairly accurately this interesting sea-urchin. Its general facies must have been similar to the species of Linopneustes and of Paleopneustes. The test is thin, covered with large distant primary radioles of uniform size. The outline of the test must have been somewhat conical, the apex slightly eccentric posteriorly, the oral plastron very prominent and flanked by the wide bare areas of the posterior ambulacra. The apical system compact, with four large genital openings; the madreporic body covers the whole of the posterior part of the apical system, and surrounds the anterior genital pores. The ocular plates are small but distinct, with large pores. The smaller plates of the abactinal part of the ambulacral areas are bare, the larger plates carry first one, and at the ambitus there are from eight to ten distant primaries. In the odd interambulacrum there is a slight median furrow extending a short distance from the apex to the anal system. The whole test is covered with distant miliaries irregularly scattered over the coronal plates. The anal system is transversely elliptical and protected by a number of irregularly shaped plates; the phyllodes are greatly developed. The largest specimens must have been 100 mm. in length, and 50 mm. in height, and from 80 to 90 mm. in width across the anterior half of the posterior interambulacral area.

Station No. 3366, in 1067 fathoms.

Homolampas hastata A. Ag.

Plate XI. Fig. 1.

This species is distinguished by the great distinctness and sharpness of its peripetalous fasciole, which is somewhat pentagonal in outline, and surrounds the few primary tubercles found near the apical extremity. The plates of both of the ambulacral and interambulacral areas of the abactinal part of the test are covered by small secondaries and miliaries; this tuberculation is closer than in any other species of the genus; the posterior extremity is more vertically truncated, and the anal groove not so pronounced as in H. fulva. The anal system is pyriform, its greatest diameter being transverse, as in H. fragilis. There are only two of the larger primary tubercles in the lateral interambulacra carrying long curved spines.

Station No. 3363, northeast of Cocos Island, in 976 fathoms.
" " 3365, northeast of Cocos Island, in 1010 fathoms.
" " 3376, South of Malpelo, in 1132 fathoms.

BRISSINA Gray.

Aërope fulva A. Ag.

Plate VIII. Figs. 5, 6.

This species is readily distinguished from the other species of the genus by its proportionally greater length, the lateral flattening of the test, and the pointed anal rostrum. The tuberculation is also closer, and the primary spines are slender in comparison with the stouter spines of Aërope rostrata. The anal plastron is elongate, triangular, closely packed with primaries, the actinostome longitudinally elliptical. The anal system is somewhat pyriform, with the anal opening in the posterior part of the anal system.

Station No. 3361, on way to Cocos Island from Mariato Pt., in 1471 fathoms.
" " 3362, on way to Cocos Island from Mariato Pt., in 1175 fathoms.
" " 3381, north of Malpelo Island, in 1772 fathoms.
" " 3398, off Galera Point, in 1573 fathoms.
" " 3399, off Galera Point, in 1740 fathoms.

Schizaster latifrons A. Ag.

Plate XI. Figs. 2, 3.

At Station 3431, in 995 fathoms, were collected specimens of a species of Schizaster remarkable for the great development of the anterior extremity, the breadth of the anterior ambulacrum, and the short posterior pair of ambulacral petals. This species belongs to the Schizaster group, of which S. Philippii is a well known representative.

Schizaster Townsendi A. Ag.

A large series of this species was collected during our cruise from a number of localities. It is marked by the flatness of the test and the great width of all the lateral ambulacra, the small size of the anal system, the close primary tuberculation of the actinal plastron, which is in striking contrast to the bare actinal surface.

Station No. 3394.	Gulf of Panama.	511 fathoms.
" " 3419.	" "	" "
" " 3424.	" "	674 "
" " 3425.	" "	680 "
" " 3426.	" "	146 "
" " 3431.	" "	995 "
" " 3436.	" "	905 "
" " 3437.	50 miles south of Guaymas.	628 "

Periaster tenuis A. Ag.

Plate XI. Figs. 6, 7.

This species is much flatter and less globular than the species from the Gulf of Mexico (P. limicola). It has no anal fasciole; the peripetalous fasciole is wide, with prominent miliaries; the actinal plastron is elongated, and the tuberculation of the test close. In life the color of the test is light brown.

Station No. 3381.	Off Galera Point.	1772 fathoms.
" " 3398.	" " "	1573 "
" " 3399.	" " "	1743 "

Brissopsis columbaris A. Ag.

The Pacific Brissopsis is readily distinguished from the Atlantic species by the great length of the lateral ambulacra, the flatness of the test, and the great width of the area enclosed by the subanal fasciole. The anal extremity of the test is also more sloping than in the European species, and characterized by the great size of the anal system. The great variation found in specimens of the genus both on the Atlantic and Pacific sides of the Isthmus of Panama leads me to think that there has been some confusion in referring to Brissopsis such elongate types of Spatangoids as I figure on Plate XXVI. Figure 7 of the Blake Echini.[1] I shall refer to this again in my final Report on the Albatross Echini.

Station No. 3353.		695 fathoms.
" " 3356.	Off Mariato Point.	546 "
" " 3382.	Off Mala Point.	1793 "
" " 3394.	Panama Bay.	511 "

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[1] Mem. Mus. Comp. Zoöl., Vol. X., No. 1, 1883.

Toxobrissus pacificus A. Ag.

Plate XI. Figs. 4, 5.

There occurs in the Pacific a Spatangoid which has been regarded as allied to Brissus. Specimens of it are known to me from the Sandwich Islands and from Zanzibar. A species closely allied to the above mentioned specimens has been dredged off Point Mala, at Station No. 3355, in 182 fathoms. I am inclined at present to place these specimens in the genus Toxobrissus of Desor. The species dredged by the Albatross are marked for the flatness of the test, the confluence of the posterior ambulacra along the median line for nearly half their length, the great width of the posterior extremity of the test, the large and uniform size of the posterior ambulacral plates on the actinal side of the test, as well as the small size of the actinal plastron.

SPATAGODESMA, A. Ag.

Plate XII. Fig. 8.

From Station 2769, during the voyage of the "Albatross" from New York to San Francisco, were obtained specimens of a small species of Spatangoid, in which the character of the apical fasciole differs widely from that of any Spatangoid known to me. It possesses a broad elliptical fasciole encircling both the ambulacra and the anal system. A transverse band divides the fasciole into two areas, one enclosing the anal system and the other becoming the peripetalous fasciole. Such a fasciole is unknown to me, and among the young Spatangoids I have had occasion to examine nothing similar exists. The nearest approach to the fasciole of this genus, for which I propose the name Spatagodesma, seems to exist in the young of Agassizia, in which an imperfect subanal fasciole branches off from the peripetalous fasciole. The actinostome is still quite central, and no prominent posterior labrum is as yet developed in the largest specimen, which is about 7 mm. in length. I have not yet been able to satisfy myself of the relations of this interesting Spatangoid.

EXPLANATION OF THE PLATES.

PLATE I.

Fig. 1. Dorocidaris panamensis A. Ag., from the abactinal side.
Fig. 2. Dorocidaris panamensis A. Ag., from the actinal side.

All figures natural size.

PLATE II.

Fig. 1. Dorocidaris panamensis A. Ag., facing the odd anterior ambulacrum.
Fig. 2. Salenia miliaris A. Ag., abactinal view.
Fig. 3. Salenia miliaris A. Ag., partly denuded.
Fig. 4. Salenia miliaris A. Ag., facing the odd anterior ambulacrum.

All figures natural size.

PLATE III.

Fig. 1. Goniocidaris Doederleini A. Ag., from the abactinal side.
Fig. 2. Porocidaris Cobosi A. Ag., in profile.
Fig. 3. Porocidaris Cobosi A. Ag., from the actinal side.
Fig. 4. Porocidaris Cobosi A. Ag., facing the posterior interambulacrum.
Fig. 5. Porocidaris Cobosi A. Ag., from the abactinal side.

All figures natural size.

PLATE IV.

Fig. 1. Porocidaris Milleri A. Ag., (female) test, seen from the abactinal side.
Fig. 2. Porocidaris Milleri A. Ag., from the actinal side.

All figures natural size.

PLATE V.

Fig. 1. Dialithocidaris gemmifera A. Ag., from the abactinal side.
Fig. 2. Dialithocidaris gemmifera A. Ag., facing the odd anterior ambulacrum.
Fig. 3. Dermatodiadema globulosum A. Ag., from the abactinal side.
Fig. 4. Dermatodiadema globulosum A. Ag., facing the odd anterior ambulacrum.
Fig. 5. Dermatodiadema horridum A. Ag., from the abactinal side.
Fig. 6. Dermatodiadema horridum A. Ag., in profile.
Fig. 7. Dermatodiadema horridum A. Ag., facing the left anterior ambulacrum.

All figures natural size.

PLATE VI.

Fig. 1. Phormosoma hispidum A. Ag., from the abactinal side, odd anterior ambulacrum on the left.

Fig. 2. Phormosoma hispidum A. Ag., (a larger specimen,) from the abactinal side, odd anterior ambulacrum on the left.

All figures natural size.

PLATE VII.

Fig. 1. Phormosoma hispidum A. Ag., (same as Fig. 1, Pl. VI.,) from the actinal side, odd anterior ambulacrum on the left.

Fig. 2. Phormosoma hispidum A. Ag., from the actinal side, odd anterior ambulacrum on the left.

All figures natural size.

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Fig. 1. Pourtalesia Tanneri A. Ag., from the abactinal side.
Fig. 2. Pourtalesia Tanneri A. Ag., in profile.
Fig. 3. Plexechinus cinctus A. Ag., in profile.
Fig. 4. Plexechinus cinctus A. Ag., from the abactinal side.
Fig. 5. Aërope fulva A. Ag., from the abactinal side.
Fig. 6. Aërope fulva A. Ag,, in profile.
Fig. 7. Urechinus giganteus A. Ag., from the abactinal side.
Fig. 8. Urechinus giganteus A. Ag., in profile.

All figures natural size.

PLATE IX.

Fig. 1. Cystechinus Loveni A. Ag., in profile.
Fig. 2. Cystechinus Loveni A. Ag., from the abactinal side.

All figures natural size.

PLATE X.

Fig. 1. Cystechinus Rathbuni A. Ag., facing the anal system.
Fig. 2. Cystechinus Rathbuni A. Ag., from the abactinal side.

All figures natural size.

PLATE XI.

Fig. 1. Homolampas hastata A. Ag., from the abactinal side.
Fig. 2. Schizaster latifrons A. Ag., from the abactinal side.
Fig. 3. Schizaster latifrons A. Ag., from the actinal side.
Fig. 4. Toxobrissus pacificus A. Ag., from the abactinal side.
Fig. 5. Toxobrissus pacificus A. Ag., from the actinal side.
Fig. 6. Periaster tenuis A. Ag., from the abactinal side.
Fig. 7. Periaster tenuis A. Ag., from the actinal side.

All figures natural size.

PLATE XII.

Fig. 1. Phrissocystis aculeata A. Ag., apical part of test.
Fig. 2. Phrissocystis aculeata A. Ag., odd interambulacral area.
Fig. 3. Phrissocystis aculeata A. Ag., odd ambulacrum.
Fig. 4. Phrissocystis aculeata A. Ag., left posterior ambulacrum.
Fig. 5. Phrissocystis aculeata A. Ag., part of left side of test.
Fig. 6. Phrissocystis aculeata A. Ag., anal system.
Fig. 7. Phrissocystis aculeata A. Ag., actinal system.

Figs. 1–7 natural size.

Fig. 8. Fasciole of Spatagodesma. $\frac{7}{1}$.

PLATE XIII.

Fig. 1. Echinocrepis setigera A. Ag., apical part of test.
Fig. 2. Echinocrepis setigera A. Ag., odd anterior ambulacrum from above.
Fig. 3. Echinocrepis setigera A. Ag., odd anterior ambulacrum from below.
Fig. 4. Echinocrepis setigera A. Ag., posterior interambulacrum from above.
Fig. 5. Echinocrepis setigera A. Ag., anal proboscis in profile.
Fig. 6. Echinocrepis setigera A. Ag., anal system from below.

All figures natural size.

PLATE A.

Chart showing the Track of the "Albatross."

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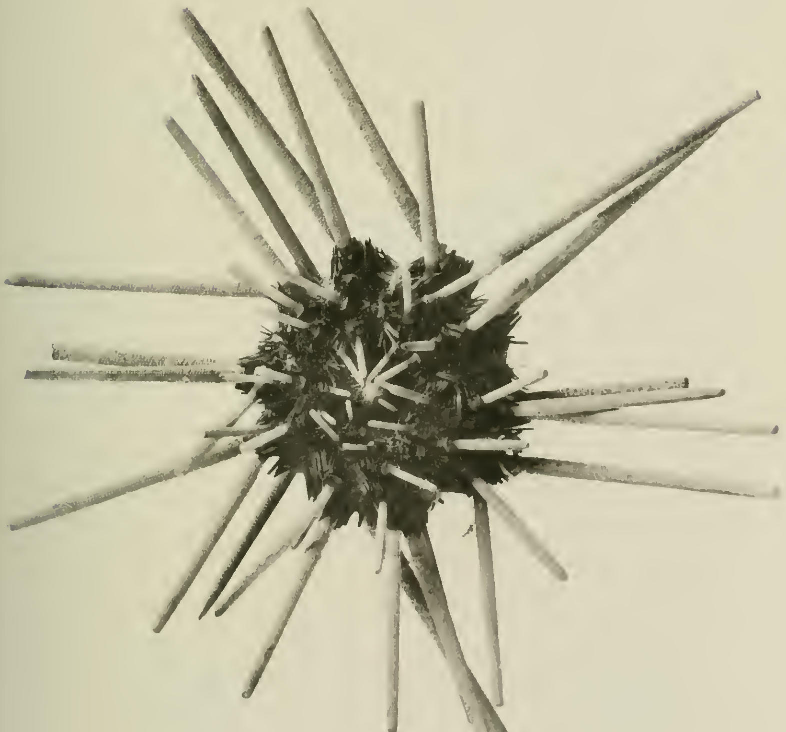

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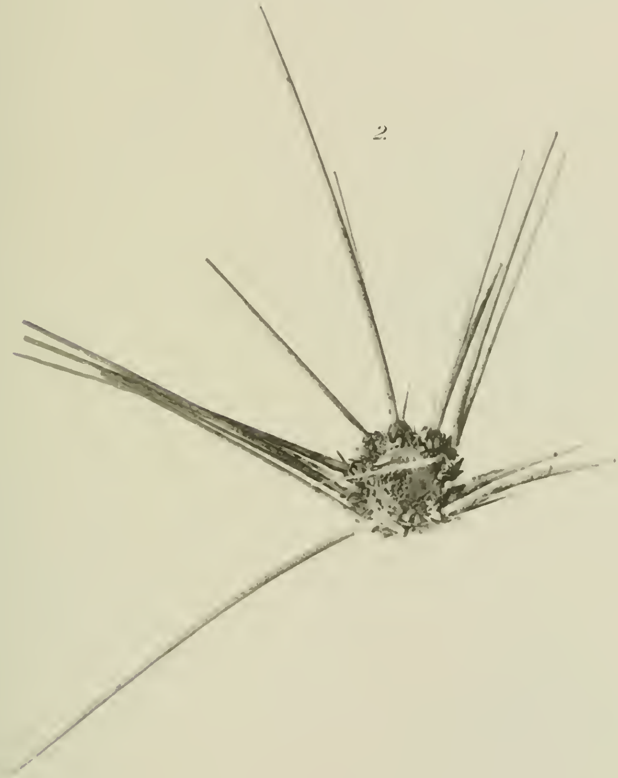

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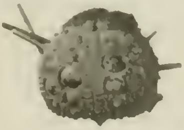

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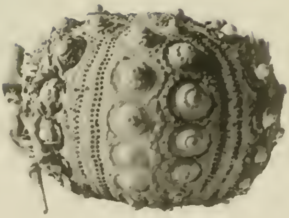

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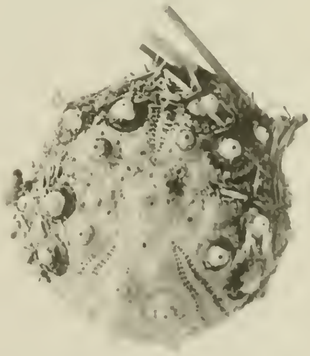

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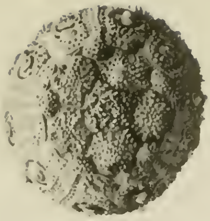

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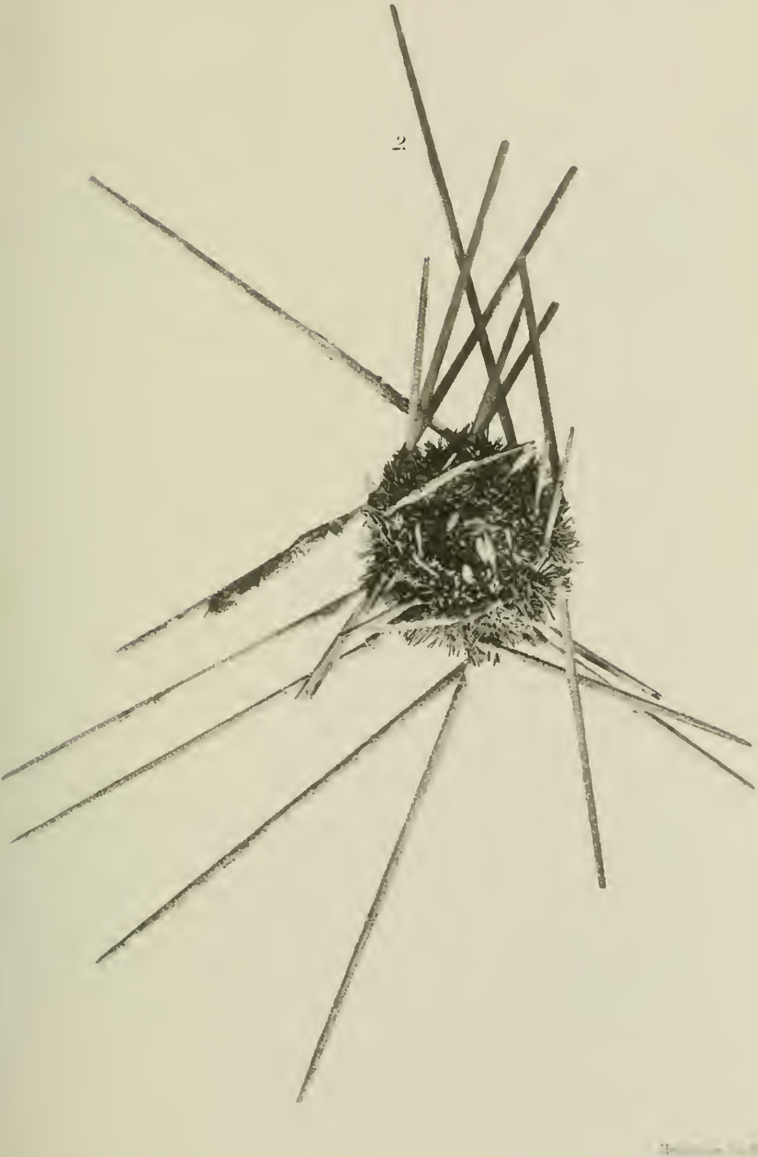

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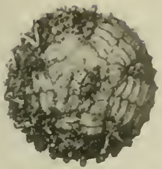

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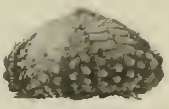

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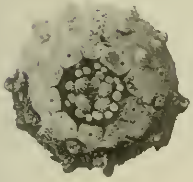

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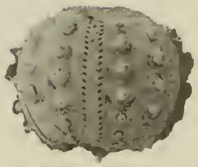

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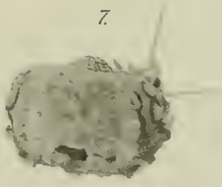

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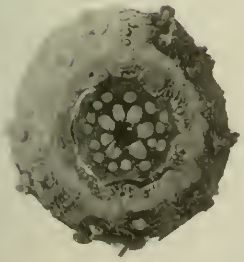

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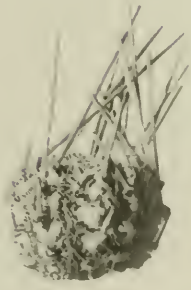

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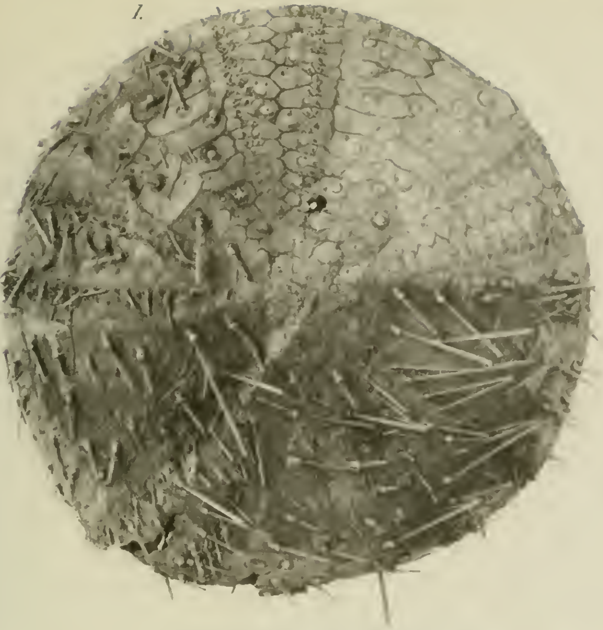

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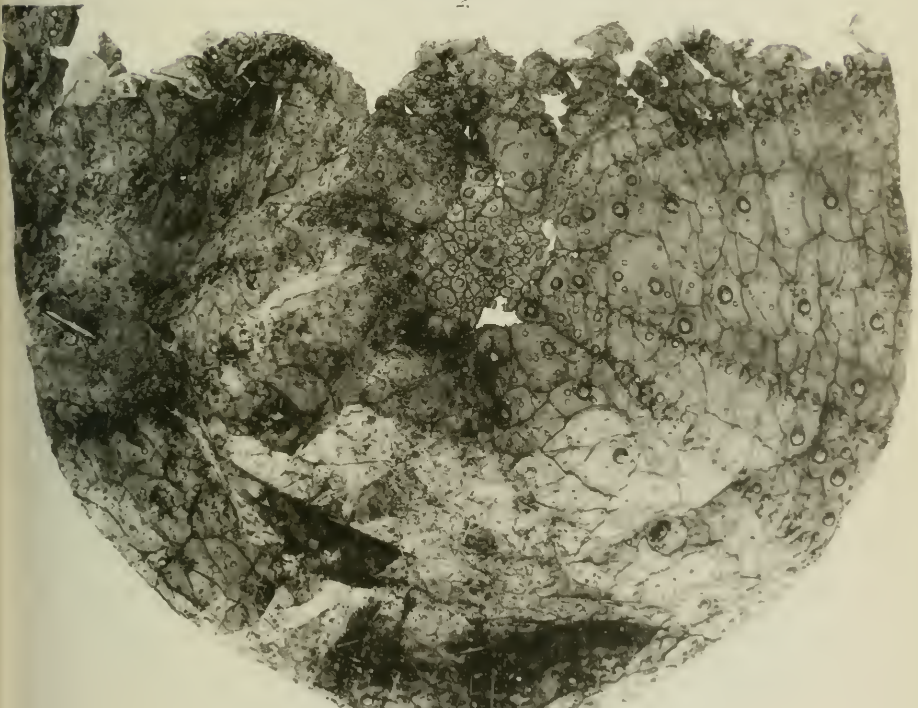

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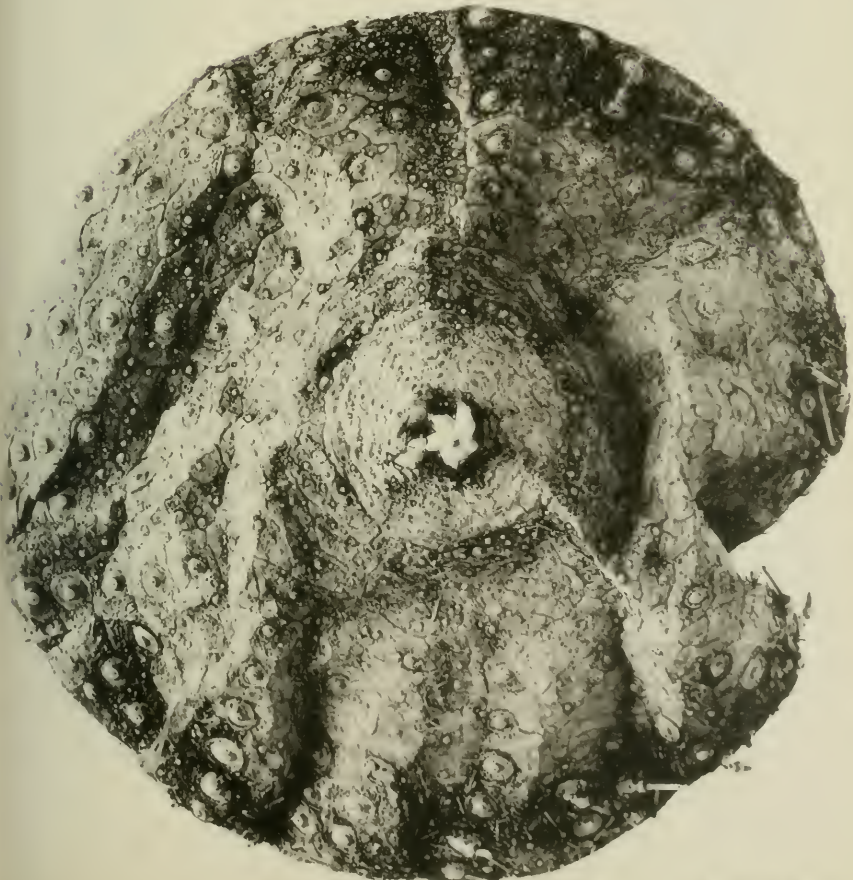

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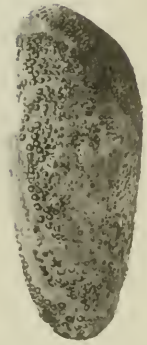

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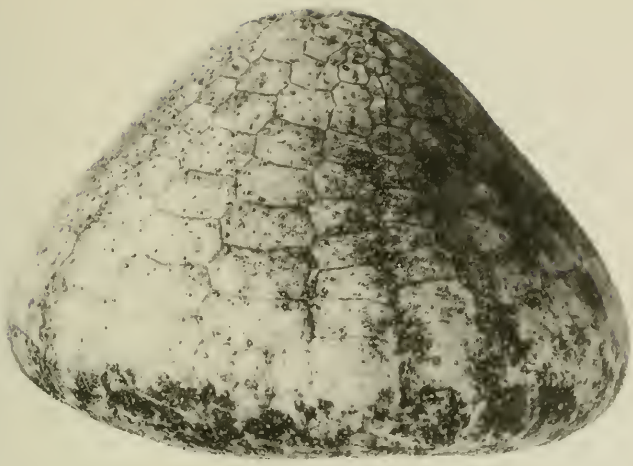

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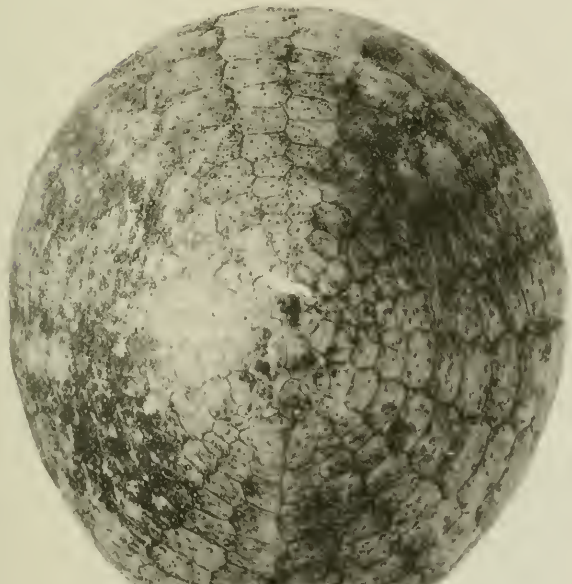

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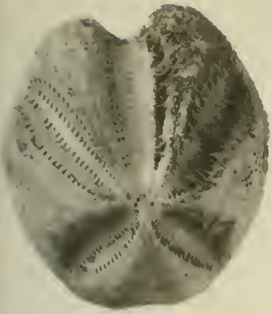

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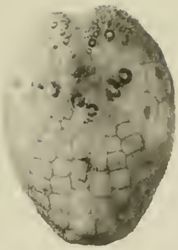

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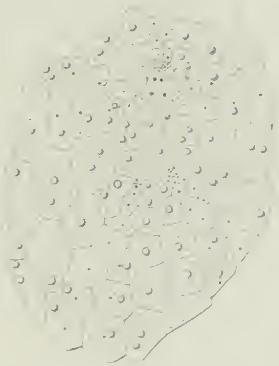

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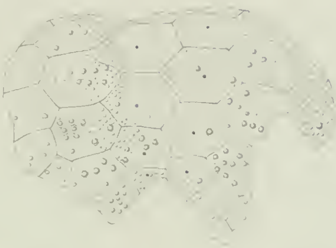

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EXPLORATIONS OF THE
U.S. FISH COMMISSION
STEAMER ALBATROSS
Lieut Comdr Z. L. Tanner U.S.N. Comdg
February to April 1891
Compiled from the latest U.S. Hydrographic Office charts with additions by the U.S.F.C. Steamer Albatross
Soundings represented thus 2756 are by the U.S.F.C. Str Albatross 1888
2380 1889
2232 1891
1886 are from other sources
100 fathom line shown thus
500
1000
1500
2000
Track of the U.S.F.C. Str Albatross 1891
GULF OF MEXICO
MEXICO
GUATEMALA
HONDURAS
SALVADOR
NICARAGUA
COSTA RICA
CARIBBEAN SEA
PANAMA
COLOMBIA
Gulf of Panama
CALIFORNIA
Agiabampo
Topolobampo
Altata
MAZATLAN
San Blas
Banderas Bay
CORRIENTES
Manzanillo
Petacalco Bay
ACAPULCO
Salina Cruz
TEHUANTEPEC
La Puerta
Champerico
S. José
La Libertad
Gulf of Fonseca
Corinto
Gulf of Nicoya
Gulf of Dulce
C. Mala
Malpelo I.
Choco Bay
C. SAN FRANCISCO
C. San Lorenzo
C. SAN LUCAS
LA PAZ
Magdalena
REVILLA GIGEDO ISLANDS
Clarion I.
Socorro
San Benedicto
GALAPAGOS ISLANDS
Culpepper I.
Wenman I.
Abingdon I.
Bindloe I.
Tower I.
Albemarle I.
Narborough I.
Indefatigable I.
Chatham I.
Hood I.
Charles I.
Cocos I.
100°
95°
90°
85°
80°

Bulletin of the Museum of Comparative Zoölogy
AT HARVARD COLLEGE.
VOL. XXXII. No. 6.

THE NERVOUS SYSTEM OF NEREIS VIRENS SARS.

A STUDY IN COMPARATIVE NEUROLOGY.

BY J. I. HAMAKER.

WITH FIVE PLATES.

CAMBRIDGE, MASS., U. S. A.:
PRINTED FOR THE MUSEUM.
JUNE, 1898.

No. 6.— *The Nervous System of Nereis virens Sars. A Study in Comparative Neurology.* By J. I. Hamaker.[1]

CONTENTS.

INTRODUCTION.

Although so much has been written on the nervous system of representatives of all the chief groups of the metazoa, we are as yet far from thoroughly understanding the action of the myo-neural mechanism of any animal. It is true, much light has been thrown upon the subject during the last decade through the use of the newer methods of investigation; but the many valuable facts that have been established are as yet so disconnected, that they can scarcely be said to be more than suggestive. In no case has the myo-neural system of an animal been at all completely worked out. In the higher animals the complexity of this system makes such a task almost impossible. At any rate, the most

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[1] Contributions from the Zoölogical Laboratory of the Museum of Comparative Zoölogy at Harvard College, under the direction of E. L. Mark, No. XCI.

promising method of approaching the subject would seem to be through the simpler forms. Some of the homodynamously segmented animals offer advantages in this respect which no other forms do.

The following considerations may be noted as applying particularly to the polychæte annelid, Nereis, as a favorable subject for this kind of study:—(1) Nereis has a sharply centralized nervous system, consisting of well defined ganglia, which occupy very definite relations to the parts they control. (2) The histological elements of the nervous system are highly differentiated and constant in their relationships. (3) A typical body segment of the animal is simple in structure, having a comparatively small number of muscles. (4) There is almost no serial differentiation of the body segments, excepting in a few of the anterior and the anal metameres; hence it is necessary to determine the structure of one segment only in order to know the structure of nearly the whole animal. (5) Since there are only a few muscles, the movements of the animal are limited in number, and may readily be analyzed and classified. (6) Physiological experiments may be performed with more than usual facility, because the worms are hardy and live well in the aquarium. To these considerations may be added the eminently practical one that Nereis may be easily obtained in unlimited quantities. With such material the problem before us seems to be presented in a comparatively simple form. By these considerations I was led to take up the study of the nervous system of Nereis. Some of the results obtained are given in what follows.

Methods.

The material used for intra-vitam staining was the atokal form of Nereis virens Sars. It was obtained from the muddy banks of the Charles River at a place where the water at low tide contains less than 0.3% salt. The worms found here may be transferred to fresh water without suffering serious injury. For ordinary histological preparations both atokal and epitokal forms were used. The latter were obtained from the mud flats of Lynn Harbor at the mouth of the Saugus River.

Before killing, the specimens were narcotized with chloral hydrate or alcohol, and the intestine cleaned by forcing a stream of water through it. The body was always opened to allow rapid penetration, and sometimes the intestine was removed. Two methods of fixing and staining were employed: either fixing in corrosive sublimate and staining in iron-hæmatoxylin, or fixing and staining by osmic acid. The value of corrosive sublimate as a fixing agent is well known, and I obtained excellent results by fixing in a 1% to 5% solution of acetic acid saturated with corrosive sublimate. Preparations fixed in this way were stained on the slide with Heidenhain's iron-hæmatoxylin. The osmic acid method of vom Rath ('95) gives results in many ways equally good, and for some purposes, such as tracing nerves, even better than the corrosive and iron-hæmatoxylin method. I found a mixture in the following proportions of osmic acid, picric acid, acetic acid, and platinic chloride very satisfactory : —

Osmic acid, 2%	12 c.c.
Picric acid, sat. aq. sol.	100 c.c.
Platinic chloride, 2%	25 c.c.
Acetic acid	1 c.c.

The results obtained are not at all uniform in quality, since the rate of precipitation of the osmium by the pyroligneous acid seems to vary. The value of successful preparations, however, counterbalances the capriciousness of the method. The results obtained by these two methods agree in almost every particular, even to the relative intensity of the stains in the various tissues.

For intra-vitam staining the following method proved most successful. Specimens of Nereis having about seventy segments were injected with a concentrated solution of methylen blue in normal salt solution. They were then laid, ventral side uppermost, in a moist chamber for about two hours, after which the stain began to appear in the subœsophageal ganglion. From this region the stain gradually penetrated caudad, and when it was thought to have reached its optimum, it was fixed by Bethe's ('95) ammonium molybdate method. The objects were then embedded in paraffine and cut.

PART I. DESCRIPTION.

1. Topography.

The central nervous system of Nereis virens is well developed. Throughout the entire length of the body the ventral nerve cord exhibits a sharp differentiation of ganglia and longitudinal connectives. The ganglia are segmentally arranged and constant in position; the nerves are regularly arranged in metameric groups of five pairs each (Plate **1**, Fig. 8). The ventral cord lies deeper than the hypodermis, from which it is partially separated by the circular muscle bundles.

The circular muscles do not form a continuous sheet, but consist of small bundles which lie partially embedded in the hypodermis. Some of these muscles cross the mid-ventral line external to the nerve, thus causing a partial separation of cord and hypodermis. Between the muscle bundles, however, the neurilemma of the nerve cord is in contact with the hypodermis. The brain also lies deeper than the hypodermis, from which it is suspended by a narrow membrane lying in the median plane.

a. Brain.

The form of the brain is roughly that of a trapezoid (Plate **1**, Fig. 1, *ceb.*), the anterior pair of eyes marking approximately the extremities of the longer one of the parallel sides, while the posterior pair marks the limits of the shorter one. The anterior angles of the trapezoid are drawn out toward the palps, thus making the anterior margin of the brain slightly concave. The dorsal aspect of the brain is broadly cordate, the re-entrant angle being at the anterior side. Fourteen pairs of nerves arise from the brain by distinct roots. As they are arranged symmetrically, it will not be necessary to describe both sides. Beginning anteriorly at the median line, and numbering and describing the nerves of one side in order, there is first near the median line a group of three nerves (I, II, III), which arise near together.

The first nerve (I) passes forward, then downward, and finally backward along the dorsal·wall of the proboscis; the second (II) goes directly forward to the antenna; the third (III) runs forward along the dorsal wall of the head.

At the anterior lateral angle of the brain there is another group of three nerves (IV, V, VI). The fourth nerve (IV) divides into two branches, one going to the ventro-median wall of the palp, the other to the dorso-median wall of the same organ. The fifth nerve (V) extends ventrally to the proboscis; the sixth (VI) is the large sensory trunk of the palp; and the seventh (VII) arises from the brain laterally, between the group just described and the anterior eye of the same side; it passes forward along the lateral wall of the palp.

The eighth, ninth, and tenth nerves are the three roots of the circumœsophageal commissure. They unite in the commissural ganglion, which lies a short distance ventral to the anterior eye. The eighth (VIII) is a small nerve arising near the seventh, passing out parallel with it, and then turning down into the ganglion. The ninth nerve (IX) arises laterally from the brain, passes out directly beneath the eye, and then bends down to the commissural ganglion. The tenth (X) arises from the ventral edge of the brain immediately ventral to the ninth, and passes out directly to the commissural ganglion.

The eleventh (XI) and twelfth (XII) nerves are the two optic nerves. They converge from the eyes toward the centre of the brain.

The thirteenth (XIII) nerve arises back of the posterior eye, and goes directly to the ciliated groove. The fourteenth (XIV) is a rather diffuse nervous connection between the brain and the dorsal surface of the head. The region innervated lies nearly midway between the posterior eye and median plane, but slightly nearer the latter.

Besides these fourteen paired nerves (I–XIV) there is a single median nervous connection between the dorsal surface of the head and the brain. This is similar to the diffuse fourteenth nerve, but is smaller and lies slightly anterior to it. Its position is shown in Figure 1.

From the commissural ganglion a nerve (α) passes forward to the proboscis, where it unites with the fifth nerve of the brain (V) in a ganglion. Another nerve (δ) passes backward along the side of the head. Four or five small connectives, not shown in Figure 1, unite the commissural ganglion with the optic ganglion, which lies in contact with the ventral side of the anterior eye. Lastly, the circum-œsophageal commissure passes from the commissural ganglion around the œsophagus to the sub-œsophageal ganglion, traversing on its way a ganglion which lies beneath the anterior pair of tentacular cirri. From this anterior cirrus ganglion two large nerves go each to an anterior cirrus, and, from the anterior side of it, a smaller one (β) to the proboscis. On its posterior side the anterior cirrus ganglion is connected by a small nerve (θ) with the posterior cirrus ganglion, which lies beneath the posterior pair of tentacular cirri. The latter ganglion gives off two large nerves, one to each of the two posterior tentacular cirri, and also sends a nerve (ζ) backward along the side of the head. The posterior cirrus ganglion is connected with the sub-œsophageal ganglion by a large nerve trunk (*n. pa-coms.*), which lies posterior to and parallel with the circum-œsophageal commissure. This trunk gives off several branches from a region midway between the posterior cirrus ganglion and the sub-œsophageal ganglion.

b. Sub-œsophageal Ganglion.

The sub-œsophageal ganglion (*gn. sb-oe.*, Fig. 1) lies on the posterior boundary of the cephalic segment. It gives off three pairs of nerves besides the commissures and the nerves of the posterior cirri. Beginning at the median plane, the first pair of nerves (γ) goes to the œsophagus; they pass forward near the median line, and then bend backward to be distributed to the ventral wall of the œsophagus. The second and third pairs are respectively the commissures and the nerves of the posterior cirri; the other two pairs pass out laterally and forward to the walls of the cephalic segment. The ganglia of the first three or four body segments are displaced backward, as compared with those of the typical segment, and are consequently crowded together, thus making them appear as a single ganglion. Each segment in this region receives the typical number of nerves, though in regard to size the nerves of each segment do not bear quite the same relation one to another as they do in a typical segment.

c. Typical Body Segment.

The ganglia of the ventral chain (Plate **1**, Fig. 8) are about half as long as the segment, and, if the segmentation of the longitudinal musculature be taken to indicate the boundaries of the metameres, they lie intersegmentally, with at least two thirds their length in the posterior segment. The longitudinal connectives are enclosed in a single sheath, so that there appears to be but one connective. At the intersegmental plane there is a constriction of the investing tissue of the ganglion, but this does not extend to the nervous part. Five larger pairs of nerves are given off from each ganglion, and there are, besides, many smaller ones, which consist of only a few fibres each. A few of the latter are given off ventrally, but most of them pass dorsally from the mid-dorsal line of the nerve cord, and probably are distributed chiefly to the digestive tube.

The paired nerves are most conveniently characterized with reference to their position in the segment. Beginning at the anterior end, there is close behind the intersegmental constriction of the ganglion the first segmental nerve (I, Fig. 8). This nerve is rather slender and passes out at right angles to the ventral nerve cord. It lies external to the longitudinal muscles, and is partly buried in the hypodermis (I′, Fig. 4). It may be traced with little change in calibre to the dorsal base of the parapodium, where it is lost either in the circular parapodial muscles, or in the hypodermal plexus, or most likely in both.

The second segmental nerve (II) is the largest of the five, and is the parapodial trunk. It leaves the segmental ganglion near its posterior end and passes diagonally backward across and external to the longitudinal muscles to the parapodial ganglion, which lies in the ventral base of the parapodium between the longitudinal muscles and the pore of the segmental organ.

The third segmental nerve (III) is very small. It arises from the posterior end of the segmental ganglion and passes diagonally outward and backward to the posterior base of the parapodium. Like all the paired segmental nerves, it lies embedded in the hypodermis throughout its length. Next in size to the parapodial trunk is the fourth nerve (IV). It arises from the anterior third of the succeeding ganglion, and hence lies in the posterior part of the segment, near the intersegmental line, where the longitudinal muscles are attached to the hypodermis. It runs parallel with the first nerve (I) of the following segment, but continues in a direct course around the body almost to the mid-dorsal line.

The fifth segmental nerve (V) is very slender. It lies close behind the fourth nerve, and very near the intersegmental plane. It extends as far as the base of the parapodium.

d. Parapodial System.

The innervation of the parapodium (Figs. 5, 8) is almost wholly from the parapodial ganglion, from which four nerves radiate toward the periphery. The most anterior one (1) is very slender and usually passes out in front of the pore of the segmental organ. It goes to the retractor muscles of the anterior side of the parapodium. The second parapodial nerve (2) is comparatively large, and innervates the ventral ramus. Near the ganglion it divides into an anterior and a posterior branch. The anterior one passes along the anterior wall of the ventral ramus to the anterior setigerous lobe. The other runs along the posterior wall to the posterior setigerous lobe, giving off a branch to the ventral cirrus and another to the inferior ligula of the ventral ramus.

The third parapodial nerve (3) passes outward and upward on the posterior wall of the parapodium. About half way up the side of the parapodium it gives off a branch to the glandular region of the dorsal base of the parapodium. Then other branches are sent to the anterior setigerous lobe of the dorsal ramus, the posterior setigerous lobe, the superior ligula, and the dorsal cirrus.

A fourth parapodial nerve (4) goes to the posterior base of the parapodium.

2. Protective Tissue.

The protective tissue of the central nervous system is of two kinds; an outer membrane, the neurilemma, and within this a spongy tissue, the neuroglia. The neurilemma is better developed in the anterior than in the posterior region of the animal, and better in the older epitokal individuals than in the atokal forms. In the cephalic segment it is very thick and forms a capsule around the brain (*n'lem.*, Plate **2**, Fig. 9), and it also envelops the nerves from the brain. A tissue similar in texture lines the dorsal wall of the head, there taking the place of a basement membrane (Plate **3**, Fig. 20). The brain capsule is continuous with this lining of the wall of the head along the mid-dorsal line, and also around the nervous connections that unite the brain with the posterior dorsal surface of the head. It likewise serves as a place of attachment for some of the muscles of the head, as the neurilemma of the ventral cord does for some of the diagonal muscles; but elsewhere the capsule is free from the wall of the head, being suspended in the cavity of the cephalic lobe.

The neurilemma of the brain is continuous with that of the ventral cord along the circum-œsophageal commissures. Except where it is pierced by nerves, the neurilemma of the cord (Plate **2**, Fig. 18) forms a closed tube, whose walls are thickest at the anterior end. Along its dorsal side the wall of the neurilemma tube is continuous with the tunica intima of the ventral longitudinal blood-vessel by means of a narrow membrane which connects the two tubes throughout their entire lengths (Fig. 18).

In structure the neurilemma is uniformly fibrous; it does not stain in iron-hæmatoxylin or osmic acid. On the outer surface of the brain capsule there is a layer of nuclei which may possibly belong to the neurilemma. I have not clearly seen such nuclei on the neurilemma of the ventral cord. The connective tissue of the muscles is continuous with the neurilemma in many places, and resembles it in every respect.

The neuroglia of the brain is a network of delicate fibres with numerous small elongated nuclei located at the nodes of the network. This tissue lines the inner surface of the brain capsule, from which it penetrates into all parts of the brain except the neuropil and the masses of small nuclei connected with it. The neuroglia of the ventral cord is like that of the brain in texture, and it surrounds and penetrates the nervous structures of the cord in the same way as in the brain. The portion immediately surrounding the cord, however, is somewhat differentiated from the more peripheral part (Plate **2**, Fig. 18). Its fibres are coarser and more compact, and they take a circular direction around the cord. Between the successive ganglia the fibres of this inner layer also pass in between the three longitudinal connectives. A few neuroglia nuclei lie scattered about among the nerve fibres of the cord.

3. Brain.

The brain of Nereis consists essentially of a central mass of interwoven fibres with a few irregular masses of neuropil, and a peripheral layer of cells loosely arranged in symmetrical groups. The cells have undergone a remarkable degree of differentiation, and the cells in each pair of groups have distinct characteristics. There are at least six distinct classes of cells; while a number of the larger cells are arranged symmetrically in pairs, each pair having individual peculiarities of form and structure. The six classes, however, are not characterized by form and structure alone. Indeed, it is the difference in chemical reaction that is most distinctive, and calls for more than passing mention. The classes are as follows: —

(1) In front, on each side of the brain, between the anterior median and the anterior lateral groups of nerves, there lie two masses of exceedingly small nuclei (Plate **3**, Figs. 21, 24). The larger ventral mass is approximately crescentic in a transverse section of the brain with the concave side of the crescent lateral and partially embracing a mass of neuropil. The smaller, dorsal mass of cells is also crescentic in transverse section, but with the concave side toward the median plane. This crescent also partially embraces a mass of neuropil. In preparations stained with osmic acid or iron-hæmatoxylin the cells of these masses show only very faint traces of cell boundaries. The nuclei stain very deeply, and always contain a number of granules of various sizes. The nuclei are about 6μ in diameter and are arranged in rows radiating from the neuropil (Fig. 21). They are set very closely in the rows, and are often almost in contact. The spaces between the rows are wider toward the neuropil, while toward the convex side of the mass the arrangement is more compact and the alignment of the nuclei almost disappears. The spaces between the rows of nuclei have a fine fibrous appearance, as though fibres from the cells passed out to the neuropil. Cells similar to these occur in other parts of the brain, e. g. a small group at the posterior border of the brain, just median to the root of the nerve which runs to the ciliated groove (XIII). Cells slightly larger, but otherwise like

these, occur scattered over the dorsal surface of the brain, and a group of them lies around the root of the fourteenth nerve (XIV).

(2) At the posterior lateral border of the brain there is a group of spindle-shaped cells, which extends backward and outward along the root of the thirteenth nerve (XIII) as far as the point where the nerve pierces the capsule (Plate **2**, Figs. 9, 15). These cells do not stain very deeply, and do not show very sharply defined cell boundaries, although the spindle form can be distinctly seen. Similar cells give rise to the fibres that form the fourteenth nerve and pass out to the dorsal surface of the head.

(3) Along the internal border of the last group there lies a third very peculiar class of cells (Figs. 9, 12). Unlike those of the two preceding classes, the cells of this class have a very definite cell boundary. They are comparatively few in number, and are narrowly pear-shaped with the process extending toward the centre of the brain. In preparations stained to best advantage for other structures these cells are so deeply stained that only in a few cases can the nucleus of the cell be seen at all. The cell process also stains so deeply that it appears in strong contrast with the other fibres.

(4) In the same transverse section as the last, but nearer the median plane, is another group of pear-shaped cells (Figs. 9, 11). These are larger and proportionately broader than the last, and stain very differently from them. In iron-hæmatoxylin the cytoplasm does not become blue, but takes on a brownish color. Its structure is almost homogeneous excepting an irregular network of a few coarse fibres which usually centres about the nucleus and does not extend throughout the body of the cell. The processes of these cells also go toward the centre of the brain.

(5) At the side of the brain beneath the nerve of the anterior eye there lies a group of cells which seem to have no direct connection with the brain except that of being enclosed in the brain capsule. The cells are rather large and spherical, and send their processes out along the ninth nerve (IX) of the brain toward the commissural ganglion. A few of the cells lie scattered along the dorsal side of the ninth nerve, and make this group of cells continuous with the group which lies beneath the anterior eye, and which we have called the optic ganglion. The cells of both groups have the same general appearance (Fig. 19). The cytoplasm presents no special peculiarities. There is no cell membrane and the limits of the cell are very indistinct, because there are very few granules at the periphery. Each cell is surrounded by neuroglia fibres

arranged loosely in concentric layers. The inner fibres seem to be embedded in the cytoplasm of the cell.

(6) Although the remaining cells (Figs. 16, 17) present a great variety of size, form, and detail of structure, there is a general similarity which permits of classing them together as a group distinct from those we have described thus far. They have the pear shape and the granular cytoplasm which are characteristics of most of the cells of the ventral ganglia. But beyond this there is little that is common to all the cells of the group. In the posterior half of the brain there are several pairs of very large cells which have the characteristics of this group, and in addition a very striking one of their own. The nucleus lies in the narrow end of the cell, and is surrounded by the granular cytoplasm. At the other end of the cell, there is a large vacuolar space containing a number of deeply staining bodies of irregular form, embedded in an indistinct coagulum. Other cells have very finely granular substance occupying a similar position, the granules being much smaller and staining less deeply than those of the body of the cell. In these cases the nucleus shows no signs of degeneration. In some cells (Fig. 16) the cortical part of the cytoplasm is penetrated by narrow lamellæ, which, when viewed from the surfaces of the cell, present the appearance of a honeycomb structure.

There is another structure within the brain capsule which is very strange, and for which I cannot account. It consists of a considerable number of spheroidal cavities (Fig. 10), containing a substance which assumes several forms. The cavities are arranged in two symmetrical groups, one on each side of the brain (Fig. 9), extending around and between the fibres of the fourteenth nerve, and backward and outward to the root of the thirteenth nerve. The cavities, which are surrounded by neuroglia, vary somewhat in size, the average being about equal to that of the average nerve cell of the brain. Each usually contains a number of spherical granules, sometimes of nearly uniform size, sometimes differing much in this respect. They are stained in iron-hæmatoxylin, but in preparations treated with osmic acid they are yellow. Sometimes the cavities are filled with an almost homogeneous substance; at other times, however, the substance only partially fills the cavities, and assumes an irregular stellate form. In a few cases there are doubtful indications of a nucleus.

These structures cannot be due to degeneration of nerve cells, because they are very regular in the place of their occurrence, and there is no indication of degenerated fibre tracts. The contents of the cavities are not fat, for they are not blackened by osmic acid, nor do they seem to be pigment, since the granules are comparatively large and at the same time quite variable in size. Racowitz ('95) found amœboid cells depositing pigment in the region of the ciliated groove, but I have no reason to think the condition in the present instance is due to the same instrumentality.

4. Ciliated Groove.

The ciliated grooves lie on the posterior margin of the cephalic lobe behind the posterior eyes (Plate **3**, Fig. 20). A fold of the anterior margin of the cephalic segment extends forward a short distance over the cephalic lobe, to which it is attached in the median plane, and also at a point just lateral to the eyes. On the ventral wall of the pockets thus formed there is an elongate eminence or ridge about 0.5 mm. long and 0.2 mm. wide, with the long axis transverse to the body. Along the crest of this ridge lies the ciliated groove. The ridge is formed by a thickening of the non-ciliate hypodermis, the cells of which are very long and arranged with their distal ends directed toward the crest of the ridge, thus producing in cross section the figure of an inverted V. The space between the cells which form the ridge is occupied by the ciliated cells. The cuticula over these cells is very thin, and the cilia project through it, forming a narrow band along the bottom of the groove. The nuclei of the ciliated cells lie much deeper than those of the non-ciliate cells on either side of them. The organ is innervated by the nerve XIII. There are no glands in the hypodermis of this region, but the overhanging fold of the cephalic segment is richly supplied with them.

5. Ventral Nerve Cord.

The structure of the ventral nerve cord can best be set forth by describing transverse and longitudinal sections of it. A transverse section between ganglia (Plate **5**, Fig. 31) shows that there are three longitudinal connectives; two large lateral and symmetrical ones, and a small, more dorsal median one. Each connective is enveloped by the fibres of the inner layer of neuroglia, which thus separates the three connectives. In preparations successfully fixed in either the corrosive sublimate or osmic acid mixtures, the cross section of the connectives shows nothing but the circular outlines of the cut nerve fibres, with their contents and a few neuroglia fibres penetrating the connective from the sides. The fibres vary greatly in size, from the large giant fibres, which are one third the diameter of a lateral connective, to the smallest, which however are large enough to enable one to distinguish the circular outline of the sheath and its contents.

There are three giant fibres, one in each connective. Those in the lateral connectives are much larger than the median one.

On the median side of each of the paired connectives, close beneath the median connective, there is another very large fibre which, in some regions of the body, is but little smaller than the median giant fibre (Plate **5**, Fig. 31). These fibres, which I shall call set *A*, also stain very lightly, but they show no traces of a network.

The numerous fibres which constitute the remaining portions of the connectives stain more deeply. Most of them show no differentiation, but frequently the larger ones are more intensely stained in the centre than at the periphery.

In longitudinal sections of the connectives (Plate **3**, Fig. 26), the fibres appear as parallel bands separated by crinkled lines, — the fibre sheaths folded by a slight longitudinal contraction of the animal at the time of fixation. Many of the larger fibres, excepting set *A*, often show a darker central band corresponding to the darker centre of the transverse section. A few nuclei are scattered among the fibres of the connectives.

Transverse sections through the ganglia of the ventral chain present a single central filrous mass bordered ventrally and laterally by ganglionic cells. Bundles of neuroglia fibres pierce the central mass at intervals along the median plane, and divide the ganglion into symmetrical halves. The greater part of the fibrous mass consists of longitudinal fibres, but there are many fibres which traverse the ganglion in other directions.

The cells of the ventral ganglia do not vary as much in size, form, and structure as do those of the brain ; however, besides the uniformly granular ones of various sizes and shapes (Plate **2**, Figs. 13, 14, *A*), corresponding to those of class six in the brain, there are some cells (Fig. 14, *B*) which stain very lightly, and the cytoplasm of which is homogeneous with the exception of a few coarse granules of very limited distribution. There are only a few pairs of these cells in each ganglion ; one of the pairs belongs to the fibres of set *A*, and these are among the larger cells of the ganglion.

The coarse irregular granules of the cells last described occupy the middle of the cell, where they are arranged in the form of a hollow sphere, at the centre of which there is a round deeply staining granule (Fig. 14, *B*). This structure is undoubtedly what has been described as a centrosome. It is not confined to this class of cells, but in good preparations occurs with such frequency that it may be said to exist in all the cells of the ventral cord (Fig. 13). The nucleus is always eccentric, and frequently, though not always, flattened. There are often two, three, or more centrosomes in a single cell. In one instance there were ten. In the cells whose cytoplasm is granular the centrosome does not appear as distinctly as it does in the others. However, when the staining has been successful, there appears at the centre of the cell a mass of granules which are larger and stain more deeply than those of the rest of the cell. The granules of this mass are arranged in the form of hollow spheres, the contents of which are destitute of all granules excepting the single round body at the centre.

6. Nerve Fibres.

a. Giant Fibres.

There are three giant fibres which traverse the ventral cord throughout its entire length (Plate **2**, Fig. 18, Plate **5**, Fig. 31); the pair of extremely large ones, which lie one on the outer side of each of the paired connectives, and the smaller unpaired one lying in the median connective. All these have the same peculiarities of structure. With the methods employed they stain very lightly and appear almost homogeneous. On close examination, however, the section of the fibre is seen to be made up of a small number of polygonal areas marked off by an indistinct network (Plate **1**, Fig. 3). This network apparently owes its existence simply to the presence of discrete masses of protoplasm, the boundaries of which give the appearance of a network. In longitudinal sections the giant fibres show the same structure, except that the polygonal areas are elongated in the direction of the axis of the fibre. When these fibres are stained in methylen blue, the stain is precipitated at the borders of the areas, producing a finely granular network in a homogeneous field of blue.

The paired fibres may be traced forward into the circum-œsophageal connectives to a point between the anterior cirrus ganglion and the commissural ganglion, where they divide into a number of small branches. The branches cannot be distinguished from other large fibres of the connective, but they appear to pass through the commissural ganglion to the optic ganglion. The fibres which connect the commissural and optic ganglia are processes of the cells of the optic ganglion, but since I was unable to trace a fibre continuously from the optic ganglion until it united with the giant fibre, I cannot be sure that there is such a connection. I have found no other cells connected with these giant fibres.

The median giant fibre divides in the sub-œsophageal ganglion into several branches, which continue forward parallel with one another along the median plane. One of them I was able to trace to one of a group of large cells lying between the ventral ends of the circum-œsophageal connectives. The other cells of the group are connected with similar fibres, but I could trace only one continuously from the cell to the giant fibre.

The three giant fibres extend back into the last segment of the body without branching or changing their relative sizes or positions. Occasionally the median fibre in passing through a ganglion divides and allows the passage of a bundle of fibres between the two parts, which then immediately reunite, and the fibre continues on as before. This condition occurs frequently, but appears to be wholly accidental, since it is very irregular in the frequency of its occurrence, as well as in the size of the loop produced, and also in the relative sizes of the two divisions of the fibre. In one instance I found a similar condition in one of the lateral giant fibres, but it was not very well marked.

The giant fibres are pierced by many smaller ones, which pass directly through them (Plate **1**, Fig. 2). In the case of the lateral giant fibres this occurs most frequently near the places where the segmental nerves are given off from the ganglion. Sometimes the small fibres branch within the large one, the branches then continuing on through the giant fibre. In preparations stained with osmic acid, the small fibres stain much more deeply than the giant fibres, thus becoming very distinct. In a part of a methylen blue preparation which had not taken the stain, the small fibres traversing the giant fibres could be readily seen because they were more highly refractive than the giant fibre.

I cannot say that in successive segments the giant fibres are pierced by corresponding sets of smaller fibres, but there is at least one set which regularly traverses the giant fibre on passing out into the fourth (IV) and fifth (V) segmental nerves. This fibre will be described as set *B*.

b. Fibres of Set A.

Along the inner margin of the lateral connectives there lies a set of fibres (Plate **2**, Fig. 18, Plate **5**, Fig. 31) which in transverse section are almost as large as the median giant fibre, and resemble it in their resistance to stains. They differ from giant fibres, however, in the following particulars (compare Plate **4**, Fig. 27, *A*): — (1) They are arranged segmentally, one pair of fibres originating in each segment;

(2) Each fibre is connected with a single cell; (3) They do not extend through more than two segments; (4) They are not pierced by other fibres, nor (5) do they show the reticulum found in giant fibres; (6) They are branched. The cell (Plate **4**, Fig. 27) of which this fibre is a process lies on the ventral side of the ganglion near the origin of the third segmental nerve (III). The general direction of the process is forward, but at the outset it crosses and recrosses the median plane, decussating twice with its companion of the other side, one decussation being immediately behind and the other in front of the origin of the second (II) segmental nerve. After the second crossing the two fibres run side by side close beneath the median giant fibre, until they pass the first point of decussation of a similar set of fibres in the next anterior segment. Here they diverge and apparently break up into fibrillations or branches too small to be traced in preparations stained in the ordinary way. I have not succeeded in staining this fibre with methylen blue. This system is well developed in every segment from the last one of the tail to within twenty segments of the head, where the fibre gradually becomes smaller until, in the first three or four segments, it cannot be distinguished among the other fibres of the cord.

c. *Fibres of Set B.*

Next in size come the cells and fibres of set *B* (Plate **4**, Figs. 27, *B*, 28). The cells lie ventrally about midway between the origin of the first (I) and second (II) segmental nerves. From each cell a process extends forward and gradually rises into the middle of the ganglion. Opposite the origin of the fourth (IV) segmental nerve, the fibre turns squarely across the ganglion, running parallel to its mate, with which it decussates, and then divides into two branches, both of which go to the periphery; one through the fourth (IV), the other through the fifth (V) segmental nerve. The two fibres of a pair lie in contact for some distance where they cross from one side of the ganglion to the other (Plate **1**, Figs. 6, 7), and they anastomose at several points along the line of contact (Plate **4**, Fig. 28). The fibres of sets *A* and *B* are intimately associated at the point where they cross each other (Plate **1**, Fig. 6, Plate **3**, Figs. 22, 23), for they are not only in contact, but the smaller fibres lie in a deep indentation on the larger one. The relation of fibre *B* to the lateral giant fibre is still more intimate. Immediately after branching, one or both branches pass directly through the lateral giant fibre before passing out of the ganglion (Plate **1**, Fig. 2). Sometimes one branch may pass around the giant fibre, but still be in contact with it, while the other branch passes directly through it. Sometimes the penetrating branch, instead of passing through the middle of the giant fibre, goes so far to one side that it does not become free from the sheath of the giant fibre, but is still wholly embedded in its substance.

d. Fibres of Set C.

The next fibre system (Plate **4**, Figs. 27, 30), set *C*, is apparently centripetal, since no cell was found connected with it, and since what appears to be the main fibre, entering the cord from the fourth segmental nerve (IV), immediately divides, forming the characteristic **Y** of centripetal fibres. One of the branches runs directly back and ends in fibrillations opposite the second nerve (II) of the succeeding segment. The other branch runs forward, and ends in a similar way opposite the second segmental nerve (II) of its own segment. Near its origin the second branch gives off a third which runs diagonally backward and across the ganglion, ending in a position symmetrical to the ending of the first branch. Since the counterpart of each of these three branches is found on the opposite side of the nerve cord, there must be six branches ending in each segment, on either side three, all of which are opposite the second segmental nerve (Fig. 27, II). The ends of the fibres are enlarged, and give off a few fibrillations. The three endings of each side of the body lie side by side, and are connected with one another by several ladder-like anastomoses (Plate **4**, Figs. 29, 30). The fibres of this set are rather large, and lie almost wholly on the ventral side of the cord. The third or decussating branches, however, are rather slender, and in crossing the ganglion first curve up and then down. Where the two fibres cross each other they are always in contact.

e. Peripheral Fibres.

The following are some of the fibres found in the parapodial ganglion (compare Plate **1**, Figs. 5, 8, Plate **5**, Fig. 39): (*a*) Fibres entering the ganglion from the second (II, Figs. 5, 39) segmental nerve pass through the ganglion and out either by the first (1) or by the fourth (4) parapodial nerves. (*b*) Fibres entering from the segmental nerve divide into two branches, one of which passes out through the second (2), the other through the third (3) parapodial nerve. Neither of these classes of fibres gives off fibrillations in the ganglion. (*c*) A third kind of fibre enters the parapodial ganglion from the segmental nerve, and ends in the ganglion in fibrillations.

The second (2) and third (3) parapodial nerves contain both motor and sensory fibres. In Figure 32 the motor fibres are shown, and in Figure 33 the sensory fibres of the third parapodial nerve. The motor fibres turn back along the muscles that move the setæ, and are lost among the muscle fibres. The cells of the sensory fibres lie far beneath the hypodermis. They send a process either to the hypodermis, or to the tissue around the openings through which the setæ project. At the latter place the fibres apparently end in fibrillations. Figure 37 represents a sensory cell of the anterior wall of the parapodium. The peripheral process of this cell enlarges just beneath the cuticula into a small knob, from which a fine prolongation extends out through the cuticula Figure 38 represents a similar cell and nervous process in the posterior wall of the parapodium. In Figure 35 is seen a sensory cell from the base of the parapodium, and in Figure 36 one from the side of the body near the fourth segmental nerve.

Figure 34 shows the manner in which the motor fibres end in the longitudinal muscles, and Figure 40 shows the bushy endings of the fibres around the glands of the hypodermis between the bundles of circular muscles.

PART II. DISCUSSION.

1. Topography.

In methylen blue preparations it is usually not easy to determine the relation of the stained fibres to other organs, because of the difficulty of seeing structures which are not stained. For this reason I first made a study of the topography of the nervous system, tracing the nerves with considerable detail in preparations made by vom Rath's method. By this means nerves consisting of but a few fibres can be traced through serial sections. The account of the topography given in Part I. is more minute, but otherwise agrees in the main with that given by Quatrefages ('50) for Nereis. There is one important point, however, in which I cannot agree with Quatrefages. He states that the segmental nerve which he designates by the letter *o* (Planche 3) passes forward through the dissepiment to the preceding segment, thus making a nervous connection between two segments, in addition to that of the ventral nerve cord. From the diagram (Plate **1**, Fig. 8) it will be seen that there is no segmental nerve passing from one segment to another in N. virens. The three nerves (I, IV, V) that arise near the intersegmental plane pass out parallel with that plane, two anterior to it and one posterior. The segmentation of the longitudinal muscles is marked by an interdigitation of the fibres of one segment with those of the next. These interdigitations lie in the plane of the constriction of the body which gives the external appearance of segmentation. The line of attachment of the longitudinal muscles to the hypodermis (Plate **1**, Fig. 4) and the constriction in the protective tissue of the segmental ganglion (Plate **1**, Fig. 8) also lie in this plane, which, as will be seen from Figures 4 and 8, thus separates the fifth (V′) and first (I′) segmental nerves throughout their length. The segmental dissepiment is concave anteriorly. Its ventral median edge is attached in the constriction of the segmental ganglion, and is therefore in the intersegmental plane. But its lateral border is attached to the hypodermis, between the dorsal and ventral longitudinal muscles, anterior to the intersegmental plane and even anterior to the position of the fourth (IV′) segmental nerve in that region (Fig. 4). Hence, if the position of the dissepiment were taken to determine the boundary of segments, the fourth (IV′) and fifth (V′) segmental nerves would appear to pass backward from the segment in which they arise to the one succeeding it. But I have found no segmental nerve passing forward through the dissepiment as described by Quatrefages, nor indeed passing out of the segment in either direction, if we determine the boundary of segments by the segmentation of the musculature.

When compared with other annelids, we find that *Nereis presents a generalized condition with respect to its nervous system.* It indeed agrees very well with the description given by Lang ('88–'94) of the nervous system typical of Chætopods. In comparison with other Polychætes, however, Nereis shows a rather high degree of development, indicated by the deep position and elaborate protective tissue of the ventral nerve cord. In the majority of Polychætes the ventral nervous system lies embedded in the hypodermis, or intimately connected with it. In a few genera, however, such is not the case. Wawrzik ('92) shows that in Hermione and Aphrodite the ventral cord is entirely free from the hypodermis, and in this respect he classes these genera with the Oligochætes. Nereis would also belong to this class, since the ventral cord lies internal to the circular muscles, as it does in the Oligochætes.

2. Protective Tissue.

The nature and origin of the protective envelopes of the nervous system of Polychætes have been the subject of considerable discussion. The differences of opinion are probably due chiefly to real differences in the animals studied. There is not much doubt, however, concerning the origin of the inner spongy layer, the neuroglia. Jourdan ('84) showed that the enveloping tissue of the central nervous system was intimately connected with the cells of the hypodermis. Rohde ('87) called this tissue "Subcuticularfasergewebe," and described it as a development of the basal processes of the cells of the hypodermis. Wawrzik ('92) made a comparison of a large number of Polychætes, and found that in all those in which the ventral cord was connected with the hypodermis the neuroglia was an integral part of the hypodermis cells. Haller ('89) denies the existence of the condition described by Rohde ('87) for Polynoë, since he found that the nerve cord was surrounded by a membrane which separated the neuroglia from the hypodermis. However it may be in this case, there certainly cannot be a connection between the hypodermis and neuroglia in such forms as Hermione, Aphrodite, and Nereis, in which these structures are clearly separated. But the condition found in so many other genera indicates that the neuroglia is derived from the ectoderm along with the nervous elements.

The neurilemma is apparently found only in those forms in which the nerve cord is free from the hypodermis. But even when present it may be so thin as to be readily overlooked. Such is sometimes the case at the posterior end of Nereis. On the other hand, it becomes very thick around the brain of Nereis, sometimes reaching a thickness of fully 100μ. Friedländer ('88) and Graber ('80) call this structure cuticular. Haller considers it simply the matted fibres of the neuroglia. Racowitza ('96) states that muscle fibres, as well as the neuroglia, contribute to make up the neurilemma. Where muscle fibres are attached to the outer surface of the neurilemma, or neuroglia fibres to its inner surface, membrane and fibre shade insensibly into each other, so as to suggest their structural identity. But, as has been shown above, as well as by other writers, the neurilemma in its reaction to stains is very different from either muscle or neuroglia. Whatever may be the weight of this evidence, it is clear that the neurilemma, the connective tissue of the muscles, and the tunica intima of the ventral longitudinal blood-vessel have the same structure, and must be derived from the same source. That source is most likely the mesoderm.

3. BRAIN.

Although the brain of Nereis gives rise to so many nerves, it is small and simple when compared with the brain, for example, of the decapod Crustacea. In the latter, the fibrous part is relatively much greater, and the fibres are collected into small bundles forming numerous commissures between the various parts of the brain. Since the number and size of the nerves leaving the brain of decapod Crustacea is small compared with the size of the brain, the increase in the fibrous substance of the brain must be due to a greater development of the association fibres of all kinds, including not only fibres which lie wholly within the brain, but also those branches of centripetal and centrifugal fibres which bring the various parts of the brain into relation with one another. This condition is apparently correlated with the increased development of the "mushroom bodies" in Arthropods, as we shall see below.

4. "Mushroom Bodies."

The compact masses of small nuclei that lie in the anterior part of the brain of Nereis (Plate **3**, Figs. 24, 21) have been described by a number of writers, who have, however, usually expressed considerable doubt concerning their significance. Ehlers ('68) and Schröder ('86) describe this structure under the name "Nervenkörner." Rohde ('87) calls a similar structure in Polynoë and other Polychætes "Nervenkernen." Retzius ('95) refers to it as a "Haufen groben Körner," which he says are larger about the periphery of the mass. He thinks the larger granules may be cells, but doubts the cellular character of the smaller ones. His preparations were stained in methylen blue, but showed no processes connected with the nuclei. Haller ('89) discusses the nature of these structures at some length, and describes the elements as small multipolar ganglion cells. He calls the mass a "Tentakelganglion," and supposes it to be connected with the sense organs of the antennæ. Racowitza ('96) applies to it a similar term, "ganglion antennaire," but he does not mean to indicate thereby that the ganglion has any direct connection with the antenna. Haller objects to Rohde's application of the descriptive term "Hutpilz" to these ganglia "weil sie sehr leicht zu einer Verwechselung mit den hutpilzförmigen Körpern am Hirn der Insecten veranlassen dürfte, mit denen aber diese Ganglien nichts Homologes aufweisen können."

Notwithstanding this statement of Haller, I think there are good reasons for considering this organ as in some degree homologous with the mushroom bodies of the insect brain. The resemblance between the two appears more strongly, if we compare both with a corresponding structure in the brain of the crayfish. On the anterior lateral border of the brain of this Crustacean there is a triangular mass of small cells which Krieger ('79) designates as gz_3. In my own preparations of the brain of the crayfish I find that this ganglion resembles the "ganglion antennaire" of Annelids in the following points. In both, (1) such ganglia are confined to the brain, no similar structure occurring in the ventral cord. (2) The ganglion is intimately associated with the masses of neuropil, which also occur nowhere but in the brain. (3) The small size of the nuclei and the meagre cytoplasm distinguish these cells from the other cells of the brain. (4) There is a peculiar arrangement of the cells in rows radiating from the neuropil. According to the description given by Kenyon ('96), the mushroom bodies of the honey bee exhibit the same peculiarities. The chief difference to be found in the three cases is the relative size of the nuclear and the neuropil masses, and in the arrangement of the two parts. In Nereis the nuclear mass partially surrounds the neuropil, whereas in the insect the relation of the two parts is reversed, the neuropil partly enveloping the nuclear mass. The crayfish presents an intermediate condition in this respect. The nuclear elements do not stain readily in methylen blue, — a condition also found by Allen and Bethe in Crustacea, and by Retzius in Nereis; but in the bee Kenyon obtained impregnations of the cells by the Golgi method. His preparations show that the cells of these ganglia send processes into the neuroglia, where they end in dendrites almost as complex as those found in the brain of Vertebrates. Since in the worm there is relatively little neuropil, the dendrites of the associated cells will probably be found to be less well developed. Kenyon's supposition that the intelligence of the insect is to be accounted for by the complexity of the relations between the nervous elements made possible by these association fibres seems quite plausible; and if we apply the same argument to the worm, we may suppose its low intelligence to be in part correlated with the small amount of neuropil, or, in other words, the limited development of the association fibres.

Aside from the cells of this ganglion and those connected with the ciliated groove, the brain of Nereis contains about as many cells as a typical ganglion of the ventral chain. If we compare the brain with the ganglia of the ventral chain, or if we compare the central nervous system of Annelids with that of Arthropods, the only structural condition to be found which warrants the supposition that it is correlated with the supposed psychic functions of the brain is the mushroom body and the related development of association fibres. This correlation has often been pointed out for insects, and I think we may extend the observation to decapod Crustacea and Annelids.

Racowitza shows that those Polychætes which lack antennæ also lack the "ganglion antennaire." He does not prove, however, that the cells of this ganglion may not be present in the brain, and therefore does not exclude the possibility that the ganglion may be present in a diffuse form.

5. OPTIC GANGLION.

The condition of the optic ganglion in Nereis virens is of interest, because it serves to explain what have hitherto appeared to be unaccountable differences between several species of Nereis. Carrière ('85, pp. 33–35) described this ganglion for N. cultrifera, and Retzius ('95) found it in N. diversicolor. On the other hand, Carrière says there is no such ganglion in a species from Norderney which he examined, and Graber ('80) and Haller ('89) also failed to find it in Nereis costæ. It seemed strange that a central ganglion, like this, should exhibit such will-of-the-wisp peculiarities in passing from one species to another so closely related to it. I think, however, that the condition of this ganglion in N. virens shows clearly what becomes of the ganglion when it disappears from its place beneath the anterior eye, as in N. costæ. In N. virens the ganglion evidently lies partly beneath the eye and partly within the brain capsule. A few scattering cells show the path the ganglion has taken in its migration inward or outward. It is not only the great similarity in the appearance of the cells and the contiguity of the two parts that makes this view seem probable, but also the cells of both groups send their processes to the commissural ganglion and neither part appears to be directly connected with the brain. It is not apparent what is the relation of the ganglion to the anterior eye. Carrière thought the ganglion formed part of the connection between the eye and the brain, but this cannot be, for later writers agree that the anterior eye as well as the posterior is innervated directly from the brain.

The posterior end of the brain deserves more careful study than I have as yet been able to give it; I shall therefore simply call attention to a few facts. Five of the six kinds of cells described for the brain are to be found in the posterior part, and of these five three are not found elsewhere. Moreover these three are the most peculiar ones, — those of the second, third, and fourth classes. This portion of the brain is partly separated from the remainder of it, and is intimately connected with the surface at the ciliated grooves and at the dorsal sensory regions through the thirteenth (XIII) and fourteenth (XIV) nerves. Perhaps the whole is to be considered a complex sensory organ, analogous to the olfactory organ of Vertebrates in its intimate relation with the brain. Retzius shows that the sensory fibres of the ciliated groove are processes from bipolar cells of this region. The fibres of the fourteenth pair of nerves are the processes of cells similar in form and position to the bipolar cells of the thirteenth nerve.

6. VENTRAL NERVE CORD.

The structure of the ventral nerve cord has been well described for Lumbricus by Friedländer ('94), and Hatschek ('89–'91) has given a good figure of a transverse section of the ventral cord of Sigalion. Most writers, however, have not succeeded in preparing the ventral cord so as to show clearly that the connectives consist wholly of longitudinal fibres. There is nowhere in the ventral cord a neuropil in the sense of that which is found in the brain. There are small masses of fibrillations in the ganglia, of course, but they simply fill up the interstices between the fibres, and never occur in masses large enough to produce the punctate appearance peculiar to the neuropil of the brain.

The paucity of nuclei among the fibres of the cord will not permit one to regard the fibre sheaths as composed of the expansions of non-nervous cells. In the decapod Crustacea the fibre sheaths are nucleate, and in the case of the sheath of giant fibres the nuclei are so numerous that the sheath may be described as a flat endothelium. In Nereis, however, the sheath must be a product of the fibre itself.

7. CENTROSOMES.

Since Lenhossék ('95) announced the discovery of the centrosome in the adult nerve cells of the frog, there have appeared a number of papers describing similar structures in Reptiles (Buehler, '95), Cyclostomes (Schaffer, '96), Molluscs (McClure, '96), and Worms (Lewis, '96). Heidenhain ('97) summarizes the evidence and gives a bibliography. Dahlgren ('97) describes what he calls a centrosome artifact in the spinal ganglia of the dog. This artifact, he says, is produced by the formation of a crystal of corrosive sublimate in the cell. In Nereis I find the best demonstrations of centrosomes in preparations that have been fixed in corrosive sublimate, but they also occur in preparations fixed in the osmic acid mixture of vom Rath. I think there is no reason for considering the phenomenon an artifact in this case. I will simply call attention in this connection to two facts that were mentioned previously;

first, the general occurrence of the centrosome in the cells of the ventral ganglia, and, secondly, the large number of centrosomes that may occur in a single cell. I have no explanation to offer for the latter condition. Since the structures appear only under special conditions of staining, and since I had only one preparation of the brain stained in iron-hæmatoxylin, I am not in a position to say whether the centrosome occurs in the brain or not, even though I failed to find it in the preparations I had at hand.

8. Nerve Fibres.

a. Giant Fibres.

The literature concerning giant fibres is voluminous, and extensive bibliographies on the subject may be found in the works of Eisig ('87) and Friedländer ('88, '94). I shall concern myself here with only a few of the many points in which these fibres have given rise to discussion. It has been frequently demonstrated that they are the processes of cells, and they have been taken by many writers to be nervous in function, but some authors still doubt that that is their nature; Lenhossék ('92), for example, has recently expressed the conviction that they are not. The most serious objection that has been urged against their nervous nature is the absence of evidence that they are related to other nervous structures, either by fibrillations within the cord or by centrifugal branches.

I think there is sufficient reason for maintaining that in Nereis virens the fibres of set *B* serve as branches for the lateral giant fibres. I therefore believe that the function of the latter is to transmit nervous impulses like ordinary nerve fibres.

The most peculiar feature of giant fibres is that they are often connected with more than one cell. In 1881, Spengel ('81) arrived at the conclusion that in Halla there was a fusion of giant fibres, but he had no direct evidence. Rohde ('87), however, shows conclusively that at least one giant fibre in the ventral cord of Sthenelais is formed by the union of the processes of two cells. These lie in the brain and send their processes through the circum-œsophageal connectives to the subœsophageal ganglion, where they fuse and whence they continue as a single fibre throughout the entire length of the animal. Friedländer ('88) found that the lateral giant fibres of the earthworm are connected with a number of cells in the posterior segments of the animal. This discovery was confirmed by Cerfontaine ('92), who also found that the median fibre is connected with several cells at the anterior end of the body. In Rhynchelmis, too, according to Vejdovsky ('88, '92), the giant fibres are connected with a number of cells and in such a way that each might well be considered a bundle of fibres. Finally, Lewis ('96) describes in a Moldanid a giant fibre which is connected with a large number of cells. There is not yet sufficient evidence to show whether the giant fibres of Chætopods are more frequently multicellular or unicellular, but there can be no doubt that they are often multicellular.

The giant fibres of Crustacea have not been so well investigated as those of Chætopoda, but in Homarus, at least, each giant fibre is the process of a single large cell, according to the description of Allen ('94).

Our present knowledge of the giant fibres (in the sense in which I use the term) might be summarized in the following way. The giant fibres of Annelids and Crustacea are much larger than ordinary fibres, and extend for long distances through the central nerve cord; they are connected either with one very large cell or with the processes of several cells, and they give off neither fibrillations nor branches. In some cases, as in Lumbricus, there are anastomosing bars, or connections, between two giant fibres; in others, the giant fibres may divide or they may fuse with one another, but in no case is there an ending corresponding to the fibrillations of other nerve fibres by which the giant fibres might be put in connection with other nervous structures. In Nereis, however, there is a very intimate connection between the lateral giant fibres and the centrifugal branches of set *B*, as I have shown, and by this system of connections the giant fibres are put in relation with every segment of the body.

What the function of such giant fibres may be is readily conceivable, and I believe the true explanation has already been offered by several writers. Vignal ('83) suggested that their purpose was to bring about a more direct connection of the nervous system as a whole than is done by less extensive fibres. Friedländer's experiments on the earthworm show that, when the ventral cord is severed, the sudden longitudinal contraction of the body can no longer be brought about. Friedländer argues that, since these fibres are the only ones, so far as we know, that pass through the entire length of the animal, it is reasonable to suppose they are the ones that conduct the stimulus for this contraction.

In Nereis I have frequently noted a sudden longitudinal contraction where there was apparently no stimulus except the passing of a shadow. I have not yet had the opportunity to test this further, to determine if the stimulus proceeded from the eyes, but I found that no tactile stimulus was sufficient to produce such a sudden and general longitudinal contraction. When the habits of the animal are considered, it is possible to understand what the function of such a contraction brought about by the stimulus of light might be. The worm lives in the mud in burrows, and frequently rests with the anterior end above the surface, while the remainder of the body is in the burrow. Under such circumstances the longitudinal contraction would cause the animal to retreat into the burrow, for longitudinal contractions are in general accompanied by the pointing of all the parapodia towards that end of the body from which the stimulus comes. For example, if the stimulus is applied at the anterior end, the parapodia are all thrown forward, and the longitudinal contraction of the body immediately follows. This will cause the anterior end to move towards the tail while the latter remains stationary, since the position of the parapodia prevents movement of the body in the opposite direction. Now, if the shadow cast by a predatory animal were to bring about this movement, the mechanism would be of vital importance to the worm. Perhaps the importance of the function and the great extent of the movement brought about help to account for the large development of the giant fibres. The objection may be urged that since the phenomena which I have described for Nereis have not been found elsewhere, they cannot be of general importance, even if the condition be admitted for Nereis. But the exceptional conditions under which such phenomena can be observed render it probable that they may have been overlooked even when present.

It must be remembered that, in order to demonstrate the passage of one fibre through another, there must be a differential staining of the substance of the two fibres. Only in preparations fixed and stained by the method of vom Rath, and not in all of these, have I obtained such a differentiation. Successful preparations, however, leave no doubt concerning the actual relation of the fibres, for I have carefully compared series of sections cut in each of the three cardinal planes, and always with the same result.

If, then, the giant fibres are nervous in function, the neuron theory of Waldeyer ('91) will require considerable modification. The nervous element is not always unicellular, but may consist of a number of cells united in function. The nervous connection between fibres is not always through fibrillations; it may be directly between the axis cylinders themselves.

b. Fibres of Set A.

Since little is known about the relations of the fibres of set *A* to other fibres, we cannot say much about their probable function. Nevertheless, there are several facts which point to a connection with the forward locomotion of the animal. The worm advances by a rhythmical movement of the parapodia, which begins at the posterior end and passes toward the head. With this movement there is usually associated a serpentine motion of the body, which also passes from behind forward. Both movements are less vigorous near the head, and the serpentine disappears entirely between the twentieth and tenth segments. The size of the fibres of set *A* in a given region corresponds to the degree of activity of the locomotor movements of that region. Whether this fact is more than a mere coincidence I cannot say, but it would seem to be so. Besides, if there is a causal relation between the condition of these fibres and the locomotor movements, we may even account for the enormous size of the fibres on the ground of their functional importance. Another evidence of this correlation is the serial arrangement of the fibres, which may be connected with the progressive character of the motor excitation, and with the postero-anterior disposition of each fibre, the latter corresponding to the direction of the movement.

Although these speculations concerning the function of giant fibres are purely tentative, they may serve as a basis for physiological experiments.

c. *Fibres of Set B.*

In describing the fibres of set *B* (Plate **4**, Figs. 27, 28) I merely mentioned the fact of an anastomosis between the axis cylinders of the components of each pair. I wish here to discuss the subject more fully. The description of these fibres was by no means based wholly on methylen-blue preparations. Indeed, all the facts, excepting that of anastomosis, were demonstrated on serial sections before an impregnation by methylen-blue was obtained. The fibres are so large that they can easily be traced through serial sections. This fact is important in considering the value of the evidence for anastomosis.

.I have carefully examined seventeen pairs of these in serial sections cut in one or the other of the three cardinal planes of the body, and in addition eight pairs stained in methylen-blue and examined before cutting. Where the fibres of a pair crossed the ganglion they were always in contact with each other, and, with one exception, they ran parallel for a considerable distance. In the exceptional case the fibres crossed each other at an angle of about ten degrees, which still allowed a line of contact equal in length to one fourth the width of the ganglion. The fibres usually cross the ganglion at right angles to its longitudinal axis, but in one instance they crossed at an angle of about sixty degrees (Plate **1**,

Fig. 7). Thus, one of the fibres partially retraces its course in order to maintain a course parallel with its fellow. Sagittal sections (Plate **3**, Figs. 22, 23) show that the fibres are always flattened on their apposed faces. That part of the sheaths which forms the dividing wall is usually very thin, and in some cases seems to be wholly wanting. In the preparations which are best preserved, however, the dividing wall can always be seen. I have not been able to demonstrate satisfactorily anastomoses in preparations made by the more usual histological methods. In methylen-blue preparations the fibres do not appear to be in contact, but this is due to a shrinking of the axis cylinder within the sheath produced during the fixing of the stain. The anastomoses, however, do exist, and are clearly shown in methylen-blue preparations (Plate **4**, Fig. 28) ; they proceed from small elevations on the opposed faces of the fibres. From what has gone before, it is evident that the anastomosing bars simply pierce the thin membrane that separates the two fibres, and that they practically lie wholly within the fibre sheaths. Hence they cannot be regarded as fibrillations fused by the action of the methylen-blue. The fibrillæ of the axis cylinder pass out into the anastomosing bars, but whether they pass completely across from one fibre to the other I cannot say. There is, however, a distinct interdigitation of the fibrillæ of the opposite fibres. The appearance of the preparations gives one the impression that there has been a breaking of the fibrillæ of the anastomoses due to the shrinking of the fibres. The anastomoses are not always as evident as they are in the case reproduced in Figure 28, but there is always some indication of them. This may consist simply of the pointed elevations arranged in pairs opposite each other on the fibres.

Since the cells of set *B* are situated in a central organ, they are probably motor, and since the fibres are united in bilaterally symmetrical pairs, they probably act in concert. Such animals as Annelids differ from more complex organisms in that many of their movements are in unison on the two sides of the body. The longitudinal contractions and expansions of the body are examples. In Nereis the movement of all the parapodia backward or forward, when the animal is touched at one end or the other, is another instance. When such movements are so frequent and of such vital importance, one may well expect to find an intimate association of the related nerve fibres.

Allen ('96) describes decussating nerve elements in the abdominal ganglia of the lobster so closely united that he was unable to resolve them into their constituent parts. He finds, however, that similar elements in the thorax are not so intimately related. At another place he makes the statement that these elements of the abdomen innervate the abdominal muscles, while those of the thorax go to the ambulatory appendages. The reason for the difference in the arrangement of the nerve elements will be immediately perceived. The muscles of the abdomen act bilaterally in unison, hence the union of the associated nerve elements. In the case of the ambulatory appendages there is little movement in unison, hence the corresponding independence of the fibres concerned.

d. Fibres of Set C.

Lenhossék ('92) makes the general statement relative to the sensory fibres of the earthworm, that they do not cross the ventral nerve cord, but end in fibrillations on the side from which they enter the cord. The fibre *C* of Nereis is an interesting exception to this rule. Concerning the anastomoses of this system I need say but little. The fibres are so large, the anastomoses so numerous and distinct, and the fibre in such excellent condition for study, that there is small chance for error. There is no vacuolation of the fibre nor other evidence to lead one to conclude that there has been a fusion of fibrillations in the manner suggested by Cajal ('96). I have seen no evidence of anastomosis between fibres except those of set *B* and set *C*, and here the anastomosis is always between fibres of the same set.

I wish to call attention to one more point relative to these fibres. The small decussating branches cross the ganglion by a sinuous course, and yet where they cross each other they are invariably in contact. Why this should be so is difficult to say, unless the function of the fibres necessitates such contact. A similar relationship is also to be found between fibres of other sets, as in the case of the fibres of sets *A* and *B*, as described above. Although physiologists do not recognize contact between axis cylinders as a means of bringing fibres into functional relation, it seems to me quite probable that such a relation exists in some cases.

SUMMARY.

1. The central nervous system of Nereis virens occupies a deeper position than does that of most Polychætes. It is separated from the hypodermis by the circular muscles, and is enveloped by an elaborate protective tissue.

2. The protective tissue consists of two parts; an inner spongy layer, the neuroglia, of ectodermic origin, and an outer sheath, the neurilemma, of mesodermic origin.

3. The "mushroom bodies" of insects and decapod Crustacea are represented in the brain of Nereis by the anterior masses of small nuclei.

4. The optic ganglion, which in some species of Nereis lies beneath the anterior eye, may in other species lie within the brain capsule.

5. There is no neuropil in the ventral nerve cord.

6. There are three longitudinal connectives between each two successive ganglia of the ventral nerve cord, one small median and two larger lateral ones.

7. The sheaths of the nerve fibres of the ventral cord have no nuclei, and hence must be a product of the fibres themselves.

8. The nerve cells of the ventral cord commonly have one or more centrosomes.

9. The giant fibres are nervous in function, and are put into relation with peripheral organs through ordinary centrifugal fibres.

10. The giant fibres give off no fibrillations, and nervous relation with other fibres is established directly between the axis cylinders.

11. Certain decussating fibres are always united in pairs by anastomoses between the axis cylinders where they cross each other.

12. Certain centripetal fibres of the same set are always united by anastomoses between the ends of the branches.

13. Contact between axis cylinders may possibly be one of the means of bringing nerve fibres into functional relation with each other.

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EXPLANATION OF PLATES.

All Figures, except 1, 5, 8, 27, and 39, were outlined with the camera lucida. Figures 28–30 and 32–41 were drawn from methylen-blue preparations.

ABBREVIATIONS.

a.	Anterior.
anastm.	Anastomosis.
ax. cyl.	Axis cylinder.
ceb.	Brain.
cir.	Cirrus.
cir. ta.	Tentacular cirrus.
cl. cil.	Ciliated cell.
cl. sns.	Sensory cell.
coms. crc-œ.	Circum-œsophageal commissure.
con't. lg. l.	Lateral longitudinal connective.
con't. lg. m.	Median longitudinal connective.
c'so.	Centrosome.
cta.	Cuticula.
di'sep.	Dissepiment.
fbr.	Fibrillations.
fbr. mot.	Motor fibres.
fbr. n.	Nerve fibres.
gn. coms.	Commissural ganglion.
gn. pa'pd.	Parapodial ganglion.
gn. sb-œ.	Sub-œsophageal ganglion.
gn. sg.	Segmental ganglion.
h'drm.	Hypodermis.
mu.	Muscle fibres.
mu. crc.	Circular muscles.
mu. lg.	Longitudinal muscles.
mu. ob.	Oblique muscles.
n.	Nerve.
n'cd.	Giant fibre.
n'gli.	Neuroglia.
nl.	Nucleus.
n'lem.	Neurilemma.
n'pil.	Neuropil.
n. pa-coms.	Para-commissural nerve.
oc.	Eye.
p.	Posterior.
po. sg.	Pore of segmental organ.
rtl.	Reticulum.
sg. ce.	Cephalic segment.
set.	Seta.
sul. cil.	Ciliated groove.
tu. fbr.	Fibre sheath.
tu. i.	Tunica intima.
va. sng.	Blood-vessel.

PLATE 1.

Fig. 1. Diagram showing the disposition of the nerves of the brain and subœsophageal ganglion in dorsal aspect. In order to show the commissural ganglion and its nerves, the right anterior eye has not been indicated; I, V, α, β, γ, nerves to the proboscis; II, nerve to the antenna; III, IV, VII, δ, ϵ, ζ, η, nerves to the muscles and the general surface of the head; θ, commissure between the anterior and posterior cirrus ganglia; VI, nerve to the palp; VIII, IX, X, nerves from the brain to the commissural ganglion; XI, XII, optic nerves; XIII, nerve of the ciliated groove; XIV, three openings in the dorsal surface of the brain capsule, through which loose bundles of nerve fibres pass to the integument of the mid-dorsal region of the cephalic lobe.

Fig. 2. Para-sagittal section of a giant fibre to show the passage through it of a fibre of set *B* (compare Fig. 27). In this case the branching of the fibre *B* takes place within the giant fibre, and the axis cylinder of fibre *B* is shrunken.

Fig. 3. Cross section of a lateral giant fibre, to show the reticulum.

Fig. 4. Frontal section of the body wall between two parapodia, to show the relative positions of nerves IV′, V′, and I′, and of the attachment of the longitudinal muscles and the dissepiment.

Fig. 5. Diagram of posterior aspect of part of a cross section, showing the disposition of the parapodial nerves. The second and third parapodial nerves (compare Fig. 8) are designated by 2 and 3 respectively.

Fig. 6. Frontal section of a segmental ganglion, showing the intimate relation between the fibres of sets *A* and *B* (compare Fig. 27).

Fig. 7. Section similar to that in Fig. 6 showing the relation of the decussating parts of fibres *B;* also showing exceptional oblique course across the ganglion.

Fig. 8. Diagram showing the disposition of the segmental and parapodial nerves of a typical segment. I, II, III, IV, V, the five segmental nerves numbered from in front backward. 1, 2, 3, 4, the four parapodial nerves.

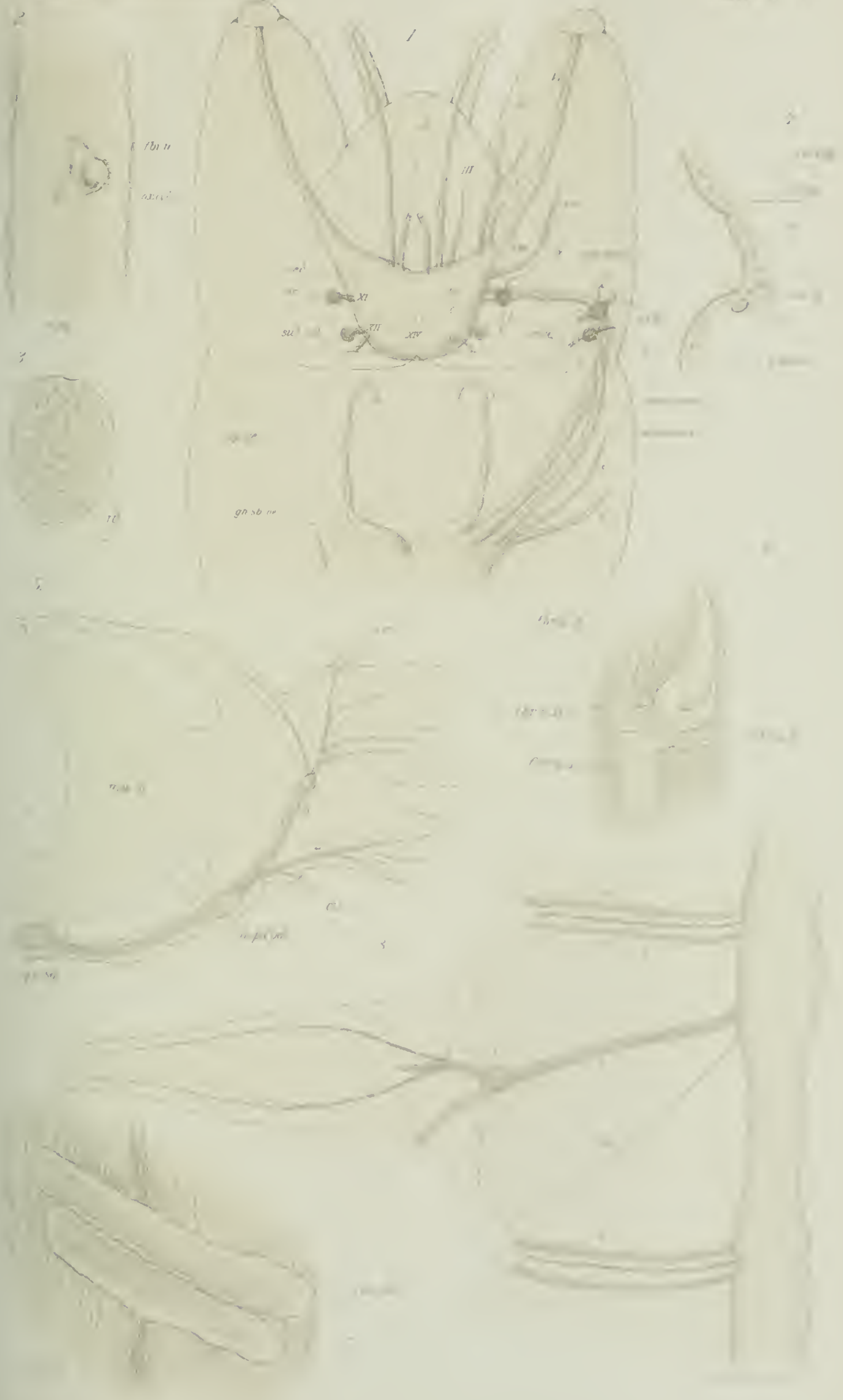

1
2
3
III
XI
XII
XIV
gn sb oe

PLATE 2.

Fig. 9. Transverse section through the posterior end of the brain.

Fig. 10. Pigment (?) from the posterior part of the brain.

Figs. 11 and 12. Nerve cells of the fourth and third classes of the brain respectively.

Fig. 13. A group of four ganglionic cells of a segmental ganglion, in frontal section, to show centrosomes.

Fig. 14. *A*, ordinary ganglionic cell. *B*, one of the large cells of set *B* (compare Fig. 27). The cytoplasm is not granular and takes little stain, excepting the large irregular granules around the centrosomes.

Fig. 15. Brain nerve cell of the second class.

Figs. 16 and 17. Brain nerve cells of the sixth class.

Fig. 18. Transverse section through the posterior end of a segmental ganglion from the region of the fifteenth segment. It shows the connection between the neurilemma and the tunica intima of the ventral blood-vessel; also the position of the ventral nerve cord relative to the hypodermis and the circular muscles.

Fig. 19. Brain nerve cell of the fifth class.


9
10
13
15
18
mu
pl
lm
cso
7
11

PLATE 3.

Fig. 20. Parasagittal section of the cephalic segment tangent to the lateral surface of the posterior eye, to show the ciliated groove.

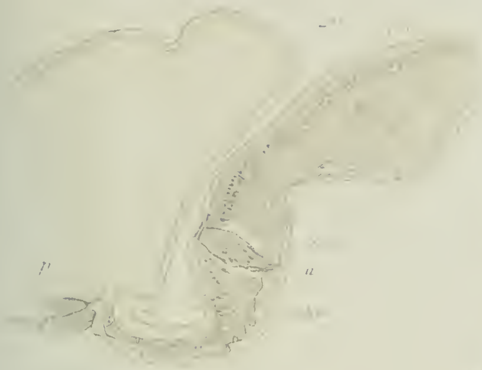
Fig. 21. Enlarged view of part of Figure 24, to show the arrangement of the nuclei of the "mushroom body."

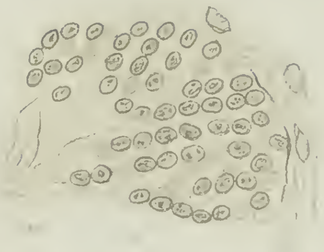
Figs. 22 and 23. Para-sagittal sections of fibre *A* (compare Fig. 27), showing relation to fibres *B*, and also contact of fibres *B* with each other. The median giant fibre also appears in Fig. 23.

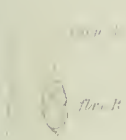
Fig. 24. Transverse section through the anterior part of the brain, showing the "mushroom body."

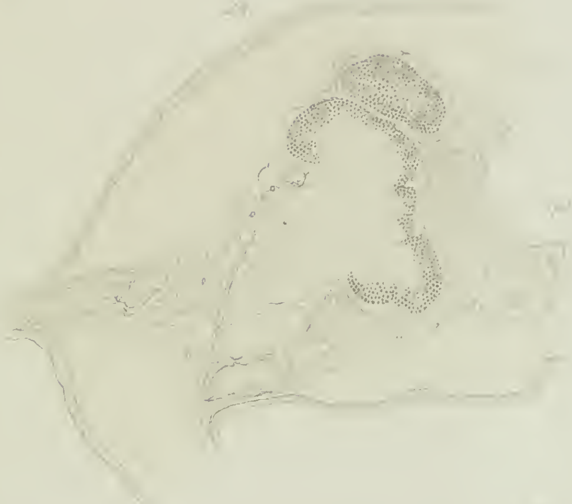
Fig. 25 is omitted.

Fig. 26. Frontal section of a longitudinal connective.


p
a




fbr.k




d
fbr.k


fbr n

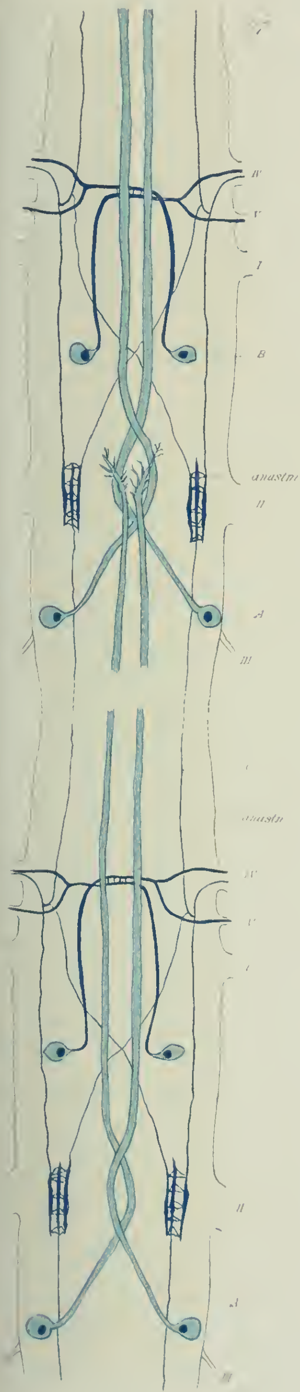
PLATE 4.

Fig. 27. Diagram to illustrate the fibre systems of sets *A*, *B*, and *C*, in two successive ganglia, as projected on the frontal plane.

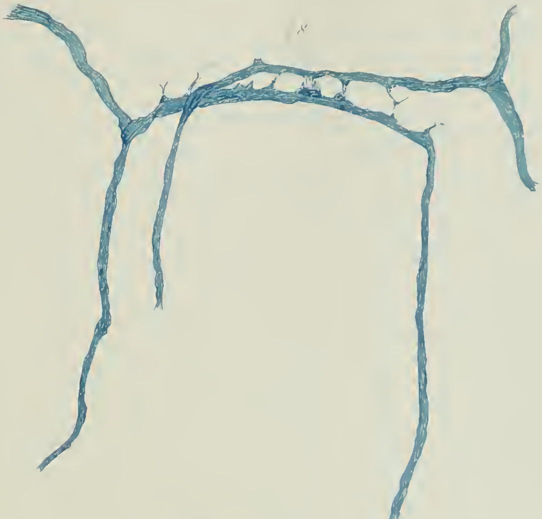
Fig. 28. A pair of anastomosing fibres of set *B*.

Fig. 29. Fibres of set *C*, showing anastomosis between a posterior and a decussating branch.

Fig. 30. Fibres of set *C*, showing anastomosis between an anterior and a posterior branch.



27



28

30

29

PLATE 5.

Fig. 31. Transverse section of the longitudinal connectives of the ventral cord.

Fig. 32. Frontal section of the ventral ramus of a parapodium (compare Fig. 8), showing motor (?) elements in the posterior branch of the second parapodial nerve.

Fig. 33. A section similar to that in Figure 32, showing sensory elements in the second parapodial nerve.

Fig. 34. Motor fibres and endings in the longitudinal muscles.

Fig. 35. Sensory cell from the base of a parapodium.

Fig. 36. Sensory cell from the side of the body near the fourth segmental nerve.

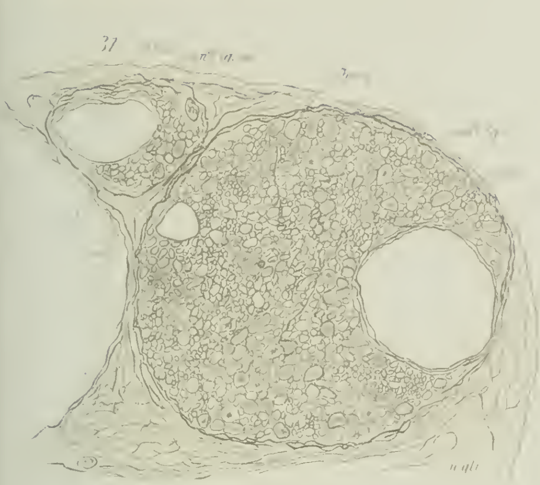
Fig. 37. Sensory nerve termination from the anterior wall of the parapodium.

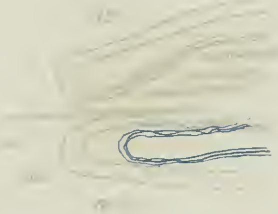
Fig. 38. Sensory cell from the posterior wall of the parapodium.

Fig. 39. Diagram to show the course of fibres in the parapodial ganglion.

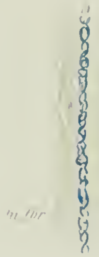
Fig. 40. Fibres of the "sub-hypodermal plexus" ending among the glands of the hypodermis.

Fig. 41. A nerve fibre showing the spiral arrangement of the fibrillæ, and also the shrinking of the axis cylinder from its sheath.


31
n.a.
n.gb




30
m.re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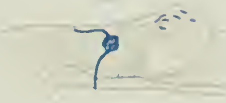
37
h.drm


34


35



Bulletin of the Museum of Comparative Zoölogy
AT HARVARD COLLEGE.
Vol. XXXII. No. 7.

ON REMAINS OF STRUTHIOLITHUS CHERSONENSIS FROM NORTHERN CHINA,

WITH REMARKS ON THE DISTRIBUTION OF STRUTHIOUS BIRDS.

By C. R. Eastman.

With One Plate.

CAMBRIDGE, MASS., U. S. A.:
PRINTED FOR THE MUSEUM.
August, 1898.

No. 7. — *On Remains of Struthiolithus chersonensis from Northern China, with Remarks on the Distribution of Struthious Birds.* By C. R. Eastman.

In the year 1857, or thereabouts, a remarkable fossil egg was discovered in the Government of Cherson, in South Russia. The circumstances of its being brought to light were peculiar, and its subsequent history is instructive enough to repay a brief recapitulation, which we give as follows.

During a spring freshet, a small stream occupying an old watercourse excavated a hollow below a milldam near the village of Malinowka, in the Chersonesus. Some peasants happening by at the time observed floating on the surface of the pool an egg-shaped object, which they lost no time in capturing. A neighboring freeholder acquired the specimen, and from him it passed into the possession of his nephew, a man by the name of Dobrowolsky, who offered it for sale to various Russian institutions. Declined by all on account of the exorbitantly high price demanded for it (1,000 roubles), it was preserved in the family for over twenty-five years, until through a deplorable mishap it was shattered into nearly forty pieces. Some of the fragments, however, were obtained by Professor W. von Nathusius, who examined them microscopically, and declared that they indicated a very close relationship to the common ostrich.[1]

But long before the destruction of this unique specimen, namely, in the year 1872, Professor A. Brandt of Charkow, to whom it was submitted by the owner, had the forethought to take a plaster cast of the fossil, and at the same time prepared a minute description of it. We are indebted to him for our principal knowledge of this egg, as well as for the news of the fatality that ultimately overtook it.[2]

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[1] Zoolog. Anzeiger, Vol. IX. No. 214, p. 47 (1886).

[2] Bull. de l'Acad. Imp. des Sci. St. Petersburg, Vol. XVIII. pp. 158–161 (1873); Mélanges Biol., Vol. VIII. pp. 730–735; Ibis, [3], Vol. IV. pp. 4–7 (1874); Zoolog. Anzeiger, Vol. VIII. No. 191, p. 191 (1885).

The matrix from which the specimen was washed out is stated by Brandt to have been a reddish brown friable loam, overlying a bed of crystalline gypsum. So symmetrical was the shell in outline that it was wellnigh impossible to determine which end corresponded to the acute, and which to the obtuse pole of ordinary birds' eggs.[1] Being perfectly intact, little more could be done than to note its general external appearance, and ascertain its weight and dimensions. The weight, which fell a trifle short of two Russian pounds, was found to be disproportionate to the thickness, but is probably to be accounted for by the mineral infiltration observed by Nathusius. According to the latter, portions of the interior were lined with a crystalline deposit having a thickness of 1.8 cm. in places, and there was also a quantity of loose calcareous matter within the ovulite, supposed to represent the fossilized *membrana testæ.*

The capacity of the egg, that is to say, its cubic contents, was determined by Brandt indirectly from the displacement of a plaster cast in water, which amounted to upwards of 2200 c.cm. Allowing say 125 c.cm. for the volume of the shell substance itself, the actual capacity of the interior is seen to be about 2075 c.cm., as indicated in the table on page 133. Now, as the shell of the largest known ostrich egg has only two thirds this capacity, it is plain that the fossil egg must be the legacy of a larger bird than the ostrich, and very likely one differing in other respects as well as size. That the egg belonged to some Struthious bird is shown in a convincing manner by the microscopic structure, which is eminently characteristic of the group.[2] But in the absence of direct skeletal evidence, such as might have been afforded by associated bones, it seems inadmissible to refer so huge an egg to the same genus as the living ostrich. Therefore we are inclined to dissent from the proposition of Nathusius to abandon the genus *Struthiolithus,* which was very properly created for its reception by Brandt, and agree with

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[1] On the cause and significance of polar deformation of egg shells, compare the following suggestive papers: Ryder, J. A., The Mechanical Genesis of the Form of the Fowl's Egg (Proc. Amer. Philos. Soc., Vol. XXXI. (1893), pp. 203–209); Wickmann, H., Die Lage des Vogeleies im Eileiter vor und während der Geburt (Journ. für Ornithologie, Vol. XLIV. (1896), pp. 81–92).

[2] Nathusius, W. v., Ueber die Eischalen von Aepyornis, Dinornis, Apteryx, etc. (Zeitschrift für wissensch. Zool., Vol. XXI. (1871), pp. 330–356); Ueber die characteristischen Unterscheidungszeichen verschiedener Straussen-eier (Journ. für Ornithol., Vol. XXIII. (1885), pp. 165–178); Hutton, F. W., On the Microscopical Structure of the Egg Shell of the Moa (Trans. New Zealand Inst., Vol. IV. pp. 166, 167), 1872.

the latter in retaining it, provisionally at least, or until information is at hand concerning the creature itself. The specific title applied by Brandt to the ovulite and its as yet unknown parent bird is *S. chersonensis.*

According to Eichwald, fossil avian remains are extremely scarce in Russia. An instance is reported by von Nordmann, however, where certain bones were recovered from Tertiary deposits near Odessa, but no hint is given as to their probable affinities. The Pliocene of the Siwalik Hills in India, as is well known, has yielded ostrich remains which indicate a species (*S. asiaticus*) apparently closely related to *S. camelus;* and other fragments, described as *S. karatheodoris*, have been found in the Lower Pliocene of Samos.

Up to the present time no further examples, either of egg shells or of the skeleton of *S. chersonensis* have come to light; and as already remarked, all that remains of the unique type are the fragments said to be still preserved in the St. Petersburg Museum. We have, therefore, no little satisfaction in being able to announce the discovery of a second perfect specimen, which has recently found its way to this country from China. The configuration of the shell and much of its surface detail are shown on the accompanying plate, which has been reproduced from photographs. The history of the new specimen is as follows. Four or five years ago, a Chinese farmer, while working at the foot of a bank of earth about six meters high, dug out what he considered to be a pair of "dragon's eggs."[1] One was broken, the other entire, and, presuming the latter to have some commercial value, he took it with him to Kalgan, and disposed of it to Rev. William P. Sprague, one of the American Board missionaries residing there. Rev. James H. Roberts, a brother missionary who has also spent many years in China, was present when the egg was sold, and on revisiting this country last spring brought the specimen with him on behalf of Mr. Sprague, to be offered for sale to some scientific institution. Eventually it was purchased for the Museum of Comparative Zoölogy, where it is now deposited.

The Chinese workman who found the egg was well known to the servants of the missionaries as a man living in Yao Kuan Chuang. This is a small village in the district of Hsi Ning, about fifty miles south-southwest from Kalgan by road, but somewhat nearer in a straight line, as that region is very mountainous. Subsequently Mr. Sprague visited the

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[1] The circumstance of two eggs being found together accords well with Owen's suggestion that the oviposition of the moa was probably in pairs. Cf. Extinct Wingless Birds of New-Zealand, Vol. I. p. 320, 1879.

exact spot where the eggs were dug up, in company with the man who found them, and thus satisfied himself of the authenticity of the discovery. The fragments of the second specimen were unfortunately not preserved, and as Mr. Sprague was in doubt whether the perfect one was indeed an egg or perhaps only a geode, he cut a hole about 1.5 cm. in diameter at one end, to ascertain if there were crystals on the inside. But on reflecting light into the interior, the walls were seen to present the same general appearance as the external surface, and a loose calcareous mass, partly in the form of powder and partly flakes that appear to have become scaled off from the inner surface, was found within the cavity. This mass is still preserved in the same condition as when found, and weighs 18.1 grams. Possibly it represents in part the calcified shell membranes, such as have been found fossilized in certain moa eggs. Examined with a pocket lens, the flakes present no appearance of having an organized structure.

Before proceeding to a description of the egg, it may be of interest to note some of the topographical features of the region as depicted by Mr. Roberts in the following sketch, which he was kind enough to draw up at the writer's request: —

"The city of Kalgan numbers about 100,000 inhabitants, and lies 140 miles northwest of Peking, China. Having lived there ever since 1880, I am familiar with the city, and all the surrounding section of country. The village of Yao Kuan Chuang I have frequently visited on my preaching tours to Yü Chou and Hsi Ning. The Hsi Ning (Western Repose) valley extends from W. S. W. to E. N. E., being from seven to ten miles wide near its eastern end, but at a distance of more than thirty miles from that end it begins to widen gradually toward the west. Yao Kuan Chuang is situated about twenty miles from the eastern end, and two miles from the mountains on the north. Through the valley, from west to east, flows the Sang Kan (Mulberry Dry), which is the largest river in the region northwest of Peking. It has no bridges, except in winter, but is fordable in certain places. The Hu Liu (Pot Flow) River, flowing northeast past Yü Chou and then north, joins the Sang Kan at a point three miles east of Yao Kuan Chuang. The Hsi Ning valley, except at its western end and where the Hu Liu River comes in, is walled with mountains several hundreds of feet above the river. The elevation above sea level, at the junction of the Sang Kan and Hu Liu, is shown by the barometer to be about 2740 feet. The mountains present the appearance of bare rock, gullied out in former times by glacial ice, and so steep that grass cannot grow on the larger part of their surface. The rocks are stratified, tilted up at a high angle, and contain a large amount of mica. In one place sheets of mica are taken out for commercial purposes, to be made into window panes.

"There are extensive formations of loess in the Yü Chou and Hsi Ning valleys, from fifty to a hundred feet deep; but the loess, or yellow clay, has been worn away from the greater part of the land north of the Sang Kan River, so that sand and gravel predominate. Wherever irrigated by a stream from the mountains, the land becomes very good and fertile. Near the eastern end of the Hsi Ning valley the Sang Kan River enters a narrow gorge, through which it flows ten or thirteen miles to the lower valley of the Pao An. Each of these valleys was once a lake, walled in by the mountains around them. The evidence of this is unmistakable. As to the Hsi Ning valley, the Chinese say it is recorded in their histories that it was occupied by a lake until about the year 1000 A. D., when the waters cut through the mountains, and the lake was drained off. The recent date assigned to this event, and the general accuracy of Chinese history, would seem to make the story credible, while the configuration of the land shows that such an occurrence must have taken place. Now the valley is tilled very carefully, and villages of a hundred families are interspersed only two or three miles apart. The soil is mostly poor and gravelly, but the stones in it, heated by the sun, radiate their heat at night, and the mountain range on the north is frequently visited with rain; yet the climate on the whole is rather arid.

"Just north of Yao Kuan Chuang is a remarkable seam of red rock [eruptive dike?] eighty feet thick, intersecting the mountains in a vertical plane. It is very conspicuous in contrast to the brown-colored mountain, and is alleged by the natives to be the trail of a serpent. Eight miles west of Yao Kuan Chuang is a ridge composed of small rounded pebbles and rock fragments [esker?], which extends from the foot of the northern mountains to the river, a distance of about two miles. Farther west are a large number of craters, the widest being about two miles in diameter, and containing numerous smaller ones. Seventeen miles southwest of Yao Kuan Chuang, on the opposite side of the river, is Fu T'ou Chiang, a market for coal, which is brought in large blocks on mules from the southern mountains. This coal is of two kinds, one that smokes, and one that does not; and the chief peculiarity of both kinds is that, if any part of a block gets on fire, the whole will slowly consume away, leaving only white ashes. A lump of it as big as a man's fist, if covered with ashes, will keep a fire all night."

Reference to the works of von Richthofen[1] and Pumpelly[2] on the geology of China shows that the above account is in substantial agreement with the descriptions of the surrounding region, as furnished by these authors. Both of them comment on the desiccation that has taken place within comparatively recent times, and note the traces of former shore lines along the mountain sides. The lower part of the Sang Kan flows through a synclinal valley, and higher up in its course it drains a number of loess basins, from one of which our fossil was derived. According to

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[1] Richthofen, F. Fr. von, China, Vols. I.–III. Berlin, 1883.

[2] Pumpelly, R., Across America and Asia. 2d edition, New York, 1872.

von Richthofen,[1] the superficial deposits of these basins were laid down over the bottoms of isolated salt lakes having no outlet, and were afterwards partially buried by alluvial detritus. The moderate depth to which ravines have cut through the ancient lake beds, and the straight narrow gorge of the Sang Kan, through which the waters were drained off, corroborate the belief that this event took place at no very remote period. At all hazards, it is certain that no earlier age can be assigned to the gravel beds from which the fossil egg was exhumed than the Pleistocene.

Turning our attention now to the specimen itself, we notice that it presents almost exactly the same appearance as the Russian egg described by Brandt, a comparison with which has been facilitated by means of a plaster cast very kindly presented to the Museum by this author. In size, symmetry of contour, and all outward respects, the two are remarkably alike. The only noticeable difference is in respect to weight, but this is readily explained by the mineral infiltration already referred to in the case of the type, and the absence of such replacement in the present example. Assuming that none of the internal calcareous mass has been lost, the Chinese egg must have weighed originally about 337 grams, as against "nicht ganz zwei russische Pfunde" for Brandt's specimen. The weight of our individual, as given in the subjoined table, is for the empty shell, perforated at one end in the manner already described. The mutilation cannot be said to be altogether regrettable, however, since it permits of an inspection of the interior, and facilitates a measurement of the volume (equal to the loss of weight in water), cubic contents, and specific gravity of the object.

Measurements of a number of other eggs were made in like manner, and the results are tabulated herewith for the sake of comparison. In the case of the South American ostrich, an average-sized and also a large-sized individual were selected from a collection of over two dozen contained in the Museum of Comparative Zoölogy. The dimensions of *Æpyornis* and *Dinornis* eggs are taken from the literature of these genera, excepting No. 3 of the list, which were derived from a plaster cast obtained from the Paris Museum of Natural History. For these two genera the cubic contents have been calculated from the formula of an ellipsoid of revolution (since no data are at hand to show that they have ever been ascertained by direct experiment) and, not being corrected for the thickness of the shell nor for its departure from the figure

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[1] *Loc. cit.*, p. 314 *et seq.* Also Vol. I. p. 110, quoted in Whitney's "Climatic Changes" as follows: "It may be stated as a certainly ascertained fact, that in Central Asia a dry climate has prevailed for a long time."

TABLE SHOWING COMPARATIVE DIMENSIONS OF THE EGG SHELLS OF STRUTHIOUS BIRDS.

Name of Species.	No.	Longitudinal Axis.	Transverse Axis.	Major Circumference.	Equatorial Circumference.	Ratio of Axes.	Thickness of Shell.	Specific Gravity.	Weight.	Volume.	Cubic Contents.	Remarks.
		cm.	cm.	cm.	cm.		mm.		gm	c.cm.	c.cm.	
Æpyornis maximus Geoff. . .	1	35.1	24.5	92.1	76.8	1.43	—	—	—	—	11,035.8	Original in Brit. Museum, No. 41,847.
" " " . .	2	34.0	22.5	85.0	71.0	1.51	3.65	—	—	—	9,012.5	" " Paris Museum.
" " " . .	3	32.0	23.0	84.0	72.0	1.39	3.45	—	—	—	8,863.5	" " Paris Museum.
" " " . .	4	31.0	23.4	84.8	73.4	1.33	—	—	—	—	8,887.8	Plaster cast in M. C. Z.
Dinornis sp.	5	25.2	17.8	—	55.9	1.42	1.78	2.714	—	—	4,180.6	Figured by Owen and Rowley.
Struthiolithus chersonensis Bdt.	6	18.0	15.0	52.0	46.0	1.20	2.65	—	819.±	125.±	2,075.±	Type specimen.
" " "	7	18.0	14.75	51.35	46.45	1.22	2.20	2.556	310.05	121.30	1,896.90	Chinese example.
Struthio camelus Linn. . . .	8	16.38	13.40	47.10	42.20	1.22	2.00	2.471	310.95	125.82	1,423.63	Largest ostrich egg in M. C. Z.
" " "	9	16.0	13.50	46.00	42.40	1.19	2.00	—	—	—	1,350.00	Brandt's largest ostrich egg.
Rhea darwinii Gould	10	13.5	9.45	35.85	29.90	1.43	0.99	2.359	79.89	33.87	570.44	From Sandy Point, Patagonia.
" " "	11	12.9	9.00	34.60	28.40	1.43	1.00	2.161	77.33	35.79	500.75	From " " "
Rhea americana (Linn.) . . .	12	13.8	9.95	37.35	31.25	1.39	1.00	2.230	106.64	47.80	639.23	" Brazil.
" " " . . .	13	13.8	9.13	35.90	28.70	1.51	1.00	2.361	74.43	31.53	534.84	" "
Casuarius bennetti Gould . .	14	14.0	9.00	36.45	28.30	1.56	—	2.272	73.86	32.51	548.72	" New Britain.
" *australis* Wall. . .	15	12.1	8.65	32.80	27.15	1.40	—	2.298	65.41	28.46	439.43	From Australia.
Dromæus novæ hollandiæ (Lath.)	16	11.3	8.08	30.04	25.40	1.40	1.19	2.405	63.47	26.40	347.67	From Victoria, Australia.
Gallus gallus Linn.	17	5.5	4.30	15.55	13.40	1.28	0.39	2.193	5.75	2.62	50.00	Medium-sized hen's egg.

of a perfect ellipsoid, are somewhat in excess of the true values. The capacity of all the other eggs was found by weighing them when filled with water, and reducing the results; hence the table can be relied upon as being more accurate than that based upon the computations of Geoffrey St.-Hilaire.[1]

This author asserts that the egg of *Æpyornis* is equal in capacity to 6 ostrich eggs, or 12 of the nandu, 16.5 of the cassowary, 17 of the emeu, or 148 of the common fowl, assuming the latter to hold on the average 60 c.cm. One arbitrary standard is as good as another, and, as the hen's egg for which measurements are given (No. 19 of the table) happened to contain exactly 50 c.cm., we may adopt it as our unit; whence it appears that a medium-sized emeu's egg is equal to 7 such units; a cassowary's (*C. bennetti*) 11; a nandu's 10 to 12; an ostrich's 27; a moa's 84; and the largest known *Æpyornis* egg no less than 220. It may be worth mentioning in this connection, for the benefit of those interested, that the eggs of *Æpyornis* and *Dinornis* have been sold at prices ranging between £100 and £200, and the price asked for the type of *Struthiolithus* equals about $770 of our money. These fabulous prices are dependent, of course, upon the scarcity of the objects; for although egg fragments of the two first named genera are tolerably abundant, the number of perfect specimens all told is less than a score.

But to return to the description of *Struthiolithus*. It is probable that the egg shell was only partially embedded in the soil when found, the evidence for this being that the greater portion of the surface is incrusted, more or less granulated, and otherwise affected by atmospheric erosion. The least weathered side is that shown in Figure 2, on which several areas are to be observed where the original shell has remained unaltered. Some discoloration has been brought about through the agency of iron oxide, and grains of ferruginous sand still adhere to the shell in places, or are even partially embedded in the crust. This side of the shell is of a brownish yellow color, somewhat darker than the opposite or more weathered side, shown in Figure 1. Numerous fine pittings are to be seen over the greater part of the periphery, some of which may be due to destructive agencies, but the majority of them are clearly to be regarded as the round terminal pores of air canals. To

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[1] Comptes Rendus, Vol. XXXII. (1851), p. 102. Cf. also Comptes Rendus, Vols. XXXIX. (1858), p. 833, and LXV. (1861), p. 476; Proc. Zoolog. Soc. London, 1852, p. 9, and 1867, pp. 892–991; Ibis, [2], Vol. IV. (1868), p. 65; Ornithological Miscellany (G. D. Rowley), Vol. III. p. 237 (1878); Owen's Extinct Wingless Birds of New Zealand, Vol. I. pp. 317–320 (1879).

determine their precise relations it would be necessary to sacrifice a portion of one of the best preserved areas for the purpose of making a thin section; but as no such area is contiguous to the aperture cut at the upper end by Mr. Sprague, no further incisions have been attempted. It is doubtful in any case whether a section would show more than has already been ascertained from Nathusius's study of the type specimen, which merely proved that the air canals terminated in a similar fashion as in *Struthio camelus*. But the variations in the structure of egg shells among different birds, or even in different parts of the same egg, are so considerable,[1] that we are averse to depending upon this method for accurate systematic identification. In the opinion of the writer, the utmost we are warranted in affirming with regard to the relationship of *Struthiolithus* is, that it probably was very like the living ostrich, but not necessarily a member of the same genus; hence the propriety of retaining Brandt's name in a tentative sense is apparent.

The occurrence of fossil ostrich remains in the loess of such widely separated regions as Northern China and Russia has a direct bearing upon the distribution of Struthious birds. It enables us to speak positively with regard to the former extension of the *Struthionidæ* over Eur-Asia and Africa since the Pliocene, and gives rise to some inferences, within duly circumscribed bounds, regarding the past history of Raft-breasted birds in general. It is necessary to distinguish between what can be affirmed of the ostrich group, properly speaking, and what we can assume with more or less plausibility concerning the rest of the so-called *Ratitæ*. For, if it were possible to recognize the latter as a natural division, embracing forms genetically related to one another, or all derived from a common ancestral type (that is to say, a "Ratite" type), then we should be warranted in establishing a single hypothesis of distribution for all branches of the *Ratitæ*. But the best modern ornithological opinion holds that the division into *Ratitæ* and *Carinatæ* is unnatural, since the differences between existing species of Raft-breasted birds are nearly as great as between any of the *Ratitæ* and *Carinatæ*.[2]

[1] Blasius, R., Ueber die Bildung, Structur, und systematische Bedeutung der Eischale der Vögel. Leipzic, 1867, pp. 48.

[2] Cf. Fürbringer, M., Untersuchungen zur Morphologie und Systematik der Vögel, Vol. II. p. 682. Amsterdam, 1888. Also (on the relations of *Gastornis*) under same caption in Biol. Centralblatt, Vol. XIX. pp. 573–587 (1898). On the taxonomic relations of *Rhea*, *loc. cit.* (1888), p. 1442: of *Hesperornis*, Ornith. Monatsber. deutsch. Vereins z. Schutze der Vogelwelt, Vol. XV. p. 488 (1890).

For our present purpose, this question as to the homogeneous or compound character of the *Ratitæ* is of prime importance, involving as it does the problem of common or multiple origin for its several members, and hence the key note of their distribution. If we admit, for instance, as has been suggested by some, that the South American ostrich was derived from the tinamous or some other Carinate stock, then it must be altogether excluded from the list of forms that migrated into the western hemisphere by means of a former land connection. But if, on the other hand, structural resemblances are sufficient to point to a genetic relationship with the ostrich or other Struthious type, then its occurrence in Patagonia can be accounted for in no other way than on the hypothesis of a land migration.

Or again, in the case of the remarkable *Stereornithes*, from the early Tertiary of Argentina and Patagonia, which were considered by Ameghino, Gadow, and for a time also by Lyddeker, as ancestral forms of *Ratitæ*, — if they could be shown really to have Struthious affinities it would be a simple matter to connect them and the modern *Rhea* with *Diatryma* from the Eocene of New Mexico; further, with the Tertiary ancestors of *Struthiolithus*, *Struthio* proper, and the moas of New Zealand; and perhaps finally with the little known *Gastornithidæ* from the London and French Eocene. Indeed, much stress was laid by Lyddeker on the resemblances between *Gastornis* and the leading genus of the *Stereornithes*, *Phororachos*. But however attractive such a theory might seem at first glance, we are obliged to renounce it as illusory in view of recent destructive criticisms at the hands of such excellent anatomists as F. A. Lucas, C. W. Andrews, and others, who have caused even Ameghino and Lyddeker to recede from their original opinions.

The last named author,[1] writing in 1893, placed *Gastornis*, *Brontornis*, and *Phororhachos* unhesitatingly among the *Ratitæ*, as the latter are commonly understood. He refers to "the modern German [Fürbringer's] view that the *Ratitæ* form a compound group, of which the various sections have been independently derived from several perfectly distinct Carinate ancestors, and that their mutual resemblances to one another are solely owing to the effects of adaptation"; but his own personal opinion is expressed in the following words: "I confess, however, that the supposed Anserine affinities of *Gastornis* appear far from clear to me, while I always feel that *the great difficulty in admitting the multiple origin of the Ratitæ is that, if this had been the case, there*

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[1] Lyddeker, R., On the Extinct Birds of Argentina (Ibis, [6], Vol. V. pp. 46, 47). 1893.

would have been far less structural similarity to one another among the various groups than we find to prevail."

Dr. Ameghino's final conclusion is that the *Stereornithes* appear to show that the division of the class of birds into *Ratitæ* and *Carinatæ* is not fundamental, — a view which has been especially advocated by Mr. Lucas among American ornithologists. The latter,[1] in a critical review of Ameghino's work, speaks as follows: "Apparently the main reasons for comparing such forms as *Phororhachos* and *Brontornis* with the *Struthiones* is because they are large and extinct, when, as a matter of fact, mere size is no reason for supposing a bird related to an ostrich; while the pelvis of *Phororhachos*, with its aborted pubis, shows that this genus at least is very many removes from any Struthious bird. Neither is *Gastornis*, with its primitive type of skull, any relation of the *Stereornithes*."

Precisely the same attitude is displayed by Mr. Andrews,[2] who denies that the *Stereornithes* have anything in common with Struthious birds or with the *Gastornithidæ*, neither are they by any possibility descended from *Hesperornis*. Says he: "The *Stereornithes* seem to be a heterogeneous group of birds in all of which the wings were reduced and the bulk increased through the operation of some peculiar local conditions; for instance, the land which they inhabited may have been an island on which no large carnivorous animals occurred. A similar example is offered by New Zealand, where the *Dinornithidæ*, *Apteryx*, *Aptornis*, and *Cnemiornis* (all flightless birds of large size, and belonging to distinct orders) were formerly found. Indeed, there seems to be no reason why at any time, from the late Secondary period onward, and in any region, similar groups of flightless birds might not have arisen under favorable circumstances. The *Gastornithidæ* may be another instance of such. In most cases such specialized races die out without leaving any descendants when the peculiar conditions to which they have become adapted pass away; but the modern *Ratitæ* may be survivors of one or several ancient groups of such flightless birds."

Still more explicit are Mr. Lucas's views as to the nature and origin of the so-called Struthious birds, which he defines as "those generalized birds which through some special adaptation to their surroundings or freedom from enemies have been able to survive to the present day. *Rhea* and *Struthio* are typical examples of this. While it would be

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[1] The Auk, New Series, Vol. XIII. (1896), pp. 62, 63.

[2] Remarks on the Stereornithes, a Group of Extinct Birds from Patagonia (Ibis, [7], Vol. II. p. 12). 1896.

assuming too much to say that the limit of size has been attained by any bird of flight, it is yet very evident that the difficulties of flight increase very rapidly with increase of size, — hence the correlation between gigantic stature and loss of flight. It is a noteworthy fact that the forms attaining the maximum size in their respective groups are generally flightless, e. g. *Cnemiornis, Notornis, Didus*, etc. Since flightless forms have originated in comparatively recent times wherever the conditions were favorable, so undoubtedly they arose in the past, and only amid unusually favorable conditions and stable environment could these ancient flightless forms persist. That existing 'Ratite' birds were long ago differentiated from the parent stock, or that they arose independently, is indicated by the great differences between forms separated by considerable stretches of water. In view of the parallel development of the horse and rhinoceros in Europe and America, it would hardly seem necessary to suppose a unity of origin for Struthious birds; moreover the palæontological history of the class is so fragmentary that phylogenetic arrangements of the birds can be regarded as little more than guesses. As to the characters of the *Ratitæ*, the absence of a keel to the sternum and the slight angle between the scapula and coracoid are purely degenerate features without the slightest taxonomic value; and the 'Ratite' type of skull is a generalized skull having resemblances to that of the reptiles. The characters in which *Hesperornis* resembles the ostrich are generalized characters, such as one would be surprised *not* to find in so early a bird; its shoulder girdle is unique among birds and decidedly reptilian, while the foot is the most highly specialized swimming foot known. That this bird is the *direct* descendant of any land bird is incredible. As for the tinamous, their skull and pelvis of a very generalized type prevents us from regarding them as recent derivatives; they are in fact 'hold-overs' in a region noted for the number of curious forms it contains, indicating the persistence of a few very old species in the midst of a more advanced yet not strictly modern fauna."[1]

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[1] The above quoted remarks are from some notes which Mr. Lucas very kindly took the pains to write out by way of comment on the present paper before it was finally prepared for press; and the writer has great pleasure here in acknowledging his indebtedness to this source for many helpful criticisms and suggestions. Reference should be made also to Mr. Lucas's review of Professor Thompson's paper "On the Systematic Position of Hesperornis," published in The Auk, Vol. VIII. p. 304 (1891), as well as to the comments of Dr. J. A. Allen in the same journal, Vol. XV. p. 70 (1898), which brings the literature of *Hesperornis* down to date. For a copious bibliography of the distribution of recent birds, see Mr. P. L. Sclater's address before the Second Ornithological Congress at Budapest, May, 1891.

Strong enough arguments, we think, have been put forward to show that the theory of a common origin of the *Ratitæ* is untenable, and hence no single hypothesis of distribution is able to account for the facts of their distribution. We cannot imagine a race of ostriches sprung from *Hesperornis* or anything of like nature in the Cretaceous, spreading over the whole earth in the Tertiary, and then, as decay set in, leaving its fragments scattered in remote corners of the globe. But the problems presented by the alternative theory, that of multiple origin, are none the less interesting or important, although decidedly more complicated. To seek the nearest Carinate affinities for the different sections of *Ratitæ* separately; to develop the palæontological history of each more fully; and to inquire into the physical and biological conditions which led to their insulation, perpetuation, and differentiation in various provinces, — these are only a few of the points that invite an extended investigation. Some of the problems have already been touched upon, notably as regards the origin of the moas, the South American ostrich, and *Æpyornis;* and we may profitably turn our attention for a moment in this direction, beginning with *Rhea*.

No one can deny that the physical resemblances between *Rhea* and *Struthio* are very great; in fact, the popular term "South American ostrich" is an obvious commentary on their similarity. Although both genera are regarded as typical of distinct families, and are even commonly placed in separate suborders, yet, if one were asked to specify the nearest living ally of the African ostrich, he would unhesitatingly point to *Rhea*. Only two interpretations of structural resemblances are possible: either they indicate direct genetic relationships, or we have here a most remarkable case of convergence. Now in this instance we confess to sharing Dr. Lyddeker's prejudice against the theory of parallel development, already quoted, as there is too striking a coincidence in the forms produced to be explained as the result of adaptation during recent times in two widely distant regions of the globe. The natural and only logical plan would be to assume blood relationship between *Rhea* and *Struthio* as a matter of course, until it is proved that by no possibility could they have been derived from the same ancestral stock. Now if *Rhea* had different progenitors from the ostrich, we are in utter ignorance as to what they were like, as no other descendants remain. That there is anything in common between *Rhea* and the tinamous we cannot believe for a moment, in view of the different organization of the latter. Hence, Captain Hutton's theory, which derives both *Rhea* and the moas from a tinamou-like ancestor which crossed into Australia and New Zealand by means of an imaginary Antarctic continent, must be relegated on both biological and geological evidence to the same category as the Lemurian hypothesis.

Rhea still enjoys a comparatively wide distribution in South America, and its remains have been found in the bone caverns of Brazil. If the evidence of *Diatryma* in New Mexico means anything at all, it would point to a connection between a fossil North American and the existing South American ostrich. It is true that the late Tertiary yields no evidence of Struthious birds in North America. But it is also true that until the discovery of *Struthiolithus* under the shadow of the Great Wall in China, no one could have suspected the whole intervening territory between Northeastern Asia, South Russia, and Africa to have been in comparatively recent times inhabited by true ostriches. The palæontological record is from the nature of things very deficient in the case of land birds, and many gaps can only be filled on indirect evidence. One such gap is now partially filled by the occurrence of *Struthiolithus* in Northern China. A race having the constitutional vigor and numerical force to establish itself in this latitude, — and in a mountainous region as well, where the struggle for existence is always intensified by a larger number of enemies than are found on the plains, to say nothing of the rigors of winter, — must have been able to penetrate still further northward, and might readily have accompanied the mammals that migrated across the land bridge formerly connecting the palæarctic and nearctic regions.

In a word, if we can predicate any blood relationship between the African and South American ostriches, it is certain that the latter could have reached its present habitat in no other way than along the route marked by *Struthio camelus*, *S. karatheodoris* and *S. asiaticus*, *Struthiolithus*, *Diatryma*, and the *Rhea* of Brazilian bone caverns. If any will presume to deny a relationship between *Struthio* and *Rhea*, they are confronted with these difficulties: to explain how two separate derivatives from Carinate birds should come to present such marvellous similarity to one another through the operation of purely fortuitous conditions, and to point out a lineage for *Rhea* connecting it more closely with Carinates than with the ancestors of *Struthio*. Sceptically inclined individuals are welcome to regard *Rhea* as one of the "waifs and strays of a lost avifauna left by the sea of time stranded on the shores of the present," but we personally prefer the more positive view, which connects the New and Old World ostriches in the manner indicated.

Turning now to the advent of the moa into New Zealand, and of *Æpyornis* upon the island of Madagascar, we note that previous writers have essayed in various ways to meet the following dilemma. If these birds migrated from what is now the mainland *prior* to the Tertiary, why have not their remains been found in strata older than the Pliocene? Or, if the islands remained inaccessible to them until the late Tertiary, how was the passage finally accomplished by wingless birds? And what is still more to the point, why were they in the latter event unaccompanied by placental mammals? Of the two principal theories put forward to explain the facts, neither, in the opinion of the present writer, sufficiently accounts for all the difficulties. In the case of the moas, Mr. Wallace[1] supposes that their ancestors either flew or swam across straits impassable to contemporaneous mammals. But Captain Hutton properly takes exception to this view, on the ground that their Ratite characters are due to their being unable to fly; moreover, the oldest known moas were entirely without wing bones, and possessed a very rudimentary shoulder girdle. As to the alternative explanation that they crossed by swimming, Captain Hutton[2] remarks as follows: "But, although the emeu and the rhea are both said to take readily to water, many placental mammals do the same, and it is very unlikely that the Struthious birds should twice have swum across the same straits — once from the Oriental to the Australian region, and again from the Australian to New Zealand — which were impassable to mammals. There are also other reasons for doubting the northern origin of the Australasian *Ratitæ*."

Now, as most persons are aware, both biological and geological evidence go to show that New Zealand has been separated from Australia, and Madagascar from Africa, at all events ever since the dawn of the Tertiary, and probably since the latter part of the Cretaceous. Accordingly, Captain Hutton supposes, after having shown the improbability of wingless birds either flying or swimming across straits, that the moas have had a different origin from the rest of the *Ratitæ*, — an opinion from which we find no reason to dissent, although rejecting his hypothesis of a tinamou-like ancestor in the Eocene, and a submerged Antarctic continent. Although the oldest known remains of the *Dinornithidæ* are of Miocene age, and no one has attributed to the family an earlier origin than the Eocene, yet the occurrence of moa remains on the continent of

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[1] Wallace, A. R., Island Life, 2d edition, p. 481, 1892.

[2] Hutton, F. W., The Moas of New Zealand (Trans. New Zealand Inst., Vol. XXIV. p. 147), 1891.

Australia (Pliocene of Queensland) furnishes ground for believing that a form of wingless bird arose in Australasia at some time previous to the detachment of the present New Zealand and adjacent islands from the mainland. If the stock really had an uninterrupted Tertiary history, it is of course immeasurably removed from any existing Carinate forms, or other *Ratitæ*. The moas are supposed to have enjoyed their period of culmination during the Pliocene, when they flourished prodigiously and covered the land, but thereafter they suffered great mortality. Their extinction was certainly not caused by the encroachment of natural enemies, any more than was the case with *Æpyornis;* nor can their decline be reasonably attributed to physical or climatic changes of which we have no evidence. Their decadence not being traceable to external influences, we can only interpret it as the result of some inherent cause or causes, — taken together with the retarded action of natural selection, — such as are frequently seen to follow in the wake of hypertrophy among various groups.

We cannot pass from this subject without calling attention to Captain Hutton's remarkably ingenious explanation of the crowding together of so many varieties of Struthious birds in the limited area of New Zealand, and the unequal distribution of species between the two islands. What appear at first sight to be unparalleled or anomalous features of distribution are all consistently explained on the theory of a simple order of geographical changes, namely, alternating elevation and subsidence of land masses. Two periods of subsidence and one of elevation are sufficient to account for all the phenomena, according to Captain Hutton's hypothesis. His interpretation, with which Mr. Wallace heartily concurs, is concisely summarized by the latter author as follows: "First, we must suppose a land connection with some country inhabited by Struthious birds, from which the ancestral forms might be derived; secondly, a separation into many considerable islands, in which the various distinct species might become differentiated; thirdly, an elevation bringing about the union of these islands to unite the distinct species in one area; and fourthly, a subsidence of a large part of the area, leaving the present islands with the various species crowded together." [1]

To revert finally and in few words to the origin of *Æpyornis*, it is plain that, if its ancestors reached the island from Africa as flightless birds, the migration must have taken place not later than the Eocene, since no mammals initiated since the Cretaceous are found in Madagascar. The

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[1] *Loc. cit.*, p. 479.

lemurs, insectivora, rodents, and reptiles now inhabiting the island bear the stamp of great antiquity. It is true that *Æpyornis* remains, so far as known, are confined to deposits of supposed Pleistocene age, and the material itself is inconsiderable.[1] The deficiency may be partially accounted for owing to lack of exploration, and imperfection of the palæontological record, especially as concerns land birds. But if it be objected that a continuous Tertiary history implies a higher degree of specialization and greater specific variation than we have any evidence of, we must not forget that here the action of natural selection was more or less suspended, owing to the abundance of food, absence of carnivorous or other powerful enemies, and generally mild conditions. The same causes produced the same effects upon the ancestors of *Æpyornis* as upon the moas, of which Captain Hutton affirms, "Under such favorable circumstances the conditions of life were very easy, and the birds grew larger and fatter, more sluggish and more stupid," — until, in fact, they became effete and were finally extirpated.

On the assumption that the forerunners of *Æpyornis* have inhabited Madagascar ever since its separation from the mainland, it is not surprising that this genus should have to stand by itself as the representative of a distinct suborder. Some resemblances to the *Struthio-Rhea* branch of the *Ratitæ* are observable, to be sure, — even the egg shells having a remarkably similar structure, as shown by Nathusius, — and anatomists like Fürbringer, Milne-Edwards, and Grandidier have endeavored to show even greater similarity to *Dromæus* and *Casuarius*, which are regarded as the most primitive of existing *Ratitæ*. But all are agreed that the differences far exceed the resemblances, being in fact fundamental. To us it seems that the amount of divergence from other known types, living and fossil, coupled with the slower rate of variation affecting insular forms, and, above all, the generalized characters observed in *Æpyornis*, go to show that this bird is far from being a modern derivative, but is the last of a very ancient race. We see no impropriety in supposing that its flightless ancestors inhabited the Madagascar region when it was still a part of Africa, and that other descendants may have migrated northward into Europe during the early Tertiary.

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[1] Andrews, C. W., Note on a nearly complete Skeleton of Æpyornis from Madagascar (Geol. Mag., Dec. 4, Vol. IV. pp. 241–250), 1897. Burckhardt, R., Ueber Æpyornis (Palaeont. Abhandl. Dames und Kayser, Vol. II. Heft 2), 1893.

DESCRIPTION OF THE PLATE.

Fig. 1. *Struthiolithus chersonensis* Brandt. From superficial deposits in the neighborhood of Kalgan, China. Obverse, or more weathered aspect, with prominent pittings. × $\frac{5}{9}$.

Fig. 2. Reverse aspect of same specimen, showing uncorroded areas. Millimeter scale at bottom of the figures. × $\frac{5}{9}$.

(Reproduced from photographs by Mr. C. H. Currier, of Boston.)

Fig. 1.

Fig. 2.

THE HELIOTYPE PRINTING CO. BOSTON

Bulletin of the Museum of Comparative Zoölogy
AT HARVARD COLLEGE.
Vol. XXXII. No. 8.

REPORTS ON THE DREDGING OPERATIONS OFF THE WEST COAST OF CENTRAL AMERICA TO THE GALAPAGOS, TO THE WEST COAST OF MEXICO, AND IN THE GULF OF CALIFORNIA, IN CHARGE OF ALEXANDER AGASSIZ, CARRIED ON BY THE U. S. FISH COMMISSION STEAMER "ALBATROSS," DURING 1891, LIEUT. COMMANDER Z. L. TANNER, U. S. N., COMMANDING.

XXIV.

PRELIMINARY REPORT ON BRANCHIOCERIANTHUS URCEOLUS, A NEW TYPE OF ACTINIAN.

By E. L. Mark.

[Published by Permission of Marshall McDonald and George M. Bowers, U. S. Fish Commissioners.]

With Three Plates.

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PRINTED FOR THE MUSEUM.
August, 1898.

No. 8. — *Report on the Dredging Operations off the West Coast of Central America to the Galapagos, to the West Coast of Mexico, and in the Gulf of California, in charge of* ALEXANDER AGASSIZ, *carried on by the U. S. Fish Commission Steamer "Albatross," during* 1891, LIEUT. COMMANDER Z. L. TANNER, U. S. N., Commanding.

XXIV.

Preliminary Report on Branchiocerianthus urceolus, a new Type of Actinian.

By E. L. MARK.[1]

ONE of the most interesting of the many new forms brought up in the dredgings of the Albatross Expedition under Mr. Agassiz in 1891 was a deep-sea actinian which bore so strong a resemblance to Cerianthus in its general appearance that the sketches made at the time are marked "new Cerianthus." An examination of the superficial characters shows, however, as Mr. Agassiz ('91, p. 187) at once recognized, that this new form differs in important points from the genus Cerianthus, and may indeed require the erection of a new family for its reception. Its two most striking morphological features are a pronounced bilateral symmetry and the possession of an incomplete circle of branching gill-like organs. The latter peculiarity I utilize in proposing for it the new generic name *Branchiocerianthus.*

A considerable number of specimens were taken at each of two hauls in the Gulf of Panama, not far from Cape Mala, at Stations 3385 and 3389, the depths being respectively 286 fathoms and 210 fathoms, and the bottom being in both instances green mud. The colors, as shown by the colored sketches drawn at the time by Mr. Westergren, were brick-red for the column, deep carmine for the marginal tentacles, and rose-pink for the oral disk, and all the structures arising from it, including the oral tentacles. The specimens were all preserved in strong alcohol.

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[1] Contributions from the Zoölogical Laboratory of the Museum of Comparative Zoölogy at Harvard College, E. L. Mark Director, No. XCIII.

The animal as sketched in the fresh condition by Mr. Agassiz consists of a vase- or pitcher-shaped "flower" surmounting a long stalk, from which it is clearly marked off by a broad shallow constriction. The outlines are extremely graceful, presenting in front and back views (Plate 1) a symmetrical vase-like figure with flaring lips. A side view (Plate 2) shows that one margin of the disk is much higher than the other, so that in this aspect the upper end of the animal resembles the lip of a broad-mouthed pitcher. The disk, when spread by pinning out the marginal tentacles, has an oval outline; but in the natural state the lateral margins of the disk are folded in symmetrically from either side, so as almost to touch at a point a little below the middle of the oval. This bending in of the margins of the disk produces at the upper end of the animal a sort of eccentric funnel-shaped depression, which, however, does not lead to the mouth opening, but to the outside again, at the lower margin of the oral disk. The fancied resemblance of the animal to a little pitcher, which this side view presents, has suggested the specific name adopted, — *urceolus.*

In this actinian we may recognize two fairly well marked regions, — the "flower" or calyx and the stalk. The former embraces the upper part of the column in addition to the disk proper and its appendages; the latter is the remaining part of the column with its swollen base. A slight and somewhat oblique constriction, often emphasized by a conspicuous line, indicates the place of transition from one to the other.

The *oral disk* is so modified in form as to bear little resemblance to that of Cerianthus. When in preserved specimens the marginal tentacles are pinned out under slight tension, the disk has, as already stated, an oval outline, the longitudinal and transverse diameters of which in the specimens measured range between 25 mm. (longitudinal) by 15 mm. and 38 mm. by 30 mm. The surface of the disk is very oblique to the longitudinal axis of the column. The marginal tentacles are interrupted at the edge of the disk nearest the base. This edge I shall, for convenience, designate as *posterior*, the opposite pole of the long axis of the disk *anterior.* I adopt these designations without the intention of advocating now any of the theoretical views concerning the broader questions of comparative morphology in Actinozoa.

The *marginal tentacles* have a deep carmine color in the living animal, becoming in alcohol a dark maroon or claret color; they vary in number from 85 to 97. I am not yet certain that there is an unpaired anterior tentacle, as in Cerianthus, but believe it probable that there is, because there are usually an uneven number of tentacles, and the method of their formation is apparently the same as in Cerianthus. They are symmetrically arranged at the margin of the disk, the hiatus at the posterior margin giving the line which connects their several insertions the form of an elongated horseshoe. The shortest, and evidently youngest, tentacles occupy the ends of the two arms of the horseshoe, and are therefore near the posterior margin of the disk; but the tentacles do not increase regularly in length toward the anterior margin. There are usually one or two pairs of posterior tentacles that are quite short; but the two of a pair are not necessarily of equal length; the more anterior ones are successively longer and longer until a maximum length of about 125 mm. (in alcoholic material) is reached in about the tenth pair from the posterior margin. From this region forward there is a gradual and not great diminution in the length of the tentacles up to and including the anterior ones. This gives to the whole disk with its marginal tentacles, when pinned out, an appearance somewhat resembling a common palm-leaf fan. The marginal tentacles are so crowded that they are much flattened at their bases, and overlap one another, as shown in the figure on Plate **3**; but the shorter tentacles near the posterior margin of the disk (one or two pairs) are usually separated from the next more anterior ones by an appreciable distance.

The middle region of the disk is raised into a nearly cylindrical oral tube, which in cross section is oval, and bears at and near its summit the oral tentacles; below these there is usually a slight constriction. The free end of this oral tube occupies a plane perpendicular to the long axis of the column, i. e. it is not oblique, like the disk from which it rises. Owing to the obliquity of the disk to this axis, one side of the oral tube — the posterior — is much longer than the opposite side. For the same reason the posterior face of the oral tube passes almost imperceptibly into the disk whereas the lateral and especially the anterior faces make with the disk an angle. Viewed from the upper end, the oral tube in the fresh specimen presents an oval outline, the oval being nearly twice as long in the antero-posterior direction as in the transverse. There is no marked difference between the two angles of the mouth; but sections may disclose the presence of a siphonoglyph. The oral tentacles outnumber the marginal ones, there being about 130 of them. They are arranged roughly in quincunx, and occupy four or five rows on the outer surface of the upper end of the oral tube. They vary in size, the largest being (in alcoholic material) about 30 to 35 mm. in length, and 0.5 mm. in diameter at the base. These, too, are so crowded as to be much flattened at their origin.

From the oral disk immediately outside the base of the oral tube there arises a row of branching thin-walled organs, which are probably to be regarded as *gills*. Like the marginal tentacles, this row of gills is interrupted at the posterior side of the disk, and consequently has the form of a horseshoe. There are usually 16 pairs of gills and an odd one, making 33 in all; but in one specimen there were only 27 in all, and in another there were 37. Mr. Agassiz has sketched one individual with only 21. There is considerable variability in the size of the gills; the posterior ones, though usually smaller than the anterior ones, are not always so. A few small gills are sometimes intercalated between those of larger size. Though arranged approximately in a single row, there is some irregularity in their position, especially toward the anterior end of the disk, where they are more crowded than near the posterior end. In fresh specimens they are of a rose-pink color, but in alcohol this color is lost.

Each gill consists of a single cylindrical, or somewhat flattened hollow stalk, terminating in quite regular dichotomously forking branches. The stalk rises abruptly from the surface of the disk, sometimes being slightly constricted at its base; it has a length of from 4 mm. to 8 mm., and a fairly uniform diameter of from 0.5 mm. to 1 mm. The forking may extend to the production of branches of the ninth or tenth order. The terminal branches, of which there may be nearly 500 to a gill, end blindly with rounded tips. In alcoholic material the branches are often varicose, owing to distention with coagulated contents. In the living condition they are probably of much more nearly uniform calibre. When not contracted the gills rise above the oral orifice, and even above the oral tentacles themselves.

Radial canals are traceable running across the disk from the base of the oral tube to the bases of the marginal tentacles, before reaching which many of them fork, each of the branches communicating with the lumen of a single tentacle.

The outer surface of the calyx constitutes the upper part of the column; its height is greatest in front, diminishing to practically zero behind. Above the constriction which marks the transition from it to the stalk proper, it gradually expands to meet the margin of the oblique oral disk. It is marked with fine longitudinal dark lines alternating with lighter ones, as in the rest of the column.

The *column* resembles that of Cerianthus in being elongated, cylindrical, and enlarged at its basal end. Below the constriction which marks the boundary of cup and stalk it presents a spindle-shaped enlargement.

In the alcoholic specimens which I have measured the stalk below the constriction varies from 105 mm. to 200 mm. in length, and from 3 mm. to 5 mm. in diameter. The enlarged bulb-like end is from 6 mm. to 8 mm., or even more, in diameter. But in preserved specimens the stalk is much folded lengthwise, so that the direct measurement of its diameter is not reliable. A portion of the stalk of a medium sized individual cut out, slit open lengthwise, and pinned out, measured 22 mm., so that the corresponding diameter would be about 7 mm. The bulbous enlargement reaches about twice that diameter. The column is smooth, except for very minute appendages at the basal end, and marked by narrow longitudinal brownish lines about 0.2 mm. broad, alternating with lighter colored brownish or buff ones about three times as wide (0.6 mm.). The darker lines in the fresh specimen are bright brick-red. Individuals differ much in the depth of color, which in all is less in the bulbous region, where the distinction between the light and dark lines almost disappears. The wall of the stalk, though not very thick, is quite rigid; that of the bulb is somewhat thinner. The bulb terminates in a small, nipple-like elevation; but a terminal pore, if present, must be very minute, for I have been unable to detect one by examination of specimens *in toto.* The bulb often contains a large quantity of the shells of Foraminifera.

The outer surface of the lower part of the bulb is provided with small tapering filamentous appendages, which are 50μ to 75μ in diameter at their bases, but diminish abruptly to less than half that diameter and then taper gradually to a point. They vary in length from 0.5 mm. to 1 mm., rarely more in alcoholic material, and are rather evenly distributed over the surface at distances of 0·5 or 0.3 mm. apart; but they are not arranged in any definite pattern. They remind one of the peculiar appendages of the egg shell in Fundulus heteroclitus, especially of those of the half grown ovarian eggs (cf. Eigenmann, '90, Plate I. Fig. 6).

The lower end of the column, its bulbous enlargement, is invested by *a case* which extends upward at least for a tenth of the length of the column, and is open at its lower end. It is, of course, the secreted product of the lower and of the column, but it has a more complicated structure than is common in sheath-inhabiting actinians. In an individual whose stalk was 200 mm. long the case was about 25 mm. long, exclusive of the peculiar hair-like appendages which it bears. The lower three fifths of the case differs from the upper two fifths in possessing very numerous long hair-like hollow appendages. The upper two fifths may be divided into two zones of about equal breadth. The secretion of the upper zone is simply corrugated and folded longitudinally; that of the lower exhibits thickened patches a millimeter or more in diameter and fairly closely set. Of these patches there are three or four rows running around the column. The secretion of all three regions has a fibrous appearance due to the fine, sinuous corrugations which run around the column, and are the expression of differences in the thickness of the secretion. The effect is as though the secretions had been formed as rings, more or less complete, which had been crowded downward by successive additions above. In the region which bears the hairs the same appearance is shown, under a low magnification, by the secretion which constitutes the hair. This is a hollow thin-walled cylinder, which gradually diminishes in size from its base, where its diameter is about 0.2 mm., to its free end. The hairs attain a length of 25 mm. or more, and are so tough that they form for the actinian a means of secure anchorage in the mud. The corrugations of the wall of the hair which run around it are not due to folds of the secreted substance, for optical longitudinal sections of the hairs show that the inner surface of the tube is smooth. When the animal is thrown into alcohol this case, with its tuft of matted hairs, is readily detached from the column, but a careful examination of those case secretions which are not thus artificially separated shows that there are at intervals exceedingly minute filaments running out from the surface of the animal to the inner surface of the case, and I am convinced that these are the minute filaments described as arising at regular intervals from the surface of the bulbous portion of the column. I believe that a single filament is enclosed in each of the hollow hair-like appendages of the case, and that the form and size of these hairs is, in part at least, determined by the presence and shape of the filaments of the column. The lower part of the case is much wrinkled lengthwise, and projects to some distance (5 or 10 mm.) below the base of the column. It has the appearance of having once surrounded the enlarged end of the column and having been slipped backward, its elasticity causing it to become wrinkled like the mouth of a meal-sack that is tied. The hair-like processes surround this open end of the case and project beyond it.

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EXPLANATION OF PLATES.

The drawings are by Magnus Westergren, from sketches by Alexander Agassiz.

PLATE 1.

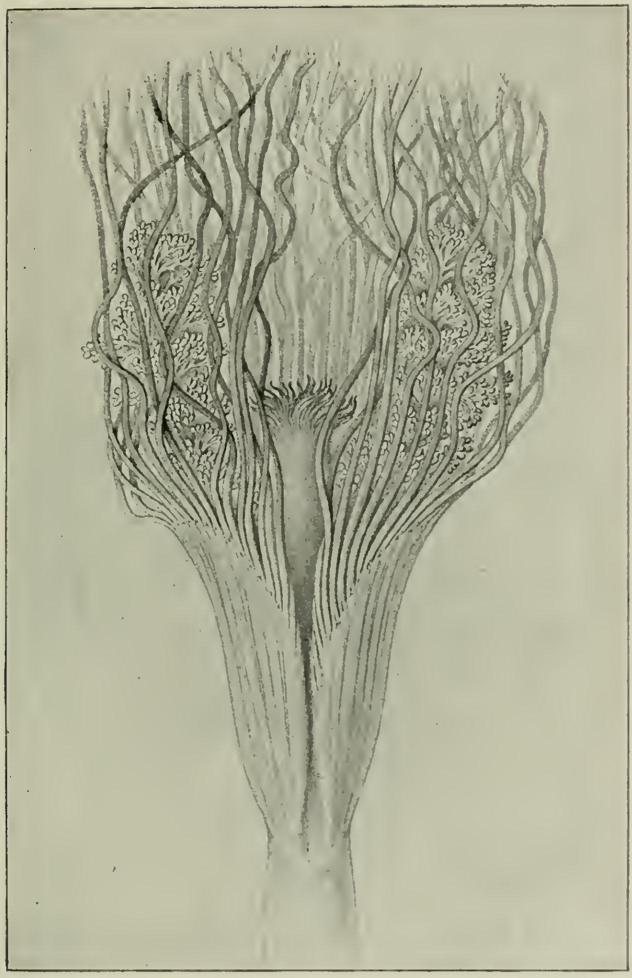
Upper end of Branchioceriauthus urceolus, seen from the side (posterior) bearing the youngest marginal tentacles. Fresh specimen. Magnified 2^1.

PLATE 2.

Side (slightly oblique) view of same.

PLATE 3.

Upper end of an alcoholic specimen of same, viewed from the same side as in Plate **1**, but as it appears when the tentacles are pinned out so as to expose the surface of the oral disk.



A. M. Westergren del. Folsom & Sunergren photo.

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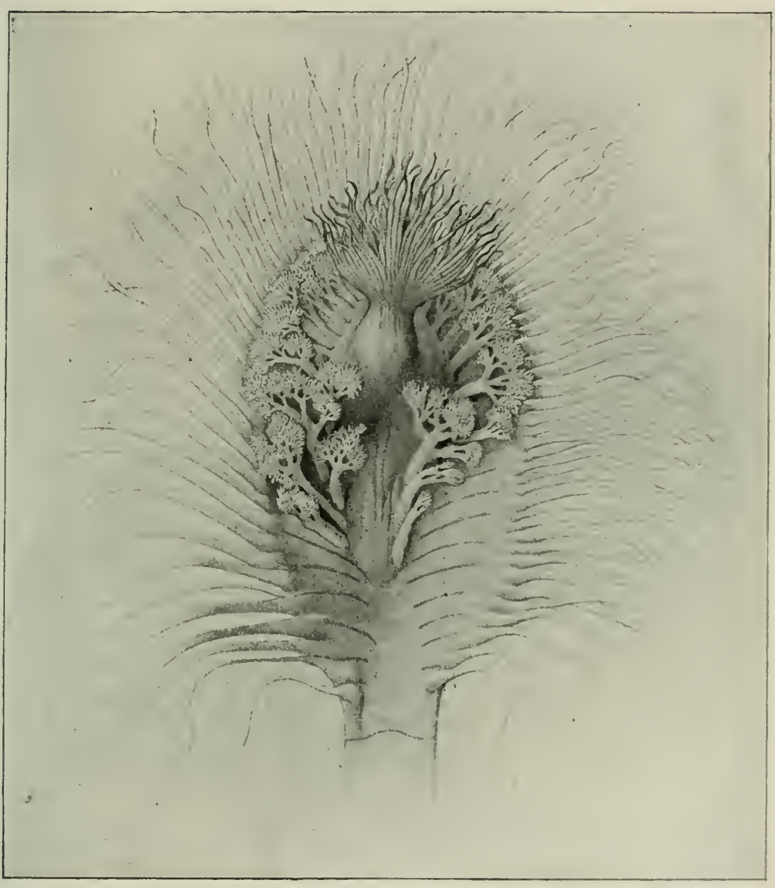

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ACALEPHS FROM THE FIJI ISLANDS.

BY ALEXANDER AGASSIZ AND ALFRED GOLDSBOROUGH MAYER.

WITH SEVENTEEN PLATES.

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No. 9. — *Acalephs from the Fiji Islands.* By ALEXANDER AGASSIZ and ALFRED GOLDSBOROUGH MAYER.

INTRODUCTION.

DURING a visit to the Fiji Islands, extending from November 7, 1897, to January 13, 1898, we devoted considerable time to a study of the Marine pelagic fauna. We made use only of open tow-nets, and while the majority of our hauls were made upon the surface, a number were also made at depths varying from twenty-five to one hundred fathoms. Most of these deeper hauls were made at a station three to five miles south of the entrance of Suva Harbor, and it was remarkable that the tows drawn from one hundred fathoms were far richer, both in number and variety of species, than were those made at twenty-five to fifty fathoms. No precise conclusions can, however, be drawn concerning the bathymetrical distribution of marine organisms from these results, for, owing to the fact that the mouth of the tow-net was constantly open, we cannot state the depth from which any given animal may have come; and, moreover, the near proximity of the land, and the extremely complex currents and eddies that are so characteristic of this region of Coral Reefs, probably play a far more important part in the distribution of pelagic organisms than does the mere fact of depth. The breakers are constantly forcing the ocean water over the reefs into the shallow lagoons, from which it finds access again into the sea through the openings in the walls of the reef, so that in some instances one finds a strong current, that is in great measure independent of the tide, constantly flowing outward from the lagoon into the open ocean. Such currents acting in conjunction with the tidal flow cause extensive eddies that result in a very ununiform distribution of pelagic life.

Besides our hauls in the neighborhood of Suva we made others off Taviuni, Kimbombo, Vanua Mbalavu, Ngamia, Wailangilala, Totoya, Mbatiki, Kandavu, and Nukulau Islands. The hauls were rich in Crustacea, but deficient in the number of Worms, Echinoderm larvæ, and Medusæ. Indeed, our success was remarkably inferior when compared with what we should expect to find in the sub-tropical regions of the Atlantic Gulf Stream. We obtained seven genera of Scyphomedusæ, twenty of Hydromedusæ, nine of Siphonophoræ, and two Ctenophoræ.

With the exception of two Rhizostomæ, all of the genera are represented by species found in the Atlantic Ocean. Indeed, the affinity between the Medusæ of the Fiji Islands and those of the West Indies is remarkably close, and in six cases we are unable to distinguish any specific differences between the Fijian species and well known Atlantic forms, and therefore venture to assert that they are specifically identical. The following table illustrates the Atlantic distribution of these Medusæ that are found also in the Fiji Islands.

1	Halitiara formosa, Fewkes.	Dry Tortugas Islands, Florida.
2	Pandea violacea, nov. sp.	Dry Tortugas Islands, Florida.
3	Rhegmatodes floridanus, L. Agassiz.	Bahamas, Gulf of Mexico.
4	Æginella dissonema, Haeckel.	Canary Islands; Dry Tortugas Islands.
5	Agalma Pourtalesii, nov. sp.	Dry Tortugas Islands, Florida.
6	Abyla (Abylopsis) quincunx, Chun.	Tropical Atlantic, Dry Tortugas Islands, Florida.

In the following ten genera the Fijian form is represented in the Atlantic Ocean by a *very* closely allied species: Linerges, Nausithoë, Tamoya, Cunina, Aglaura, Gonionemus, Mitrocoma, Tiaropsis, Eutima, and Sphæronectes. Indeed, the acalephan fauna of the Fiji Islands, if one excepts the Rhizostomæ, is more closely related to that of the Dry Tortugas Islands, Florida, than is the latter to the fauna of the Mediterranean Sea.

In this connection it is interesting to notice that A. Agassiz[1] has shown that the deep sea fauna of the Gulf of Mexico and the Caribbean Sea is far more closely allied to that of the Pacific than it is to that of the Atlantic, and this is accounted for upon the supposition that before the Cretaceous period the Gulf of Mexico and the Caribbean were in freer communication with the Pacific than with the Atlantic. Again, in 1892,[2] the same author found that in nearly all the groups of deep sea

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[1] Agassiz, A., 1883, Mem. Mus. Comp. Zoöl., Vol. X. pp. 79–84.

[2] Agassiz, A., 1892, Bull. Mus. Comp. Zoöl., Vol. XXIII. pp. 74–82.

Fishes, Crustaceans, Mollusks, Worms, Echinoderms, and Polyps dredged off the west coast of Central America there were familiar West Indian types, or east coast forms.

A recent survey of the region of the Isthmus of Panama has been made by Hill,[1] who considers that it is impossible to make any serious deductions concerning the relations of North and South America during epochs preceding the Jurassic period, owing to the lack of data. He also concludes (p. 261) that the waters of the Atlantic and Pacific were probably as completely separated by a great continental land barrier in Cretaceous times as they are to-day, a proposition fully as tenable as the opposite hypothesis that they were united. If the marine passage ever existed across the Isthmus of Panama, or elsewhere in Tropical America, it must have been during the later Eocene period, and this strait was probably of a shallow and restricted character, and had finally disappeared before the close of the Miocene period.

If straits of considerable width and depth have ever connected the waters of the Tropical Atlantic with those of the Pacific, it is probable that the great Equatorial current would pour through them from the Atlantic into the Pacific, and thus the Pacific Ocean would become impregnated with Atlantic species. Once having gained access to the Pacific, the westerly Equatorial set would soon distribute the pelagic animals widely over the ocean.

It is interesting to notice that while so many characteristic types of Tropical Atlantic Medusæ are also found in the Pacific, the most *eminently* characteristic Tropical Pacific genera, the Rhizostomæ have remarkably few analogues in the Atlantic.[2] This, indeed, is what we should expect as a result of the westerly set of the great Equatorial current that would freely sweep animals from the Atlantic into the Pacific, but would in like measure hinder the entrance of Pacific forms into the Atlantic.

Of the thirty-eight species of Acalephs found by us in the Fiji Islands, twenty-six are new to science.

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[1] Hill, R. T., 1898, The Geological History of the Isthmus of Panama, etc. Bull. Mus. Comp. Zoöl., Geological Series, Vol. XXVIII. No. 5, pp. 151–285, Plates I.–XIX.

[2] In this connection, see Lendenfeld, R. von, 1884, The Geographical Distribution of Australian Scyphomedusæ, Proc. Linn. Soc. New South Wales, Vol. IX. pp. 421–433. Also, Vanhöffen, E., 1888, Bibliotheca Zool., Bd. I. Heft 3, p. 46, Map.

DESCRIPTION OF SPECIES.

I. HYDROMEDUSÆ.

Halitiara formosa, Fewkes.

Halitiara formosa, Fewkes, J. W., 1882, Bull. Mus. Comp. Zoöl., Vol. IX. p. 276, Plate IV. Fig. 2.

This Medusa is found in both Atlantic and Pacific Oceans. It is exceedingly abundant throughout the summer at the Dry Tortugas Islands, Florida, and we also found it in considerable numbers late in December in Suva Harbor, Viti Levu Island, Fiji Islands. The entoderm of the proboscis and tentacle bulbs of the male is usually dull brown or drab, while in the female it is bright green.

Pandea violacea, nov. sp.

This Medusa is common throughout the summer at the Dry Tortugas Islands, near the entrance to the Gulf of Mexico. We also obtained several specimens in Suva Harbor, Fiji Islands, early in January, 1898. We hope soon to present a figure of the Medusa in a paper upon "Medusæ from the Dry Tortugas," that is to be published in the Bulletin of the Museum of Comparative Zoölogy. At present we will content ourselves with a description of the animal.

Generic Characters. Pandea, Lesson, 1843. Tiaridæ with numerous tentacles, 8–16 or more arranged in a single row. The outer surfaces of the tentacle bulbs bear ocelli. There is no peduncle to the proboscis. The upper edges of the proboscis are bound to the 4 radial tubes by means of 4 mesenteries. There are 4 simple gonads, with smooth outer surface.

Specific Characters. The bell is 4 mm. in height, and is pear-shaped. The bell walls are of only moderate thickness. There are 32 tentacles. Eight of these are large, being about three times as long as the bell height; and 24 are rudimentary. The bulbs of the large tentacles are hollow. Each and every tentacle bulb bears a single ocellus, making in all 32 ocelli. The velum is well developed. The proboscis is flask-shaped, its proximal portion being distended by the 4 genital glands. The lips are simple and cruciform. There are 4 straight radial tubes and a broad circular tube. The color of the entoderm of the proboscis and tentacle bulbs is delicate pink or light purplish brown. A green streak runs along the outer surface of the entoderm of each of the 4 radial canals. The ocelli of the tentacle bulbs are purple in color.

Pennaria vitrea, nov. sp.

Plate 1, Figs. 1, 2.

Generic Characters. Pennaria, Goldfuss, 1820. Four rudimentary marginal tentacles that are reduced to mere basal bulbs. No ocelli. Four radial tubes. Gonads within the proboscis. No peduncle nor oral appendages to the proboscis.

Specific Characters. The bell is 3 mm. in height; and the walls are thick and rigid. There are 4 rudimentary tentacle bulbs. The velum is not prominent. The 4 radial canals are straight and narrow. The proboscis in the female specimen (Fig. 1) was retracted within the cavity of the bell, but in the male (Fig. 2) it was flask-shaped, and projected for a little distance beyond the velar opening of the bell. These conditions, however, may be merely different states of contraction and not constant differences; but, as we observed only two individuals, one a male and the other a female, we cannot be certain upon this point. The ova are large and pyriform, and are grouped in 4 radially arranged clusters within the proboscis. The mouth opening of the proboscis is very simple, and there are no fimbriations or appendages.

Prominent circular muscles were observed in the ectoderm of the cavity of the bell in the female, but these were not seen in the case of the male. It is possible, however, that they become apparent only during certain states of contraction. In the female the ovæ and tentacular bulbs were flesh-colored, and the entoderm of the mouth of the proboscis was green. In the male the tentacular bulbs were green, the entoderm of the proboscis pink, and the lips green.

Found off Kimbombo Island, November 25, and off Mbatiki Island, December 5, 1897.

Cytæis vulgaris, nov. sp.

Plate 2, Figs. 3, 4, 5.

Generic Characters. Cytæis, Eschscholtz, 1829. Margellidæ with simple unbranched oral tentacles upon the proboscis, and with 4 radially situated marginal tentacles.

Specific Characters. The bell is thin and slightly pyriform in shape, and is 3 mm. in height. The 4 marginal tentacles are somewhat stiff, and are usually seen curled upward in a semicircular curve. The tentacle bulbs are large and prominent. The velum is well developed. There are 4 thin straight radial tubes. The proboscis (Figs. 3, 4) is pyriform, and possesses a slightly developed peduncle. Sixteen simple oral tentacles surround the mouth. The entodermal cells of these tentacle are disk-shaped, and their free ends are armed each with a battery of nematocysts (Fig. 5). The mouth opening is simple, and, excepting for the oral tentacles, there are no other appendages. The color of the entoderm of the tentacle bulbs is dark salmon-red, as is also the entoderm of the proboscis near the peduncle. The remainder of the entoderm of the proboscis and of the tips of the marginal tentacles is green.

Young Medusa. The youngest Medusa observed by us had only 4 oral tentacles. The red color of the basal bulbs of the marginal tentacles extended for a considerable distance upward along the radial tubes. The bell was 1 mm. in height.

This form is very abundant all over the Fiji Islands in November and December. We came across a great swarm of these Medusæ within the crater of Totoya Island.

Bougainvillea fulva, nov. sp.

Plate 2, Fig. 6.

Generic Characters. Bougainvillea, Lesson, 1843. Margellidæ with dendritically branching oral tentacles, and with 4 radially arranged bunches of marginal tentacles. Proboscis wide and quadratic in cross section. Gonads developed in the ectoderm of the proboscis.

Specific Characters. The bell is pyriform, and 2.5 mm. in height. The bell walls are of moderate thickness. There are 4 radially arranged bunches of marginal tentacles, each one of which consists of 3 tentacles. A dark purple ocellus is found in the ectoderm of the tentacle bulbs at the base of each tentacle. The velum is well developed. There are 4 straight narrow radial canals. The proboscis is wide and quadratic in cross section. There are 4 oral tentacles, each one of which branches dendritically twice. The gonads are found in the ectoderm of the proboscis. The entoderm of the tentacle bulbs and of the proboscis is flesh-colored.

Single specimen, obtained in towing with an open net at 100 fathoms, three miles south of the mouth of Suva Harbor, December 16, 1897.

Laodicea marama, nov. sp.

Plate 3, Figs. 7, 8.

Generic Characters. Laodicea, Lesson, 1843. Leptomedusæ without otocysts, and with 4 simple unbranched radial canals, upon which lie the gonads. Tentacles numerous. The tentacle bulbs are well developed, and many of them possess ectodermal ocelli. There are clubs and cirri upon the bell margin, between the tentacles.

Specific Characters. The bell is quite flat and disk-shaped, and is 5.5 mm. in diameter. There are about 50 long, slender, flexible tentacles, each one of which possesses a well developed basal bulb. A single dark purple ocellus is found upon the inner side of the bulb of most of the tentacles. This ocellus is situated in the ectoderm. There are numerous clubs and cirri (Fig. 8) between the tentacles. The velum is prominent. There are 4 narrow radial canals, in the upper portions of which, near to the proboscis, the gonads are found. The proboscis is short and slender, and the lips not prominent. The entoderm of the radial tubes and of the basal bulbs of the tentacles is opaque and slightly bluish in color. The entoderm of the proboscis is often green.

This species is common in Suva Harbor in December. It is closely allied to Laodicea ulothrix, Haeckel, of the Canary Islands and Bahamas.

Laodicea fijiana, nov. sp.

Plate 3, Figs. 9, 10.

Specific Characters. The umbrella is thin and bell-shaped, and 6 mm. in diameter. There are about 70 long, slender, marginal tentacles, the free ends of which are usually coiled in a close helix. These tentacles are very fragile, and in the adult Medusa most of them are found to have been broken off near to the basal bulbs. In the young jelly-fish, however, they are usually seen in a perfect condition. A single dark brown pigment spot, or ocellus, is found in the ectoderm on the inner side of the basal bulbs of about three quarters of the tentacle. There are no cirri between the tentacles, but there are about 8 clubs that occupy this situation. The velum is well developed. The lower portions of the 4 radial tubes, near to the circular canal, are straight and narrow; but their upper portions, near to the proboscis, exhibit complex diverticulæ. The gonads are situated upon this complexly developed portion of the radial canals; and in the female (Figs. 9, 10) the ova are prominent, and project outward in grape-like clusters over the surface of the genital organs. The proboscis is short and quadratic in cross section, and there are 4 well developed fimbriated lips. The entoderm of the proboscis and radial and circular canals is opaque and slightly blue in color.

Common at Suva, Viti Levu Island, in December.

Eutimeta levuka, nov. sp.

Plate 9, Figs. 30, 31.

Generic Characters. Eutimeta, Haeckel, 1879. Leptomedusæ with 8 otocysts, and 8 tentacles, and with marginal cirri. The proboscis is borne upon a long peduncle. The gonads are found upon the 4 radial canals.

Specific Characters. The bell is thin, and flatter than a hemisphere. It is 8 mm. in diameter. There are 8 well developed hollow tentacles. Four of these are about as long as the diameter of the bell, and the 4 others are only about one half of this length. Small lateral cirri (see Fig. 31) are found upon the sides of these tentacles. In addition to the large tentacles already described, there are 24 small papillæ upon the bell margin, and these are flanked by lateral cirri exactly as are the large tentacles. There are 8 otocysts, each one of which contains 3–5 otoliths. The velum is large. The 4 radial canals are straight and narrow, and the gonads are found upon them near to the circular vessel. The peduncle of the proboscis is slender, and $1\frac{1}{2}$ times as long as the diameter of the bell. The proboscis is flask-shaped, and there are 4 flanged lips. The genital organs, tentacles, and proboscis are slightly opaque and bluish in color.

Several specimens, Suva Harbor, January, 1898.

Staurodiscus nigricans, nov. sp.

Plate 4, Figs. 11, 12.

Generic Characters. Staurodiscus, Haeckel, 1879. Leptomedusæ without otocysts, but with clubs between the tentacles. There are 4 radial canals, each of which gives rise to a pair of lateral canals. The gonads are situated upon the canals.

Specific Characters. The bell is thin and flexible, and is 14 mm. in diameter. There are 12 short tentacles having well developed basal bulbs. Between each successive pair of tentacles there are 7 knot-like protuberances upon the bell margin, each one of which bears a sensory club. The velum is insignificant in size. Each of the 4 radial canals gives rise to a pair of lateral branches; and thus 12 canals reach the circular vessel. The gonads are developed upon these canals (see Fig. 11). The proboscis is very short, and the mouth opening wide. The gelatinous substance of the bell has a brownish tinge. The genital organs, basal bulbs of the tentacles, and the proboscis are light sepia in color. The bulbs of the sensory clubs are dark brown.

Single specimen, captured in an open tow-net that was drawn from 100 fathoms, three miles south of the entrance of Suva Harbor, December 11, 1897.

This form differs from the two Atlantic species of Staurodiscus described by Haeckel (1879, Syst. der Medusen, pp. 145, 146) chiefly in that the side branches of the 4 radial canals reach the circular canal, whereas in the Atlantic forms they end blindly.

Gonionemus suvaensis, nov. sp.

Plate 5, Figs. 14–16.

Generic Characters. Gonionemus, A. Agassiz, 1865. Trachomedusæ, not Leptomedusæ (see Haeckel, 1879, Syst. der Medusen, p. 146), with numerous sucker bearing tentacles that are all similar each to each. There are otocysts situated between the tentacles. The gonads are sinusoidally folded, and are situated upon the 4 radial canals. The proboscis is cruciform in cross section, and the lips are prominent.

Specific Characters. The bell is flat and of moderate thickness. It is about three times as broad as it is high, and is 8 mm. in diameter. There are about 70 long, stiff tentacles. The proximal portion of each tentacle is straight, but near the free end there is a small sucking disk, and beyond this the tentacle makes a sharp bend (see Figs. 14, 15). There are about 16 otocysts, 4 in each quadrant. The velum is well developed. There are 4 straight radial tubes, upon the lower portions of which, near to the circular tube, the gonads are situated. The gonads are folded in a sinusoidal curve alternately to the right and left of the radial tube. The proboscis is cruciform in cross section (see Fig. 16), and the lips are prominent. Green pigment spots are found in the ectoderm of the basal bulbs of the tentacles, and also upon the radial tubes close to their junction with the proboscis (Fig. 16). The entoderm of the radial tubes in the region of the gonads is tinged with green. The ectoderm of the bell margin is of a delicate rose color, and the proboscis and gonads are brown.

This Medusa was common in Suva Harbor late in December. It is more closely allied to the species described by Murbach[1] from Wood's Hole, Massachusetts, than it is to Gonionemus vertens, A. Agassiz,[2] of the Gulf of Georgia, Washington.

Aglaura prismatica, Maas.

Plate 4, Fig. 13.

Aglaura prismatica, Maas, O., 1897. Mem. Mus. Comp. Zoöl. at Harvard Coll., Vol. XXIII. No. 1, p. 24, Pl. III. Figs. 4, 5.

Lessonia radiata? Eydoux, F., et Souleyet, L., 1841–52, Voyage de la Bonite, Vol. II. p. 643, Zoöphytes, Pl. II. Fig. 16.

Generic Characters. Aglaura, Péron and Lesueur, 1809. Aglauridæ in which the 8 gonads are situated upon the peduncle of the proboscis, directly over the points of juncture of the 8 radial canals with the gastric portion of the proboscis. There are numerous tentacles, and 8 otocysts.

Specific Characters. The bell is about 3 mm. in height, and about as broad as it is high. The walls, although rigid, are exceedingly thin. The side walls of the bell are vertical, and the top is quite flat with, however, a slight apical projection. There are about 60 tentacles that are so fragile that they were broken off short in every specimen observed by us. There are 8 club-shaped otocysts, situated midway between the 8 radial canals. Each otocyst contains a single otolith. The velum is very large and powerful, and it is chiefly by means of its rapid movements that the Medusa is enabled to dart through the water. The 8 radial tubes are straight, and very narrow. The proboscis is flask-shaped, and provided with a well developed peduncle. There are 4 prominent cruciform lips. The 8 sausage-shaped gonads project outward from the sides of the peduncle at the point of juncture of the 8 radial tubes with the gastric portion of the proboscis. The gonads and entoderm of the proboscis are usually brownish red in color. Some specimens, however, are almost transparent. The Medusa was very common among the Fiji Islands.

Maas, 1897, has figured a Medusa from the Gulf of Panama that we believe to be identical with our Fijian form. The differences between our figure and

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[1] Murbach, L., 1895, Journ. Morphol., Boston, Vol. XI. p. 493.

[2] Agassiz, A., 1865, North American Acalephæ, p. 128, Figs. 197–200.

those of Maas may readily be accounted for by the circumstance that his figures were drawn from preserved specimens that were probably distorted by contraction. A *very* closely allied species is found at the Dry Tortugas Islands, Florida.

Liriope hyalina, nov. sp.

Plate 9, Fig. 32.

Generic Characters. Liriope, Lesson, 1843. Geryonidæ with 4 gonads upon the 4 radial canals. The circular canal is simple, and without blind, centripetal branches. There are 8 permanent tentacles; 4 of these are long, hollow, and radially situated, and 4 are short, solid, and interradial. Eight otocysts; 4 radial, and 4 interradial.

Specific Characters. The bell is about 1½ times as broad as high, and the sides are straight and sloping. It is 6.5 mm. in diameter. There are 8 tentacles; 4 of these are radial, and are about as long as the diameter of the bell. They are hollow, and are covered with rings of nematocysts. The other 4 tentacles are interradial and very short, and are carried curled sharply upward.

There are 8 otocysts (4 radial and 4 interradial), each containing a single spherical otolith. The velum is prominent. The radial canals are wide in the neighborhood of the circular vessel, where the gonads are found. In the upper portions of their length, however, near the proboscis, they are straight and slender. The proboscis projects for a considerable distance beyond the velar opening. The mouth opening is surrounded with nematocysts. This Medusa is extremely hyaline, excepting that the entoderm near the mouth of the proboscis is slightly rose colored.

This form was found off Taviuni Island and in Suva Harbor. It is closely allied to Liriope scutigera, McCrady, of Charleston Harbor and the West Indies.

Æginella dissonema, Haeckel.

Æginella dissonema, Haeckel, E., 1879, Syst. der Medusen, p. 340, Taf. XX. Fig. 16.

This Medusa was found by us in the Fiji Islands. Haeckel describes it from the Canary Islands, and we have found it at the Dry Tortugas, Florida. In a paper that will soon be published in this Bulletin, we hope to present a figure of it.

? Cunina octonaria, McCrady.

Cunina octonaria, McCrady, J., 1857, Gymn. Charleston Harbor, p. 109, Pl. XII., Figs. 4, 5. Also Proc. Elliot Soc., Vol. I. Pl. IV. VII.

Several specimens of a Cunina that is closely allied if not identical with Cunina octonaria of Charleston Harbor, South Carolina, were found by us in the Fiji Islands early in January, 1898. The Fijian form may be slightly less highly colored than McCrady's species; the entoderm of the proboscis exhibiting no trace of the sage-green color that usually characterizes the Atlantic form. On this account we are in doubt as to whether the two forms are identical species.

Oceania pacifica, nov. sp.

Plate 5, Fig. 17.

Generic Characters. Oceania, Péron and Lesueur, 1809. Eucopidæ with numerous otocysts scattered irregularly between the numerous tentacles. No marginal cirri. The 4 gonads are developed upon the 4 radial canals. There is no peduncle to the proboscis.

Specific Characters. The bell is of moderate thickness, but is very flexible. It is hemispherical in shape, and is 6 mm. in diameter. There are 16 thin flexible tentacles of moderate length. The tentacle bulbs are large. There are two otocysts between each successive pair of tentacles, and each of these otocysts contains a single spherical otolyth. The velum is well developed. There are 4 straight, narrow, radial canals, in the middle regions of which the gonads are developed. The proboscis is short, and possesses 8 simple lips. The entoderm of the tentacle bulbs, of the proboscis, and of the radial tubes in the region of the gonads is emerald green.

Several specimens found at Suva and at Nukulau Island.

Oceania ambigua, nov. sp.

Plate 6, Figs. 18, 19.

The bell is pyriform, and 4 mm. in diameter. The gelatinous substance is very thick. There are 16 short tentacles with large basal bulbs. There are either one or two otocysts between each successive pair of tentacles. Each otocyst contains a single spherical otolith. The velum is well developed. There are 4 straight, moderately wide radial canals. The gonads are situated upon these canals near to the proboscis. The proboscis is flask-shaped, and there are four simple lips.

The entodermal axis of each tentacle is brown in color, and the ectoderm of the proboscis, gonads, and tentacles is green.

Single specimen found at Suva, January 4, 1898.

Clytia polynesiæ, nov. sp.

Plate 6, Fig. 20.

Generic Characters. Clytia, L. Agassiz, 1862. Eucopidæ with 16 tentacles alternating with 16 otocysts. Gonads upon the 4 radial canals. No peduncle to the proboscis.

Specific Characters. The bell is thin and hemispherical in shape, and is 5 mm. in diameter. There are 16 short, sharply coiled, marginal tentacles, with large basal bulbs. Sixteen otocysts, each containing a single spherical otolith, alternate with the 16 marginal tentacles. The velum is well developed. There are 4 straight, narrow, radial canals, upon the lower region of which, near the circular canal, the gonads are developed. In the female the ova are very large and prominent. The proboscis is small and flask-shaped, and there are 4 curved lips. The entoderm of the proboscis, tentacle bulbs, and radial canals in the region of the gonads is green.

Several specimens found in Suva Harbor early in January.

Tiaropsis rosea, nov. sp.

Plate 7, Figs. 21, 22.

Generic Characters. Tiaropsis, L. Agassiz, 1849. Eucopidæ with 8 otocysts and 8 pigment spots (2 in each quadrant). There are numerous otoliths within each otocyst. The gonads are developed upon the 4 radial canals. There is no peduncle to the proboscis.

Specific Characters: Young Medusa. The bell in the young Medusa observed by us was ellipsoidal in shape, and 2.5 mm. in height. There were 4 well developed marginal tentacles that were coiled in a close helix. The bulbs of these tentacles were large. In addition to the tentacles mentioned above, there were 4 small protuberances upon the bell margin that probably represented the beginnings of other tentacles. There were 8 marginal sense organs (Figs. 21, 22), 2 in each quadrant. These consisted (Fig. 22) of an entodermal pigment spot, and a number of otoliths contained in an open fold of the velum. A cross section (Fig. 23) of the sense organ of Tiaropsis diademata, L. Agassiz, will serve to illustrate their structure. In Figure 23 the entoderm is represented in brown and the ectoderm in gray; the section is taken through the bell margin. It will be seen that the pigment spot (*pg.*) is situated within the entoderm upon the inner side of the circular tube (*ct.*); and that the otoliths (*ot.*) are ectodermal and enclosed within an open fold of the velum (*vel.*).

There were 4 straight broad, radial tubes. The proboscis was small, and there were 4 prominent, fimbriated lips. The gonads had not yet made their appearance. A number of immature specimens were found in Suva Harbor early in January.

A species that is closely allied, if not identical, with this Medusa is found at the Dry Tortugas Islands, Florida.

Mitrocoma mbengha, nov. sp.

Plate 8, Figs. 24, 25.

Generic Characters. Mitrocoma, Haeckel, 1864. Eucopidæ with numerous open otocysts, and numerous tentacles and cirri. Gonads upon the 4 radial canals. No peduncle to the proboscis.

Specific Characters. The bell is slightly flatter than a hemisphere, and is 9 mm. in diameter. There are 16 short tentacles with large basal bulbs. In addition to these there are about 80 short cirri upon the bell margin. There are 32 otocysts (2 between each successive pair of tentacles). The otocysts each contain 5–9 otoliths. The velum is well developed. There are 4 straight, narrow radial canals, upon the lower regions of which the gonads are developed. The proboscis is short and flask-shaped, and cruciform in cross section. There are 4 prominent, fimbriated lips. The entoderm of the tentacle bulbs and of the proboscis, and the ectoderm of the gonads, are dull yellow. The entoderm of the radial canals is grass-green.

Suva Harbor, Fiji Islands, in January.

Polycanna purpurostoma, nov. sp.

Plate 8, Figs. 26–28.

Generic Characters. Polycanna, Haeckel, 1879. Æquoridæ with numerous simple radial canals. Proboscis very wide; the mouth opening surrounded by numerous small lappets. Gonads upon the radial canals.

Specific Characters. The bell is lens-shaped, and about three times as broad as it is high. It is about 30 mm. in diameter. The gelatinous substance of the bell is very thick, so that the cavity is shallow. There are 16 short tentacles with wide basal bulbs. In addition to these there are about 120 very small tentacles, or papillæ, upon the margin of the bell (see Fig. 28). There are about 100 otocysts, each one of which contains two small, spherical otoliths. The velum is prominent. There are about 100–120 straight, narrow radial tubes, upon the lower halves of which the gonads are developed. The proboscis is very wide and shallow, and the mouth opening large; there are 100–120 small lappets surrounding the mouth (*M.*, Fig. 27). The entoderm of the basal bulbs of the tentacles is flesh colored. The gonads are slaty blue; and the proboscis, especially in young Medusæ, is pink. In old individuals it is usually hyaline.

Common among the Fiji Islands in December.

Rhegmatodes floridanus, L. Agassiz.

Rhegmatodes floridanus, Agassiz, L., 1862, Cont. Nat. Hist. U. S. A., Vol. IV. p. 361.

A Medusa that we are unable to distinguish from Rhegmatodes floridanus of the Bahamas and Gulf of Mexico was met with occasionally in the Fiji Islands.

Eirene kambara, nov. sp.

Plate 8, Fig. 29.

Generic Characters. Eirene, Eschscholtz, 1829. Eucopidæ with numerous otocysts and tentacles, and sometimes also marginal cirri. There is a distinct peduncle to the proboscis. The gonads are developed upon a restricted portion of the 4 radial canals.

Specific Characters. The bell is flat with sloping sides, and is 8 mm. in diameter. There are about 32 very small, slender tentacles, having well developed basal bulbs. There are 64 otocysts, 2 between each successive pair of tentacles. Each otocyst contains a single spherical otolith. The velum is distinct. The 4 radial canals are straight and narrow, and the gonads occupy their lower portions. There is a distinct peduncle. The proboscis is simple, and possesses 4 curved lips. The entoderm of the basal bulbs of the tentacles and the proboscis are turquoise in color.

Single specimen found in Suva Harbor, December 29, 1897. This form differs from Eutima pyramidalis,[1] L. Agassiz, of the West Indies, in that the peduncle is smaller and the proboscis larger than in the Atlantic form.

II. SCYPHOMEDUSÆ.

Tamoya, sp.

A single specimen of Tamoya, in a very imperfect condition, was found by us in towing with an open net at 100 fathoms, three miles south of the entrance of Suva Harbor.

Nausithoë punctata, var. pacifica, nov. var.

Nausithoë punctata, Kölliker, A., 1853, Zeit. für Wissen. Zool., Bd. IV. p. 323.

This Medusa is extremely close to if not identical with Nausithoë punctata, Kölliker. It appears to differ from the latter, however, in that the brownish yellow spots upon the ectoderm of the ex-umbrella are not so prominent. As this difference appears to be constant, we consider the Fijian form to be a close variety of Nausithoë punctata. Nausithoë punctata is found in the Mediterranean, and we have taken it at the Dry Tortugas Islands, Florida.

Linerges aquila, Haeckel.

Plate 10, Figs. 33, 34.

Linerges aquila, Haeckel, E., 1879, Syst. der Medusen, p. 496.

In the absence of a figure and an accurate description by Haeckel, we are far from certain that the species about to be described by us is identical with L. aquila of the east coast of Madagascar.

Generic Characters. Linerges, Haeckel, 1880. Discomedusæ with simple quadrangular proboscis without mouth arms, and with simple quadratic lips.

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[1] We hope soon to publish a figure of Eutima pyramidalis in the Bulletin of the Museum.

There are 8 marginal sense organs, 8 tentacles, and 16 marginal lappets. There are 16 broad radial pouches and branched sac-shaped canals within the lappets. There is no ring canal. There are 4 horseshoe-shaped gonads, the convex proximal arches of which are divided into two adjacent wings by means of a median septum. There are 48–52 (in this species 52) wart-like, hollow protuberances upon the floor of the sub-umbrella.

Specific Characters: Adult Medusa. The bell is 13 mm. high, and 16 mm. in diameter. The side walls are straight and vertical, and the top flat. There are 16 marginal lappets that are about twice as wide as they are long. There are 8 small tentacles that are about 1½ times as long as the lappets. Eight marginal sense organs alternate with the tentacles. The entoderm of these sense organs contains a spherical mass of otoliths (Fig. 34). The 4 gonads are crescent-shaped, the two horns of each crescent being separated by means of a median partition. There are 16 gastro-vascular pouches, and no marginal ring canal. Projecting inward from the floor of the sub-umbrella into the bell cavity there are 52 hollow wart-like protuberances. These are arranged in three rows. The most proximal row contains 4, the middle row 16, and the most distal row 32 of these protuberances. The proboscis is quadrangular in cross section, and there are 4 flanging lips. The general color of the Medusa is brown. There are 8 rows of dark brown pigment spots running longitudinally down the inner surface of the lips of the proboscis. Separated areas of brown entodermal cells are found in the distal portions of the 16 gastro-vascular pouches.

Young Medusa. Ephyræ of this Medusa were common among the Fiji Islands in November and December. They resemble the adult in general color, but the umbrella is very flat and disk-shaped. The youngest specimen observed by us was 2.5 mm. in diameter.

We observed the ephyræ of this Medusa off Taviuni, Ngamia, Wailangilala, and Vanua Mbalavu Islands, and in Suva Harbor. We also came across a large swarm of the adults in the lagoon of Wailangilala Atoll on November 20.

This Medusa differs from Linerges mercurius, Haeckel, of the West Indies in that there are 52 wart-like protuberances upon the sub-umbrella, instead of 48, as in the Atlantic species. Also the brown colored entodermal cells approach nearer to the stomach, and their color is perhaps slightly duller than in the West Indian form.

Aurelia vitiana, nov. sp.

Plate 10, Fig. 35.

Generic Characters. Aurelia, Péron and Lesueur, 1809. Discomedusæ with a simple central mouth, and 4 mouth arms or palps. The radial canals are narrow and branched, and there is a ring canal. There are 8 marginal sense organs, and 8 broad, sometimes bipartite, marginal lappets, each of which bears on its dorsal side, some distance away from the umbrella margin, a row of numerous short tentacles, that alternate with as many dorsal lappets.

Specific Characters. The bell is hemispherical and 80 mm. in diameter. The gelatinous substance is quite thick. There are 8 simple marginal lappets that bear upon their dorsal surfaces, at a slight distance from the bell margin, a row of numerous short tentacles. The 8 marginal sense organs are large and deeply set within niches between the marginal lappets. Sixteen narrow chymiferous tubes radiate outwards from the stomach cavity. Eight of these are straight and unbranched, and go to the middle of the marginal lappets. The 8 others give off side branches that anastomose. They go to the marginal sense organs (see Fig. 35). The mouth arms, or palps, are short and narrow, and do not protrude beyond the bell margin. Their free edges are lined by a row of numerous short slender tentacles. The 4 gonads are horseshoe-shaped, and the subgenital pits are wide and open. The gonads, palps, and tentacle bulbs of the adult Medusa are of a delicate lilac. The bell is hyaline. Young Medusæ lack the lilac color, and are quite transparent.

This species was common upon the surface in Suva Harbor in the early morning hours in December, when the water was smooth and calm. A slight ripple seemed to be sufficient to cause them to sink out of sight.

RHIZOSTOMÆ.

Cephea dumokuroa,[1] nov. sp.

Plates 11, 12, Figs. 36-39.

Generic Characters. Cephea, Péron and Lesueur, 1809. Discomedusæ without tentacles, and without a central mouth opening. There are 4 sub-genital cavities, and ventral suction cusps upon the 8 mouth arms. The mouth arms give off short branches that are simple and not dichotomous. There are 8 ocular canals, and numerous other radial canals. There are 8 marginal sense organs.

Specific Characters. The umbrella is disk-shaped, and the walls near the peripheri are vertical. It is about 300 mm. in diameter. A large dome, covered with thick conical protuberances, arises from the centre of the aboral surface of the umbrella. There are about 20 protuberances upon the dome. About 8 of these are large, and the remainder are much smaller. There are 8 marginal sense organs that are deeply sunken within niches upon the bell margin (Fig. 39). The entodermal chore of these sense organs terminates in a mass of small white (calcareous?) granules. There are about 9 very short marginal lappets in each octant of the umbrella. There are 8 short, thick, mouth arms, the ventral surfaces of which give rise to numerous short branches covered with suction mouths. Rows of very small tentacles surround these suction mouths. There are 4 sub-genital pits (*gpt.*, Fig. 38). A general idea of the internal structure of the medusa is given by Figure 38. The stomach (*S*) is a wide cavity lying within the great central dome of the umbrella. It is completely separated from the sub-genital porticus (*s. por.*) by means of the double membranous folds of the genital organs (*ov.*). Thirty-two tubes (see Fig. 37) radi-

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[1] Dumokuro is the native Fijian name for this species.

ate outward from the stomach cavity. Four of these tubes are wider than the remainder, and lead into 4 of the marginal sense organs. All of the radial vessels are connected one with another by means of a broad ring of anastomosing canals that occupies the peripheral zone of the umbrella. The 4 genital organs (*ov.*, Fig. 38) are stretched upon 8 fleshy radii, and serve to separate the stomach cavity (*S*) from the cavity of the sub-genital porticus (*s. por.*). Eight chymiferous tubes spring from the cavity of the stomach, and enter the 8 mouth arms, where they send off side branches to the suction mouths. These tubes also give off side branches that ramify and anastomose within the gelatinous lower floor of the sub-genital porticus. None of these tubes, however, enter the cavity of the sub-genital porticus, that is thus separated entirely from the gastro-vascular system of the Medusa. The general color of the gelatinous substance of the Medusa is blue. There are numerous deep blue streaks upon the apex of the central dome, and a deep blue band runs around the outer surface of the Medusa just above the mouth arms. This band is broad and biforked in the regions of the mouth arms. The chymiferous tubes in the mouth arms and the radial tubes of the umbrella are deep blue. The tentacles of the suctorial mouths and the anastomosing chymiferous vessels of the umbrella are coffee colored.

We suddenly came upon a swarm of these Medusæ off Vanua Mbalavu Island on November 25, and in all our subsequent voyaging through the Fiji group we never saw another specimen. The Medusæ were accompanied by a number of small fish.

Pseudorhiza Thocambaui,[1] nov. sp.

Plate 13, Figs. 40-44.

Generic Characters.[2] Pseudorhiza, von Lendenfeld, 1884. Rhizostomæ with a single sub-genital cavity. There is a central mouth opening upon the lower side of the brachial disk. There are 8 mouth arms, the inner or ventral sides of which contain a deep groove. The mouth arms bifurcate, and there is a single long filament that arises from the place of bifurcation of each mouth arm, making in all 8 filaments. The canal system consists of 16 main radial canals and a ring canal. Centrifugally from the ring canal there is an anastomosing network of canals, and centripetally there are between two adjacent main radial canals about 10 canals running from the ring canal inwards radially.

Specific Characters. The bell is hemispherical and 32 mm. in diameter. There are 8 marginal sense organs, the sensory portion of which consists of a spherical chore of dark brown pigment granules, surrounded by a mass of small transparent otoliths (Fig. 41). There are 9 small marginal lappets between each successive pair of marginal sense organs. The brachial disk, upon which

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[1] Named after Thocambau, king of Fiji.

[2] See Lendenfeld, R. von, 1884, Proc. Linn. Soc. New South Wales, Vol. IX p. 292. Also, 1887, Descrip. Catalogue Medusæ, Australian Museum, p. 23.

the mouth arms are borne, is attached to the lower floor of the umbrella by means of 4 pillars. There is a central mouth opening upon the lower floor of the brachial disk. Eight mouth arms arise from the brachial disk. Near their distal ends they bifurcate, and a single long filament arises from the place of bifurcation of each arm. Thus there are in all 8 of these filaments. These are each about 20 mm. in length, and their surface is covered with wart-like protuberances. Numerous suctorial mouths are found upon the inner and lower sides of the mouth arms. They are surrounded by a great number of small tentacles, forming a row around each mouth opening. In addition to these small tentacles there are numerous club-shaped papillæ between the suctorial mouths. The surface of these papillæ is covered with clusters of nematocysts. The 4 gonads are V-shaped, the apex of the V being pointed inwards toward the centre of the disk. The canal system has been described under "Generic Characters." The color of the gelatinous substance of the umbrella is dull blue. The sub-umbrella, brachial disk, and mouth arms are dull green, and the 8 long filaments are deep blue. The 8 radial canals that run to the 8 marginal sense organs are green in color. The remaining radial canals, however, are almost colorless. There are a number of white spots upon the peripheral portions of the exumbrella, and the wart-like protuberances upon the 8 filaments are also white.

The medusa was common in Suva Harbor in December. It swims with great rapidity by means of an incessant contraction and expansion of the umbrella. This movement is accomplished by the action of a powerful system of circular muscles in the sub-umbrella.

Young Medusa (Figs. 42–44). A young ephyra of this species was captured in Suva Harbor on January 11, 1898. The bell was 5 mm. in diameter and quite flat and disk-shaped. There were 8 marginal sense organs. The central mass of dark brown pigment granules of the sense organ was developed, but the peripheral shell of transparent granules had not yet made its appearance (compare Figs. 41 and 44). There were 24 marginal lappets, the 16 ocular lappets being about twice as long as the 8 intermediate lappets. There were 16 radial pouches from the stomach. Eight of these went to the sense organs, and 8 to the intermediate lappets. The sub-genital porticus was already present, and the brachial disk was suspended from the floor of the sub-umbrella by means of 4 gelatinous pillars exactly as in the adult. The ephyra possessed only a simple central mouth opening, having 4 cruciform lips. The margins of the lips were lined with a row of short, slender tentacles, with knob-like ends exactly like those that surround the suctorial mouths on the mouth arms of the adult Medusa. No trace of the genital organs could be detected, but the gastric cirri were represented by 12 short filaments (3 in each quadrant). The color of the ephyra was very similar to that of the adult.

Were it not for the sub-genital porticus and brachial disk, this little Rhizostoma would resemble, in all respects, the young of the Semostomæ. We have observed the ephyra of an allied genus, Stomolophus meleagris, L. Agassiz, that was in a slightly more advanced stage than the one here figured; and in this individual the central mouth was still used for the capture of food. It seems probable that in those genera of Rhizostomæ that possess a single sub-genital space (the Monodenmia of Haeckel), the brachial disk has become separated from the floor of the sub-umbrella by the enlargement and final coalescence internally of the 4 sub-genital pits of the Semostomæ.

Cassiopea ndrosia,[1] nov. sp.

Plate 14, Figs. 45, 46.

Generic Characters. Cassiopea, Péron and Lesueur, 1809. Discomedusæ without tentacles and without central mouth. There are 8 pinnately or trichotomously branching mouth arms, the lower or ventral surface of which is occupied by numerous suction mouths and vesicles. There are 4 sub-genital cavities, and 4 gonads. There are 12 or more marginal sense organs, and numerous anastomosing radial canals.

Specific Characters. The bell is flat and disk-shaped, and 50 mm. in diameter. The number of marginal sense organs appears to be variable. In the specimen here figured there were 22, but in another individual there were only 18. Whatever their number may be, they are situated at equal distances one from another. There are 4 small sub-genital ostia. There are 8 pinnately branching mouth arms, each arm being about 30 mm. in length. Their ventral surface is occupied by a great number of suction mouths surrounded by small tentacles. In addition to these there are also a large number of leaf-shaped vesicles scattered among the suction mouths. These vesicles are more numerous near the centre than they are at the free ends of the arms. The umbrella possesses two powerful sets of radial muscle bands. Twenty-two of these (in specimens with 22 marginal sense organs) are situated in the floor of the sub-umbrella, and radiate outwards toward the marginal sense organs. An equal number are situated in the exumbrella, and alternate in position with the set in the sub-umbrella. The muscle bands of the floor of the sub-umbrella usually appear opaque and white in color, especially in states of contraction. The muscles of the exumbrella, on the other hand, are deep blue-green. The general color of the umbrella is ashy brown. A large spearhead-shaped white spot is situated upon the radius of each sense organ at a little distance inward from the bell margin. Thus in a medusa with 22 marginal sense organs there are 22 of these large spots. The apex of each of these spots is directed outward toward the sense organ. In addition to these large spots there are usually 4 short white radial streaks between each pair of adjacent sense organs. There are numerous white spots upon the inner portions of the sub-umbrella. The upper fleshy portions of the 8 mouth arms are white or slightly grayish. The tentacles surrounding the suction mouths are deep brown in color, and the leaf-shaped vesicles are olive-green.

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[1] Ndrosi is the native Fijian name for this species.

We found a specimen of this Medusa in Suva Harbor, November 14, 1897. And we also came upon a small swarm of them at Komo Island on November 27, 1897.

On January 3, 1898, we observed an individual of this species resting upon the muddy bottom of Suva Harbor. The aboral surface of the umbrella was pressed against the bottom, while the mouth arms and oral surface were uppermost. In this position it remained quiescent for more than an hour, merely waving its mouth arms in a slow, sweeping manner. Indeed, its appearance reminded one far more of an Actinian than of a Medusa. It is interesting to observe that the common Cassiopea frondosa of the West Indies, and also Cassiopea Mertensii, Brandt, of the Caroline Islands possess similar habits.

The number of marginal sense organs in this species is certainly quite variable, and is greater than has as yet been observed in any other species of the genus Cassiopea. We prefer, however, on account of its close resemblance in all other respects, to place it in the genus Cassiopea.

III. CTENOPHORÆ.

Eucharis grandiformis, nov. sp.

Plate 15, Figs. 47, 48.

The body of this Ctenophore is 135 mm. in length, and our figures represent the natural size of the animal. The lappets in this species are by no means so wide and voluminous as in the Mediterranean Eucharis multicornis,[1] Eschscholtz. The whole outer surface of the body and lappets is covered with numerous long papillæ. The auricles are long, and are often carried coiled in a close helix (see Fig. 48). A pair of long unbranched tentacles arise from either side of the body near the region of the mouth. The ciliated plates are very numerous and close together, and are arranged in 8 rows. The oral sense organ is situated at the bottom of a deep cleft. The windings of the canal system through the lappets are far less complex than is the case in E. multicornis. The ciliated plates, gastric cavity, and chymiferous tubes are cinnamon-yellow in color. All other parts of the animal are hyaline. This Ctenophore is extremely delicate in structure, the least touch being sufficient to tear the tissues of the animal.

We found them in considerable numbers, floating near the surface, in Suva Harbor, early in the mornings of December when the water was perfectly calm. The least ripple caused them to sink to an unknown depth.

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[1] Compare our figures with those of E. multicornis by Chun, C., 1880, Fauna und Flora des Golfe von Neapel, I. Monographie, p. 296, Taf. V. Figs. 1–3.

Beroë australis, nov. sp.

Plate 16, Figs. 49, 50.

The animal is 40 mm. in length, and the body is compressed laterally, one side being about three times as broad as the other. Our figure exhibits the broad side. The aboral otocyst is surrounded by a figure 8-shaped row of branched papillæ. The long axis of this row lies in the plane of the broad side of the Ctenophore. There are 8 rows of ciliated plates that are bordered by masses of stellate pigment cells (see Fig. 50). Eight radial canals run beneath the ciliated plates, and in addition to these there are two wide, straight lateral tubes (*l.*, Fig. 49). All of these tubes communicate with the circular canal (*c.*, Fig. 49); and are also put into further communication, one with another, by means of a simple network of connecting tubes (*k.*, *k.*, Fig. 49). The mouth opening is very wide and deep. The pigment cells of the ciliated plates, and of the papillæ surrounding the aboral sense organ, are crimson-lake in color. The gelatinous substance of the animal is quite transparent.

Many specimens of this Ctenophore were found in Suva Harbor in December. The animal swims with remarkable rapidity by means of the movements of its combs of cilia.

IV. SIPHONOPHORÆ.

Physalia utriculus, Eschscholtz.

Physalia utriculus, Eschscholtz, F., 1829, Syst. der Acalephen, p. 163, Taf. XIV. Figs. 2, 3.

Physalia australis, Lesson, R. P., 1830, Voy. de la Coquille, Zoophytes, p. 38, Pl. V. Fig. 1.

Physalia utrlculus, Haeckel, E., 1888, Challenger Report, Zoölogy, Vol. XXVIII. p. 351.

Several specimens of this Siphonophore were captured by us among the Fiji Islands. It is well represented by Lesson's figure.

Sphæronectes Köllikeri, Huxley.
Diplophysa Köllikeri, Haeckel.

S. Köllikeri, **Plate 16, Figs. 51, 52.** *D. Köllikeri*, **Plate 17, Fig. 53.**

Sphæronectes Köllikeri, Huxley, T. H., 1859, Oceanic Hydrozoa, Ray Soc. Publication, p. 50, Pl. III. Fig. 4.

Sphæronectes Köllikeri, Haeckel, E., 1888, Challenger Report, Zoölogy, Vol. XXVIII. pp. 130, 361.

Diplophysa Köllikeri, Haeckel, E , 1888, Challenger Report, Zoölogy, Vol. XXVIII. pp. 107, 130, 359.

Generic Characters (Polygastric generation = Sphæronectes). Polygastric Calyconectæ with a single, rounded, edgeless, subspherical, swimming bell. There is a complete tubular hydrœcium on the ventral side of the swimming bell, from the inner apex of which arises the long tubular hydrosoma. The groups of units are eudoxiform, and separated by free internodes. Each feeding polyp possesses a single covering scale.

Generic Characters (Monogastric generation = Diplophysa). Monogastric Calyconectæ, representing a single group of units, consisting in a feeding polyp with tentacle and covering scale, and a fertile gonophore that serves also as a swimming bell. The covering scale is hemispherical, or subspherical, and possesses a simple ovate or cylindrical canal (phyllocyst) within its ventral axis.

Sphæronectes Köllikeri. — The swimming bell is about three quarters of a sphere in shape, and is about 10 mm. in diameter. The cavity of the bell is shallow; and there is a large and powerful velum, by means of the movements of which the animal is enabled to swim. The bell possesses a circular canal, and 4 narrow, somewhat crooked, radial canals (*r*, *r*, *r*, *r*, Fig. 51). These communicate, by means of the narrow duct (*c*), with the gastro-vascular cavity of the hydrosoma (*h*). There is a straight spindle-shaped vacuolated vesicle (*f*) buried within the gelatinous substance of the nectophore. The hydrosoma (*h*) arises from the inner end of a long, narrow invagination of the outer wall of the swimming bell (the hydrœcium). The order of appearance of the various organules upon the hydrosoma is shown in Figure 52. The first to develop are the feeding polyps (*p*); then follow, in order, the tentacles (*t*), the covering scale (*c. s.*), and gonophore (*g*). The hydrosoma attains a length of about 50 mm., and there are numerous groups of units (cormidia) separated by free internodes. One of these groups of units that has very recently become separated from the hydrosoma, and is therefore in the Diplophysa stage, is represented, highly magnified, in Plate **17**, Figure 53.

Diplophysa Köllikeri (Plate **17**, Fig. 53). — This is merely the free Monogastric or Eudoxia form of Sphæronectes Köllikeri, and consists of a single group of units that has become separated from the hydrosoma of the latter animal, and leads an independent existence. The covering scale (*c. s.*) is thick and hemispherical in shape. It contains a simple ovate canal or phyllocyst (*phc.*). There is a single feeding polyp (*p*), a single tentacle (*t*), and a gonophore (*g*). The tentacle gives rise to many small filamentous side branches, which terminate in nematocystic bulbs. The gonophore serves also as a swimming bell, and its manubrium will become much larger than is shown in Figure 53, and will contain the genital products. The tube *ad.* is the means by which the animal was once attached to the hydrosoma of S. Köllikeri. This tube soon atrophies. The entoderm of the feeding polyps of the manubrium of the gonophore and of the nematocystic bulbs of the tentacles is rich yellow or orange. This animal, in the Sphæronectes stage, was met with in various places among the Fiji Islands. Our drawings are derived from a specimen found upon the surface of Suva Harbor, December 12, 1897.

This species is very closely related to Sphæronectes gracilis, Claus, of the Mediterranean and Tropical Atlantic.[1] We have taken S. gracilis at the Dry Tortugas Islands, Florida.

Diphyopsis angustata, Haeckel.

Plate 17, Fig. 54.

Diphyes angustata, Eschscholtz, F., 1829, Syst. der Acalephs, p. 136, Taf. 12, Fig. 6.

Diphyopsis angustata, Haeckel, E., 1888, Challenger Report, Zoöl., Vol. XXVIII. pp. 152, 363.

Generic Characters. Diphyopsis, Haeckel, 1888. Diphyidæ with two angular, slenderly pyramidal swimming bells of similar form and subequal size, one placed behind the other. The first swimming bell possesses a complete infundibular hydrœcium on its ventral side. The groups of units upon the hydrosoma are Eudoxiform, and are separated by free internodes. Each feeding polyp possesses a covering scale. The covering scales are spathiform, with a deep ventral groove.

Specific Characters. The specimens found by us conform to the definition of the genus Diphyopsis, with the notable exception that we observed no posterior swimming bell, such as is figured by Haeckel (1888, Plate XXXIII.) in Diphyopsis compressa. It is possible that no such structure exists in Diphyopsis angustata, but knowing the ease with which swimming bells are broken off and lost, we hesitate to make such a statement. The anterior swimming bell (the only one observed) is 37 mm. in length. The bell cavity is long and spindle-shaped, and terminates in a long, narrow neck, in the end of which there are usually a number of vacuolated cells containing green pigment (*cp.*, Fig. 54). There is a well developed velum, the sudden contractions of which cause the animal to shoot rapidly through the water. There is a circular vessel within the swimming bell, and also two long curving side tubes (*r*, *r*, Fig. 54). These communicate by means of a long duct (*c*) with the gastro-vascular cavity of the hydrosoma. The cavity of the hydrœcium is about 17 mm. in depth. There is a long spindle-shaped mass of vacuolated cells (*f*) extending from the inner apex of the hydrœcium into the gelatinous substance of the swimming bell. The hydrosoma also arises from the inner apex of the hydrœcium. It often attains a length of 100 mm., and there are numerous groups of units (cormidia) found upon it. These are separated one from another by free internodes. The cormidia all arise from the ventral side of the hydrosoma. The first to appear are the feeding polyps. Then follow, in order, the tentacles and the covering scales. No gonads or swimming bells were seen. Each covering scale possesses a deep open groove along its ventral side. The tentacles give off simple lateral filaments that terminate in nematocystic bulbs. The ento-

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[1] See Chun, C., 1892, Abhandl. d. Senckenb. naturf. Ges., Bd. XVIII. p. 84, Fig. 5.

derm of the feeding polyps is rose colored, and the nematocystic bulbs of the tentacles are orange-yellow.

This is the largest species of Diphyidæ known at the present time.

Common among the Fiji Islands in December, 1897.

Abyla quincunx, Chun.

Abylopsis quincunx, Chun, C., 1888, Sitzungs Berichte Akad. Wissen. Berlin, p. 1160.

Abyla (*Abylopsis*) *quincunx*, Chun, C., 1897, Verhandl. Deutsche Zool. Gesell., p. 71, Fig. 13.

A large number of specimens of a polygastric Calyconectæ that appears to be identical with Abyla quincunx, Chun, of the Tropical Atlantic, were found by us among the Fiji Islands. Huxley (1859, p. 58) mentions having found this form in the Indian and Pacific Oceans, and he describes it under the name of Abyla pentagona. Several specimens of the Eudoxia form of this species (see Aglaisma quincunx, Chun, 1888) were found by us while in the Fiji Islands. This Fiji form appears to be identical with one observed by us at the Dry Tortugas Islands, Florida.

Agalma Pourtalesii, nov. sp.

We obtained this beautiful new Siphonophore near the mouth of Suva Harbor, Viti Levu Island. We have also found a number of specimens that appear to be identical in all respects with the Fijian form, at the Dry Tortugas Islands, Florida. We hope soon to present a number of figures of this animal in a paper upon "Medusæ from the Tortugas" that is now in preparation, and will appear in the Bulletin. At present we will content ourselves by presenting a description of the species.

Generic Characters. Agalma, Eschscholtz, 1825. Siphosome short and rigid, about as long as the nectosome. The whole siphosome is densely covered with thick prismatic bracts. The dactylozooide and feeding polyps are thickly scattered along the stem of the siphosome. The gonostyles spring from the internodes between the dactylozooide and feeding polyps. The tentilla are tricornuate, with a terminal ampulla and two paired horns.

Specific Characters. The entire animal is about 25 mm. in length. The feeding polyps, tasterns, gonostyles, and tentacles all spring from the ventral side of the siphosome. The float is of small size, and is balloon-shaped, and the pneumatopore is surrounded by radially arranged streaks of dark red pigment. The swimming bells are dovetailed alternately on either side of the nectosome, so that their velar openings are found on two diametrically opposite sides of the nectosome. The siphosome is densely covered upon all sides with thick prismatic bracts. The feeding polyps are somewhat stouter in shape than the tasterns, but in other respects are quite similar to them in appearance. The tentacles arise from the bases of the tasterns and feeding polyps. Each tentacle gives off a number of lateral branches which terminate in a coiled nematocyst battery, an ampulla, and two paired horns. Both male and female gonostyles are found upon the same siphosome, and they arise from the side of the siphosome between the tasterns and feeding polyps. The male gonostyles are long and slender, while the female are short and stout, and contain each one of them a considerable number of ovæ. Both male and female gonostyles are borne upon long, slender filaments that are highly contractile. The color of the entoderm of the hydrosoma, swimming bells, feeding polyps, and tasterns is rose-red or pink. The nematocyst batteries upon the terminal portion of the tentacles are dark red. The gonads and bracts are colorless.

LIST OF SPECIES.

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[1] Medusæ whose names are preceded by an asterisk are represented both in the Fiji Islands and in the Atlantic Ocean by identical or *very* closely allied species.

Siphonophoræ.

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EXPLANATION OF THE PLATES.

PLATE 1.

Fig. 1. Pennaria vitrea, nov. sp., female.
Fig. 2. " " " male.

PLATE 2.

Fig. 3. Cytæis vulgaris, nov. sp.
Fig. 4. " " Proboscis.
Fig. 5. " " One of the oral tentacles of the proboscis.
Fig. 6. Bougainvillea fulva, nov. sp.

PLATE 3.

Fig. 7. Laodicea marama, nov. sp.
Fig. 8. " " Edge of bell.
Fig. 9. Laodicea fijiana, nov sp.
Fig. 10. " " Edge of bell.

PLATE 4.

Fig. 11. Staurodiscus nigricans, nov. sp.
Fig. 12. " " Edge of bell.
Fig. 13. Aglaura prismatica, Maas.

PLATE 5.

Fig. 14. Gonionemus suvaensis, nov. sp.
Fig. 15. " " Edge of bell.
Fig. 16. " " Aboral view of the proboscis.
Fig. 17. Oceania pacifica, nov. sp.

PLATE 6.

Fig. 18. Oceania ambigua, nov. sp.
Fig. 19. " " Oral view of a quadrant of the bell.
Fig. 20. Clytia polynesiæ, nov. sp.

PLATE 7.

Fig. 21. Tiaropsis rosea, nov. sp.
Fig. 22. " " Marginal sense organ.
Fig. 23. Section through the marginal sense organ of Tiaropsis diademata, L. Agassiz: *ent.*, entoderm; *ect.*, ectoderm; *ct.*, circular vessel, cut across; *vel.*, velum; *pg.*, pigment spot in the entoderm of the circular vessel; *ot.*, otolith enclosed within an open pocket of the velum.

PLATE 8.

Fig. 24. Mitrocoma mbengha, nov. sp.
Fig. 25. " " Edge of bell.
Fig. 26. Polycanna purpurostoma, nov. sp.
Fig. 27. " " Oral view of a portion of the bell. *M.*, mouth.
Fig. 28. " " Edge of bell showing otocysts and tentacles.
Fig. 29. Eirene kambara, nov. sp.

PLATE 9.

Fig. 30. Eutimeta levuka, nov. sp.
Fig. 31. " " Edge of bell.
Fig. 32. Liriope hyalina, nov. sp.

PLATE 10.

Fig. 33. Linerges aquila, Haeckel.
Fig. 34. " " Marginal sense organ.
Fig. 35. Aurelia vitiana, nov. sp.

PLATE 11.

Fig. 36. Cephea dumokuroa, nov. sp. Side view.
Fig. 37. " " Aboral view of the disk.

PLATE 12.

Fig. 38. Cephea dumokuroa. Section to show the internal structure: *gpt.*, subgenital pit; *m. s. o.*, marginal sense organ; *ov.*, genital organ; *r*, one of the 8 thick gelatinous pillars that support the membranes of the genital organs; these radial pillars correspond in position with the 8 mouth arms; *S*, stomach cavity; *s. por.*, sub-genital porticus; *rt.*, radial chymiferous vessel; *t*, chymiferous tube in the mouth arm.
Fig. 39. Cephea dumokuroa: Marginal sense organ.

PLATE 13.

Fig. 40. Pseudorhiza Thocambaui, nov. sp. Adult Medusa.
Fig. 41. " " Marginal sense organ of adult Medusa.
Fig. 42. " " Side view of a young Ephyra.
Fig. 43. " " Oral view of a young Ephyra.
Fig. 44. " " Marginal sense organ of young Ephyra.

PLATE 14.

Fig. 45. Cassiopea ndrosia, nov. sp. Side view.
Fig. 46. " " Aboral view of disk.

PLATE 15.

Fig. 47. Eucharis grandiformis, nov. sp. View of narrow side.
Fig. 48. " " View of broad side. (Figure uncolored.)

PLATE 16.

Fig. 49. Beroë australis, nov. sp. View of broad side: *l*, lateral tube; *k*, side connecting tubes; *c*, circular tube.

Fig. 50. Beroë australis, nov. sp. View of ciliated plates and of stellate pigment cells.

Fig. 51. Sphæronectes Köllikeri, Huxley: *c*, duct connecting radial vessels with the gastro-vascular cavity of the hydrosoma; *c. s.*, covering scale; *f*, vacuolated vesicle; *g*, gonophore; *h*, hydrosoma; *p*, feeding polyp; *r*, *r*, *r*, *r*, radial vessels of the swimming bell; *t*, tentacle.

Fig. 52. Sphæronectes Köllikeri, Huxley. Enlarged view of the hydrosoma. Lettering similar to Figure 51.

PLATE 17.

Fig. 53. Diplophysa Köllikeri, Haeckel. The free Eudoxia form of Sphæronectes Köllikeri: *ad.*, tube by means of which the group was once attached to the hydrosoma of S. Köllikeri; *c. s.*, covering scale; *g*, swimming bell-gonophore; *p*, feeding polyp; *phc.*, phyllocyst of the covering scale; *t*, tentacle.

Fig. 54. Diphyopsis angustata = Diphyes angustata, Eschscholtz: *c*, duct connecting the chymiferous vessels of the swimming bell with the gastro-vascular cavity of the hydrosoma; *c. p.*, oleocyst; *f*, vacuolated vesicle; *h*, hydrosoma; *p*, feeding polyp; *v*, *v*, ascending vessels of the swimming bell; *t*, tentacle.

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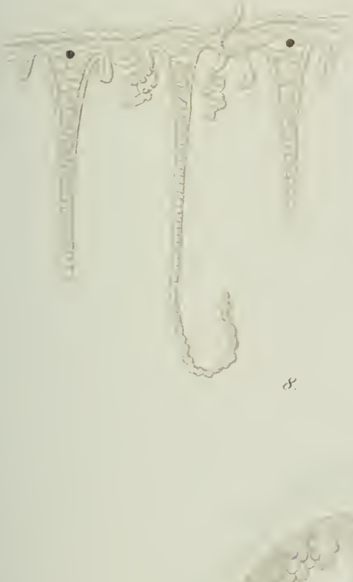
Plate 2.

Plate 3.



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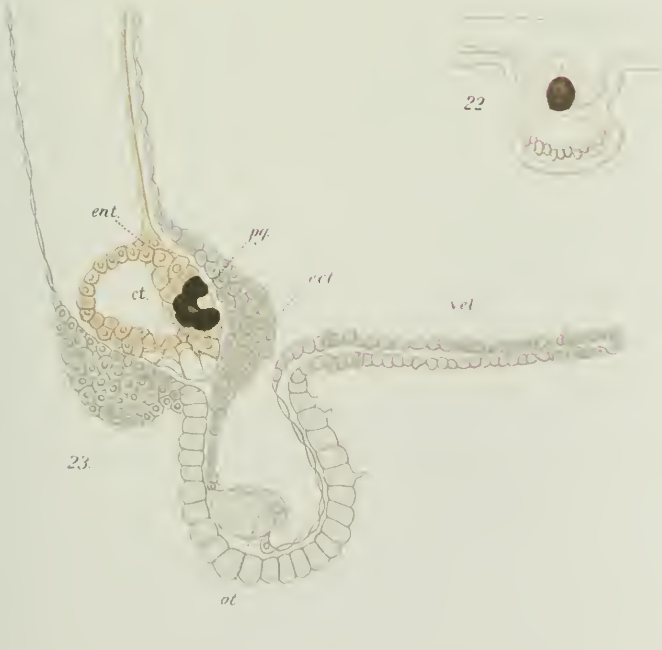

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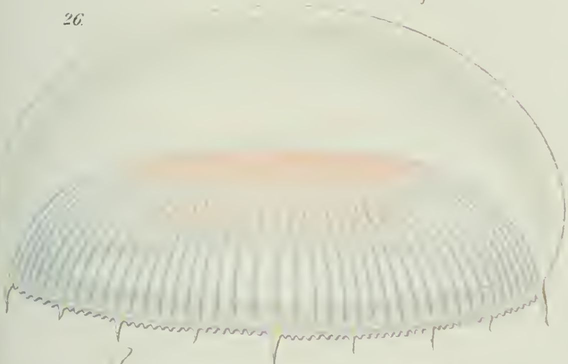

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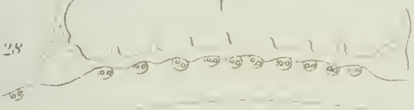

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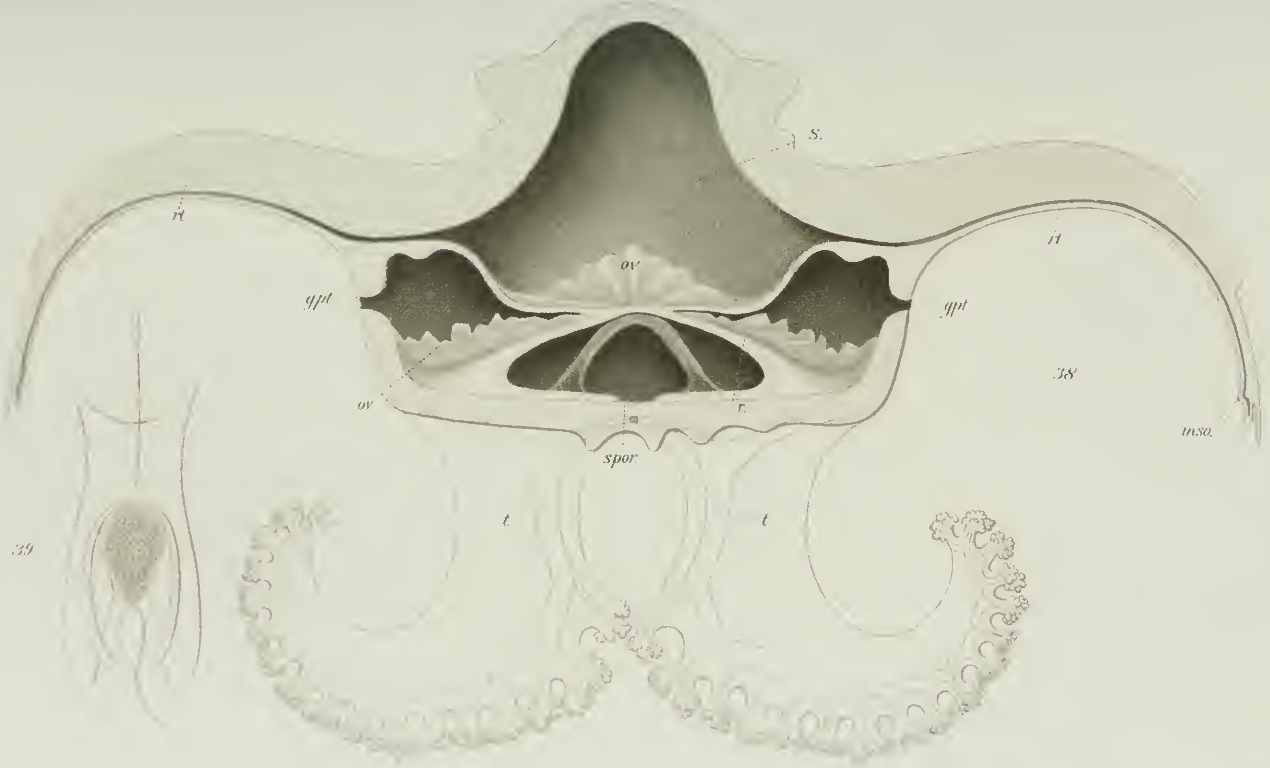

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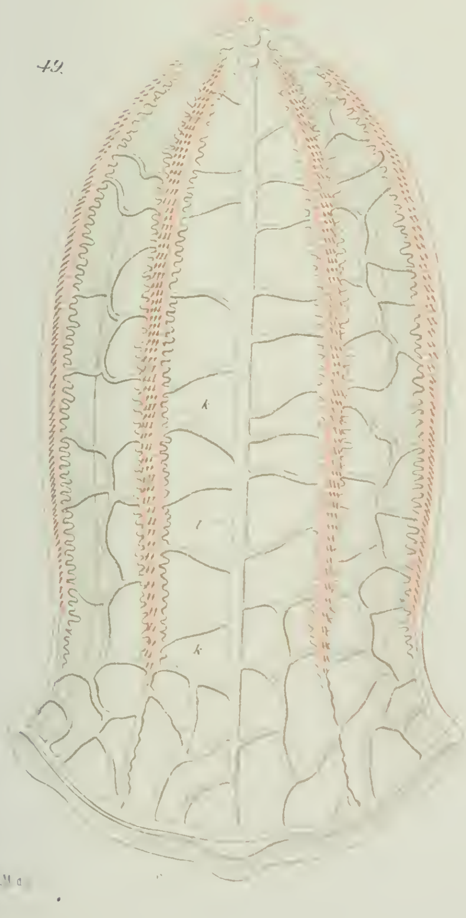

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Bulletin of the Museum of Comparative Zoölogy
AT HARVARD COLLEGE.
Vol. XXXII. No. 10.

REPORTS ON THE RESULTS OF DREDGING, UNDER THE SUPERVISION OF ALEXANDER AGASSIZ, IN THE GULF OF MEXICO AND THE CARIBBEAN SEA, AND ON THE EAST COAST OF THE UNITED STATES, 1877 TO 1880, BY THE U. S. COAST SURVEY STEAMER "BLAKE," LIEUT.-COMMANDER C. D. SIGSBEE, U. S. N., AND COMMANDER J. R. BARTLETT, U. S. N., COMMANDING.

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XXXVIII.

ÉTUDE MONOGRAPHIQUE
DES
PLEUROTOMAIRES ACTUELS.

Par E. L. Bouvier et H. Fischer.

Avec quatre Planches.

CAMBRIDGE, MASS., U. S. A.:
PRINTED FOR THE MUSEUM.
Sept. 1899.

No. 10. — *Reports on the Results of Dredging, under the Supervision of Alexander Agassiz, in the Gulf of Mexico and the Caribbean Sea, and on the East Coast of the United States,* 1877 *to* 1880, *by the U. S. Coast Survey Steamer "Blake," Lieut.-Commander C. D. Sigsbee, U. S. N., and Commander J. R. Bartlett, U. S. N., Commanding.*

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XXXVIII.

Étude Monographique des Pleurotomaires actuels. Par E. L. BOUVIER et H. FISCHER.

LE mémoire que nous présentons aux zoologistes est une sorte de monographie où nous nous sommes efforcés de réunir les faits les plus importants relatifs à l'histoire des Pleurotomaires actuels. Il se compose de deux parties bien distinctes, l'une purement historique, où nous avons condensé les observations de nos prédécesseurs et les renseignements que nous avons pu recueillir sur les exemplaires connus de ce curieux genre; l'autre anatomique et essentiellement consacrée à nos recherches personnelles. Si la première partie est destinée à rendre des services aux hommes de science et à faciliter leurs recherches, la seconde, croyons-nous, jettera quelque lumière sur les animaux qui nous occupent et sur l'évolution des Gastéropodes. Les Pleurotomaires, en effet, sont les plus anciens de tous les Mollusques aujourd'hui connus; on les rencontre dans les couches fossilifères les plus primitives, et l'on était en droit de supposer, même avant de connaître leur animal, qu'ils serviraient quelque jour à rattacher les Gastéropodes archaïques aux formes qui leur ont donné naissance. Ces prévisions furent confirmées en partie quand, à la suite des heureux dragages entrepris par le "Hassler" et le "Blake," M. Dall put examiner des animaux de ce genre et se convaincre qu'ils avaient deux branchies bipectinées symétriques, deux orifices rénaux et un anus situé sur la ligne médiane dorsale. Il restait toutefois à pousser plus loin les recherches et à faire, pour les organes vitaux, ce que M. Dall avait réalisé pour la morphologie.

Ce desideratum, formulé par beaucoup de zoologistes, sera satisfait, dans une certaine mesure, par la publication du présent mémoire. Grâce à la libéralité éclairée et à la générosité scientifique de M. Alexandre Agassiz, nous avons eu la fortune, que beaucoup nous envieront, sans doute, de posséder un des animaux du *Pleurotomaria Quoyana* recueillis par le "Blake." C'est le premier animal du genre dont on ait fait l'anatomie; nous avons eu toute liberté pour l'étudier; il nous a été livré généreusement, sans condition aucune, et c'est pourquoi nous avons réussi, bien qu'il fût incomplet, à en tirer un parti qu'on ne trouvera pas sans intérêt, nous l'espérons, du moins.

Quelle que soit, du reste, la valeur des observations qui vont suivre, nous en rapportons tout le mérite à l'éminent directeur des campagnes du "Blake," à M. Alexandre Agassiz. A l'auteur de tant de belles découvertes, au naturaliste qui a su retrouver dans les océans les restes de faunes qu'on croyait éteintes, nous sommes heureux de dédier ce mémoire, en lui présentant l'hommage de notre respectueuse reconnaissance.[1]

PREMIÈRE PARTIE.

État Actuel de nos Connaissances sur les Pleurotomaires.

PLEUROTOMARIA (DEFRANCE), SOWERBY, 1821.

Le terme générique *Pleurotomaria* n'est pas apparu subitement dans la nomenclature zoologique et il semble avoir été assez généralement employé avant d'être décrit et publié. C'est en juin 1821,[2] que nous trouvons la première indication du nouveau genre, dans les "Tableaux systématiques" de Férussac. Il s'agit de la simple citation suivante:

"Genre VI, PLEUROTOMAIRE, *Pleurotomaria?* Defrance." Le point d'interrogation placé après *Pleurotomaria* se rapporte probablement au nom latinisé *Pleurotomaria* (qui pouvait avoir différentes terminaisons), traduction du nom *Pleurotomaire* de Defrance; il est peu probable, en effet, que le baron de Férussac ait eu quelques doutes en attribuant la paternité du genre à Defrance, car les auteurs suivants n'ont pas la

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[1] Nous remercions également M. Agassiz d'avoir bien voulu nous permettre de publier en France ce travail qui fait partie des "Reports on the Results of Dredging, under the Supervision of Alexander Agassiz, . . . by the U. S. Coast Survey Steamer, 'Blake.'"

[2] Cette date de publication nous est fournie par Dall ('81, 77). D'autres auteurs indiquent soit 1821, soit 1822.

moindre hésitation à ce sujet. L'ouvrage en question fait partie de "l'Histoire naturelle générale et particulière des Mollusques terrestres et fluviatiles," etc., du père Férussac dont la publication a commencé en 1819.

En décembre, 1821, James Sowerby ('21) dit quelques mots du genre *Pleurotomaria* sans en nommer l'auteur; ces quelques mots suffisent d'ailleurs pour le caractériser:

"*Trochus Gibsi*. . . . the upper part (of the shell) is smooth, except the concentric band, upon which are semicircular striæ, indicating a sinus in the outer lip. . . .

"This and several other shells, hitherto called Trochi, with the band around the spire, may more properly belong to the genus *Pleurotomaria*, which I may be induced at some future period to adopt."

Cette description, d'après M. le professeur Dall,[1] confère la priorité du genre à James Sowerby.

Il est certain que la citation faite par le baron de Férussac ne peut pas être considéré comme suffisante pour établir le genre; au contraire, la description de James Sowerby met en évidence les caractères essentiels du *Pleurotomaria;* mais il est beaucoup plus douteux que James Sowerby ait entendu décrire explicitement ce genre comme résultant de ses recherches personnelles. Dans le passage que nous venons de citer, l'auteur parle, en effet, du *Pleurotomaria* comme d'un genre bien connu, familier à tous les zoologistes de cette époque et dont il est superflu, par conséquent, de nommer l'auteur. Il ajoute qu'il pourra être conduit ultérieurement à l'adopter; cette dernière expression suffirait presque à prouver que le paléontologiste anglais n'est pas l'auteur du genre en question.

Deux ans plus tard (sept. 1823),[2] Defrance publie ('23) les figures de deux espèces, avec la légende suivante:

2. Pleurotomaire ornée (Defr.).
3. Pleurotomaire tuberculeuse (Defr.).

En 1824, Defrance ne fait que citer le genre Pleurotomaire dans son "Tableau des corps organisés fossiles" ('24); enfin, en 1826, il donne la description du genre et cite cinq espèces:

Pleurotomaria tuberculosa Defr., *Pl. anglica* Defr., (*Trochus anglicus et similis* Sow.); *Pl. granulata* Defr. (*Trochus granulatus* Sow.); *Pl.*

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[1] Dall ('81 et '91, 396).

[2] Voir, pour la date de publication des planches du vingt-sixième cahier de "l'Atlas du Dictionnaire des sciences naturelles, la bibliographie de la France," ou "Journal général de l'imprimerie et de la librairie," Pillet aîné, Paris, 1823.

ornata Defr. (*Trochus ornatus* Sow.); *Pl. elongata* Defr. (*Antrochus elongatus?* Sow.).

J. Sowerby ('31), dans un fascicule de son "Genera of Recent and Fossil Shells," publié fin 1830 ou commencement de 1831,[1] donne la diagnose du genre et figure deux espèces (*Pleurotomaria reticulata* et *Pl. elongata*). Il ajoute: "On the genera distinguished by a more or less deep fissure or notch in the upper part of the outer lip, the *Pleurotomaria* of Defrance has no canal. . ." Ce passage de Sowerby luimême reconnaît formellement la priorité à Defrance. Une deuxième fois, en 1844, Sowerby ('44), cite Defrance comme l'auteur du genre.

C'est à l'aide des documents précédents que nous devons attribuer la priorité soit à Defrance, soit à Sowerby. Il nous semble que, dans le cas actuel, l'application stricte des lois de priorité est impossible; la citation des "Tableaux systématiques" doit être écartée; la description de *Trochus Gibsi* par J. Sowerby ('21), avec les remarques qui l'accompagnent renferment, au contraire, une bonne définition; mais il y aurait encore là matière à discussion, car le nouveau terme *Pleurotomaria* n'est pas proposé à titre définitif par l'auteur, qui se contente d'annoncer qu'il l'adoptera peut-être plus tard.

La première définition réellement complète et indiscutable du nouveau genre est celle qu'a donnée Defrance en 1826, précédée par la planche publiée en 1823. Il faut donc choisir entre les deux notations: *Pleurotomaria* J. Sowerby 1821 et *Pleurotomaria* Defrance 1826: la première a l'avantage de la priorité, mais sa valeur n'étant pas absolument démontrée, la question nous paraît insoluble, comme nous le disions plus haut.

Il faut donc renoncer à faire ici l'application étroite des règles de la nomenclature. Il nous semble que l'idée première du genre nouveau revient à Defrance, qui l'avait reconnu depuis un certain temps déjà, sans le publier; Sowerby eut naturellement connaissance de la nouvelle coupe générique grâce aux rapports qu'il entretenait avec Defrance; on lit, en effet, dans la préface des "Tableaux des corps organisés fossiles,"[2] que ce dernier avait obtenu de J. Sowerby la communication d'un certain nombre de fossiles; on comprend très bien, dans ces conditions, que Sowerby, en 1821, ait parlé du nouveau genre, sans d'ailleurs se prononcer complètement sur sa valeur, et qu'il ne l'ait adopté définitive-

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[1] Voir, pour la date de publication du trente deuxième cahier de cet ouvrage: D. Sherborn, "On the Dates of Sowerby's Genera of Recent and Fossil Shells" (Annals and Magazine of Natural History, Vol. XIII, 1894, p. 370; R. B. Newton, Syst. List Edwards Collection (Catal. Brit. Mus., 1891, p. 321).

[2] Defrance ('24, x).

ment, en 1831, qu'après la description de Defrance, et en lui rendant entière justice. Il nous semble donc tout indiqué de nous ranger à l'opinion de Sowerby lui-même et de considérer Defrance comme le véritable auteur du genre; nous croyons avoir ajouté quelques arguments à l'appui de cette manière de voir, que nous partageons avec H. Woodward ('85). En résumé, nous admettrons comme références originales, à la fois la citation de Férussac ('21), prouvant que le genre était adopté par Defrance en 1821, et le passage du "Mineral Conchology" de J. Sowerby ('21), évidemment inspiré par Defrance, et qui met en évidence les caractères du nouveau genre. Nous adopterons donc la notation suivante :

Pleurotomaria Defrance (Sowerby) ['21, x].

En terminant ce chapitre, nous adressons nos vifs remerciements à MM. Deniker, de Paris, Sherborn et Gude, de Londres, qui nous ont fourni de précieux renseignements sur les dates de publication des premiers ouvrages où il est question du genre *Pleurotomaria.*

Le genre *Pleurotomaria* est largement représenté dans les terrains sédimentaires. En 1885, Etheridge et H. Woodward ('85) ont fait le recensement des espèces fossiles et en ont signalé 1156 : ce nombre a été un peu augmenté depuis.

La première espèce connue se rencontre dans le cambrien inférieur (zone à *Olenellus*) des États-Unis, c'est-à-dire dans les plus anciens sédiments fossilifères : c'est le *Pleurotomaria* (*Raphistoma*) *Attleborensis* Shaler et Foerste ('88), décrit d'après un fragment trouvé à North Attleborough, Mass. Les Pleurotomaires sont donc contemporains des plus anciens Trilobites et des plus anciens Brachiopodes, qui ont été longtemps considérés comme les plus vieux animaux.

A l'époque silurienne, les espèces sont déjà très nombreuses, surtout en Amérique; leur nombre augmente encore au carbonifère et atteint son maximum pendant la période jurassique (367 espèces d'après Woodward). La diminution commence à se faire sentir au crétacé. Les sédiments tertiaires ne renferment que très peu d'espèces, et, pendant longtemps, on n'en connaissait que quelques unes dans l'éocène; l'absence complète du genre à partir du miocène avait même fait supposer que les Pleurotomaires étaient complètement et définitivement éteints : ceci explique le vif intérêt qu'a excité la découverte de la première espèce vivante.[1] Cette lacune est maintenant en partie comblée. E. Vincent ('90)

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[1] Mörch avait cru retrouver à l'état vivant un autre genre fort intéressant. Voir la description de *Murchisonia* (*Murchisonella*) *spectrum*, de l'île Saint-Thomas (Malak. Blätter, 1885, T. XXII, p. 184); mais cette forme est actuellement placée par les auteurs près des *Turbonilla.*

signale, en 1896, treize espèces éocènes; H. Crosse ('82, 6) en indique deux dans la miocène: *Pleurotomaria Sismondai* Goldfuss du miocène de Bünde et *Pl. tertiaria* MacCoy d'Australie. Deux autres espèces ont été trouvées dans les tufs madréporiques quartenaires de la Guateloupe: *Pleurotomaria Fischeri* Mayer *ms* et *Pl. Duchassaingi* Schramm ('69); malheureusement elles n'ont pas été clairement définies. Nous ajouterons à cette liste une forme des terrains tertiaires récents d'Italie: *Pleurotomaria gigas* Borson et une espèce miocène de l'île Santa-Maria (Açores): *Pl. atlantica* Cotta.[1]

COMPARAISON DES ESPÈCES VIVANTES AVEC LES ESPÈCES FOSSILES.

Les espèces vivantes sont rangées dans les deux sections *Entemnotrochus* P. Fischer et *Perotrochus* P. Fischer ('85). Les *Entemnotrochus* (*Pleurotomaria Adansoniana* et *Pl. Rumphii*), caractérisés par la position élevée (supra- médiane) du sinus et par leur ombilic, se relient à une série de formes crétacées rangées dans la section *Leptomaria*. Une espèce éocène le (*Leptomaria*) *landinensis* Vincent ('96), du landénien inférieur belge, présente aussi quelques rapports avec le *Pl. Adansoniana*. En outre, il existe dans le tertiaire de l'Italie septentrionale un véritable *Entemnotrochus*, le *Pleurotomaria gigas* Borson. Dans un travail récent ('97), Sacco signale, en effet, les rapports étroits qui unissent cette espèce au *Pl. Rumphii;* d'autre part, elle a aussi des affinités avec l'espèce miocène de Bünde, *Pl. Sismondai* Goldfuss. Sacco n'est même pas éloigné d'admettre que *Pleurotomaria Rumphii* provienne directement de *Pl. gigas* et celui-ci de *Pl. Sismondai*. D'après l'auteur, le *Pleurotomaria atlantica* Cotta présente également les plus grands rapports avec les *Entemnotrochus*, et est peut-être même identique à *Pl. gigas*.

Les *Perotrochus* (*Pleurotomaria Quoyana* et *Pl. Beyrichii*), caractérisés par la situation inframédiane du sinus et par l'absence d'ombilic se relient à quelques formes jurassiques[2] qui semblent appartenir à cette section.

Les deux sections actuellement vivantes du genre *Pleurotomaria* sont donc représentées à l'état fossile, mais il n'est pas encore possible de préciser la filiation de chaque espèce.

ESPÈCES VIVANTES DE PLEUROTOMARIA.

Les espèces vivantes du genre sont actuellement au nombre de quatre: le lecteur trouvera plus loin, dans la liste des spécimens, l'indication des descriptions et des figures originales, à propos de chaque type; nous

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[1] Sacco ('97) et Borson ('21).

[2] P. Fischer ('85, 850).

nous contenterons donc ici de donner leurs caractères différentiels et leur habitat.

Ces espèces sont, par ordre de découverte :

Pleurotomaria Quoyana P. Fischer et Bernardi, 1856.
Pleurotomaria Adansoniana Crosse et P. Fischer, 1861.
Pleurotomaria Beyrichii Hilgendorf, 1877.
Pleurotomaria Rumphii Schepman, 1879.

Ces quatre espèces doivent être réparties en deux sections, qui ont déjà été définies par H. Crosse en 1882 ('82, 8), mais sans être nommées. En 1885, P. Fischer ('85) a proposé pour ces deux sections les noms *Entemnotrochus* et *Perotrochus.*

Nous résumons en un tableau les caractères differentiels les plus évidents qui permettent de reconnaître ces espèces, d'ailleurs très distinctes :

SECTION I : *Entemnotrochus.* Sinus situé au-dessus du milieu du dernier tour ; un ombilic.[1]	Dernier tour fortement strié longitudinalement et portant des granulations au voisinage de la suture. Coloration : flammules rouges sur fond rosé. Espèce de très grande taille, habitant les Antilles. *Pleurotomaria Adansoniana*, Cr. et Fisch.
	Sculpture très atténuée sur le dernier tour ; entaille beaucoup plus étroite que dans l'espèce précédente. Coloration : flammules passant du rouge orangé au rouge carmin et au violet clair, sur fond jaune blanchâtre. Espèce de taille gigantesque, provenant des Moluques. *Pleurotomaria Rumphii,* Schep.
SECTION II : *Perotrochus.* Sinus situé au-dessous du millieu du dernier tour ; pas d'ombilic.	Sculpture très accentuée formée de cordons spiraux rendus subnoduleux par leur croisement avec des stries longitudinales. Coloration : flammules rouge vif sur fond jaune clair. Espèce de grande taille, habitant les mers du Japon. . . *Pleurotomaria Beyrichii,* Hilg.
	Sculpture beaucoup plus fine et plus régulière que dans l'espèce précédente. Coloration : taches ou flammules obscures rouge brunâtre sur fond rosé. Espèce de taille médiocre, habitant les Antilles. *Pleurotomaria Quoyana*, Fisch et Bern.

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[1] Le sinus fournit un excellent caractère pour ces deux sections ; il est très long chez les *Entemnotrochus,* beaucoup plus court chez les *Perotrochus.*

Recensement des Exemplaires Connus de Pleurotomaires Actuels.

Les Pleurotomaires actuels figurent encore aujourd'hui parmi les grandes raretés conchyliologiques; le nombre des exemplaires trouvés jusqu'à présent déposés soit dans des musées, soit dans des collections particulières, dépasse à peine une vingtaine. Il est certain que ce nombre s'accroîtra fortement par la suite, lorsque les conditions d'existence de ces animaux seront mieux connues; mais en attendant ce moment, peut-être encore lointain, il nous a semblé utile de recueillir tous les renseignements possibles sur ces premiers spécimens et d'indiquer ceux qui ont été figurés. Nos recherches nous ont été grandement facilitées par MM. Crosse et Dautzenberg, de Paris; MM. les professeurs Dall, de Washington; Döderlein, de Strasbourg; E. von Martens, de Berlin; Smith et Woodward, de Londres; ainsi que par MM. Damon, de Weymouth; Fulton et Sowerby, de Londres; Schneider, de Bâle, auxquels nous adressons nos bien vifs remerciements.

Il existe au moins vingt et un spécimens distincts dont voici l'énumération.

1. *Pleurotomaria Quoyana* (Type). — C'est en 1855 que le premier exemplaire de *Pleurotomaria* actuel a été recueilli par le commandant Beau "sur une nasse mouillée à une grande profondeur, à plusieurs milles du rivage de Marie-Galante, entre cette île et la Dominique." [1] La coquille était intacte; l'animal et l'opercule manquaient. P. Fischer et Bernardi ('56) ont décrit et figuré ce premier spécimen et signalé l'importance exceptionnelle de sa découverte. Cette belle coquille fit ensuite partie de la collection de M. Rolland du Roquan; à la mort de ce dernier, elle fut vendue successivement à M. Moitessier, à M. R. Damon, et enfin, en 1872, pour le prix relativement faible de 25 guinées à Mrs. de Burgh [2] dont la collection, après sa mort, est échue à Miss de Burgh, qui en est actuellement propriétaire.

2. *Pleurotomaria Adansoniana* (Type). — La seconde espèce connue a été décrite et figurée par H. Crosse et P. Fischer ('61)), d'après un exemplaire incomplet qui gisait ignoré dans la collection du docteur Commarmand. Cette coquille a été achetée, en 1858, par M. H. Crosse, qui la possède encore actuellement.[3]

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[1] H. Crosse et P. Fischer ('61), p. 155.

[2] H. Crosse et P. Fischer ('61, 155); H. Crosse ('82, 16); Cooker ('95, 122).

[3] Ce spécimen vient d'être légué à l'un de nous par le savant et regretté Directeur du "Journal de Conchyliologie," décédé pendant l'impression de ce mémoire.

3. *Pleurotomaria Quoyana.* — Cet exemplaire est le premier qu'on ait recueilli avec l'animal; il a été capturé par L. Agassiz, en décembre 1871, lors de l'expédition du "Hassler," près des Barbades, par 100 brasses environ de profondeur. Quelques détails concernant son organisation ont été publiés, en 1872, par L. Agassiz ('72) et reproduits, peu de temps après, dans une note de E. von Martens ('72).[1] L'opercule manquait. Ce spécimen est déposé dans les collections du Museum of Comparative Zoölogy, à Cambridge (U. S.).

4. *Pleurotomaria Beyrichii* (Type). — L'espèce a été décrite, en 1877, par Hilgendorf ('77), d'après un exemplaire en médiocre état, acheté à Enoshima (Japon) à un marchand de coquilles locales. Cet échantillon a été, plus tard, figuré par E. von Martens ('80, Pl. VIII); il fait, actuellement, partie des collections du musée de Berlin.

5. *Pleurotomaria Quoyana.* — Exploration du "Blake," station 290 (1879), au large des Barbades, 73 brasses. Cet exemplaire avait l'ouverture un peu brisée; il était pourvu de l'animal, qui a été étudié par Dall ('89, 397, Pl. XXXI, Fig. 1). La coquille est actuellement déposée au U. S. National Museum de Washington ('89, 397).

6. *Pleurotomaria Quoyana.* — Exploration du "Blake," st. 296 (1879) au large des Barbades, 84 brasses.[2] Exemplaire en parfait état, avec l'animal et l'opercule, déposé au Museum of Comparative Zoölogy de Cambridge (U. S.): c'est celui qui a été étudié dans le présent mémoire.

7. *Pleurotomaria Adansoniana.* — Exploration du "Blake," st. 278 (1879), au large des Barbades, 69 brasses. Un individu mort, brisé, déposé au Museum of Comparative Zoölogy de Cambridge.

8. *Pleurotomaria Adansoniana.* — Exploration du "Blake," st. 276 (1879), au large des Barbades, 94 brasses. Individu avec l'animal, déposé au U. S. National Museum de Washington, figuré par Dall ('89, Pl. XXXVII, Fig. 4).

Dimensions: diamètre maximum, 88 millimètres; hauteur maximum, 70 millimètres.

9. *Pleurotomaria Adansoniana.* — Exploration du "Blake," st. 291 (1879), au large des Barbades, 200 brasses. C'est un superbe échantillon, pourvu de l'animal; il a été déposé au Museum of Comparative Zoölogy de Cambridge.

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[1] Voir aussi H. Crosse et P. Fischer ('72); H. Crosse ('76); A. Agassiz ('88), Vol. II, p. 69.

[2] Les figures publiées par Agassiz ('88) et par Dall ('89) se rapportent aux spécimens de *Pleurotomaria Quoyana* et de *Pl. Adansoniana*, dont il est maintenant question.

Dimensions : diamètre maximum, 130 millimètres ; hauteur maximum, 130 millimètres.

10. *Pleurotomaria Rumphii* (Type). — Le type de la quatrième espèce a été trouvé dans un lot de coquilles des Moluques appartenant au Jardin zoologique de Rotterdam ; c'est le plus grand de tous les exemplaires connus de Pleurotomaires vivants. Il a été décrit, en 1879, par Schepman ('79), figuré trois ans après par le même auteur ('82), et, plus tard, par Sowerby ('87) et par A. Pilsbry.[1]

Dimensions : diamètre maximum, 190 millimètres ; hauteur, 170 millimètres.

11. *Pleurotomaria Beyrichii.* — Un exemplaire en partie brisé, acheté en 1881 à Enoshima (Japon) par le docteur Döderlein dans une des nombreuses boutiques où sont en vente, à titre de curiosités, des animaux marins de diverses espèces (*Hyalonema Sieboldi*, *Fusus pagoda*, Crustacés, etc.). Cet exemplaire appartient au docteur Döderlein, actuellement professeur à Strasbourg.

12. *Pleurotomaria Beyrichii.* — Un très bel exemplaire, en parfait état, acheté à Enoshima, en avril 1881, par le docteur Döderlein à un pêcheur japonais qui l'avait rapporté, avec d'autres espèces, de Misaki (Japon). Ce spécimen a été communiqué ultérieurement à M. Schneider, de Bâle, puis acheté, pour la somme de 950 marks, par Pætel, qui l'a légué, avec sa collection, au musée de Berlin.[2]

Dimensions : diamètre, 89 millimètres ; hauteur, 83 millimètres ; longueur de la fissure à l'ouverture, 33 millimètres.

13. *Pleurotomaria Adansoniana.* — Cet exemplaire, qui était habité par un Pagure, fut recueilli dans une nasse à homard, à l'ilet au Fajou, dans le grand cul-de-sac de la Pointe-à-Pître (Guadeloupe), à 150 brasses de profondeur. Il a été figuré, en 1882, par H. Crosse ('82, 12, Pl. I, Fig. 1–2) et déposé au musée Lherminier, à la Pointe-à-Pître.

14. *Pleurotomaria Beyrichii.* — Un bel exemplaire très frais, acquis, en 1882 ou 1883, par le docteur Gottsche à Enoshima (Japon), a été acheté ensuite par M. R. Damon, de Weymouth, pour la somme de 500 marks, puis décrit et figuré par Woodward ('85). Miss Farrington, de Preston, s'est rendue propriétaire de cette belle coquille et l'a léguée, avec ses collections, à sa sœur qui la possède encore actuellement.

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[1] Pilsbry ('90), Pl. LVII, Fig. 13, 14, et H. Crosse ('80 et '82^{a}).

[2] Nous croyons devoir rectifier une annotation de Woodward ('85, au bas de la page 435), qui peut prêter à confusion. L'auteur, d'après une communication du docteur Gottsche, signale les deux exemplaires du docteur Döderlein comme incomplets et ne présentant pas la fissure, ce qui n'est pas exact, car l'exemplaire du musée de Berlin est intact.

15. *Pleurotomaria Beyrichii.* — Un bel exemplaire, acheté à Londres par M. Sowerby, sans indication de provenance, se trouve dans une collection particulière en Angleterre.

16. *Pleurotomaria Beyrichii.* — Un exemplaire, acheté par M. Fulton à un négociant du Japon, fait aujourd'hui partie d'une collection particulière de New-York.

17. *Pleurotomaria Beyrichii.* — Un autre spécimen, ayant la même origine que le précédent, a été acquis, en 1895, par le U. S. National Museum de Washington.[1]

Dimensions : diamètre maximum, 65 millimètres ; hauteur, 60 millimètres.

18. *Pleurotomaria Quoyana.* — Exploration de U. S. Fish C. S. "Albatross," st. 2354 (1885 ?), au large des côtes du Yucatan, prés Arrowsmith Bank, 130 brasses. Un individu mort, en bon état, à part une cassure à l'ouverture ; déposé au U. S. National Museum de Washington.

Dimensions : diamètre maximum, 48 millimètres ; hauteur, 40 millimètres.

19. *Pleurotomaria Adansoniana.* — Ce magnifique exemplaire, le plus grand et le plus beau de l'espèce, a été remarqué, en 1890, par Lechmeer Guppy,[2] à l'exposition de la Trinité et de Tobago. Il a été acheté par M. R. Damon et figuré par lui ('91), puis acquis pour la somme de 55 livres sterling par le British Museum de Londres, où il est exposé.

20. *Pleurotomaria Beyrichii.* — Un bel exemplaire, avec l'animal, a été pêché, en 1897, au Japon, au large de Boshu, sur le banc Okinosé ; il fut communiqué aussitôt à M. Alan Owston, de Yokohama, et au professeur Mitsukuri, de Tokio, qui put l'observer vivant.[3] Ce spécimen est maintenant dans les collections du British Museum de Londres.

21. *Pleurotomaria Beyrichii.* — Un bel exemplaire a été acquis tout récemment par M. Dautzenberg, de Paris.

En résumé, les exemplaires connus se répartissent de la manière suivante :

Pleurotomaria Quoyana, 5 ; *Pl. Adansoniana*, 6 ; *Pl. Rumphii*, 1 ; *Pl. Beyrichii*, 9.

Il est fort probable que cette liste n'est pas complète, surtout en ce qui concerne le *Pleurotomaria Beyrichii* dont un ou deux exemplaires, autres que ceux mentionnés, existent encore en Europe. Il semble même que cette dernière espèce soit appelé à devenir moins rare que les

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[1] Pilsbry ('95), W. E. Collinge ('94).

[2] Lechmere Guppy ('90 et '91), Pilsbry ('92).

[3] Mitsukuri ('97).

autres, car les pêcheurs japonais en capturent de temps en temps. Souhaitons que les spécimens soient un jour assez nombreux pour permettre d'entreprendre une étude anatomique complète de ces formes si intéressantes.

Résumé de nos Connaissances sur l'Aspect Extérieur et l'Organisation de l'Animal.

Une courte description de l'animal a été donnée par Agassiz ('72). Plusieurs figures, prises sur l'animal vivant par M. J.-H. Blake, tant de *Pleurotomaria Quoyana* que de *Pl. Adansoniana,* ont été publiées par M. Dall,[1] qui a complété, sur bien des points, la description précédente; récemment enfin, Mitsukuri ('97) a publié une courte note sur l'animal vivant du *Pl. Beyrichii.*

1° *Pleurotomaria Quoyana* et *Pl. Adansoniana.* — Dall a surtout décrit en détail le *Pleurotomaria Quoyana,* et les lignes suivantes se rapportent spécialement à cette espèce, à moins d'indication contraire; les deux formes diffèrent d'ailleurs assez peu.

Coloration générale, téguments. — Le corps est brun rouge; de fines lignes sombres transversales s'étendent sur la tête, plus serrées en avant des tentacules qu'en arrière. Le bord du manteau est plus sombre que le pied. La tête, en arrière des tentacules, présente une surface rugueuse et ridée transversalement; le reste du corps, à l'exception de la sole pédieuse, est finement granuleux ou papilleux.

Chez le *Pleurotomaria Adansoniana,* la surface du corps est moins rugueuse que chez *Pl. Quoyana.*

Pied. — Le pied, très développé, est presque deux fois plus long que la coquille. Sa partie postérieure porte un opercule corné multispiré, semblable à celui des Trochidés,[2] mais de petite dimension relativement à la taille de la coquille. En arrière du lobe operculigère se trouve une surface triangulaire limitée de chaque côté par les prolongements postérieurs des lobes épipodiaux; cette surface est légèrement tuberculeuse chez le *Pleurotomaria Quoyana,* tandis que chez le *Pl. Adansoniana,* elle est sillonnée de fortes rides transversales et creusée d'un sillon médian; d'après M. Dall, c'est cette différence qui fournit le caractère le plus net pour séparer les deux espèces d'après l'animal.

Epipodium. — Il est large, mince, muni, comme les bords du manteau, d'une rangée de petites papilles courtes; il est dépourvu des

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[1] Dall ('89, Pl. XXIX, Fig. 1; Pl. XXX, Fig. 1–6).

[2] Dall ('89, Pl. XXXII, Fig. 10).

filaments et prolongements qu'on observe chez les Trochidés et chez les Scissurellidés. Sur l'animal vivant, l'épipodium est intimement appliqué sur le manteau, qu'il double en contournant le bord de la coquille et se comporte donc tout autrement que chez les Trochidés, dont l'épipodium s'épanouit librement dans l'eau. Celui du *Pleurotomaria Adansoniana* est moins développé que celui du *Pl. Quoyana.*

Tête. — La tête est pourvue de deux tentacules droits et pointus et prolongée antérieurement par un gros muffle cylindrique, dont l'extrémité, arrondie en forme de disque, porte la bouche au centre et, inférieurement, un sillon médian. Les yeux, situés à la base des tentacules, sont ronds, petits et noirs ; ils montrent une perforation centrale, de sorte que l'eau de mer occupe la place du cristallin absent et pénètre dans la coupe formée par le fond de l'œil.

Manteau. — Ses bords sont garnis de papilles, surtout le long de l'entaille qui correspond à la fissure de la coquille. Lorsque l'animal est en extension, les deux lèvres de cette entaille s'accolent, sauf à l'extrémité interne du sinus, où il reste une ouverture ayant le rôle d'un siphon.

Branchies. — Les branchies n'ont été observées que chez le *Pleurotomaria Adansoniana ;* elles sont au nombre de deux, situées à l'intérieur de la cavité palléale, près de la soudure du manteau avec le corps, et leur ensemble forme deux séries presque symétriques de feuillets aplatis, déposés de chaque côte d'un bourrelet longitudinal, à parois minces, contenant le vaisseau branchial, et qui s'étend parallèlement à l'entaille du manteau.[1] L'extrémité antérieure du bourrelet est libre sur une petite distance et forme une pointe où les feuillets branchiaux diminuent de grandeur. Chacune des deux branchies contient environ trois cent soixante feuillets. Dans la région où le bourrelet devient libre, on observe un renflement des téguments, et, à côté de lui, un petit organe hémisphérique qui est peut-être sensoriel (osphradium?).

Appareil digestif. — M. Dall a décrit la mâchoire et la radule dont il sera question plus loin ; il a observé, chez le *Pleurotomaria Adansoniana,* les restes d'un jabot à parois très minces. L'extrémité de l'intestin se recourbe fortement en S avant de s'ouvrir à l'anus.[2]

Reins (?). — Immédiatement au-dessous de l'intestin se trouve une glande ou bien une paire de glandes en contact sur la ligne médiane qui paraissent s'ouvrir, près de l'extrémité postérieure de l'entaille palléale, par deux orifices obliques et symétriques. M. Dall

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[1] Dall ('89, p. 401 ; p. 434, Fig F ; Pl. XXX, Fig. 2).

[2] Dall ('89, Pl. XXX, Fig. 3).

suppose que ces deux glandes et ces deux orifices sont les reins avec leurs pores excréteurs.

Enfin, M. Dall ('89, Pl. XXX, Fig. 3), figure, près des orifices rénaux ou supposés tels, une autre paire de pores sur lesquels il ne s'explique pas; peut-être faut-il y voir des pores génitaux.

2° *Pleurotomaria Beyrichii.* — Ce que nous savons sur cette espèce se réduit à fort peu de chose : d'après M. Mitsukuri ('97), la sole pédieuse est jaune-paille; les côtés du pied sont marqués de taches et de traînées carmin foncé sur fond orange; le muffle est rouge-carmin. Le tentacule gauche de l'individu observé avait une petite branche près de la pointe. Les deux lobes épipodiaux se relèvent jusque sur la coquille, et il semble même, d'après la description de l'auteur japonais, que ces lobes épipodiaux présentent un développement considérable.

DEUXIÈME PARTIE.

Étude Anatomique du Pleurotomaria Quoyana.

L'animal que nous avons eu entre les mains avait été extrait de sa coquille, que nous n'avons, par conséquent, pas pu examiner. L'étiquette jointe à l'échantillon portait les indications suivantes :

"U. S. Coast Survey, C. P. Patterson, Supt. Carribean Islands Exploration. U. S. C. S. S. 'Blake,' Alex. Agassiz, 1878–1879.

"*Pleurotomaria Quoyana.*

"No. 296. Depth 73 fathoms, Barbados.

"This is the best of the specimens and (except the operculum) is exactly as when it was taken from the shell."

L'animal a été représenté tel qu'il nous parvint dans la figure 1, Pl. I, du présent mémoire. Arraché avec effort de sa coquille, il avait perdu le tortillon tout entier, les branchies, la plus grande partie du manteau et des viscères, à l'exception de la radule et d'une portion déchirée de l'œsophage et de la masse buccale. Le pied se trouvait intact, mais il était recroquevillé, comme le montre la figure ; le muscle columellaire, les tentacules, les yeux, une partie des parois de la cavité antérieure du corps et une faible partie de la région inférieure du manteau n'étaient pas trop endommagés et se prêtaient encore parfaitement à des recherches anatomiques; l'épipodium n'était pas apparent au premier abord et nous pûmes croire un instant qu'il faisait défaut ; mais un examen ultérieur plus attentif nous a permis de le voir, contracté par l'alcool, à la partie supérieure du pied. Il paraît peu développé et s'arrête assez loin des tentacules.

Pour plus de détails sur la morphologie externe, nous renvoyons à nos figures et aux mémoires de M. Dall, que nous avons résumés plus haut.

DESCRIPTION DE LA RADULE.

M. Dall ('89, 399, Pl. XXXI, Fig. 1) a décrit et figuré en partie la radule du *Pleurotomaria Quoyana:* en plus de la dent impaire, il distingue trois séries de dents : 1° les *laterales,* au nombre de vingt-six, plus ou moins aplaties ; 2° les *uncini,* ayant un à trois denticules presque aussi longs que la pointe principale ; les uncini situés antérieurement (*uncini majores*) sont plus forts et ont plus de denticules que les suivants (*uncini minores*) ; on compte dix-huit à vingt de ces uncini ; 3° les *laterales minores,* très nombreuses, petites, transparentes et si rapprochées qu'il est presque impossible de les compter. M. Dall pense qu'il en existe quarante à cinquante ; elles sont minces et spatuliformes, l'auteur n'a observé sur aucune de ces dents les touffes qu'il a décrites chez le *Pleurotomaria Adansoniana.* La formule radulaire serait donc $\mathrm{R}\left(\frac{21}{1}+\frac{5}{0}\right)+\left(\frac{18}{3-1}+\frac{45\,?}{0}\right)$.

La lettre R désigne la dent rachidienne (impaire) ; les chiffres inscrits en dénominateur indiquent le nombre de cuspides qui caractérise chaque dent.

Nous allons compléter la description de M. Dall en y apportant quelques modifications.

La radule des Pleurotomaires est extraordinairement compliquée ; il existe peu de Mollusques qui présentent d'aussi importantes modifications le long d'une série transversale ; mais ces modifications présentent un remarquable caractère de continuité qu'on ne trouve à un pareil degré chez aucun Diotocarde ; nous reviendrons d'ailleurs en détail sur cette particularité spéciale aux Pleurotomaires.

Les rangées transversales n'ont nullement une direction transverse, mais sont repliées en forme de V. La figure 12 (Pl. III) représentant la radule, vue par dessous, montre cette disposition d'ensemble ; il est clair que de ce côté les dents ne peuvent pas être aperçues ; seules leurs surfaces d'insertion sont visibles. Nous avons représenté une demi-rangée (Pl. III, Fig. 1) à un plus fort grossissement, également vue par dessous ; on remarque que la surface d'insertion de chaque dent varie de forme et de grandeur depuis la ligne médiane jusqu'à l'extrémité ; c'est à la limite du premier et du deuxième tiers que la base des dents présente le plus de force.

Nous avons pu établir le nombre exact des dents d'une rangée; il existe une dent médiane impaire, et, de chaque côté, cent dix-sept dents paires; on trouve, en outre, au-delà de la cent dix-septième dent, la base rudimentaire d'une cent dix-huitième. La forme de ces dents est très variée, et, pour la commodité de la description, nous diviserons les dents paires en cinq groupes, qui n'ont pas d'ailleurs de limites précises: 1° dents *centrales;* 2° dents *lamelleuses;* 3° dents *à crochets* (ou *uncini*); 4° dents *à brosses;* 5° dents *flabelliformes.*

Nous désignerons chaque dent par son numéro d'ordre à partir de la dent impaire (exclusivement). Les dents ayant même numéro d'ordre dans deux rangées différentes sont toujours rigoureusement identiques; nous avons constaté le fait très minutieusement, notamment dans les régions de transition entre deux groupes consécutifs, où l'on pouvait s'attendre à des variations individuelles; il n'en est rien; la vingt-neuvième dent, par exemple, a toujours identiquement la forme figurée.

La disposition générale des dents présente quelques particularités dignes d'être signalées; les deux moitiés ne se correspondent pas exactement, mais il y a un léger chevauchement (Pl. III, Fig. 2 et Fig. 12); en outre, la surface où s'attachent les dents (épithélium lingual) est loin d'être plane; la dent impaire et ses voisines sont insérées sur une forte saillie longitudinale, de chaque côté de laquelle on trouve une forte dépression où sont les dents lamelleuses triangulaires. Au-delà de cette dépression court une nouvelle saillie qui supporte les grosses dents à crochet. Ces dispositions se voient facilement en examinant la radule par dessous.

Dent impaire. — La dent impaire (Pl. III, Fig. 4, 5, 6), de petites dimensions,[1] est presque couchée sur l'épithélium lingual; elle est constituée par une lame vaguement quadrangulaire, située dans le plan médian, et prolongée antérieurement[2] par une pointe assez aiguë; elle s'insère sur l'épithélium lingual suivant une bande étroite et allongée dans le sens de la ligne médiane (cette bande d'insertion est représentée obliquement, vue de trois quarts, dans la figure 5); son bord postérieur, très incliné, porte, de chaque côté, deux expansions minces et foliacées, visibles à droite et à gauche dans la figure 5.

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[1] Les dents figurées isolément sont toutes figurées au même grossissement de 70 diamètres: ce sont toutes des dents du côté gauche.

[2] Dans les pages qui suivent, nous appellerons *extrémité antérieure d'une demi-rangée de la radule,* celle qui se trouve sur la ligne médiane; par exemple, la figure 2 représente la moitié antérieure de la demi-rangée gauche.

Dents centrales paires. — De part et d'autre de la dent impaire, les premières dents que l'on rencontre sont de beaucoup plus grande taille que la dent impaire et que les suivantes ; elles sont insérées (Fig. 3) sur une ligne à peu près transversale ; on peut les appeler *les dents centrales paires* en limitant cette région, arbitrairement d'ailleurs, aux trois premières. Elles sont larges et aplaties (Fig. 7, 8, 9), c'est la deuxième qui présente la largeur maximum ; elles portent, du côté externe, une crête de renforcement qui se prolonge latéralement et inférieurement par une expansion mince et foliacée (Fig. 3), homologue de celles de la dent médiane, mais diminuant rapidement de grandeur. Leur surface d'insertion est concave (Fig. 7–9).

On remarquera qu'il existe une assez brusque différence de forme et de taille entre la dent impaire et la première centrale : celle-ci n'a point l'équivalent de la pointe que possède la dent impaire. Au contraire, la quatrième dent ne diffère de la troisième que par le rétrécissement de son extrémité supérieure. La quatrième établit donc une transition très ménagée entre les dents centrales, et les dents lamelleuses ; nous n'avons, d'ailleurs, attribué à ces distinctions qu'une valeur absolument artificielle.

Dents lamelleuses. — A partir de la troisième dent inclusivement, la direction générale de la rangée change et, au lieu d'être transversale, s'éloigne de l'axe suivant en angle aigu d'environ 30 degrés. La taille des dents diminue légèrement jusqu'à la sixième ou septième (Fig. 2), en même temps que la forme tend à devenir triangulaire ; entre la septième et la vingt-cinquième la taille reste à peu près constante, puis s'accroît rapidement au-delà. Les petites expansions foliacées qui se trouvent à la base des dents centrales persistent sur les dents lamelleuses, mais disparaissent sur la vingt-neuvième. La huitième et la vingt-huitième dent sont représentées sur les figures 3 (Pl. III) et 2 (Pl. IV).

Dents à crochets. — La vingt-neuvième dent établit la transition entre les dents lamelleuses triangulaires et les dents à crochets. Elle présente encore une forme générale triangulaire (Pl. IV, Fig. 1, dent du milieu) et son extrémité est assez mince ; d'autre part, vue de côté (Fig. 3), elle présente une remarquable analogie de forme avec la dent suivante (Fig. 4) et montre très nettement le début de deux cuspides ; il est impossible de rapporter cette dent aux précédentes plutôt qu'aux suivantes, car elle a des caractères exactement intermédiaires.

Les dents à crochet qui suivent perdent assez rapidement la forme triangulaire, tout en restant aplaties latéralement ; elles s'allongent, s'incurvent, et leur extrémité se munit de cuspides. La trentième (Fig. 4) est bicuspide, mais elle possède une faible indication d'une troisième cuspide qui va se développer sur les suivantes. La trente et unième (Fig. 6) et la trente-deuxième sont très caractérisées comme dents tricuspides; on observe que le bord externe et le bord interne présente l'un et l'autre bourrelet d'épaississement: le bourrelet interne, du côté concave, forme deux des cuspides que nous appellerons *cuspides internes*, tandis que le bourrelet externe, du côté convexe, se termine par la cuspide externe. Dans la région comprise entre les deux bourrelets, la dent est mince et aplatie. La trente-troisième (Fig. 7) ne porte plus que deux cuspides: la cuspide interne inférieure a avorté, et sa place n'est plus indiquée que par une légère ondulation du bord, dont on ne trouve même plus de trace dans la trente-quatrième. Les dents numérotées de 32 à 35 sont les plus fortes de toutes; ce sont aussi celles dont la base présente les plus grandes dimensions (Pl. III, Fig. 1).

A partir de la trente-sixième, la partie recourbée de la dent diminue d'épaisseur; en même temps, le bourrelet externe de renforcement prend de moins en moins d'importance dans la partie terminale, en sorte que la cuspide externe, toujours médiocrement saillante, même à la trente et unième dent où elle présente son maximum de développement, est de plus en plus en retrait avec la cuspide interne; en somme, la trente-quatrième dent prend déjà l'aspect d'une dent unicuspide, aspect qui ne fait que s'accentuer (Pl. 4, Fig. 21) et devient très marqué pour la quarante et unième; toutefois la cuspide externe, quoique pratiquement invisible, existe toujours morphologiquement comme terminaison émoussée du bourrelet externe, toujours présent.

La quarante-deuxième dent (Pl. IV, Fig. 9) est encore unicuspide, mais elle montre, sous la forme d'un léger renflement, le rudiment d'une nouvelle cuspide interne, qui se développe rapidement sur les dents suivantes (voir Fig. 11) et qui paraît se former au même point où avait disparu la cuspide interne inférieure des trentième, trente et unième et trente-deuxième dents. Les quarante-troisième et quarante-quatrième dents deviennent donc bicuspides, mais sont fondamentalement du même type tricuspide que la trente et unième, en tenant compte de ce que nous venons de dire sur la cuspide externe. Cette structure ne tarde pas à se compliquer: la quarante-cinquième dent (Pl. IV, Fig. 11) montre, en effet, entre ces deux cuspides internes, le début d'une troisième cuspide interne (cuspide moyenne) qui va se développer sur les dents suivantes (ex : 48e dent, Fig. 25), qui deviendront donc tricuspides, mais d'un type différent des triscuspides rencontrées antérieurement, puisque les trois cuspides dépendent du bourrelet interne. On voit que la série des dents à crochet est loin d'être uniforme. Les dernières d'entre elles s'amincissent sensiblement.

Dents à brosses. — La quarante-huitième dent fait la transition entre les dents à crochet et les dents à brosse. Le bourrelet externe est toujours présent ; mais son extrémité distale (qui équivaut à la cuspide externe de la trente et unième dent) s'étant de plus en plus retirée de la pointe, n'arrive plus qu'au niveau de la cuspide interne inférieure et se termine par une sorte de petit épaississement irrégulier, qui se garnit de minuscules baguettes sétiformes, dont on n'observe qu'une trace à peine perceptible sur la quarante-huitième dent, mais qui forment déjà une petite touffe sur la cinquantième (Pl. IV, Fig. 13). Ces soies sont transparentes avec une vague structure transverse ; leur diamètre mesure environ .002 millimètre à quelque distance de leur insertion. Leur extrémité distale est assez pointue. Sur la cinquante-septième dent, ces soies sont bien développées et atteignent l'extrémité libre de la dent, qu'elles dépassent même sur les suivantes : elles se courbent en enveloppant l'extrémité de la dent de chaque côté, ainsi que son bord convexe (Pl. IV, Fig. 27).

La forme générale des dents à brosse n'est plus celle des dents à crochet : leur courbure est beaucoup plus faible (Fig. 15) et tend à s'atténuer encore en approchant de l'extrémité de la série (Fig. 16) ; leur tige est très amincie.

Les dernières dents à brosse se modifient sensiblement : leurs cuspides sont moins saillantes (ex : 103^e dent, fig. 16) ; une expansion foliacée, latérale et externe, se développe tout du long de la tige ; elle est déjà sensible sur la cent troisième dent et devient extrêmement développée vers la cent dixième (Pl. IV, Fig. 17) et sur les suivantes ; cette expansion va même former la totalité des dents flabelliformes, par suite de l'atrophie graduelle de la tige et de la brosse.

Les cuspides paraissent disparaître un peu avant la brosse : nous les avons encore aperçues sur la cent neuvième dent ; la brosse existe jusqu'à la cent onzième inclusivement, mais en s'atrophiant rapidement.

Dents flabelliformes. — La cent douzième dent ne présente plus trace de brosse : une petite incurvation du bord indique seulement sa place. Les dernières dents, jusqu'à la cent dix-septième (Pl. IV, Fig. 5) sont minces, aplaties, spatuliformes, un peu recourbées ; leurs bases sont tellement petites qu'elles prennent une disposition divergente rappellant assez celle des feuillets d'un éventail, dont les lames un peu courbes iraient en décroissant lentement. On voit sur la figure, juxtaposée à la base de la dernière dent, la base rudimentaire d'une cent dix-huitième dent non développée.

Plaques basales accessoires. — Dans toute la région moyenne de chaque demi-série, la base des dents est accompagnée d'une petite pièce accessoire fortement adhérente à l'épithélium lingual : on l'aperçoit en examinant la radule par sa face inférieure (Pl. III, Fig. 1) ou encore en observant l'épithélium lingual par transparence, après avoir enlevé chaque dent. La première plaque s'observe sur la trente-quatrième dent ; il y a déjà, à vrai dire, sur la trente-troisième, une pièce analogue, d'un peu plus grande dimension, mais qui paraît encore soudée à la base. A partir de la trente-quatrième dent, cette plaque diminue un peu de dimension, puis augmente à partir de la trente-neuvième ; entre la quarante et unième et la soixante-quatorzième, elle conserve à peu près la même taille et la même forme : elle est ovale et disposée obliquement ; puis elle diminue rapidement et disparaît après la quatre-vingt-unième dent. En résumé, la radule présente une dent impaire, quelques dents centrales transversales, une série de dents lamelleuses, puis des dents à crochet, d'abord bicuspides, ensuite tricuspides, de nouveau bicuspides, ensuite unicuspides, puis tricuspides, mais suivant une disposition différente, et, enfin, des dents flabelliformes. Il existe des transitions ménagées entre ces divers types de dents, sauf entre la dent impaire et la première centrale.

COMPARAISON DE LA RADULE DES PLEUROTOMARIA AVEC CELLE DES AUTRES DIOTOCARDES.

La structure de la radule du *Pleurotomaria Quoyana* est absolument spéciale et on ne trouve rien d'analogue chez les autres Scutibranches ; ces derniers montrent, en effet, une tendance très nette à la division d'une série transverse en régions spécialisées ; on y distingue presque toujours une région centrale formée par la dent impaire et un petit nombre de dents paires (généralement cinq de chaque côté), et deux régions marginales (une à droite et une à gauche), constituées par des dents alongées et recourbées en forme de crochet ; entre la région centrale et chaque région marginale se trouve assez souvent une dent latérale différenciée, tantôt rudimentaire, tantôt, au contraire, très forte, et qui vient encore accentuer la séparation des deux régions, déjà bien marquée par les différences de structure et de grandeur des dents.[1]

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[1] Ce schéma est parfois modifié ; la dent latérale n'est pas toujours différenciée. En outre, les premières marginales sont parfois différentes des suivantes ; mais, dans aucun cas, on n'observe de dispositions comparables à celles des Pleurotomaires.

Chez le *Pleurotomaria*, il y a sans doute des variations considérables entre les diverses dents d'une rangée, mais il est impossible de tracer des limites précises entre les régions qu'on peut y distinguer, car les dents se modifient de l'une à l'autre (sauf la dent impaire et sa voisine) par des transitions ménagées ; on voit donc la différence profonde qui distingue les Pleurotomaires des autres Diotocardes.

En outre, après les dents que nous avons appelées *centrales*, il existe une longue série de dents lamelleuses triangulaires, mal séparées des précédentes et dont il est impossible de trouver l'équivalent chez aucun autre Diotocarde ; si nous les rapportions aux dents centrales, il faudrait admettre, pour ces dernières, un nombre voisin de vingt huit, c'est-à-dire près de six fois le nombre (cinq) qu'on observe chez les autres Diotocardes. D'autre part, il semble impossible de les comparer aux dents à crochet ; elles constituent donc une série bien spéciale aux Pleurotomaires.

Il est possible que ces dents aient avorté chez les autres Diotocardes; ainsi s'expliquerait la brusque différence de structure entre les dents centrales et les dents marginales de ces derniers. L'atrophie de la dent latérale chez certains genres de Trochidés,[1] où une simple lamelle rudimentaire sépare les centrales des marginales semble appuyer cette manière de voir et prouve, en tous cas, que des dents peuvent disparaître dans cette région de la radule. Malheureusement, cette hypothèse, quelque satisfaisante qu'elle soit, n'est pas étayée par un nombre suffisant de faits.

La présence des dents à brosse signalée, par Dall, chez le *Pleurotomaria Adansoniana* et, par nous, chez le *Pl. Quoyana*, paraît également caractéristique du genre.

Il est intéressant de noter que la radule des *Scissurella* n'a aucun rapport avec celle des Pleurotomaires, mais se rattache facilement au type qu'on observe chez les autres Diotocardes.

On voit que l'étude de la radule du *Pleurotomaria* présente un très grand intérêt ; cet organe possède, en effet, au moins trois caractères particuliers à ce genre ; transitions ménagées entre les dents d'une série, présence des dents lamelleuses triangulaires, dents à brosses. Le premier de ces caractères est capital, car il est en rapport avec un état d'organisation primitif par rapport à celui des autres Prosobranches, chez lesquels les dents de la radule sont groupées en régions spécialisées et dépourvues de termes de transition. Pour mieux faire comprendre notre pensée, en employant une comparaison d'ailleurs tout artificielle, nous pouvons dire qu'on observe, chez les Pleurotomaires, quelque chose

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[1] Troschel, Gebiss der Schnecken, Bd. II.

d'analogue à ce qui se passe chez les Mammifères fossiles les plus anciens, dont la dentition est remarquablement homogène et présente des transitions ménagées entre les dents spécialisées, incisives, canines, prémolaires, etc., qui sont beaucoup mieux séparées chez les Mammifères plus récents.

MÂCHOIRES.

Les mâchoires ont déjà été décrites par M. Dall ('89). Ce sont deux pièces cornées minces, très faibles, et qui n'ont probablement qu'un rôle fonctionnel très restreint; nous donnons la figure de l'une d'elles (Pl. III, Fig. 2). Du bord le plus épais partent de nombreuses stries irrégulières et serrées, qui couvrent plus de la moitié de la surface.

ORGANES DES SENS.

Œil. — L'œil a été décrit par Dall ('89, 398) et il en a été question dans un autre passage de ce mémoire. Nous avons vérifié, à l'aide de coupes, que c'est un œil très simple, ouvert à l'extérieur et tapissé à l'intérieur par la rétine; son diamètre mesure environ un demi-millimètre; l'orifice extérieur est un peu plus étroit. Nous aurions voulu savoir si sa cavité intérieure est absolument vide comme chez les Nautiles, ou bien si elle contient une substance transparente plus ou moins molle, faisant fonction de cristallin rudimentaire, comme chez les *Trochus;* mais le médiocre état de conservation ne nous a pas permis de résoudre sûrement la question. D'après M. Dall, il n'y a pas de cristallin et l'eau de mer pénètre librement dans la cavité. Notons toutefois une grande analogie de forme et de structure avec l'œil des *Trochus.*[1]

Cette disposition générale de l'œil est certainement très primitive.

Otocystes. — Les deux otocystes (Pl. III, Fig. 10) sont situés en avant et un peu au-dessus de la grosse commissure palléo-pédieuse: ils sont ovoïdes, leur plus grand diamètre mesure .55 millimètres. Leurs parois sont épaisses et laissent voir par transparence une cavité bourrée d'otolithes hyalins, de dimensions très inégales, comparables par conséquent à ceux qui ont été décrits par M. de Lacaze-Duthiers ('72, 141) chez les *Patella;* les petits (2 μ à 7 μ) sont exactement sphériques; les gros (jusqu'à 15 μ et 20 μ) sont quelquefois sphériques, mais plus fréquemment ovoïdes allongés ou bosselés; on ne saurait mieux les comparer qu'aux concrétions qui se déposent concentriquement autour de plusieurs centres d'attraction voisins; deux, trois ou davantage; la surface extérieure, au lieu d'être une sphère, est composée de plusieurs fragments de sphère

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[1] Pelseneer ('94, 59).

qui correspondent chacun à un centre d'attraction; il semble donc que les gros otolithes bosselés soient formés par l'accroissement de deux ou trois petits qui se sont accidentellement soudés.

Le nerf acoustique, après avoir quitté l'otocyste, remonte le long de la corne antérieure des cordons scalariformes en adhérant très intimement à la membrane conjonctive de cette corne; nous n'avons pas pu le suivre jusqu'aux ganglions cérébroïdes.

Le grand nombre et l'inégalité des otolithes, ainsi que leur structure très simple, viennent encore accentuer les caractères primitifs des Pleurotomaires; on sait, en effet, que, chez les formes spécialisées, les otolithes ont une taille uniforme, une structure plus ou moins compliquée et constante et que leur nombre subit une réduction parfois considérable.

Système Nerveux.[1]

Par tous ses caractères essentiels, le système nerveux du *Pleurotomaria Quoyana* ressemble à celui des autres Prosobranches diotocardes, surtout à celui des Fissurellidés et des Trochidés; ses ganglions cérébroïdes, ses centres stomato-gastriques, sa commissure viscérale et ses cordons palléo-pédieux sont construits sur le même type; différences, qui sont toutes de détails, ont d'ailleurs leur importance et rapprochent, à notre avis, le système nerveux des Pleurotomaires de celui des Amphineures.

1° *Centres cérébroïdes* (Fig. 2, 3, 8, 9, 10, *C*). — Les centres cérébroïdes occupent la même place et ont la même forme que ceux des Trochidés; toutefois leur commissure est sensiblement plus large, ce qui tient à un état de condensation moins avancé des cellules ganglionnaires. Cet état primitif des centres cérébroïdes est rendu manifeste par l'étude des *nerfs labiaux supérieurs* (m^1) et *latéraux* (m^2); ces nerfs, en effet, n'ont pas leur origine dans les ganglions, mais, comme dans l'Haliotide sur la commissure (c), au voisinage de la partie renflée des ganglions. Cette dernière est triangulaire et, comme de coutume, se prolonge latéralement et en-dessous, sur les côtés de la masse buccale, pour former une longue *saillie labiale* (L); les connectifs cérébro-pédieux (k^1) et cérébro-palléaux (k^2) naissent côte à côte sur le bord des ganglions, en arrière de cette saillie.

Sur le bord antérieur des ganglions on voit naître, de haut en bas,

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[1] Nous présentons nos vifs remerciements à M. le professeur de Lacaze-Duthiers, qui a fait recueillir pous nous, à Roscoff, de magnifiques *Chiton fascicularis*, à M. le professeur Perrier, qui nous a communiqué des *Turbo radiatus* recueillis par M. Jousseaume dans la mer Rouge. Comme on le verra plus loin, ces Mollusques nous ont été fort utiles pour interpréter le système nerveux des Pleurotomaires.

trois *nerfs labiaux* (m_3, m_4, m_5) aussi puissants que les deux premiers; le troisième se détache de la *saillie labiale* dans sa région basilaire qui est très renflée; plus inférieurement, cette saillie émet encore un autre nerf labial (m_6), puis se rétrécit beaucoup et devient alors purement fibreuse; elle forme alors la *commissure labiale* (c^1) qui ne présente rien de particulier.

Sur la face externe des ganglions cérébroïdes prend naissance le puissant *nerf tentaculaire* (t^1); il émet, près de sa base, une petite branche nuquale et, un peu plus haut, le *nerf optique* (f). Il va sans dire que ce dernier est simplement accolé au nerf tentaculaire, mais qu'il n'est point fusionné avec lui.

2° *Stomato-gastrique.* — Comme chez tous les Diotocardes, le système nerveux stomato-gastrique a son origine sur le bord postérieur de la saillie labiale (L^1) à une faible distance de sa base; comme dans ces derniers aussi, ses connectifs (k) sont allongés, remontent latéralement sous les muscles dans les flancs de la masse buccale, et envoient, chemin faisant, quelques ramuscules nerveux (s^5) à ce dernier organe.

La partie ganglionnaire (Fig. 12) présente la forme normale caractéristique du groupe, celle d'un fer à cheval. Mais ici, le fer à cheval ne présente pas les renflements prononcés qu'on observe chez les Trochidés et même chez certains Chitons (Fig. 6 et 7), et qui indiquent d jà un commencement de condensation ganglionnaire; à son origine connectivale, il est un peu dilaté, mais, partout ailleurs, son diamètre est sensiblement le même.

Les *nerfs stomato-gastriques* nous ont paru plus gros et moins nombreux que chez les autres Diotocardes; nous n'avons pas pu tous les suivre, en raison du mauvais état de la masse buccale, mais nous croyons avoir observé l'origine de tous, soit sur l'animal, soit en préparations microscopiques. En dehors des ramuscules issus des connectifs, ils sont de chaque côté au nombre de trois: deux (s^3, s^4) se détachent du renflement antérieur et correspondent vrai-semblablement aux nerfs que l'un de nous a désignés par les lettres s^3 et s^4 dans le *Turbo* (*Bouvier*, '87, Fig. 5), l'autre (s) se détache du bord postérieur du fer à cheval, au voisinage de son millieu, et doit être l'équivalent des nerfs s^1 et s^2 du même animal. L'un (s^3) des deux nerfs antérieurs se dirige en arrière et correspond aux trois nerfs (s^3) des *Turbo;* il est très volumineux et paraît renfermer des cellules nerveuses. Le nerf postérieur se bifurque peu après son origine.

3° *Connectifs issus des ganglions cérébroïdes et commissure viscérale* (Fig. 3, 8, 9, 10, 11). — Issus du bord postéro-inférieur des ganglions cérébroïdes, le *connectif cérébro-palléal* (k^2) et le *connectif cérébro-pédieux* (k^1) descendent, en divergeant, dans la dépression profonde produite en avant par la cavité du corps (Fig. 3); le connectif cérébro-palléal est en arrière et le connectif cérébro-pédieux en avant; le premier est plus puissant que le second.

A droite les deux connectifs atteignent leur maximum d'écartement vers le tiers supérieur de leur longueur; à gauche ils divergent sur une plus grande étendue, mais, comme du côté droit, se rapprochent ensuite peu à peu, et viennent aboutir dans les *cornes* proximales (Fig. 9 et 10, C^1) que forment avant leur réunion les cordons palléo-pédieux. Chemin faisant, les connectifs envoient quelques branches nerveuses aux parois du corps; les connectifs cérébraux-pédieux en émettent au moins deux (e, b, b') et les connectifs cérébro-palléaux une (c, c^1). Ces derniers, d'ailleurs, présentent le caractère tout particulier de donner naissance, sur leur trajet, à la branche correspondante de la *commissure viscérale.* A droite, la *branche sus-intestinale* (h) se détache du connectif cérébro-palléal (k^2) au point où celui-ci s'écarte le plus du connectif cérébro-pédieux, c'est-à-dire à une faible distance du ganglion cérébroïde droit (C). A gauche, la *branche sous-intestinale* (h^1) se détache plus bas du connectif cérébro-palléal (k^1) un peu au-dessous du millieu de ce dernier. Quoiqu'il en soit, on observe ici ce fait unique, chez les Gastéropodes, d'une commissure viscérale issue, non point des centres palléaux, mais des connectifs qui réunissent les ganglions cérébroïdes à ces centres.

4° *Cordons palléo-pédieux* (Fig. 4, 8, 9, 11). — Chez les autres Gastéropodes diotocardes (voir Fig. 5 et 13), chaque cordon palléo-pédieux se prolonge proximalement, au-dessus de la grosse commissure, par une corne ganglionnaire palléale (C') qui se continue avec les connectifs (k^1, k^2) issus du cerveau, et la commissure viscérale vient aboutir dans une autre corne (Cg, $Cd.$) qui provient de la bifurcation de la première. Dans le *Pleurotomaria Quoyana*, il n'en est plus de même : *la corne* (C^1) *de chaque cordon, fort grosse et très allongée, ne se bifurque pas et ne donne pas naissance à la commissure viscérale ; elle se dirige obliquement en arrière et en haut et les connectifs* (k^1, k^3) *issus du cerveau viennent aboutir à son extrémité supérieure.*

D'ailleurs, ces cornes ganglionnaires ne sont pas exclusivement de nature palléale; sur leur face externe (Fig. 4 et 11) elles sont creusées d'un sillon profond (s) qui les divise en deux rubans superposés; le ruban supérieur (Ps) continue exactement le connectif cérébro-palléal (k^2) correspondant, et le ruban inférieur (Pi) le connectif cérébro-pédieux (k^1). Il est donc manifeste que les cornes du Pleurotomaire, au lieu d'être exclusivement palléales, sont de nature mixte, que la bande supérieure est de nature palléale et l'inférieure de nature pédieuse. C'est ce que prouve, du reste, l'étude des nerfs qui émanent de cette région; les nerfs (a, a^1, a^2) issus du ruban supérieur se rendent, en effet, dans les muscles qui forment le plancher de la cavité antérieure du corps, et qui sont nettement columellaires, ceux qu'émet le ruban inférieur, s'enfoncent, au contraire, dans la musculature du pied ou dans la paroi du corps.

Or, s'il est impossible de contester la nature mixte des cornes proximales des cordons pédieux, il faut en conclure que les cordons sont mixtes, comme les cornes elles-mêmes. En effet, le profond sillon que nous avons constaté sur la face externe des cornes se prolonge manifestement, sinon sur toute la longueur des cordons, au moins sur une grande étendue de ces derniers; il apparaît même, mais beaucoup moins nettement, sur leur face interne (Fig. 11). Comme les cornes proximales, chaque cordon se trouve dès lors partagé en un ruban supérieur qui continue le ruban palléal des cornes et en un ruban inférieur qui continue leur ruban pédieux.

Ainsi, les deux rubans de chaque cordon, en effet, ne sont certainement pas de nature identique, du moins au point de vue de leurs rapports et de leurs fonctions. La preuve en est encore dans la position des commissures qui les relient d'un côté à l'autre et dans la nature des nerfs qu'ils émettent.

Les cordons se dirigent d'avant en arrière dans le pied (Fig. 9), où ils figurent presque un ovale très peu convexe. Au point où ils se continuent avec les cornes, ils sont unis par une commissure puissante (Fig. 11, i), à la fois ganglionnaire et fibreuse, qui s'étend entre les deux rubans de chaque côté. Plus en arrière se trouvent d'autres commissures exclusivement fibreuses; nous en avons pu réparer neuf;[1] mais leur nombre est certainement plus considérable. Elles sont moins régulièrement transversales que la première et émettent des ramuscules qui se rendent dans la sole pédieuse. Ces commissures sont donc vraiment de nature pédieuse; d'ailleurs, dans le Pleurotomaire, comme dans les Fissurelles, les Haliotides et les Trochidés, elles paraissent indépendantes des rubans supérieurs et rattachent l'un à l'autre les rubans inférieurs. Ce fait prouve, à notre avis, que les deux rubans de chaque côté ne sont pas de même nature.

Un autre fait vient encore rendre plus évidente cette manière de voir.

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[1] Ces commissures sont représentées dans la figure 9; en arrière de la neuvième, les coupes nous en ont fait voir cinq autres, ce qui porterait à quatorze le nombre des commissures accessoires.

Comme dans les autres Diotocardes à cordons divisés en deux parties par un sillon, le ruban supérieur et le ruban inférieur émettent des nerfs qui n'ont pas la même distribution. Ainsi que l'ont montré M. de Lacaze Duthiers dans l'Haliotide ('59), M. Boutan ('86) dans la Fissurelle et le *Parmophora*, M. Béla Haller dans divers Diotocardes ('84, 20, Fig. 2), les rubans supérieurs envoient des nerfs (a^2, a^3, a^4,) en avant dans les parois du corps, plus en arrière dans la partie supérieure du pied, qui est de nature columellaire, ainsi que dans l'épipodium qui l'orne de ses franges. Toutefois, dans notre Pleurotomaire, nous n'avons pu suivre ces nerfs jusqu'à l'épipodium, réduit et recroquevillé, de l'animal. Entre les nerfs antérieurs issus des rubans supérieurs des cordons, et ceux qui proviennent du connectif cérébro-palléal ou du ruban qui lui fait suite dans les cornes, il y a tous les passages et le champ de distribution est le même, comprenant les parois latérales du corps et tout ce qui, de près ou de loin, fait partie de la région collumellaire. Tout autre est la distribution des nombreux nerfs issus des rubans inférieurs des cordons; ces nerfs (p) se rendent dans la sole inférieure du pied et sont manifestement de nature pédieuse; en outre, comme chez les autres Diotocardes, les deux nerfs les plus antérieurs (p^1) sont très gros et se rendent dans la partie antérieure du pied.

En résumant ce qui précède, on voit: 1° que les cordons palléo-pédieux sont le prolongement direct de leurs cornes antérieures; 2° que les deux rubans qui les constituent de chaque côté sont aussi les prolongements directs des rubans des cornes; 3° que les rubans supérieurs sont la continuation des connectifs cérébro-palléaux et les rubans inférieurs la continuation des connectifs cérébro-pédieux; 4° que, dans les cordons comme dans les cornes, les rubans supérieurs envoient des nerfs aux parois du corps, au muscle columellaire ou à ses dépendances, tandis que les rubans inférieurs donnent surtout des nerfs exclusivement pédieux; 5° enfin que les rubans supérieurs paraissent indépendants l'un de l'autre, en arrière de la commissure antérieure, tandis que les rubans inférieurs sont réunis par de nombreuses commissures d'où partent des rameaux pédieux.

En conséquence, nous croyons pouvoir dire que les cordons, comme les cornes qui les terminent, sont de nature mixte, que leur partie inférieure est pédieuse, et que leur partie supérieure est palléale, en donnant au mot *palléal* une signification étendue et que nous préciserons plus loin.

La structure mixte des cordons est rendue très manifeste par la présence de certains nerfs (*pn*) qu'on voit se détacher sur leur face externe et qui sont mixtes dans leur nature, comme le montrent les coupes, ou, plus simplement, un examen à la loupe. Ces nerfs sont surtout communs et faciles à observer dans la partie antérieure des cordons; quand on examine ceux-ci par la face externe, on voit que leur sillon est interrompu, de distance en distance, par des saillies linéaires obliques qui prennent leur origine dans les rubans supérieurs, se dirigent vers les rubans inférieurs, et, après les avoir atteints, se fusionnent, pour former un nerf, avec une racine nerveuse émanée de ces derniers. Ces nerfs mixtes se rendent dans le plan moyen du pied, et, bien que nous n'ayons pu suivre leur trajet jusqu'au bout, doivent avoir une distribution mixte, certains de leurs ramuscules se rendant à la partie supérieure et columellaire du pied, les autres dans sa partie inférieure ou pédieuse. L'existence de ces nerfs prouve, une fois de plus, que des parties contiguës, mais de nature différente, peuvent confondre leurs organes d'innervation tout en restant distinctes dans leur origine et dans leur distribution. Il en est de même des nerfs acoustiques: dans le *Pleurotomaria Quoyana*, par exemple, les *octocystes* (*o*) sont situées, comme dans les autres Diotocardes, sur le bord antérieur de la grosse commissure pédieuse (*i*), où un tractus fibreux les réunit, aussi les *nerfs acoustiques* (o^1) se confondent-ils avec les connectifs cérébro-palléaux, et il nous a même été impossible, dans notre animal, de les suivre jusqu'aux ganglions cérébroïdes, où ils prennent pourtant leur origine. Cette loi a été rendue parfaitement évidente par M. de Lacaze-Duthiers ('72) en ce qui concerne les nerfs acoustiques des Gastéropodes, mais l'étude du système nerveux des Mollusques en fournirait sans difficultés d'autres exemples.

5° *Commissure viscérale, nerfs palléaux* (Fig. 3, 8, 9, 11). — Ainsi que nous l'avons fait remarquer plus haut, les branches de la commissure viscérale ont une origine connectivale qu'on n'observe nulle part ailleurs chez les Gastéropodes, et qui donne au système nerveux du *Pleurotomaria Quoyana* un aspect des plus caractéristiques. La *branche sus-intestinale* (*h*) se détache du connectif cérébro-palléal (k^2) à une faible distance du ganglion cérébroïde droit; elle se dirige en arrière en suivant la paroi dorsale du corps, puis se recourbe progressivement à gauche et passe au-dessus du jabot de l'animal. Dans notre animal, cet organe était en mauvais état et réduit à ses parois déchirées et affaissées; au point où s'effectua la rupture quand on arracha le Mollusque de la coquille, s'étaient produites des lésions qui, heureusement, n'avaient pas enlevé la branche nerveuse; nous avons pu la suivre jusqu'au point où les parois dorsales du corps cessaient d'exister, comme l'indique la figure.

Quant à la *branche sous-intestinale* (h^1) elle se détache beaucoup plus bas du connectif cérébro-palléal gauche (k^2), nous l'avons vu se diriger à droite sous le tube digestif, mais elle était rompue à peu près au niveau de ce dernier.

En tous cas, nos recherches sont suffisantes pour établir que les Pleurotomaires possèdent, comme les autres Prosobranches, une commissure viscérale croisée.

Nous avons été moins heureux dans notre étude des *nerfs palléaux* proprement dits, et c'est une lacune que nous sommes les premiers à déplorer. Ordinairement ces nerfs sont volumineux et d'une dissection des plus faciles, au moins à leur origine ; ici, nous ne sommes pas certains de les avoir aperçus ; à droite, nous ne voyons rien qui puisse leur correspondre ; mais, à gauche, nous considérons comme nerf palléal une branche nerveuse (Fig. 8, *m*) qui se détache du connectif cérébro-palléal presque au même point que la commissure viscérale. Au reste, comme on peut s'en convaincre en jetant un coup d'œil sur la figure 1, qui représente l'animal tel qu'il nous fut communiqué, c'est à peine si notre Pleurotomaire présentait les restes de la partie inférieure du manteau, et nous nous demandons si les déchirures n'auraient pas arraché, jusqu'à leur racine, les grands nerfs palléaux. Si l'on considère cette hypothèse comme improbable, et nous convenons qu'elle en a toutes les apparences, il faut admettre que nous n'avons pas su apercevoir, au moins à droite, les vraies origines palléales. On sait que, chez les autres Diotocardes, les grands nerfs palléaux se détachent des cornes palléales supérieures ou dans le voisinage de celles-ci.[1]

De la branche sus-intestinale de la commissure viscérale, nous n'avons vu naître qu'un nerf assez grêle (Fig. 3 et 8, *d*), qui se rendait en arrière dans les téguments dorsaux. De la branche sous-intestinale naissaient deux *nerfs columellaires postérieurs* (l, l^1), dont l'un était très volumineux. Entre le point où elle se détache du connectif cérébro-palléal gauche et la corne palléo-pédieuse correspondante, cette branche est très volumineuse ; nous avons vu qu'elle émet, au premier de ces points, un nerf assez puissant (Fig. 8 et 9, *m*), qui plonge, à gauche, dans les parois du corps, et qu'on doit considérer, à notre avis, comme un nerf palléal gauche.

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[1] Peut-être faut-il considérer comme les nerfs palléaux deux gros nerfs (Fig. 11, a^2, a^{12}) qui naissent des rubans supérieurs un peu en arrière de la commissure palléo-pédieuse.

Nature des Centres Nerveux du Pied chez les Gastéropodes.

Les faits qui précèdent nous paraissent propres à jeter la lumière sur un point de l'histoire naturelle des Mollusques qui a soulevé les plus nombreuses et les plus vives controverses, nous voulons parler de la nature des cordons ganglionnaires du pied des Diotocardes et de l'étendue que présentent les centres palléaux de ces Gastéropodes. Sans vouloir remonter au début de cette controverse, ce qui n'aurait aucune utilité, nous dirons que M. de Lacaze-Duthiers ('59, '90), et, à sa suite, MM. Wegmann ('84) et Boutan ('86, '88, '90, '98) considèrent les cordons du pied des Diotocardes comme formés par la fusion, suivant leur longueur, des centres palléaux et pédieux de chaque côté, tandis que MM. Spengel ('81), Béla Haller ('84, '89, '94), Thiele ('90) et Pelseneer ('87, '88, '90, '91), les regardent comme franchement pédieux et considèrent comme centres palléaux les cornes ganglionnaires qui les précèdent et qui donnent naissance à la commissure viscérale et aux nerfs palléaux. Abstraction faite de la nature de l'épipodium, sur laquelle nous reviendrons plus loin, les arguments essentiels fournis par les premiers sont les suivants: 1° les cordons du pied sont divisés en deux rubans superposés par un sillon externe; 2° le ruban inférieur est en relation avec le connectif cérébro-pedieux et le ruban supérieur, plus ou moins directement, avec le connectif cérébro-palléal et les nerfs palléaux. Les arguments de la partie adverse sont essentiellement tirés de l'existence d'un vrai ganglion palléal chez les Diotocardes, ganglion qui se trouve dans la région proximale des cordons, en avant de la grande commissure antérieure; si l'on admettait, disent-ils avec M. Pelseneer, que ces ganglions se continuent dans le ruban supérieur des cordons, il faudrait admettre aussi que les ganglions palléaux sont commissurés, ce qui n'existe pas chez les Mollusques. Les arguments de second ordre seront signalés plus loin.

Pour notre part, nous croyons que la première théorie est l'expression exacte de la vérité, mais que la seconde est loin de s'en éloigner, au fond, autant qu'on pourrait le croire. Commençons d'abord par préciser, aussi exactement que possible, le sens qu'on donne communément au terme de *palléal* ou à son équivalent, celui de *pleural*, en anatomie comparée des Mollusques.

Si l'on s'en tenait à l'étymologie même des mots *palléal* ou *pleural*, on devrait réserver les noms de *ganglions palléaux* ou de *ganglions pleuraux* aux ganglions qui président à l'innervation du pallium ou manteau et des parois du corps des Mollusques. Mais, en réalité, ces termes ont dû, par la force des choses, recevoir une signification plus large. Chez les Gastéropodes, où les ganglions palléaux (ganglions pleuraux) sont bien distincts — et c'est le cas chez tous les Monotocardes — ces ganglions donnent naissance aux nerfs du manteau ou vrais nerfs palléaux, à certains nerfs des parois antérieures du corps et à certains nerfs des muscles columellaires. Qu'il y ait ou non communauté d'origine entre ces dernières parties, il est certain que les nerfs qui les innervent présentent des caractères communs, non seulement à cause de leur origine dans un même centre, mais aussi en raison des anastomoses qu'ils contractent fréquemment ou de leur champ de distribution, qui est mixte : le plus souvent, en effet, sinon toujours, on voit les nerfs palléaux envoyer des rameaux dans les parties du muscle columellaire et des parois du corps qu'ils traversent. Quoi qu'il en soit, il ressort de ce qui précède que le champ d'innervation des centres palléaux appelés aussi *centres pleuraux*, est des plus vastes et s'étend bien au-delà du manteau proprement dit ou des parois du corps.

1° *Pleurotomaires.* — Ceci dit, revenons au Pleurotomaire. L'intérêt essentiel de ce curieux Gastéropode, c'est qu'il ne présente pas, comme les autres Diotocardes, de corne palléale distincte en avant des cordons ganglionnaires du pied ; de sorte que, si l'on interprétait au sens étroit la théorie de M. Haller et de M. Pelseneer, il faudrait dire que le Pleurotomaire est dépourvu de centres palléaux. *A priori*, cette interprétation est inexacte, car notre Mollusque a un manteau, un muscle columellaire et des parois du corps aussi développées que les *Haliotis* ou les *Trochus*, de sorte qu'il doit avoir comme eux, c'est évident, des ganglions et des nerfs palléaux. Aussi bien, nous voulons rejeter cette interprétation, que seul, peut-être, M. Thiele[1] pourrait accepter, et nous croyons entrer tout à fait dans les vues de MM. Haller et Pelseneer, en disant que les centres palléaux sont formés, en partie du moins, par le ruban supérieur (Fig. 4 et 11, *Ps*) de la corne unique, qui prolonge proximalement de chaque côté les cordons pédieux. Nous avons vu, en effet, que ce ruban est le prolongement direct du connectif cérébro-palléal (k^2) et qu'il émet, par l'intermédiaire de ce connectif, la commissure viscérale, des nerfs pariétaux, des nerfs palléaux proprement dits et des nerfs columellaires. Quant au ruban inférieur (*Pi*), qui se continue par le connectif cérébro-

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[1] Thiele ('92), en effet, ne considère point comme des centres palléaux les cordons latéraux des Chitons, mais il les assimile au plexus épipodial de l'Haliotide, sans d'ailleurs en donner de raison sérieuse. Pour lui, les ganglions palléaux se développeraient ultérieurement chez les Prosobranches. Cette opinion, qu'aucun auteur n'a pu adopter, est en contradiction manifeste avec les faits signalés dans le présent mémoire.

pédieux (k^1), aucun fait ne saurait nous permettre de le considérer comme palléal, et ses connexions indiquent manifestement qu'il est de nature pédieuse.

Nous voici, dès lors, en présence de cornes ganglionnaires (c^1) qui sont mixtes à tous égards, palléales dans leur ruban supérieur et pédieuses dans leur ruban inférieur. Or, chacune de ces cornes est le prolongement d'un cordon ganglionnaire du pied, et chacun des rubans qui les compose est le prolongement du ruban correspondant de chaque cordon. Si les cornes sont palléales dans leur partie supérieure et pédieuses dans leur partie inférieure, tout semble dès lors indiquer qu'il en est de même des cordons. En fait, c'est ce que montre également l'étude des nerfs émis par les rubans qui constituent chacun d'eux. Ainsi qu'on le savait depuis longtemps, et comme on peut s'en convaincre par les figures qu'a données M. Béla Haller ('84, 38, Fig. 4), le pied des Diotocardes et des autres Gastéropodes se compose de deux parties: l'une, supérieure, qui est formée par les fibres musculaires antérieures du muscle columellaire et qui recouvre les cordons; l'autre, inférieure, qui constitue la sole pédieuse. Or les nerfs issus du ruban supérieur se rendent dans la partie supérieure du pied, et, comme il est facile de s'en convaincre par la dissection des nerfs les plus antérieurs des cordons, dans sa partie columellaire; tandis que les nerfs émis par le ruban inférieur se rendent en divers points de la sole pédieuse. En d'autres termes, le ruban supérieur des cordons innerve la zone columellaire comme le ruban supérieur des cornes, dont il est impossible, d'ailleurs, de le séparer; il est dès lors, comme lui, de nature palléale.

Ainsi dans le Pleurotomaire, chaque cordon du pied se compose d'un cordon de nature palléale et d'un cordon de nature pédieuse, de sorte que ces centres ganglionnaires sont mixtes, sinon de leur naissance à leur extrémité, au moins sur une grande partie de leur étendue.[1]

Ceci étant établi, et la grosse commissure des cordons réunissant aussi bien les rubans supérieurs que les rubans inférieurs, il faut conclure de ce qui précède que *les centres palléaux sont commissurés au même titre que les centres pédieux*. C'est un fait contre lequel, dans le Pleurotomaire, du moins, il nous paraît difficile de s'élever. Il n'est donc pas juste de prétendre, avec M. Pelseneer ('88, 91) que les ganglions palléaux ne sont

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[1] Il est possible, en effet, que la partie palléale ne s'étende pas jusqu'au bout des cordons, et c'est ce que sembleraient indiquer les centres pédieux des Fissurellidés. Pour être fixé sur ce point, il faudrait étudier l'exacte distribution des fibres du muscle columellaire et connaître le point précis où s'arrête le sillon en arrière. Cette observation s'applique à tous les Diotocardes.

jamais commissurés; sans doute, la commissure qui réunit les ganglions n'est jamais distincte de la commissure pédieuse, mais les recherches sur la structure intime des centres nerveux des Gastéropodes permettent d'établir qu'il existe, dans la commissure pédieuse, des fibres, qui se rendent aux ganglions palléaux transversales. Au reste, l'exemple du Pleurotomaire suffirait, à lui seul, pour montrer qu'il en est ainsi, même si l'on admettait que la partie palléale de ce mollusque se limite au ruban supérieur des cornes. Dans ce cas, en effet, le centre palléal des cornes s'arrêterait au niveau de la grosse commissure des cordons, et, comme le montrent les coupes, recevrait quand même des fibres de cette commissure.

2° *Fissurellidés, Haliotidés, Trochidés.* — Le système nerveux des Diotocardes primitifs diffère surtout de celui des Pleurotomaires, par la présence de deux cornes proximales (Fig. 5 et 13), à l'extrémité antérieure de chaque cordon du pied, l'une supérieure (*Cq*, *Cd*), que chacun s'accorde à reconnaître comme palléale et qui sert de point de départ aux branches de la commissure viscérale; l'autre inférieure (C^1), à laquelle aboutissent les connectifs cérébro-palléaux et cérébro-pédieux. Ces deux cornes ont été désignées par M. Béla Haller ('84, 17) sous le nom de *centres pleuro-cérébraux*, le même auteur donne le nom de *centre pleural* ou *commissural*, c'est-à-dire de centre palléal,[1] à chaque corne supérieure; mais, comme il passe outre sur les cornes inférieures, on doit croire, sinon qu'il les tient tout entières pour pleurales, du moins qu'il ne leur attribue, à aucun degré, la nature pédieuse. Au surplus, il est nécessaire de rappeler que les partisans de la théorie des cordons pédieux simples ne cherchent pas à caractériser la nature des cornes inférieures; M. Béla Haller les a bien figurées, mais M. Pelseneer, qui a consacré le plus de travaux à la question, ne les mentionne même pas, et, pourtant, elles sont très développées dans les Fissurelles ('86, Pl. XXXV), dans les *Cemoria* (Haller, '94, Fig. 142, voir Pl. II, Fig. 13), un peu moins dans certains *Turbo* (Fig. 95) et *Trochus*; dans les Haliotides, elles sont à peine sensibles. Or, toutes les fois qu'elles existent, ces cornes servent, comme dans les Pleurotomaires, de point d'arrivée aux connectifs cérébro-palléaux et cérébro-pédieux, et, comme chez ces derniers aussi, elles sont parcourues par un sillon longitudinal et divisées en deux rubans qui continuent ceux des cordons du pied. Ces rubans et ce sillon se voient surtout bien dans la Fissurelle, ainsi qu'il résulte des figures de

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[1] Spengel ('81) a donné le nom de *ganglions pleuraux* aux centres que nous appellons *ganglions palléaux*; M. von Ihering les nomme aussi *ganglions commissuraux* ('77).

M. Boutan ('86, Fig. 10, Pl. XXXV), et, comme ils ressemblent en tout à ceux des Pleurotomaires, comme les cordons offrent avec eux les mêmes rapports, il y a lieu, croyons-nous, de leur accorder la même signification.

Toutefois, il existe ici une différence importante, qui est précisément la cause de la controverse qui nous occupe; une partie de la substance palléale des cornes et des cordons s'est accumulée à l'origine de la commissure viscérale pour former des ganglions palléaux déjà distincts sous la forme de cornes supérieures, en même temps qu'une partie de la substance pédieuse des cornes inférieures se concentrait dans le ruban inférieur des cordons. De là le développement réduit des cornes inférieurs des Fissurelles, *Turbo, Trochus,* etc., qui sont beaucoup moindres que les cornes uniques des Pleurotomaires.

Ainsi, chez les animaux qui nous occupent, le système ganglionnaire palléal tend à se localiser en deux masses: l'une antérieure, qui s'isole et émettra des nerfs pour les parties palléales de la région antérieure du corps; l'autre, en contact sur toute sa longueur avec les centres pédieux, qui desservira une partie des parois du corps, et surtout la partie du muscle columellaire qui forme les plans supérieurs du pied. Aux nerfs issus de cette partie palléale située dans le pied, M. Béla Haller a donné le nom de *nerfs latéraux,* ils se rendent, dit-il, dans *les parois du corps, et les plus antérieurs dans le muscle columellaire* ('84, 21).

3° *Patellidés, Néritidés, Cyclophoridés, Paludinidés, Cypræidés.* — Le processus de concentration, dont nous venons de voir un exemple dans les formes précédentes, s'accentue davantage encore chez les Patellidés, chez les Néritidés et chez certains Monotocardes primitifs (voir p. 238, Fig. E). Les ganglions palléaux destinés aux parties palléales de la région antérieure du corps (manteau, partie du muscle columellaire la plus voisine de la coquille, une partie des parois du corps) se séparent de plus en plus des cordons et forment les ganglions palléaux proprement dits; ils s'isolent ainsi du ruban palléal supérieur, qui restera logé dans le pied, au voisinage immédiat des parties qu'il innerve (parois les plus antérieures du corps, parties du muscle columellaire situées dans le pied). Dès lors, les rubans pédieux et palléaux de chaque cordon, destinés à innerver des parties contiguës se fusionnent et se concentrent de plus en plus, leur sillon de séparation s'efface, et l'on arrive ainsi à des cordons simples en apparence, mixtes en réalité, auxquels tous les auteurs ont donné le nom de *cordons pédieux,* bien qu'ils renferment une partie palléale et une partie pédieuse. Ces cordons ne diffèrent guère de ceux des Diotocardes primitifs que par l'atrophie de leurs cornes inférieures, l'isole-ment plus grand de leurs cornes supérieures appelées *ganglions palléaux*, la disparition de leur sillon et la moindre quantité de cellules palléales qu'ils renferment. Pour le reste, tout est semblable, et la fusion dont leurs deux parties constituantes ont été le siège n'est rien autre chose que le résultat de la concentration de centres ganglionnaires contigus, concentration dont les exemples abondent dans l'histoire des Gastéropodes.[1]

4° *Autres Gastéropodes.* — Des formes précédentes on passe sans difficulté, par une concentration plus grande encore, aux Gastéropodes dépourvus de cordons ganglionnaires dans le pied (voir p. 238, Fig. F). Les ganglions palléaux proprement dits se séparent nettement de la région pédieuse, et les cordons de cette dernière se condensent d'arrière en avant pour former les ganglions pédieux, arrondis ou ovoïdes, des divers auteurs. Mais ces prétendus ganglions pédieux sont mixtes, en réalité; ils innervent, comme on sait, les parties pédieuses et columellaires du pied et n'ont point perdu toute relation avec les ganglions palléaux proprement dits. Ces derniers, en effet, comme chez le Pleurotomaire et les Diotocardes, sont commissurés à travers les ganglions et la commissure pédieuse. Il y a longtemps qu'on s'était aperçu de ce fait, et Walter en a donné un bel exemple dans ses études micrographiques sur le système nerveux de la Lymnée ('63, Taf. IV, Fig. 1); on trouve quelque chose d'analogue dans le travail de M. Garnault ('87, Fig. 32) sur le Cyclostome.

En résumé, nous pensons, avec MM. de Lacaze-Duthiers et Boutan, que les cordons du pied des Fissurelles, des Haliotides, des *Turbo* et des

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[1] Dans son travail les organes glandulaires d'*Helcion pellucidam* L. (*Lottia pellucida*), M. Boutan ('98, 472) cherche à établir que le système nerveux de cette espèce est un terme de passage entre le système nerveux des autres Patellidés et celui du Parmophore. Pour établir ce fait, qui serait au moins singulier, M. Boutan reproduit en schéma la belle figure du système nerveux de l'*Helcion* qu'a donnée M. Haller ('94, Fig. 1) et en fait une sorte de système nerveux de Chiton où la commissure viscérale croisée serait surajoutée. C'est interpréter trop librement, selon nous, le texte et les figures de M. Haller; l'énorme cordon ganglionnaire, semblable à celui des Chitons, que représente M. Boutan dans son schéma, n'a pas son équivalent dans la figure de M. Haller, ou du moins il ne s'y trouve qu'à l'état de nerfs palléaux fusionnés en arrière, comme on l'observe fréquemment chez les Patellidés. Ces nerfs, il est vrai, renferment quelques cellules ganglionnaires, mais le fait n'est point rare dans l'innervation palléale des Mollusques, et c'est vraiment exagérer que de transformer en cordons palléaux de Chitons, les nerfs palléaux des Patellidés. L'interprétation de M. Boutan n'est donc pas fondée, mais le fût-elle, ce n'est pas entre les Patellidés et les Fissurellidés que devraient se placer les *Helcion*, mais bien entre les Chitons et les Pleurotomaires.

Troques, sont palléaux dans leur partie supérieure, pédieux dans leur moitié inférieure; avec MM. Haller, Pelseneer, Thiele, etc., qu'ils sont les homologues des cordons pédieux des Patelles, des Nérites, des Cyclophores, des Paludinés, des Cyprées, et des ganglions pédieux de tous les autres Gastéropodes, abstraction faite de la masse ganglionnaire palléale un peu plus abondante qu'ils renferment. Nous différons des uns et des autres en attribuant une nature mixte, à la fois palléale et pédieuse, aux centres ganglionnaires (ganglions pédieux de tous les auteurs), condensés ou non, qui envoient des nerfs à la masse musculeuse complexe qu'on désigne sous le nom de *pied* chez tous les Gastéropodes. Les Pleurotomaires se distinguent de tous les autres Mollusques de la classe en ce que la masse ganglionnaire palléale ne tend pas encore à isoler sa partie antérieure, et reste en relation, dans toute son étendue, avec la masse ganglionnaire pédieuse.

Nature de l'Épipodium des Prosobranches.

La comparaison des Diotocardes avec les Pleurotomaires et les Monotocardes nous ayant conduit à établir la nature mixte des cordons ou des ganglions qui se rendent au pied des Gastéropodes, il nous est facile maintenant d'interpréter comme il convient la frange pariétale connue sous le nom d'*épipodium* qui borde la partie supérieure du pied, chez la plupart des Diotocardes et chez certains Monotocardes tels que la Janthine.

Il est un fait bien établi par tous les auteurs, c'est que les nerfs de l'épipodium sont précisément les nerfs latéraux de MM. Béla Haller ('84, 20) qui naissent du ruban supérieur du cordon palléo-pédieux. M. de Lacaze-Duthiers l'a, depuis longtemps, montré dans l'Haliotide ('59), plus récemment, M. Boutan a observé la même disposition chez la Fissurelle, ('86) et M. Béla Haller ('84, 94) chez les Diotocardes qu'il a étudiés.

M. Pelseneer ('90, 91), qui a consacré plusieurs mémoires à cette question, ne met pas en doute ce fait, mais il en conteste la valeur en objectant que les nerfs de la partie antérieure de l'épipodium chez les Diotocardes, partent du connectif cérébro-pédieux et que, parmi ceux de la partie postérieure, certains sont mixtes et prennent à la fois leur origine dans les deux rubans des cordons. Pour ce qui est du premier point, l'observation de M. Pelseneer est exacte, mais n'a pas l'importance que lui attribue cet auteur. Si l'épipodium "était palléal, dit M. Pelseneer, il est bien évident que, dans cette région, il devrait être innervé partiellement par le connectif cérébro-pleural." Cet argument ne nous paraît pas fondé, car les connectifs sont formés de fibres nerveuses, et ne peuvent dès lors, donner naissance à des nerfs. Il s'agirait de savoir si les fibres épipodiales qui se détachent des connectifs cérébro-pédieux prennent naissance dans le ruban supérieur ou dans le ruban inférieur du cordon et, jusqu'ici, personne ne nous a fixés sur ce point. Mais si l'on observe que les nerfs épipodiaux postérieurs se détachent tous du ruban supérieur, il y a des raisons pour croire que ceux issus des connectifs cérébro-pédieux prennent aussi leur origine dans le même ruban et que s'ils émergent des connectifs précédents, c'est que ceux-ci sont externes par rapport aux connectifs cérébro-palléaux et, par conséquent, plus rapprochés de l'épipodium. Il ne faut pas oublier, en effet, que les nerfs se rendent, par la voie la plus directe, à leur champ de distribution particulier et, ici, cette voie ne saurait être que celle des connectifs cérébro-pédieux. Si, comme l'affirme M. Thiele ('92), certains nerfs épipodiaux paraissent se détacher des ganglions cérébroïdes, leur origine réelle devrait être, à notre avis, dans le ruban supérieur des cordons.

Quant aux nerfs épipodiaux qui, d'après M. Pelseneer, prendraient leur origine à la fois dans les deux rubans de chaque cordon, il y a lieu de croire que ce sont des nerfs mixtes, dont certaines branches se rendent à l'épipodium et d'autres dans les parties avoisinantes de la sole pédieuse. La dissection de toutes les branches d'un nerf du pied étant des plus pénibles, il ne sera pas facile de donner des arguments pour ou contre cette manière de voir; mais ce qu'il y a de bien certain, c'est que, chez les Diotocardes très primitifs, tels que les Pleurotomaires, les nerfs mixtes sont beaucoup moins concentrés que dans les autres formes du groupe, et présentent encore au dehors deux racines, l'une qui se détache du ruban inférieur, l'autre qui émerge du ruban supérieur.

Chez les Janthines, ainsi que l'un de nous (*Bouvier*, '86, 91, Pl. III, Fig. 2) l'a établi, les nerfs de l'épipodium naissent tous des deux ganglions pédieux et paraissent dès lors être de nature exclusivement pédieuse. Mais cette apparence n'est point d'accord avec la réalité: les nerfs de l'épipodium des Janthines sont les plus supérieurs du pied, comme ceux de la partie columellaire pédieuse, et sont dès lors de nature palléale comme ces derniers. Cela revient à dire, comme nous l'avons établi précédemment, que les ganglions du pied sont de nature mixte, à la fois palléaux et pédieux.

Nous laissons de côté les formations latérales des Patellidés du genre *Lottia* (*Helcion*) qui sont innervées par le cordon pédieux. M. Pelseneer ('90, 152) tient ces formations pour épipodiales, mais M. Béla Haller ('94, 73–76) et tout récemment M. Boutan ('98) ont établi qu'elles sont de nature glandulaire et sans homologie aucune avec l'épipodium. Fût-elle même épipodiale, son innervation par les cordons du pied ne prouverait nullement la nature exclusivement pédieuse de l'épipodium, car les cordons du pied sont, nous l'avons dit, à la fois palléaux et pédieux.

De ce qui précède, il résulte qu'on doit, avec MM. de Lacaze-Duthiers et Boutan, considérer l'épipodium des Prosobranches comme étant de nature *palléale*, en donnant à ce mot la signification que nous lui avons attribuée précédemment. Tant qu'on n'aura pas établi qu'il provient d'un dédoublement du manteau, on ne pourra pas dire que l'épipodium a la même origine et la même nature que ce dernier, mais il est au moins pleural comme le manteau lui-même, comme le muscle columellaire et comme les régions des parois du corps qu'innervent les ganglions palléaux isolés.

Un mot encore, pour en finir avec cette question de l'épipodium. D'après MM. Béla Haller et Pelseneer, la division des cordons du pied des Diotocardes en deux rubans superposés serait due à la présence des nerfs épipodiaux qui se détachent de la partie supérieure des cordons, tandis que les autres nerfs du pied prennent naissance dans leur partie inférieure.

Pour nous, cette s paration des deux sortes de nerfs montre tout simplement que les deux rubans des cordons sont des centres ganglionnaires distincts et la preuve, c'est que le sillon qui les sépare n'est nulle part plus accentué que chez le *Pleurotomaria Quoyana*, espèce dont l'épipodium est, comme on sait, très peu développé. Si la séparation des rubans atteint son maximum chez les Prosobranches les plus primitifs, en dépit de leur épipodium très réduit, c'est que, selon toute vraisemblance, *ces rubans ne sont autre chose que des centres ganglionnaires primitivement séparés qui se sont rapprochés peu à peu, et ont fini par se fusionner suivant leur longeur. Au début, la ligne de démarcation des deux sortes de centres s'est trouvée indiquée par un sillon large et profond, puis la concentration s'accentuant, le sillon a disparu peu à peu, en même temps que s'isolait en avant* UNE PARTIE *de la substance ganglionnaire palléale sous la forme de ganglions palléaux distincts.*

Origine du Système Nerveux des Prosobranches.

Si l'on se demande maintenant quels sont les Mollusques dont le système nerveux a pu, en se modifiant, servir de point de départ à celui des Diotocardes, on est conduit à considérer les Amphineures, et principalement les Chitonidés, comme étant les formes qui se rapprochent le plus de ces Mollusques.

Système nerveux des Chitonidés et des Diotocardes. — Comme les Diotocardes, en effet, les Chitonidés (voir p. 233, Fig. A) sont pourvus de cordons ganglionnaires palléaux et de cordons pédieux, qui présentent entre eux et avec les ganglions voisins les mêmes relations essentielles. Ainsi que nous avons pu nous en convaincre par la dissection du *Chiton fascicularis* Poli et de l'*Acanthopleura Savatieri* Rochebr., les cordons ganglionnaires pédieux des Chitonidés s'étendent parallèlement sur toute la longueur du pied, ils émettent les nerfs pédieux proprement dits et sont mis en relation par des commissures transversales plus ou moins irrégulières dont certaines se bifurquent parfois et envoient des branches dans la sole pédieuse. Ces faits ont été mis en évidence par M. Béla Haller ('82), mais nos observations diffèrent de celles qu'a publiées cet auteur en deux points qui méritent d'être signalés : le premier, c'est que la commissure pédieuse antérieure est, comme l'a montré M. von Ihering ('77, 45, Fig. 4), plus volumineuse que les autres et régulièrement transversale ; le second, c'est que chaque cordon pédieux se rattache aux centres cérébroïdes du même côté par un prolongement qui s'atténue régulièrement d'arrière en avant. Ce prolongement anastomotique est muni de cellules nerveuses comme les cordons, mais, contrairement aux observations de M. Béla Haller ('82, Fig. 1) sur le *Chiton siculus* Gray, il est plus grêle que les cordons, surtout dans sa partie antérieure qui se rattache aux centres cérébroïdes ; c'est un connectif cérébro-pédieux encore riche en cellules ganglionnaires, et, si l'on rapproche de ce fait l'existence d'une commissure pédieuse grosse et régulièrement transversale, on trouve que les cordons pédieux des Chitonidés sont semblables, à tous égards, aux rubans pédieux des Diotocardes, surtout à ceux des Pleurotomaires et des Fissurelles, cordons qui se prolongent en avant de la grosse commissure, comme on sait et se continuent progressivement avec les connectifs cérébro-pédieux.

Mêmes homologies entre les cordons palléaux des Chitonidés et les rubans palléaux des Pleurotomaires. Ils donnent naissance, comme eux, aux nerfs du manteau et des muscles columellaires, et, comme eux aussi, envoient des branches aux viscères ; bien plus, chaque cordon palléal se met en relation avec le cordon pédieux du même côté par des anastomoses transverses très nombreuses. La présence de ces anastomoses est d'une grande importance pour éclaircir le problème qui nous occupe ; elle montre que les cordons pédieux et palléaux des Chitonidés ne sont pas plus indépendants que ceux des Diotocardes, et qu'il suffira d'un raccourcissement progressif des anastomoses palléo-pédieuses pour que les cordons pédieux et palléaux de chaque côté arrivent à se confondre et forment des cordons palléo-pédieux semblables à ceux des Diotocardes. Les anastomoses palléo-pédieuses sont très nombreuses chez certains Amphineures vermiformes où elles ont été mises en évidence par M. Hubrecht ('81, '82) dans la *Proneomenia Sluiteri* Hubr.; M. von Ihering en avait trouvé une de chaque côté dans le *Chiton salamander* ('77, Fig. 47) et M. Béla Haller dans le *Chiton fascicularis* ('82, 11, 14); mais, depuis, M. Plate ('95^a, '96) et M. Thiele ('95) ont mis en évidence, chez divers Chitonidés, un ensemble d'anastomoses aussi riche que celui des *Proneomenia*, et nous avons observé le même fait dans le *Chiton fascicularis*.

Plus frappantes encore, si c'est possible, sont les ressemblances et les homologies qui existent dans la partie antérieure du système nerveux chez les Chitonidés et les Diotocardes. Les centres cérébroïdes des Chitons, il est vrai, sont moins condensés et émettent des nerfs sur toute leur partie commissurale, mais on sait que la concentration des mêmes ganglions est loin d'être complète chez les Diotocardes et que l'Haliotide, à ce point de vue, ressemble singulièrement aux Chitons. Au reste, les homologies qui nous occupent ne portent pas seulement sur la structure générale du système, mais s'étendent jusqu'à ses détails: les saillies labiales des Chitonidés ont la même forme et la même origine que celles des Diotocardes, et, comme chez ces derniers, donnent naissance à la commissure labiale (Fig. *A*, c^1) et à un certain nombre de nerfs labiaux; le système stomato-gastrique a la même forme caractéristique dans les deux groupes et se trouve au même état de concentration imparfaite, il occupe la même position sur les parois de la masse buccale et, fait plus remarquable encore, prend ses origines (*k*) au même point sur la saillie labiale des centres cérébroïdes. D'après M. Béla Haller ('94, Fig. 1), on retrouverait même, chez les Patellidés, les ganglions subradulaires qu'on observe chez tous les Chitons.

Ayant montré les homologies étroites qui existent entre le système nerveux des Chitonidés et celui des Diotocardes, il nous reste à interpréter les dissemblances qu'on observe dans le même système, entre les deux groupes. La plus importante, celle qui, à vrai dire, domine et comprend toutes les autres, c'est la forme et l'étendue particulière du système ganglionnaire palléal chez les Chitonidés. Grâce à la position du manteau qui, sous la forme d'une frange épaisse, entoure le corps des Chitonidés et passe juste au-dessus de la bouche et de l'anus, le système ganglionnaire palléal des Chitonidés forme un anneau allongé parfaitement clos qui passe lui-même, comme le manteau, au-dessus de la bouche et de l'anus. Produit par une concentration nerveuse très peu accentuée, cet anneau palléal a conservé des relations étroites avec les centres nerveux voisins : en arrière de la région céphalique, nous avons vu qu'il se rattachait aux cordons pédieux par de nombreuses anastomoses ; dans la région céphalique, à cause de la superposition du manteau et des lèvres, l'anneau s'est fusionné avec les centres cérébroïdes et ne s'en distingue plus que par un sillon (Fig. *A.*, *s.*). M. von Ihering ('77, 44, Fig. 4) s'est parfaitement rendu compte de cette coalescence et, avant tout autre, s'est efforcé de mettre en évidence la nature complexe des centres ganglionnaires antérieurs des Chitons. Nous ne voyons pas pourquoi M. Béla Haller ('82, 4) a essayé de combattre une opinion aussi juste ; il suffit de jeter un coup d'œil sur le système nerveux d'un Chiton pour acquérir la conviction que M. von Ihering a dit vrai. Bien plus, les figures de M. Béla Haller ('82, Fig. 32) établissent elles-mêmes manifestement que le système nerveux céphalique des Chitonidés se compose de deux centres différents dont l'un innerve exclusivement le manteau, tandis que l'autre envoie une rangée de nerfs aux lobes céphaliques et une seconde à la région labiale. Nous faisons allusion à la coupe représentée dans la figure 32 du mémoire de M. Béla Haller sur les Chitons de l'Adriatique ; quant à la figure 1 du même travail, elle donne l'idée la plus fausse des relations qui existent entre les centres antérieurs et la partie libre des cordons palléaux, car les nerfs des lobes céphaliques

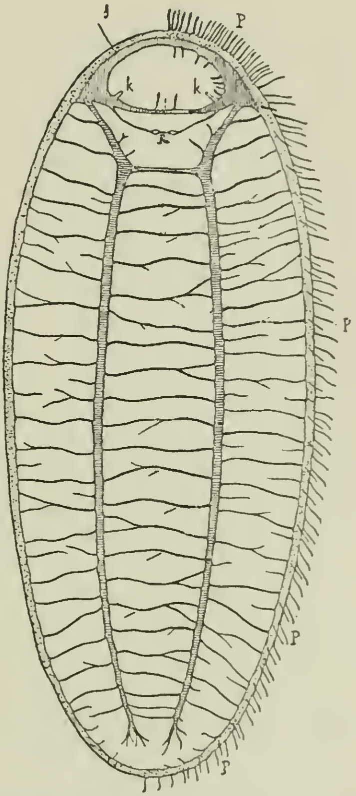

Fig. A. — Système nerveux du *Chiton fascicularis.* — P nerfs palléaux ; *s* sillon séparant les centres cérébroïdes de la partie antérieure des centres palléaux ; *k* origine du stomato-gastrique ; R ganglions subradulaires. (Dans cette figure et dans les cinq suivantes les centres cérébroïdes sont marqués de traits verticaux |||, les centres pédiaux de traits horizontaux ═ et les centres palléaux de ponctuations .....)

(nerfs 2 de l'auteur) y paraissent naître du ruban qui continue les cordons palléaux, tandis que les nerfs palléaux (nerfs 1 de l'auteur) et les nerfs labiaux prendraient leur origine dans la partie des centres antérieurs qui continue les cordons pédieux. C'est tout le contraire de ce que l'on observe en réalité, quand on étudie les Chitonidés.[1] Au reste, des traces manifestes de la disposition particulière au système nerveux de ces derniers se rencontrent chez les Gastéropodes ; dans ces derniers, en effet, des fibres nerveuses de la commissure cérébroïde traversent les centres cérébroïdes eux-mêmes, et, par les connectifs cérébro-palléaux, se rendent aux ganglions palléaux (voir *Walter*, '63, Pl. IV, Fig. 1 ; de *Nabias*, '94, 14, Pl. IV, Fig. 79).

Une autre différence entre le système nerveux palléal des Chitonidés et celui des Diotocardes, c'est l'absence, chez les premiers, de toute commissure viscérale. Comme les Diotocardes, les Chitonidés émettent des nerfs branchiaux et viscéraux issus du système palléal, mais ces nerfs ne se rattachent pas à une anse viscérale fermée et vont séparément se rendre aux organes qu'ils desservent. C'est, nul ne le conteste, un état primitif auquel a dû faire suite un état où certains nerfs viscéraux s'anastomosaient d'un côté à l'autre par-dessous l'intestin ; toutefois, on n'a rien observé *jusqu'ici*, chez les Chitonidés, qui montrât le début de ces anastomoses. M. von Ihering avait cru trouver cette commissure primitive, dans le *Chiton cinereus* ('77, Fig. 4); mais il avait pris pour elle la commissure subradulaire, dont les origines ne sont pas, comme il le croyait, sur les cordons palléaux. Depuis, M. Haller a signalé dans le *Chiton fascicularis* ('82) et dans *le Ch. magnificus* ('94^a) une paire de nerfs palléaux antérieurs qui viendraient se fusionner dans des ganglions sous la partie antérieure de l'estomac ; mais les recherches de M. Thiele ('95) et de M. Plate ('95, '95^2, '96), quoique portant sur de nombreux Chitonidés, n'ont pas confirmé cette découverte, et les recherches les plus minutieuses nous ont conduits aux mêmes résultats négatifs que ces derniers. Malgré ces observations déconcertantes, tous les auteurs admettent, et nous admettons avec eux, que la commissure viscérale primitive a dû se produire par un procédé analogue et former

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[1] La même figure ayant été relevée dans presque tous les ouvrages classiques, il y a lieu de signaler, croyons-nous, les autres corrections qu'elle demande ; 1° la commissure pédieuse antérieure est plus forte que les autres ; 2° les connectifs cérébro-pédieux s'atténuent au lieu de se dilater au voisinage des centres cérébroïdes ; 3° la saillie labiale ne se détache pas de ces connectifs, mais bien des centres cérébroïdes ; 4° les racines du système nerveux subradulaire se trouvent sur le bord postérieur de la saillie labiale ; 5° de nombreuses anastomoses transversales rattachent les cordons pédieux aux cordons palléaux.

une anse sous-intestinale anastomotique, qui reliait entre eux les cordons palléaux. Les Chitonidés sont assez variables dans leur structure (Voy. *Plate*, '96, 176) pour qu'on puisse espérer y découvrir quelque jour les débuts de cette anse commissurale.

Modifications progressives du système nerveux des Amphineures et des Gastéropodes. — Puisqu'il est impossible de contester les homologies profondes qui existent entre le système nerveux des Chitonidés et celui des Gastéropodes primitifs, il nous faut indiquer maintenant le processus par lequel a dû passer le premier pour former le second. Quelle que soit l'idée que l'on se fasse du système branchial des Chitonidés, ou des formes voisines qui ont servi de point de départ aux Diotocardes, on doit admettre, avec M. Bütschli ('87) et les autres zoologistes que ce système était réduit à deux branchies chez les Diotocardes primitifs, que ces deux branchies étaient situées en arrière à droite et à gauche de l'anus, qu'elles étaient innervées par l'anse viscérale primitive dont nous avons parlé plus haut, et que l'ensemble de ce complexe anal s'est déplacé progressivement à droite et a fini par se placer en avant du côté dorsal, dans une cavité palléale située en arrière de la région céphalique. On sait que le résultat de ce déplacement a été la torsion en 8 de chiffre de la commissure viscérale chez les Prosobranches, et (ainsi que l'un de nous l'a montré (*Bouvier*, '92, '93) et comme M. Grobben ('94) et M. Pelseneer ('94) l'ont reconnu dans la suite) que les Gastéropodes à système nerveux orthoneure dérivent des Prosobranches diotocardes par un retour, vers sa position primitive, du complexe anal, et par la distorsion de la commissure viscérale qui a été la conséquence de ce déplacement rétrograde.

Ceci dit, nous allons examiner les divers stades qu'a dû suivre le système nerveux *chitonien* des Gastéropodes primitifs, des Prærhipidoglosses comme les appelle M. Plate ('95), pour arriver à se transformer en un système nerveux typique de Gastéropode.

Premier stade. (Fig. *B*). — Le manteau recule en arrière de la tête, qui fait de plus en plus saillie en avant, ce qui a pour conséquence de séparer complètement des centres cérébroïdes, les cellules ganglionnaires palléales qui formaient un ruban sur leur bord dans les Chitons ; il se forme ainsi, de chaque côté, un connectif cérébro-palléal à peu près dépourvu de cellules et les cordons palléaux, grossis dans leur partie antérieure, se prolongent plus ou moins sur ces connectifs. A l'autre extrémité du corps, la chambre qui renferme les deux branchies devient de plus en plus profonde, les cordons palléaux s'arrêtent à l'extrémité antérieure de cette chambre dont les bords sont innervés par deux nerfs anastomosés qui sont les prolongements, à peu près dépourvus de cellules nerveuses, des cordons palléaux. Telle est l'origine des nerfs palléaux primitifs; des branches nerveuses moins puissantes partent aussi de la commissure viscérale pour se rendre dans le manteau. En même temps, la coquille gagne en importance, les muscles columellaires se développent et se superposent au pied, dont ils constituent la partie supérieure. Les muscles columellaires et pédieux forment, de plus en plus, un ensemble morphologique distinct, et, par un raccourcissement progressif des anastomoses palléo-pédieuses, les centres ganglionnaires de ces muscles se rapprochent de plus en plus. — La forme orthoneure, qui réalise ce type, ne nous est pas connue; intermédiaire entre les Chitonidés et les Diotocardes, elle devait avoir un système nerveux peu concentré et différait par conséquent beaucoup du Prærhipidoglosse, à ganglions condensés, tel que l'a conçu M. Plate.

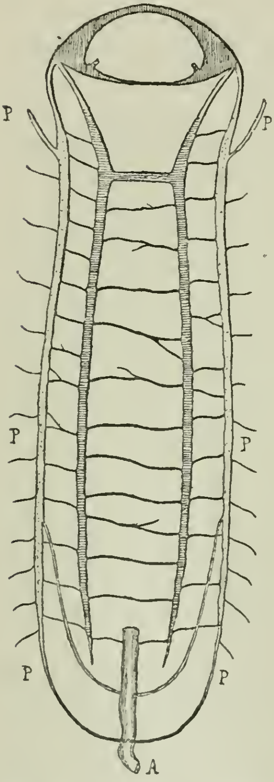

Fig. B. — Système nerveux hypothétique intermédiaire entre celui des Chitons et celui des Pleurotomaires. — P nerfs palléaux; A anus.

Deuxième stade (Fig. C). — La cavité palléale est plus profonde et vient peu à peu se placer dorsalement en arrière de la tête, ce qui amène le croisement de la commissure viscérale et le déplacement en avant de ses racines, qui sont issues, comme on sait, des cordons palléaux. Grâce au processus de condensation qui continue, ces derniers ont fini par se fusionner, suivant leur longueur, avec les cordons pédieux, pour former, de chaque côté, entre les muscles pédieux et une partie des muscles columellaires, un cordon unique où ils apparaissent, l'un sous forme de ruban palléal, l'autre sous la forme de ruban pédieux séparé du premier par un profond sillon. Au reste, la condensation ganglionnaire, dans le sens de la longueur, est encore fort peu avancée, et les deux rubans se prolongent en une corne, en avant de la grosse commissure des cordons, jusqu'aux connectifs cérébro-pédieux et cérébro-palléaux.

Le *Pleurotomaria Quoyana* se trouve précisément au stade que nous venons de signaler.

Troisième stade (Fig. D). — Ce stade ne diffère du précédent que par la condensation plus grande de tous les centres nerveux, et, dans bien des cas, par l'atrophie de la branchie droite des Pleurotomaires. Du ruban supérieur de chaque corne des cordons, et probablement des parties voisines de ces derniers, se sépare une corne dorsale exclusivement palléale ; des deux cornes qui se trouvent, dès lors, en avant de chaque cordon, celle qui est située du côté dorsal tend de plus en plus à grandir et à s'isoler, tandis que la corne ventrale se réduit progressivement, tant par le passage de sa partie palléale dans la corne dorsale, que par la condensation en arrière du ruban pédieux qui la compose. En même temps s'atténue le sillon qui sépare les deux rubans de chaque cordon. Les Fissurellidés, Haliotidés et Trochidés se trouvent à ce stade : leurs

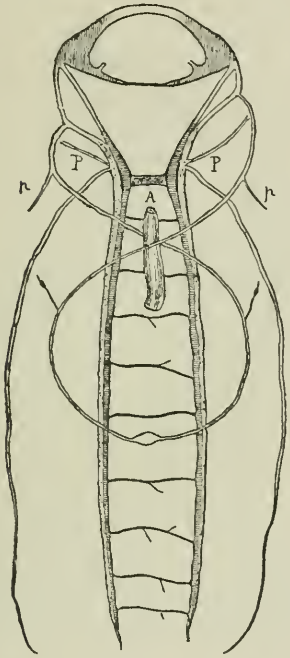

Fig. C. — Système nerveux du *Pleurotomaria Quoyana*.

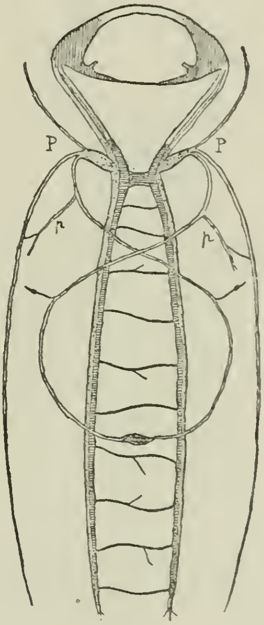

Fig. D. — Système nerveux dialyneure des Trochidés.

nerfs palléaux d'origine commissurale sont assez peu importants, mais s'anastomosent déjà avec les nerfs palléaux primaires.

Quatrième stade (Fig. E). — Les rubans palléaux et pédieux de chaque cordon se fusionnent complètement et l'on ne voit plus trace des sillons qui les séparent ; les cornes ganglionnaires dorsales forment des ganglions palléaux plus ou moins isolés et les cornes ventrales ont disparu. Les Patellidés, les Néritidés, les Hélicinidés, les Paludinidés, les Cyclophores et les Cyprées sont à ce stade.

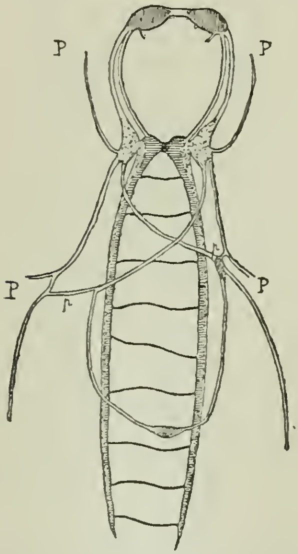

Fig. E. — Système nerveux presque zygoneure du *Cyclophorus*.

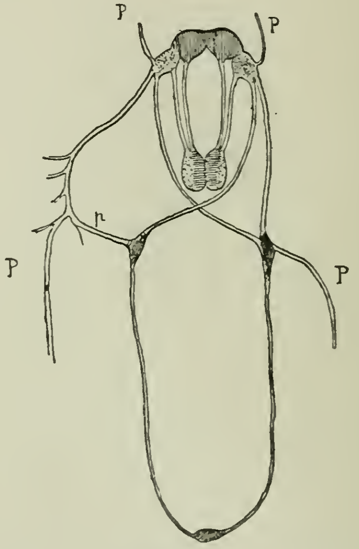

Fig F. — Système nerveux zygoneure du Triton.

Cinquième stade (Fig. F). — Les cordons palléo-pédieux se condensent suivant leur longueur et forment des ganglions palléo-pédieux ovoïdes, plus connus sous le nom de *ganglions pédieux ;* les cornes palléales deviennent des ganglions palléaux très distincts qui se rapprochent de plus en plus des centres cérébroïdes, du moins dans la majorité des cas. En même temps, on voit, chez les Prosobranches, les nerfs palléaux secondaires contracter des anastomoses de plus en plus étroites avec les nerfs palléaux primaires correspondants, ce qui conduit à la zygoneurie. Chez les Gastéropodes orthoneures, le complexe anal revient du côté droit, et la distorsion du système nerveux se produit à divers degrés.

Telle est, croyons-nous, l'idée la plus nette et la plus exacte que l'on puisse se faire de l'évolution du système nerveux chez les Gastéropodes. Muni de cordons palléo-pédieux profondément sillonnés et dépourvus de cornes palléales distinctes le *Pleurotomaria Quoyana* se trouve à un stade, inconnu jusqu'ici, qui permet de concevoir tous les autres et qui rapproche singulièrement les Gastéropodes archaïques des Amphineures, dont ils paraissent tirer leur origine.

Au reste, ce n'est point seulement par son système nerveux que le *Pleurotomaria Quoyana* se place, avant tout autre, en tête des Mollusques Gastéropodes. Avec ses branchies presque rigoureusement symétriques et égales, ses orifices rénaux (et génitaux ?) également pairs et symétriques, sa radule à régions mal délimitées, ses yeux en cupule ouverte à l'extérieur, et ses nombreux otolithes toujours petits et de dimensions inégales, il fait songer aux formes les plus primitives du groupe et permet de concevoir, mieux que par le passé, les formes plus primitives encore dont les Diotocardes sont issus.

Il est à présumer que des recherches anatomiques entreprises sur d'autres espèces du genre viendront combler les lacunes nombreuses que laisse forcément notre travail, et étendre plus sûrement le champ de généralisation que nous avons ouvert. A ce propos, qu'il nous soit permis de signaler aux zoologistes l'intérêt tout particulier qui s'attache aux origines de la commissure viscérale chez les Pleurotomaires ; situées sur les connectifs cérébro-palléaux dans le *Pleurotomaria Quoyana*, elles sont certainement fort curieuses et ne ressemblent guère à celles des autres Gastéropodes. Mais avant de chercher la raison de ces origines remarquables et d'en tirer parti pour expliquer l'origine des Gastéropodes, il faut être bien certain qu'elles ne sont pas spécifiques et secondaires, mais primitives et caractéristiques du genre. C'est un point important, sur lequel nous fixeront bientôt, il y a lieu de l'espérer, d'autres anatomistes.

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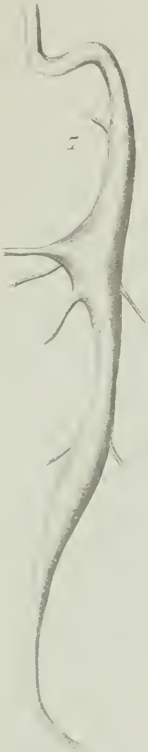

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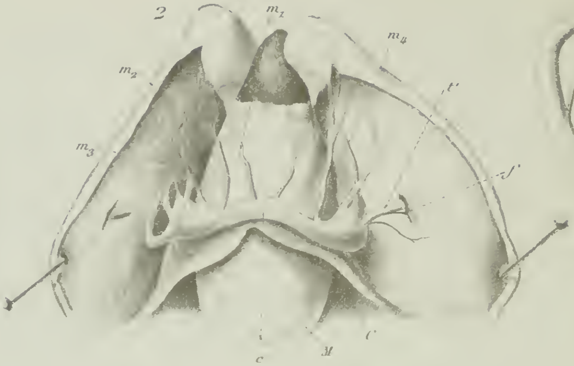

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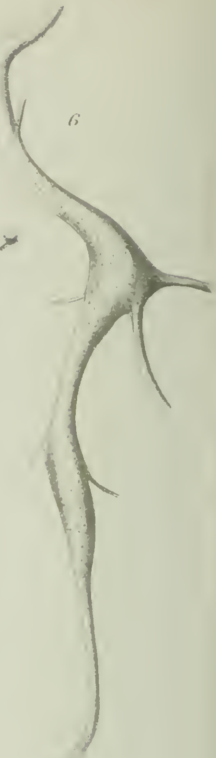

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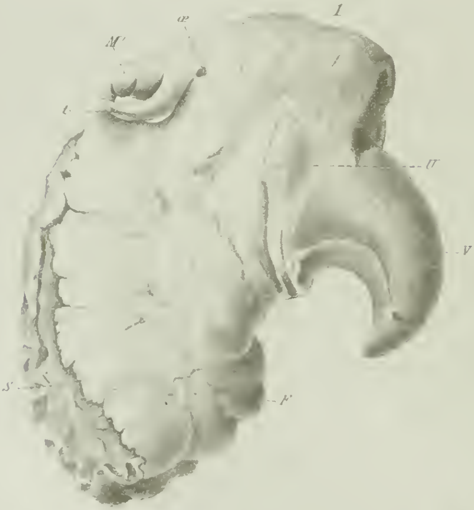

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EXPLICATION DES PLANCHES.

Lettres Communes.

Organes divers. — *Ao*, aorte antérieure ; F, pied ; *M*, masse buccale ; M', mufle ; *o*, otocyste ; *œ*, œil ; *t*, tentacule ; *U*, manteau ; *V*, muscle columellaire.

Ganglions. — *B*, ganglions buccaux (stomato-gastrique), *C*, ganglions cérébroïdes ; *L*, saillie labiale ; *Cd*, ganglion palléal droit ou corne palléale supérieure droite ; *Cg*, ganglion palléal gauche ou corne palléale supérieure gauche ; C^1, corne palléale unique des Pleurotomaires ; *Ps*, partie palléale des centres nerveux du pied ; *Pi*, partie pédieuse des centres nerveux du pied ; *s*, sillon palléo-pédieux.

Commissures, connectifs, nerfs. — *c*, commissure cérébroïde ; c^1, commissure labiale ; *h*, branche sus-intestinale de la commissure viscérale ; h^1, branche sous-intestinale de la commissure viscérale ; *k*, connectif cérébro-buccal ; k^1, connectif cérébro-pédieux ; k^2, connectif cérébro-palléal ; *i*, commissure palléo-pédieuse ; *f*, nerf optique ; *o'*, nerf acoustique ; m^1, m^2, m^3, ... nerfs labiaux ; s^1, s^2, s^3 .... nerfs buccaux ; *t'*, nerf tentaculaire ; *p*, nerfs pédieux ; *p'*, nerfs pédieux antérieurs ; *pu*, nerfs mixtes (palléo-pédieux).

PLANCHE I.

Fig. 1. Exemplaire de *Pleurotomaria Quoyana*, tel qu'il nous a été communiqué, vu du côté gauche. *S*, sole pédieuse.

Fig. 2. Région céphalique du même, ouverte sur la ligne médiane dorsale.

Fig. 3. Cavité antérieure du corps du même exemplaire ouverte sur la ligne médiane dorsale ; la masse buccale est enlevée. *S*, sole pédieuse ; *d*, nerf issu de la branche sus-intestinale de la commissure viscérale.

Fig. 4. Partie antérieure du cordon palléo-pédieux gauche, vue par sa face externe. *a*, a^1, a^2, nerfs issus de la partie palléale.

Fig. 5. Partie antérieure du cordon palléo-pédieux droit du *Turbo radiatus* Gmelin, face externe ; *a*, grand nerf palléal droit ; a^1, a^2, a^3, autres nerfs issus de la partie palléale du cordon.

Fig. 6 et 7. Branches gauche et droite du système nerveux stomato-gastrique dans le *Chiton fascicularis ;* les cellules nerveuses se concentrent de chaque côté en deux ganglions.

PLANCHE II.

Fig. 8. Même préparation que celle de la Figure 3, mais le lobe antérieur du pied ayant été fendu et la cavité antérieure largement ouverte, on peut voir les parties nerveuses qui avoisinent le pied. *v*, tronc vasculaire qui paraît plonger dans le pied en s'y bifurquant; *e*, *b*, *b′*, nerfs pariétaux qui se détachent des connectifs cérébro-palléaux; *c* et *c′*, nerfs pariétaux ou columellaires issus des connectifs cérébro-palléaux; *l*, *l′*, nerfs columellaires postérieurs; *d*, nerf des parois dorsales.

Fig. 9. Même préparation que la précédente, mais la sole pédieuse a été étalée et en partie disséquée du côté ventral pour mettre à découvert les cordons palléo-pédieux. Lettres accessoires comme pour la Figure 8.

Fig. 10. Ganglion cérébroïde droit du *Pleurotomaria Quoyana*, vu par la face interne.

Fig. 11. Figure indiquant la disposition anatomique et les connexions des parties antérieures des cordons palléo-pédieux. La préparation est vue sous le même aspect (face inférieure) que celle de la Figure 9, seulement les cordons ont été disposés de telle sorte que celui de gauche est vu par sa face externe, tandis que celui de droite est vu par sa face externe en avant de la grosse commissure palléo-pédieuse *i*, par sa face interne en arrière a, a^1, a'^2, nerfs émis par le ruban palléal du cordon gauche; a', a'^2, a'^3, nerfs émis par le ruban palléal du cordon droit. Les autres lettres accessoires comme dans la Figure 8.

Fig. 12. Système stomato-gastrique du *Pleurotomaria Quoyana*.

Fig. 13. Partie antérieure des cordons palléo-pédieux de la *Cemoria noachina*, L., d'après M. Béla Haller ('94, Fig. 142). *C′*, cornes inférieures ou palléo-pédieuses; *Cg*, *Cd*, cornes supérieures purement palléales (ganglions palléaux gauche et droit).

PLANCHE III.

Fig. 1. Une demi-rangée de gauche de la radule, vue par-dessous. × 50.

Fig. 2. Dent impaire et quarante-trois premières dents du côté gauche. × 50.

Fig. 3. Région antérieure d'une rangée; dent impaire, les trois premières dents droites; les huit premières dents gauches. × 70.

Fig. 4. Dent impaire, vue de profil. La ligne d'insertion est à droite. × 70.

Fig. 5. Dent impaire, vue par dessous et un peu de trois quarts. × 70.

Fig. 6. Dent impaire montrant, vue de trois quarts, la surface antérieure pourvue de ses deux expansions foliacées. × 70.

Fig. 7. Première dent gauche, du côté externe. × 70.

Fig. 8. Deuxième dent gauche, du côté externe. × 70.

Fig. 9. Troisième dent gauche, du côté interne. × 70.

Fig. 10. Les deux otocystes, avec l'origine des nerfs acoustiques. × 20.

Fig. 11. Groupe d'otolithes. × 500.

Fig. 12. Fragment de la radule, vu par dessous, limité à la longueur d'une rangée, montrant le mode d'insertion des dents. Sur les bords extrêmes, les téguments ont été enlevés sans laisser apercevoir, dans leur partie libre, les dernières dents flabelliformes × 20.

Fig. 13. Une mâchoire. × 8.


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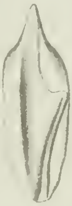
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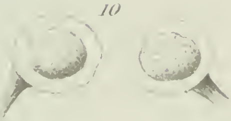
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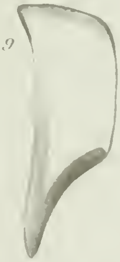
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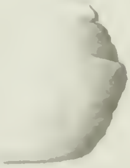
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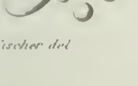
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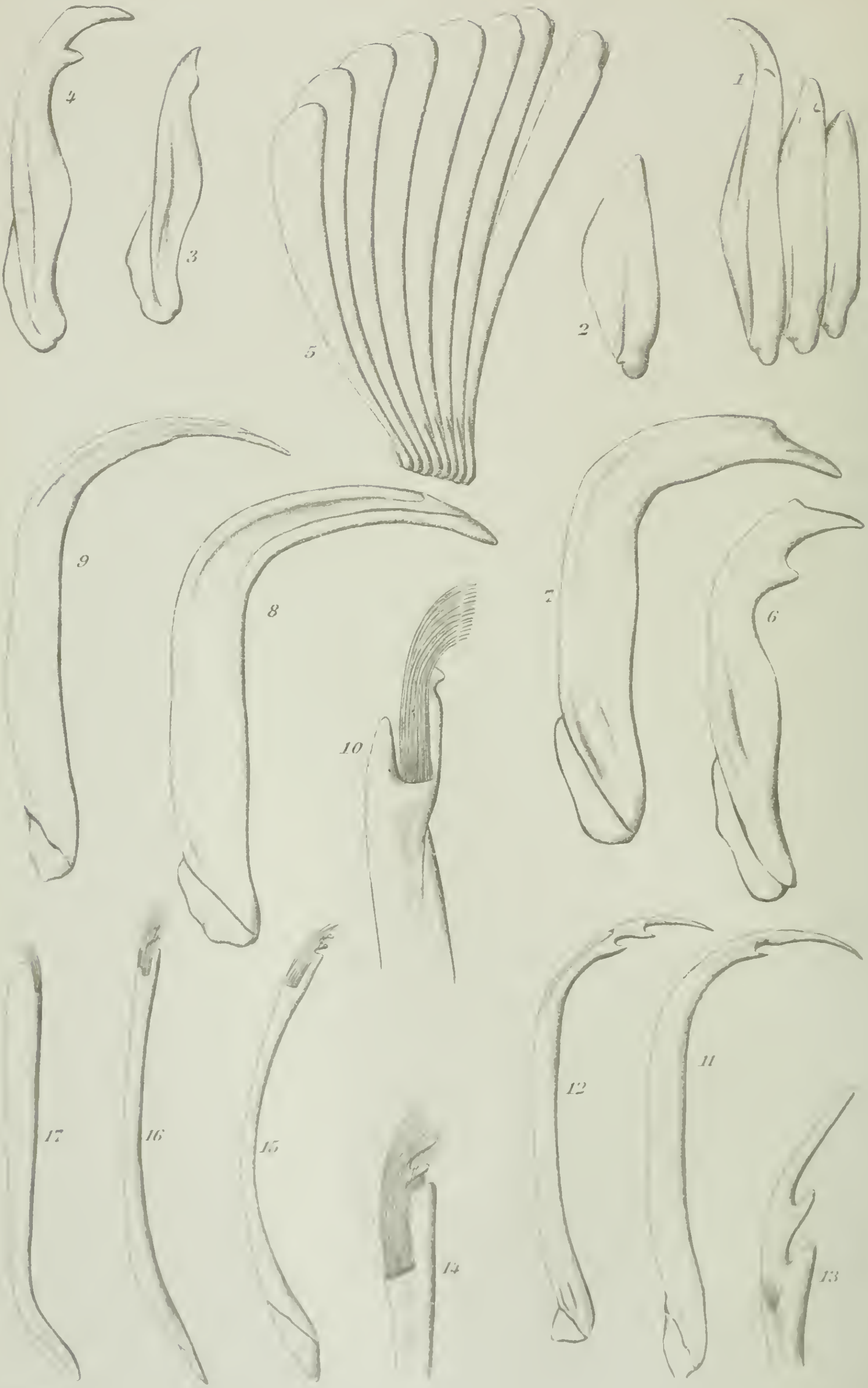

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PLANCHE IV.

Fig. 1. Groupe des trois dents 28, 29 et 30, du côté gauche. × 70.
Fig. 2. Vingt-huitième dent gauche. × 70.
Fig. 3. Vingt-neuvième dent gauche. × 70.
Fig. 4. Trentième dent gauche. × 70.
Fig. 5. Groupe des huit dernières dents (110–117) du côté gauche. × 70.
Fig. 6. Trente et unième dent gauche. × 70.
Fig. 7. Trente-troisième dent gauche. × 70.
Fig. 8. Trente-septième dent gauche. × 70.
Fig. 9. Quarante-deuxième dent gauche. × 70.
Fig. 10. Extrémité supérieure de la cent neuvième dent gauche. × 260.
Fig. 11. Quarante-cinquième dent gauche. × 70.
Fig. 12. Quarante-huitième dent gauche. × 70.
Fig. 13. Extrémité antérieure de la cinquantième dent gauche. × 140.
Fig. 14. Extrémité antérieure de la soixante-sixième dent gauche. × 140.
Fig. 15. Soixante-sixième dent gauche. × 70.
Fig. 16. Cent troisième dent gauche. × 70.
Fig. 17. Cent neuvième dent gauche. × 70.

BULLETIN

OF THE

MUSEUM OF COMPARATIVE ZOÖLOGY

AT

HARVARD COLLEGE, IN CAMBRIDGE.

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THE ISLANDS AND CORAL REEFS OF FIJI.

By Alexander Agassiz.

With One Hundred and Twenty Plates.

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The Fiji Islands and Coral Reefs. By ALEXANDER AGASSIZ.

INTRODUCTION.

On our arrival in Suva the first day of November, 1897, we found the "Yaralla," a twin screw steamer of about five hundred tons, chartered from the Australasian United Steam Navigation Company, awaiting us. The boat proved admirably suited for our purpose, the managing agent of the company at Brisbane, Mr. Elliot Bland, and Captain Downs, of Sydney, having spared no pains in fitting her out.

Previous to our departure I shipped to Australia our outfit for dredging, sounding, and deep-sea towing, as well as all the materials necessary for preserving our collections. This equipment we found safely stored in the "Yaralla." Dr. W. McM. Woodworth and Dr. A. G. Mayer accompanied me as assistants. Dr. Woodworth and my son Maximilian have taken a large number of photographs illustrating the physiognomy of the islands and reefs. Dr. Woodworth devoted his time in part to the care of the Worms, and Dr. Mayer to the Acalephs of Fiji.

I have to thank the State Department at Washington for their kind offices in obtaining for me letters from the British Foreign Office to the Government of Fiji. Sir George O'Brien, the High Commissioner of the Western Pacific, gave us all possible facilities for visiting the different islands of the group. I am also indebted to the Hon. J. Stewart, Colonial Secretary, and to the Hon. W. L. Allardyce, Assistant Native Commissioner, for assistance and advice. To Dr. Corney and the Hon. John Berry I owe information of value regarding the existence of elevated reefs at points I have not examined. To Captain Calder, the agent of the Australasian United Steam Navigation Company at Fiji, I am greatly indebted for his exertions on our behalf. Finally, Captain R. Cocks, our pilot, and Captain Thomson, as well as the officers and crew of the "Yaralla," were indefatigable in promoting our interests. I have also to thank specially Sir William C. Van Horne and Mr. T. G. Shaughnessy, the President and Vice President of the Canadian Pacific Railway, for placing at our disposal a private car from

Montreal to Vancouver, and for despatching to Fiji a number of cases which could not be shipped via Australia. I am also under great obligations to Admiral Sir W. J. L. Wharton, R. N., and to Captain W. U. Moore, R. N., for their unceasing interest and advice while planning my trip to Fiji.

Thanks to the admirable charts of Fiji, which owe their origin to the surveys of the United States Exploring Expedition under Wilkes, and their elaboration in great detail by the subsequent British surveys of Captain Denham and Lieutenants Moore and Richards, it was possible to cover a great deal of ground by picking out from the charts the interesting and critical points for examination, and thus to make a very rapid yet fairly accurate survey of the coral reefs. The accuracy of the Admiralty Charts enabled us to enter safely into the lagoons, and to select our anchorages with confidence. The reproduction here of the Fiji charts, together with photographs of the most characteristic views, will better serve to give a faithful picture of the islands and reefs of Fiji than lengthy descriptions, and I hope in the discussion of the general questions to be able to illustrate my arguments either by references to the charts or to the photographs of a group of islands of which Dana says, "The facts from the Feejee Archipelago illustrate the subject well."[1] The larger scale charts of the Admiralty, such as those of Kandavu (A. C. 167), of the south and east coasts of Viti Levu (A. C. 167, 845, 905), of Vatu i'ra Channel (A. C. 379), of Makongai and Wakaya (A. C. 1250), of Suva (A. C. 1757), of Levuka Harbor (A. C. 1244), of Ovalau (A. C. 1249), of such islands as Nairai (A. C. 741), of Moala (A. C. 1252), of Ngau (A. C. 1251), and of Totoya (A. C. 1248), contain an inexhaustible fund of information regarding coral reefs, and would serve as an invaluable basis for a minute zoölogical and geological survey of any island group such as I attempted for the Tortugas.[2]

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[1] Dana, Corals and Coral Islands, p. 262.

[2] Mem. Am. Acad., Vol. XI. p. 107 (1883).

Cambridge, September 1, 1898.

NOTE. — Owing to my absence from Cambridge and to the delay in preparing the Plates for this volume its publication has been delayed until May, 1899.

SOME POINTS IN THE LITERATURE ON CORAL REEFS.

It will prevent considerable confusion if, before proceeding with the account of our expedition to Fiji, I should devote a few pages to the examination of some of the literature on coral reefs, in the light of the observations we made while at Fiji.

On looking over the literature on coral reefs, one cannot fail to be struck with the amount of irrelevant matter which has been passed down from writer to writer. Statements made on hearsay have gradually become facts. The observations of inexperienced persons receive general recognition. Special cases are discussed without reference to their limited or exceptional application. The whole question is often threshed out *de novo*, so that it is difficult to separate the new from the old. And, finally, information gathered from charts is substituted for observation in dealing with questions which the latter alone can settle. Every new investigator naturally adds important information from the field he surveys, and each has in his way described the numerous and varying conditions affecting the growth and existence of coral reefs in the tropical waters of the Atlantic and the Pacific. Recent explorations have only increased the number of questions to be solved regarding coral reefs; and until the whole field has been examined in the light of these questions, it is hopeless to attempt a general revision of the theories regarding the formation of coral reefs. A revision based upon a partial examination, though it be more extensive than that of our predecessors, is usually brushed aside with the statement that even if the exception described is true, the old theory may yet be true in some other atoll region. Of course, such criticism can never end, and we may go on searching forever for this imaginary atoll, or until the last remaining atoll has been hunted down.

In many quarters it has become a question of creed to uphold the Darwinian theory of subsidence as essential to the formation of atolls and of barrier reefs. Facts and arguments supporting other explanations are ignored or explained away in the most extraordinary manner. Regions which are cited by Darwin and Dana as typical become exceptions when shown to be no longer characteristic regions of subsidence. Typical barrier reefs become patch reefs, atolls are dubbed pseudo atolls; so that the regions where true barrier reefs or typical atolls, which owe their origin to subsidence, can be examined, are little by little becoming very restricted. In fact, if we are to judge of the regions not yet examined, and which have not been examined by Darwin and Dana, there remain as extensive regions of possible subsidence only such islands as the Marshall and Carolines, some of the atolls of the Gilbert and Ellice groups, and of the Paumotus. Yet, judging by analogy of the adjoining districts of Fiji and Tonga, and of the descriptions given by Dana of the Paumotus, and by what we may gather from the charts in the light of our own exploration, it would not be launching a very doubtful proposition to assert that even in these island groups we shall find that the explanations we have given of the formation of atolls and of barrier reefs applies equally well to them. This still leaves the field open for observations in some of the coral regions of the Indian Ocean, and of the East Indian Archipelago. But in the districts which have been described as typical by both Darwin and Dana, recent observations have shown that other and more natural explanations than the theory of subsidence are sufficient to account for the formation of atolls and of barrier reefs.

As is well known, Darwin's experience among coral reefs was limited to a part of Tahiti, to the west side of Mauritius, and to the Keeling Atoll. Though he passed through the Paumotus without examining any of the islands;[1] according to the narrative of the "Beagle," Darwin saw in the distance Honden Island, passed by Taiaro along the shore of Kauehi and sailed between Elizabeth Island and Fakarava (Wittgenstein) to Otaheite. Captain Fitzroy also sailed through the Navigator, Friendly, and Fiji Islands without anchoring anywhere. Dana[2] worked among the reefs at Tahiti, Samoa, and the Feejees, though he did not visit the Eastern Archipelago, limiting his observations to the larger islands, Viti and Vanua Levu and Ovalau. He "twice visited the Hawaian Islands, landed and gathered facts from fifteen coral islands, some of them in the Paumotu Archipelago;[3] one, Tongatabu, in the

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[1] Narrative of the Surveying Voyages of his Majesty's Ships Adventure and Beagle (1826–1836), Vol. III. p. 539. London, 1839.

[2] In "Nature" (September 17, 1874, p. 408), Dana reviews a new edition of Darwin's Coral Reefs suggesting that he had not given sufficient weight to the effects of temperature in limiting the distribution of coral reefs, and differing widely from Darwin as to the limits of the area of elevation and of subsidence in the Pacific. But in spite of minor differences he speaks of the "array of facts of his own (Darwin's) observations, which illustrate the growth of coral formation"; and subsequently, in 1885, when reviewing the whole subject again, Dana says in the American Journal of Science, Vol. XXX., August–September, 1885. p. 90: "The evidence which had satisfied him (Darwin) was satisfactory to me when I first learned of his views in Australia (in 1839), . . . and more decidedly later when I had been among the Friendly, Feejee, and other Pacific Islands."

[3] Honden, Dean, Aratica, Ahii, Raraka, Manhii, Kawehe, Metia, Clermont Tonnerre, and others examined by other members of the Exploring Expedition.

Friendly group; two, Taputeaua and Apia, in the Gilbert group, and five others near the equator, east of the Gilbert group: Swain's, Fakaofu, Oatafu, Hull and Enderbury Island, as well as the reef region of the Sooloo Sea and of the Straits of Malacca."

In my account of the coral reefs of the Sandwich Islands,[1] I have given a short *résumé* of the results of the principal investigations on coral reefs since the days of Darwin and Dana down to 1889. What has been done since that time will be found referred to in Bonney's edition of Darwin's Coral Reefs,[2] in Kent's "Great Barrier Reef," in Langenbeck's sketches[3] of recent work on the subject, as well as in the reports of the explorations I have carried on in the Bahamas and Cuba,[4] the West Indies,[5] Florida,[6] and the Bermudas[7] in the Atlantic, and of the expeditions I have made to the Galapagos,[8] the Great Barrier Reef of Australia,[9] and Fiji.[10]

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[1] Bull. Mus. Comp. Zoöl., Vol. XVII. p. 121 (1889).

[2] Professor Bonney (Coral Reefs, Darwin, 1889, 3d ed., Appendix II. p. 290), has evidently confounded the views of Professor L. Agassiz on the extent of the formation of the southern extremity of Florida by coral reefs, dating back to 1854, with those which I have published in 1877, in 1880, in 1888, and again in 1896. Neither Dall nor Heilprin has examined the Florida reefs; their studies have been devoted to other parts of the peninsula, and did not extend south of the northern limit of the Everglades. Their criticisms in both cases apply to the views of Professor L. Agassiz, as my observations were limited to the reef region, and did not encroach on the area examined by Dall or Heilprin. But I have plainly shown by the borings at Key West that the recent coral formation is of moderate thickness, not more than about fifty feet, and that it is underlaid by a substratum of tertiary limestones, occasionally coralliferous, of a thickness of nearly two thousand feet. The area probably covered by the coral reef of Florida at the time of its greatest expansion is approximately shown on Plate XVII., Bull. Mus. Comp. Zoöl., Vol. XXVIII. No. 2, 1896. I never made the statement quoted by Bonney that the recent coral reefs extended over any part of Florida north of the Everglades. On the contrary, I said in the conclusion of my memoir on the Tortugas and Florida Reefs (Mem. Am. Acad., Vol. XI. p. 116, 1883), "All this evidence tends to show that the coral reefs had little, if anything, to do with the building up of the peninsula of Florida, north of Cape Florida."

[3] R. Langenbeck, Die neueren Forschungen über die Korallenriffe, Hettner, Geog. Zeits., Bd. III., 1897, pp. 514, 566, 634.

[4] Bull. Mus. Comp. Zoöl., Vol. XXVI. No. 1, 1894.

[5] Three Cruises of the Blake, 1888, Vol. I. p. 66.

[6] Bull. Mus. Comp. Zoöl., Vol. XXVIII. No. 2, 1896.

[7] Ibid., Vol. XXVI. No. 2, 1895.

[8] Ibid., Vol. XXIII. No. 1, 1892.

[9] Ibid., Vol. XXVIII. No. 4, 1898.

[10] Am. Journ. of Science, February, 1898, Vol. V. p. 113.

An excellent account of the Samoan Reefs has been published by Dr. Krämer,[1] supplementing the earlier short notice of Dr. Graeff[2] on the reefs of the group; also interesting notes by Admiral Wharton,[3] on Submarine Banks of the Pacific. A careful account of the geology of the Friendly Islands by Lister,[4] published in 1891, seems to have escaped the attention of writers on coral reefs. A few notes on the reefs of some of the islands of the Bismarck Archipelago have been published by Dr. Dahl,[5] but the evidence he gives does not seem to me to warrant his conclusions. The great thickness of elevated reef he found (570 m.) may (as is the case elsewhere in the Pacific) not belong to the present epoch, as he takes it for granted, and no one supposes that elevation has necessarily always taken place uniformly either in time or space over any great stretch of territory.

The articles by Heilprin[6] and by Ortman[7] on what they call "Patch Reefs," do not seem to me to have any special bearing on the general theory of coral reefs. The existence of such "patches" has long been known and referred to by Darwin, and by many writers on coral reefs, as reef patches. These patches occur in localities where fringing reefs for local causes would not flourish except at a little distance from shore and play a very subordinate part in the physiognomy of the coast. I am at a loss to understand the statements of Ortman regarding the reefs of Kaneohe Bay on the north shore of Oahu. The accurate observations of Hartt[8] and of Rathbun on the moderate thickness of coral reefs off the coast of Brazil seem to have escaped Heilprin and Ortman, as well as other writers on coral reefs. Rathbun[9] has described the reefs along the Brazilian shore, and finds them all as "having very little height, but from the surface looking like massive structures." Hartt[10] and Rathbun have described the formation of extensive coral patches and the mode of

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[1] Ueber den Bau d. Korallenriffe, Kiel, 1897.

[2] Samoa, Journal d. Museum Godeffroy, Vol. I.

[3] Foundations of Coral Atolls, Nature, February 25, 1897, p. 390.

[4] On the Geology of the Tonga Islands, Quart. Jour. Geol. Soc. London, No. 188, 1891, p. 890.

[5] Zool. Jahrbücher, Bd. XI. p. 141.

[6] Proc. Acad. N. S. Phila., 1890, p. 313.

[7] Zool. Jahrb., Bd. VI. p. 632.

[8] Hartt, in Chapter IV. p. 174, of the Geol. and Phys. Geog. of Brazil, 1870, describes the islands and coral reefs of the Abrolhos and the Recife de Lixo, where exist the "chapeirões," as rising straight up from the bottom from a depth of forty to fifty feet.

[9] American Naturalist, Vol. XIII., June and September, 1879, Nos. 6 and 9.

[10] Geology and Physical Geography of Brazil, Boston, 1870.

building up columnar masses which may eventually reach the surface forming mushroom- or even bell-shaped structures, of which enlarging rims may meet, "resulting in the formation of a connected reef surface supported by many upright pillars underneath from forty to fifty feet high," the so called "chapeirões" of the Portuguese. These patches frequently occur near the shore along the margin of a fringing reef, but are best developed in the deeper water of the Abrolhos regions and between these and the city of Bahia, growing upon the submerged rocky ledge. The number of reef building corals in Brazil is quite small, and Nullipores seem according to Rathbun to play a very important part in the building up of the limestone reefs.

Professor Bonney[1] summarizes the position of the theory of coral reefs as now left (1889) in the following terms: "That this theory may have been expressed in terms a little too comprehensive, that there may be a larger number of exceptional cases than was at first supposed, is quite possible. . . . It may very possibly be found that, as remarked by Mr. Bourne, the history of coral reefs is more varied and complicated than was at first supposed, but it seems to me that, as the evidence at present stands, it is insufficient to justify a decision adverse to Mr. Darwin's theory as a general explanation."

Professor Bonney, in spite of his intention to present an absolutely unbiassed expression, has, in common with most geologists not familiar with coral reefs, retained the view of the correctness of Darwin's theory.[2] It can scarcely be said that the earlier examinations of coral reefs were made with the detail which has characterized the later explorations. The original work of Darwin was limited to a narrow field, and supplemented by data derived from charts and descriptions. Its correctness depends wholly upon the existence of masses of coral reefs of great thickness, where coral reefs exist as barrier reefs or atolls, and having assumed this the rest naturally followed. For no one will deny that subsidence is one of the possible modes of formation of masses of limestone of great thickness. But subsequent observers showed most distinctly that both atolls and barrier reefs occurred in regions of elevation. These exceptions are not limited to a single area. They occur in regions of the globe widely separated. While it undoubtedly is true, as remarked

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[1] *Loc. cit.*, p. 332.

[2] Dana's support of Darwin's theory, based as it was upon very great experience among coral reefs, has probably been the principal cause of the general acceptance of the theory in late years, in spite of the attacks of recent investigators.

by Professor Bonney,[1] that Darwin has noticed most of the causes on which stress is laid by his critics, it should also be remembered that Darwin did not observe the phenomena subsequently examined, but merely suggested them as possibilities, and his critics may be excused for giving their observations a relatively greater value than to his theoretical views.

The whole argument of the great thickness of coral reefs based upon the analogy of the so called raised reefs of Cuba, described by Prof. Crosby and myself, or of the fossil reefs, is of little value, as it has been pretty conclusively shown that these elevated reefs, not only in Cuba but in the Pacific, are beds of tertiary limestone intercalated with beds of moderate thickness in which corals are found, and the same is true of older fossil reefs. Furthermore, these huge masses of tertiary limestone which form the substratum upon which both in Cuba and in the Pacific recent corals have found a footing, have played no part in the shaping of the barrier or encircling reefs, or atolls, which, as we have attempted to show, owe their origin in the main to mechanical causes.

Professor Bonney states that "Much stress is laid upon the fact that many coral islands afford evidences of a certain amount of upheaval; this amount, in most cases, is but slight, and its significance appears to me to have been exaggerated"; and he considers these indications to prove only oscillation. As far as the Fijis are concerned, the elevation extended over the whole group, and has been shown to amount to more than a thousand feet. In Australia it extended along the whole east coast of Queensland for more than a thousand miles, and was more than twenty-five hundred feet in height! He further says, "If the coral reef be only a sort of cap concealing a hill of pre-existent rock, we may reasonably be surprised that the 'ashlar rock' of coral limestone has in no case so far yielded to the action of the atmospheric agencies as to lay bare its inner support." We can answer this point most decidedly. In Florida the substratum underlying the recent coral reefs crops out at many places, and the highest points of some of the Keys consist of it. So do some of the hummocks in the southern part of the Everglades near Key Biscayne. In the Bermudas the greater part of the land of that group consists of the æolian rocks which underlie the recent coral reef. In the Bahamas the same is the case, and along the northern coast of Cuba the tertiary limestone forming the substratum of the recent reefs crops out in all directions, while in Australia rocks underlying the Great Barrier

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[1] *Loc. cit.*, p. 324.

Reef can be traced as islands, islets, or negro-heads all along its line for more than a thousand miles. Finally, in the description of the islands of Fiji this substratum appears over and over again, either composed of volcanic rocks, or of great tertiary limestone banks. No better example can be found of the appearance of the substratum of the recent reefs than in Kaneohe Bay, Oahu, at the Sandwich Islands, where the reef is studded with islets and negro-heads consisting of volcanic rocks.

That corals grow in lagoons is well ascertained, and nowhere is it better seen than in Fiji, where nearly all the islands enclosed by barrier reefs are edged with fringing coral reefs. But why that should prevent a lagoon from being formed I cannot see. A lagoon is not bounded by a reef forming a closed wall rising well above the level of the sea. The greater part of the reef of many a lagoon of an atoll or barrier reef has from two to three fathoms of water upon it at high tide. The reef is also riddled on all sides with narrow channels or openings with from one to two fathoms or more at low tide, in addition to the wider and deeper passages to leeward, through which access is gained into the lagoon. But for all this the lagoon exists, while it may not have more than a few fathoms in maximum depth. This, however, does not prevent the coral heads on the inner slope of the reef from gradually becoming connected with the reef, and from encroaching little by little, but very slowly, upon the outer margin of the lagoon to a depth of seven or eight fathoms, at which the growth is checked either from the sediment accumulating on the floor, or from the strength of the currents scouring the bottom of the lagoon. The amount of dead coral which is ground up upon a reef flat is considerable. Much of it is cemented together and forms a breccia in the cavities of the coral heads, or in the open spaces between them. Still more of it is changed into sand and mud, which cover the floor of the lagoons of barrier reefs and of atolls, and finally a quantity is carried off in solution after the dead coral has become thoroughly rotten and crumbling.

Darwin also visited the western side of Mauritius, where, he says:[1] "It is probable that a reef on a shelving shore, like that of Mauritius, would at first grow up not attached to the actual beach, but at some little distance from it; and the corals on the outer margin would be the most vigorous. A shallow channel would thus be formed within the reef; and this channel could be filled up only very slowly with sediment,

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[1] Darwin's Coral Reefs, 3d ed., 1889, p. 72.

for the breakers cannot cut on the shores of the island,[1] and they do not often tear up and cast inside fragments from the outer edge of the reef, while every streamlet carries away its mud through breaches in the reef. . . . A fringing reef, if elevated in a perfect condition above the level of the sea, would present the singular appearance of a broad dry moat bounded by a low wall or mound."

Darwin, when meeting Semper's objection that the existence of atolls or barrier reefs in a region of elevation was a fatal argument against his (Darwin's) views, is obliged to say that therein "seems to me no improbability in their having originally subsided, then having been upraised . . . and again having subsided." [2] He further says, "The existence of atolls and of barrier reefs in close proximity is manifestly not opposed to my views." Certainly not, but their existence in an area of elevation as claimed by Semper is. Darwin also says that, "When the land is prolonged beneath the sea in an extremely steep slope, reefs formed there during subsidence will remain closely attached to the shore, and will be undistinguishable from fringing reefs." [3] This seems to me impossible. The disintegration of the inner edge of the fringing reef, the action of the sea upon this disintegrated material, the solvent action of sea water, all will tend to form a channel between the outer parts of the reef and the shore, as is evidently the case in almost all fringing reefs, which show either an incipient channel where boats may circulate at high water, or a belt of considerable width in which the coral fringing the land has been killed by the silt brought down from the adjacent slopes, and has been decomposed, and, crumbling to sand or mud, is gradually being carried off at each high tide, forming a channel which when wide enough and deep enough becomes sufficiently prominent to change the fringing reef into a barrier reef.

The difficulties encountered in attempting to meet the many suggestions made by Darwin regarding reefs which he did not examine are well exemplified in the account which he gives of Rose Island, one of the Samoa group.[4]

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[1] This would depend upon the width and slope of the fringing reef. Many of the narrow fringing reefs in Fiji have a uniform slope towards the lagoon, and do not present the structure described by Darwin.

[2] Darwin's Coral Reefs, 3d ed., p. 228.

[3] Ibid., p. 229.

[4] Ibid., p. 212: "The lagoon is very shallow, and is strewn with numerous large boulders of volcanic rock." (Negro-heads, A. Ag.) He further says: "This island, therefore, probably consists of a bank of rock, a few feet submerged, with the outer margin fringed with reefs. Hence it cannot be properly classed with atolls,

Bonney[1] similarly takes Dana's account of the eastern half of the Fiji Archipelago, as if it were based upon actual observations. Dana did not visit that part of Fiji, but derived his information from the surveys of these islands made by the officers of the United States Exploring Expedition. His statements are derived from the charts.

TRACK OF THE "YARALLA."

The track which we followed (Plate 1) was so arranged as to include for our first trip one or two of each type of island, and of the different types of atolls and barrier and fringing reefs in the group. Starting from Suva the day after our arrival, we visited Mbengha, returned to Suva, and went in the following order to Ovalau, Wakaya, Makongai, and Koro, skirted along the western shores of Taviuni, examined the northeastern coast of the same island, passed out through the Matangi Passage to Motua Levu and Motua lai lai, and skirted along the western extremity of the Nanuku reefs. From there we steamed to Wailangilala, where we landed our boring apparatus and the crew of whites and of natives needed for working the same. We then turned north, passing close to Nuku Mbasanga and Adolphus Reef, and entered Ngele Levu Lagoon. We next examined the Ringgold Islands, paying special attention to Thombia in Budd Reef. From there we returned to a former anchorage off Thurston Point on Taviuni, and followed much the same track back to Wailangilala, where we found our boring party settled and at work. We then steamed south, examining Williamson Reef, the Kimbombo islets, Bell Reef, and entered the Vanua Mbalavu Lagoon through the Ngillangillah Passage. Passing out of the lagoon by the Tonga Pass, we touched at Mango, Tuvutha, Naiau, and Lakemba. We steamed past Aiwa, entered the Oneata Lagoon, visited Thakau Lekaleka, touched at Mothe, entered the Komo Lagoon, the Yangasá Cluster, and the Ongea Lagoon. We passed by Fulanga close to the entrance, which was too

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in which, as we have reason to believe, the foundations *always lie at a greater depth* [The Italics are mine. — A. AG.] than that at which the reef constructing polyps can live." Yet Dana and Wharton, as well as Krämer, say that it is an atoll, and the charts show it to be an atoll fully as much as any similar island in Fiji. So that if the islands in Fiji which resemble it, and which according to Dana and my own observations are atolls, yet according to Darwin they would not be so regarded, we shall have to seek for an atoll answering his requirements outside of the Fiji group.

[1] *Loc. cit.*, p 310.

shallow to allow our vessel to enter, but near enough to get an excellent idea of its characteristic structure. We next touched at Kambara, anchored in the crater of Totoya, made for Moala, and thence for Solo Lighthouse, examined the North Astrolabe Reef, steamed through the Great Astrolabe Reef, coming out west of Ono, examined a part of the northern shore of Kandavu, and then made for Vatu Leile, returning to Suva. On our second trip we visited Ngau, Nairai, the Horseshoe Reef, Mbatiki, and, entering the Moturiki Channel south of Ovalau, examined the inner side of the barrier reef as far as Mbau, and explored the barrier reef from Moturiki to Suva. During our third trip we steamed along the southern coast of Viti Levu, going as far west as Nandronga. Skirting the reef as closely as was prudent, we were able to follow the changes of the great barrier reef of Viti Levu west of Suva as it gradually passes into a fringing reef and disappears off the Singatoka River, to reappear again, first as a fringing reef, next as a barrier reef extending beyond the Nandi waters to the west of Nandronga. We then paid a second visit to Vatu Leile, which we had not been able to examine properly owing to bad weather, and returned to Suva, having steamed a little over thirteen hundred miles.[1]

While we were exploring the reefs in the vicinity of Suva, the "Yaralla" made two trips in charge of Captain Thomson, one to the Nandi waters entering through the Navula Passage, extending as far north as the Waia Islands to the south of the Yasawa group; the other passing close to Vatu Vara, Yathata, and Naitamba, on the way to Wailangilala in order to bring back the crew left there to carry on the boring.

THE PELAGIC FAUNA OF FIJI.

I brought with me deep-sea tow-nets of the various patterns used by the Prince of Monaco, by Dr. Giesbrecht of the Naples Zoölogical Station, and by Hensen on the "National" Expedition, in order to compare their efficiency with the Tanner deep-sea self-closing net in use on the "Albatross," and which I have adopted on my various expeditions. Unfortunately, our time in Fiji was so limited and the conditions for towing at great depths are such, among so many intercepting islands, that the results likely to be obtained seemed to make it unadvisable to

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[1] The Islands and Coral Reefs of the Fiji Group, by Alexander Agassiz, Am. Journ. Sci., Vol. V., February, 1898.

devote the time necessary for such a comparison. So nothing was done to test the comparative efficiency of the various deep-sea self-closing towing nets. When practicable we collected on the reef flats of various islands and atolls.

A number of hauls were made with the deep-sea Tanner net at several points in Fiji, such as the Strait of Somo Somo, off the Matangi Passage, off the west face of Nukusemanu Reef, off Blackswan Point, off the north point of Vatu Leile, across the eastern opening of Mbengha Passage, and off Suva Harbor. The depth at which we towed varied between one hundred and seventy-five fathoms and thirty fathoms to the surface. At the localities where each deep haul was made, a surface haul was also made. We were rather disappointed in the character of our catch. There were no great novelties; the number of Medusæ was usually quite small, but we obtained a large number of Crustacea.

The contents of the nets varied but little at the different localities. We obtained young Fishes, Fish eggs and Salpæ, Doliolium, Alcyopidæ, Copepods, Squillæ, embryos of Macrurans and Brachiurans, Sapphirina, Sergestes, Euphausia, several species of pelagic Macrurans, and Rhegmatodes, Halopsis, Agalma, the bell of a large Siphonophore unknown to me, Tamoya, many Diphyes, Ectopleura, Oceania, Berenice, Liriope, Polygordius, Tomopteris, Octopus, Mollusk embryos, Hyalea, Atlanta, Styliola, Tiedemannia, and other Pteropods. In fact, the pelagic fauna seemed singularly like that of the Straits of Florida, but far less abundant.

Mr. Mayer made also a number of surface hauls, and collected many species of Acalephs which had escaped the large tow-net, two species of a Rhizostome, a Eucharis, an Aurelia, and an Idya. The Sagittæ we collected were unusually large; Collozoon was quite abundant, and occasionally we collected Globigerinæ of a reddish tint, and other Foraminifera.

During our cruise we constantly passed long windrows of Algæ torn from the reefs, extended patches of a yellow Trichodesmium, and masses of leaves and flowers, and branches of all kinds of trees, floating at the mercy of the winds and currents.

It is interesting to note that the surface hauls made during our trip have developed the fact that the majority of the genera of Acalephs collected in Fiji belong to the same genera as those found on the east side of the Isthmus of Panama. The great geographical range in the Pacific of many of the genera of Echinoderms and of Crustacea as well as of Fishes found in the West Indies has already been noted. The collections of Acalephs made by the "Albatross" in 1891,[1] and those we have made in Fiji, show a remarkable similarity between the West Indian Acalephian genera and those of this part of the Pacific. We found in Fiji Linerges, Polyclonia, Aurelia, Halopsis, Tiaropsis, Gonionemus, Liriope, Bougainvillia, Eutima, Oceania, Aglaura, Eucharis, Idya, Agalma, two genera of Diphyes and Physalia, all genera occurring in the Gulf of Mexico. This will be brought out in greater detail by Mr. Mayer, who has in preparation a paper on the Acalephs of our Southern States, which will appear somewhat later than his report on the Acalephs collected at Fiji. This similarity will undoubtedly be found to extend to other groups of pelagic animals.

We were fortuuate enough to be at Levuka at the time of the appearance of the "Bololo." On the morning of the 17th of November we left the ship at three o'clock, bound for a spit named Bololo Point, about three miles south of Levuka. We had scarcely reached the spot when our guide put his hand in the water and pulled out one of the worms. In a few minutes the water was full of them, canoes put out from the shore, men, women, and children were wading on the reef exposed by the tide, with nets, and all kinds of utensils to catch Bololo. As the light increased, the Bololo increased, and at one time they were so plentiful that the water surrounding our boat must have been filled with them so thickly as to resemble vermicelli soup. A bucket put overboard seemed to contain nothing else. We made an excellent collection, and preserved a large number by different methods. We found, as we had expected, that their sudden appearance was connected with spawning; there were males and females swimming about full of eggs and of sperm. When in captivity they soon discharged these, the water became milky, and masses of dark eggs were left on the bottom of the dish. With the escape of the eggs came the collapse of the worm, and nothing was left but an empty skin scarcely visible. Thus the Bololo seems suddenly to disappear. The males are light yellowish brown, the females dark green. Their activity is something wonderful, and the bursting of the animal when it discharges its eggs is quite a peculiar phenomenon.

Dr. Woodworth made it an object to collect all the material that could be got together in regard to the Bololo, and he will prepare a paper on these interesting Annelids.

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[1] Reports on the Dredging Operations off the Coast of Central America, Mexico, off the Galapagos, and in the Gulf of California, in Charge of Alexander Agassiz, by the U. S. Fish Commission Steamer "Albatross," in 1891, in command of Lieut. Com. Z. L. Tanner, U. S. N. — XXI. Die Acalephen, von Otto Maas, Mem. Mus. Comp. Zool., Vol. XXIII. No. 1, 1897.

CLASSIFICATION OF THE ISLANDS OF FIJI.

It will greatly facilitate understanding the relations of the islands and coral reefs of Fiji, if we follow in their description a classification which will bring together islands and reefs of identical or similar geological structure.

We may take at first such volcanic islands as Koro, Ngau, and pass to the larger islands like Taviuni and Kandavu, finishing that class of islands with descriptions of Mbengha, Komo, and the like. We will take up next islands and reefs composed wholly of elevated coralliferous limestones like Marambo, passing to such islands as Namuka, Ongea, Fulanga, and to such reefs as Wailangilala and Ngele Levu. Next the island groups in which we find both volcanic and coralliferous limestones, such as Lakemba, Mothe, Vanua Mbalavu, Kimbombo, and the like, the two large islands of Viti Levu and Vanua Levu being treated separately. This will be followed by an account of the islands and reefs we did not examine, and finally by a sketch of the atolls, the geological structure of which could not be determined, and which might owe their origin to banks of submarine erosion, derived either from volcanic or from elevated coralliferous limestone islands.

Undoubtedly the islands of Fiji, whether of volcanic origin or of limestone, would vary greatly in the height to which they had been elevated. Naturally, the volcanic islands would be denuded and eroded to a less extent than the limestone islands, and the comparison of the islands in Lau might give us some idea of the extent of this erosion and denudation. The volcanic islands, consisting mainly of breccia, are of course far more rapidly eroded than if they consisted of compact volcanic rocks.

Of course some of the islands which have been named here as volcanic or as composed of tertiary limestones may prove on more extended examination to be composite islands, and in the rapid visit made to some of the islands we may not always have discerned their most characteristic features. Yet in a general way steaming between the islands, one cannot fail to be struck with the totally different aspect of the volcanic islands and of the islands composed of elevated limestone. A mere glance is sufficient to distinguish the rounded and gradual volcanic slopes (Plates 46, 51, 57, 58) from the flat-topped summits and precipitous cliffs characterizing the limestone islands (Plates 75, 76, 79, 86, 88, 90).

Gardiner has, as we have, classified the islands of Fiji into elevated limestone islands, into elevated limestone and partly volcanic, and into volcanic,[1] a division which Lister had previously applied to the Tonga group. Gardiner was, as we were, struck with the difference in the physiognomy of the islands, the volcanic islands, with their gentle slopes, rounded summits, or conical peaks, being in striking contrast to the flat-topped hills with precipitous sides, and the glistening white cliffs of the islands consisting of elevated coralliferous limestones.

I obtained from various localities in Viti Levu specimens of the older crystalline rocks belonging to the same series, which, according to Wichman[2] and Horne, have a very considerable extension both in Viti Levu and in Vanua Levu. The tufas and conglomerates are in many instances fossilliferous, and are considered by Martin as tertiary, not older than miocene. Wichman concludes that the larger islands must have existed as a continent during mesozoic and palæozoic periods, and that oscillations of level only took place in latest tertiaries. From the specimens examined by him, Wichman also concludes that Kandavu, Ovalau, Ono, and some of the Exploring Isles consist principally of andesites and basalts, and their tufas. According to Horne, Taviuni is the only island of the group which is of purely volcanic origin. This certainly is not the case. I would mention, among others, Moala, Thombia, and Totoya.[3]

VOLCANIC ISLANDS.

Koro.

Plates 3^a, 19^a, Fig. 8.

Koro is one of the larger volcanic islands which has not been greatly affected by submarine erosion. It is about ten miles long with a northern face of five, the east and west sides run to a point. The shores, with the exception of the southern part of the west coast, which runs nearly north and south, are bordered by a fringing reef extending about a mile and a half from shore; on the east coast the fringing reef is cut into small incipient lagoons (Nangaidamu Harbor), and has several boat harbors, generally opposite the mouth of a small river. On the north coast the reef patches extend nearly four miles from shore, forming an

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[1] Proc. Camb. Phil. Soc., Vol. IX. Part VIII. p. 457 (1898).

[2] Min. u. Petrog. Mittheil. v. Tschermak, Vol. V. Pt. I. p. 1 (1882).

[3] The specimens of rocks we collected in Fiji at the different islands are now under examination, and a report on them will follow later.

indistinct lagoon called Stone Axe Roads. The northeastern extension of the east coast fringing reef forms an open roadstead. This spur is covered with magnificient patches of coral in from one to three fathoms. One can trace from the long line of lava negro-heads — some of these are quite large — covering the reef flats, the former northern extension of the island. We could also trace to the south the low bluffs from the erosion of which have been formed the flats upon which the fringing reef has found a footing. A very strong current was flowing over the spur of Nathomaki Point, driven westward by the easterly trades.

The principal ridge of the island runs transversely across it from the southern point to its northeastern end. Its highest point is over 1,800 feet. The faces of the island are furrowed by deep valleys.

Mbatiki.

Plate 12.

We did not land on Mbatiki, but steamed close enough to the shores to obtain some idea of its characteristic features. The highest peak on the northern side is a little over 600 feet. There are two deep indentations, one on the west, the other on the south side. It is surrounded by a shore fringing reef from three points of which spurs extend parallel to the shore, impounding three narrow shallow lagoons with a depth of from three to five fathoms. The lagoons are full of coral heads. There are boat passes into two of the lagoons. The island is of volcanic origin.

Moala.

Plates 16, 57.

Moala is an island of volcanic origin, triangular in form, the eastern face indented by a deep bay, fully two miles long, by about three fourths of a mile in width, with sixteen fathoms in greatest depth. The highest point of Moala is over fifteen hundred feet. The ridges surrounding the deep bay have the appearance of being the rim of an extinct crater (Plate 57), broken to the eastward, some points of which rise from over twelve hundred to over fourteen hundred feet, the bay forming the bottom of the extinct crater.

The western part of the north coast is edged by a fringing reef extending nearly a mile off shore ; towards the east the fringing reef proper becomes quite narrow, while disconnected coral patches of considerable width extend towards the northeast extremity of the outer reef. The outer reef flats are narrow, and run in a southerly direction, forming an elbow opposite the eastern point of the island at a distance of from one to two miles, and enclosing the lagoon off the eastern face of the island, the continuation of the deep bay. South of the deep bay the outer reef nearly connects with the edging reef of the island, leaving a passage across the outer reef about a mile in width, the southern horn of which extends about three miles to the south, then in a westerly direction, then north until it strikes spurs of the fringing reef on the northwestern coast of the island, where the outer reef forms in connection with the fringing reef a series of reef flats full of coral patches and heads. The lagoon to the southwest of the island is also full of coral patches and heads, some of them of considerable size, which extend to Herald Roadstead, the northeastern part of the lagoon, which alone is comparatively free from obstructions. Owing to the presence of so many patches and heads the depth in the lagoon is most irregular. In Herald Sound it is as great as twenty-five fathoms, and somewhat less off the southwest and northern coasts. The characteristic heads which crop out from the shore at so many points are well illustrated by the heads composed of volcanic rocks which form the spit protecting the anchorage to the west of Naroi village, on the north shore of the island. Wherever we dredged we found that the bottom inside the lagoon consisted of fine volcanic mud mixed with coral ooze and broken shells.

DEEP BAY, EAST FACE OF MOALA.

There are two entrances to the lagoon on the east face, one opposite the deep bay, the other to the south, while on the west there is an entrance to Herald Sound (the lagoon of the southwest side of the island) near its northern extremity.

Ngau.

Plates 12, 13, 11^a, Figs. 1-3.

Ngau Island is about eleven miles long, by an average of nearly four miles in width. It consists of volcanic rocks; a high ridge runs along the middle with spurs separated by deep valleys extending towards the east and west coast. One of these spurs forms a deep bay on the northwestern coast. The peaks of the main ridge vary in height from 1,000 to over 2,300 feet. Ngau is protected on the east and north by a broad fringing reef of a width of over three miles. At the northern extremity and on the east face there are a few reef boat harbors, cut out of the fringing reef which also extends along the whole western shore as a very narrow fringe. As will be seen from the chart (Plate 13), the small reef harbors are without exception off the mouth of the mountain streams both on the north and east faces of the island; these in the rainy season bring down a large amount of mud and prevent the growth of corals at their mouth. From the southern end of the island extends in a northwesterly direction an outer barrier reef, varying in width from a quarter of a mile to three quarters of a mile. This reef is continuous being only broken in the middle by a narrow ship passage. The general depth of the lagoon is about twenty fathoms, with a greatest depth of twenty-nine. The western reef sweeps round the northern face of the lagoon, its eastern extension becomes broken into disconnected patches, and the greater part of the northeastern bay of the lagoon is filled with coral patches which connect it with the fringing reef of the north shore of the island. There are also numerous patches in the southern bight of the lagoon, and along the inner edge of the outer reef near the northwestern elbow of the reef. As far as we examined the reef of Ngau the reef flat was covered with most extensive patches of thriving corals.

There is a small island, Yathiwa, on the very edge of the reef forming the southern horn of Ngau. It holds to Ngau very much the same relation which Kobu Island does to Nairai, but is nearer the outer edge of the reef, while Kobu is in the lagoon surrounded by comparatively deep water.

Mambulitha Reef.

To the south of Ngau we could see the breakers giving the outline of Mambulitha Reef (Plate 12), separated from Ngau by a channel having a depth of 750 fathoms. This reef is pentagonal in outline, about one mile and a quarter long, is awash, has no opening, and encloses a shallow lagoon of pale green water, the sea breaking heavily upon the edges. I consider this reef as having been denuded and eroded to its present stage, which precedes that of a more sunken atoll, like Adolphus Reef, with a deeper lagoon.

Nairai.

Plate 11^a, Fig. 4, and Plates 12, 14, 58, 59.

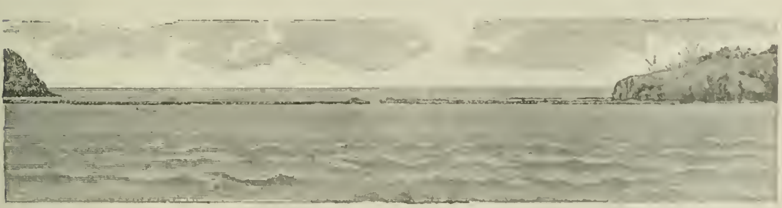
Nairai is a volcanic island, triangular in shape (Plates 12, 14), with sides of about four miles in length. Its central ridge forms an open arc to the east, its central peak rising to a height of over eleven hundred feet The western slope of the island is much less steep than the eastern side. (Plate 58.) The island is edged by a narrow fringing reef, with the exception of the most western point, where it expands into a broad fringing reef, the outer patches of which extend into the outer encircling reef. The encircling reef surrounding the island is a narrow reef flat, from a quarter to a mile distant from the eastern side, and from one to one and a half on the western side. But the prolongations of the horns of the outer reef to the northeast, south, and west are from four to five miles distant, forming thus three lagoons separated by long passages. (Plate 14.) The greatest depth in the lagoons is twenty-six fathoms off one of the western passages. The general depth is from ten to fifteen fathoms. The inner edge of the eastern outer reef is fringed with coral patches. This part of the reef is continuous, having only one boat entrance nearly opposite the southern extremity of the island. The western reef has two deep passages, and a boat passage near the southern horn of the atoll. This as well as the other points of the outer reef, both at the northeastern and northwestern horns, are studded with coral patches. The greater part of the lagoon, extending from the northern part of the island to the Nayatha Passage, is studded with rocks and coral patches, undoubtedly the remnants of fragments of the main island, which crop out in every direction within the lagoon, and as negro-heads upon the reef flats. Naikobu (Plate 59), or Magnetic Island, a small island to the south of Nairai, is one of these outlyers; it is ninety feet in height, the base running into ten fathoms, and is covered with corals. It is further remarkable for the great variation it causes to the compass. We observed on the top a westerly deflection of 87°. The bottom of the lagoon consists of fine coral, coralline sand, and broken shells, which form large white areas separating the coral patches and the numerous patches of coralline algæ which flourish upon the floor of this lagoon wherever we examined it. The corals of the fringing reefs of both Nairai and Ngau were growing specially vigorously.

Makongai and Wakaya.

Plates 3^a, 11^a, Fig. 9; Plates 3^a, 11^a, Figs. 7, 8, and Plates 15, 55, 56.

Makongai and Wakaya present features nearly identical. They are both long lines of narrow reefs, enclosing in the one case an irregularly triangular lagoon open on its northern face, and in the other an irregularly shaped parallelogram, with undulating sides and rounded corners. The island of Makongai is somewhat rectangular, with many indentations; it is of volcanic nature, and attains a height of nearly 900 feet. On its eastern face the encircling outer reef becomes its fringing reef at several points. It is separated by a narrow channel having a depth of twelve fathoms from Makondranga, a small island similar in structure to Makongai, about half a mile from the outer reef. The whole eastern encircling barrier reef is broken up into a number of small patches with boat passages between them. With the exception of one boat passage the western reef forms a continuous line of breakers, but on the northern side the reef patches are limited to rocks, grown over at the base with corals, judging from those we saw while passing into the lagoon.

NORTHWEST POINT OF MAKONGAI.



LEDGE OFF MAKONGAI.

Makongai is edged with a fringing reef. The islands in the Makongai lagoon are in the northeast corner close to the eastern face of the outer reef. The lagoon has a general depth of from thirteen to seventeen fathoms, with a greatest depth of twenty-one fathoms in the northern part. The southern part of the lagoon is full of coral patches, remnants of islands and islets similar to those of the small island of Tambaka, still connected with Makongai by a neck of boulders, which reaches to the westward as an extensive flat, and fringed below low water mark with flourishing patches of corals. Such a patch with a few angular blocks still visible above high water mark, lies off the southwest point of Makondranga, and many others off the southeastern face of Makongai. Corals within the lagoon grow in from seven to one or two fathoms. The rest of the bottom of the lagoon consists of coral and coralline sand.

LEDGE OFF MAKONDRANGA.

Makongai and Wakaya are connected by a narrow reef ridge about a mile in length. The island of Wakaya is nine miles long, triangular in shape, tapering to a point, and situated close to the western edge of the outer reef of the lagoon. A fringing reef edges its eastern face, while the extension of the outer reef forms the wider fringing reef of the western shore. Towards the south this part of the fringing reef encloses two secondary lagoons, one of which has a depth of five fathoms. The southern part of the outer reef is continuous; the northeastern face is broken by several passages, and there are three to the north of Wakaya on the western face. The highest point of Wakaya is nearly 600 feet, forming a range of steep bluffs along the northern part of the island, which slopes very gradually to the east. The southern part of the island is not more than 300 feet high, and is joined to the rest of the island by a comparatively low neck. The depth of the Wakaya Lagoon is greater on the average than that of Makongai; it reaches a maximum depth of thirty-six fathoms, with a general average depth of over twenty. There are comparatively few patches in the lagoon. The bottom consists of coralline sand and shells. We entered through the northern passage and crossed the lagoon, and on our way out examined the reef patches forming the boat passages to the south of it. On the shore of the bay, near the boat passage, we found a good deal of pumice. We found traces of elevation on the neck connecting the point on which Lieutenant Langdale's house is built.

We could not examine the corals on the weather face of the weather reef, but on the inner side and on the lee reef we found corals flourishing most luxuriously, mainly Madrepores, Pocillopores, Astreans, Mæandrinas, Fungiæ, and a few Gorgonians. They form a belt mainly between two and seven or eight fathoms, beyond which there seem to be only coral sand and corallines both on the inner and outer faces of the lee reef. With the disappearance of Wakaya through denudation and erosion, we should have an atoll with a substratum of volcanic rocks which very likely might be covered to a limited depth with islets of coral sand blown up from the encircling reef, — an atoll in no way to be distinguished by outward appearances from the theoretical atoll built up by corals and by subsidence.

Mbengha.

Plates 8, 11^a, Fig. 5, and Plates 46-49.

Mbengha Island is irregularly shaped, with three deep indentations, one on the western side, the others on the eastern, nearly cut off the high point forming the eastern side of Malumu Bay from the main body of the island. (Plate 48.) The principal ridge, running nearly north and south across the central part of the island, rises abruptly from the south to a height of over a thousand feet, and has several peaks attaining heights varying between 1,200 and over 1,400 feet. The secondary ridge to the east of Malumu Bay is somewhat less than a thousand feet. On the east face to the south of Solianga are exposed some fine bluffs consisting of volcanic conglomerate breccia. (Plate 46.) They are perhaps as good examples as we have seen of the great erosion and denudation which have taken place in this part of the Fiji group.

A more detailed view of the appearance of the volcanic rocks of Mbengha is given in Plate 47, an eroded shore bluff immediately in the rear of the beach at Rukua on the west side of Mbengha. Similar volcanic breccia bluffs are characteristic of many points in Fiji.

In adition to the main island there are three other islands. Moturiki and Stuart, which are small satellites of Mbengha, and Yanutha, a larger island near the western edge of the lagoon. These islands have the same geological structure as that of Mbengha. (Plate 8.)

Mbengha is on the eastern point of the lagoon, separated from the inner edge of the outer reef by a channel varying in width from a half to one and a quarter miles, with a greatest depth of twenty-three fathoms closer to the island than to the reef. The channel between Yanutha and the outer reef is about three quarters of a mile in width, with a depth of from eleven to thirteen fathoms. There are in addition a number of patches of coral rising from a depth of from ten to twelve fathoms, irregularly scattered over the western part of the lagoon and along the inner edge of the outer reef.

Mbengha and Yanutha Islands are enclosed within a long reef over thirty miles in length, forming an irregularly shaped pentagonal lagoon with rounded angles. The northern side is open, forming a passage fully five miles wide, and studded with patches. This part of the lagoon slopes very gradually from 17 fathoms to 130 or 140 fathoms in the centre of the Mbengha Passage, separating Mbengha from the island of Viti Levu.

The northeastern face of the lagoon is flanked by the Pratt Reefs, those upon which the low sandy Storm Island is placed, and the Nanuku Reef. There are several passages available for vessels on that side of the lagoon. The Nanuku, Sulphur, and Cutter Passages with a depth of from nine to thirteen fathoms. The southern and southwestern sides of the lagoon are flanked by a long unbroken coral reef, the Mbengha Barrier Reef, varying in width from half a mile to over a mile and a quarter, extending from Cutter to Frigate Passage. There is a small sand key about the middle of the Mbengha Reef on its inner edge. To the north of Frigate Passage the Yanutha Reefs form the northwestern side of the Mbengha Lagoon. They are separated by broad channels ending in the reef of Bird Island and a long line of patches, the Nisithi Rocks, which form the western spit of the wide opening on the northern side of the lagoon. As will be seen from the chart, the bottom of the Mbengha Lagoon is most irregular; it is very uneven, varying greatly in depth, and full of heads and patches overgrown with corals. The rocks and heads and patches are fragments of volcanic rock, the remnants of the island of Mbengha when it extended over the greater part of the area now enclosed by the outer reef,

— remnants left from the disintegration and erosion of the former greater Mbengha.

The bottom in the lagoon is a mixture of volcanic mud and coral sand in the vicinity of the islands, but as we proceed towards the reef it carries a greater admixture of coralline algæ and of coral sand, and in the belt adjoining the inner edge of the outer reef is made up entirely of fragments of coral, of coral sand, and of coralline algæ. In the central parts of the lagoon it is algæ and corallines.

The reef rises very gradually from seven fathoms to a depth of from two to three feet on the reef flat. This is covered with fragments of dead corals which increase in number towards the sea edge of the reef. The fragments are covered with algæ, corallines, and nullipores, which cement them together. In depths of seven to eight fathoms heads and clusters of corals begin to grow. They are separated by wide lanes of coral sand, and as we rise on the slope of the reef they grow more closely, forming a wide belt of thriving corals from six to three or two fathoms in depth, when they grow less profusely, and finally pass into the wide flat area of the outer reef, made up of broken corals and fragments, and large masses thrown up on the sea face of the reef, which are gradually being broken up by the surf beating upon the reef flat.

Storm Islet[1] (Plate 49) is an excellent specimen of a sand key thrown up by the waves upon the outer reef flats. It is somewhat less than three hundred yards long and about eighty yards wide. The beach is quite steep, protected by large patches of beach rock, which surround the southern extremity of the island. The crest of the island is covered with cocoanut trees, screw pines, and casuarinas, as well as with an outer fringe of bushes and shrubs.

STORM ISLET.

The greater part of the shores of Mbengha Island are edged with a fringing reef, and coral patches forming an irregular belt extend into six or seven fathoms in depth. As the sea breaks but little on the outer

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[1] Dana has called attention (Coral Islands, p. 241) to the advantage which coral island accumulations have over other shore deposits, "owing to the ready agglutination of calcareous grains," and, as he suggests, with the formation of coral sand rocks along the beaches and reef rock in the water a rock defence against encroachment is produced. So that limestone rocks thus formed will prove a most effectual barrier to the destructive action of the waves.

Mbengha Reef, I was able to examine the sea face of the reef, and found that in Frigate Passage both sides of the reef were flanked with large heads of corals beginning in from five to seven or eight fathoms. On the outer face, though corals were growing, there were no large heads, at about six fathoms we found Madrepores, Fungiæ, Pocillopores, small heads of Porites, Astreans, and of Mæandrinas and Gorgonians. This belt extended to the line of breakers pounding upon the reef flat. Outside of six to eight fathoms the corals seem to have disappeared, as the lead brought up nothing but coral and coralline algæ sand.

Kandavu.

Plates 10, 11, 50.

The extent of the erosion and denudation which has taken place along the coast of Kandavu is well exemplified by the John Wesley Bluffs near the village of Tavuki (Plate 10), and similar bluffs rising to the westward of Tavuki Bay. The John Wesley Bluffs (Plate 50) are a line of nearly vertical cliffs of volcanic origin cut into wide rounded lamellar masses, rising to a height of fully 500 feet on the east side of Tomba ni Tavuki. A part of the hill slopes on the west side of the bay are covered by the rounded tops of similar rocks cropping out on the surface, giving the slope the appearance of a graveyard crowded with dome-shaped monuments.

The heads studding the Bay of Tavuki, and forming the extension of the outer reef patches parallel to the coast, are covered with thriving corals, growing upon a substructure of volcanic rocks, as is clearly seen from the nature of the negro-heads cropping out in the bay.

With the exception of the broad fringing reef stretching to the west of Tavuki, the north shore of Kandavu is edged by a narrow fringing reef (Plate 10), and from Yale Point to Tomba ni Richmondi an indistinct barrier reef extends, made up of small distant patches, except where the Malatta Reefs enclose a wide bay north of John Wesley Bluffs, studded with coral patches and heads. The south shore of Kandavu is likewise edged with a narrow fringing reef in Soso and Kandavu Bays inside of the broad barrier reefs across their entrance. The islands and islets within the North Astrolabe Reef Lagoon are also edged with narrow fringing reefs.

The platform of submarine erosion extending north of the eastern extremity of Kandavu is one of the best examples of its kind we find in Fiji. The great lagoon, with its islands and islets, represents a stage of denudation and erosion somewhat more advanced than that existing on the eastern half of the south shore of Kandavu.

We cannot fail to notice also the greater width of the shore platform wherever the coast has a northerly trend, as, for instance, west of Tomba ni Richmondi on the north coast, and north of the John Wesley Bluffs, where the platform is edged by the Malatta Reefs and studded with heads and patches. On the northern coast, however, the fringing reefs are narrow, while on the south coast of Kandavu (Plate 10) they take their greatest development, exposed to the full sway of the southeast trades. A glance at Plate 11 cannot fail to show the relatively great width of the eastern belt of the encircling reef, as compared with that of the western side of the Great Astrolabe Lagoon.[1] In a smaller lagoon like North Astrolabe Reef, where the breakers pour over the eastern face, and water flows constantly over the western edge, the difference in the width of the reef on the two sides is not so marked.

While undoubtedly the width of a reef depends in great measure on the nature of the platform upon which it grows, yet I do not see the force of Lendenfeld's statement,[2] that while "lateral growth of corals no doubt takes place, it is not the actual cause of the formation of the great coral reefs." There certainly is nothing to prevent the swarms of embryos which float at certain times in the vicinity of a coral reef from attaching themselves and growing upon any surface within reach having the proper depth on both sides of any growing reef. Undoubtedly the extension within the lagoon, both in barrier reefs and atolls, of the coral heads is due to such a cause, and the wider the reef the closer do the heads come together as we pass upon the reef flat from the inner edge of the reef towards the outer margin. In an account of a discussion on coral reefs[3] by Sollas, Hickson, Rothpletz, and others, Stebbing stated that young corals might start on either rising or subsidence, but only subsidence is favorable. That, it seems to me, depends entirely on the depth at which they start; they may have 120 feet, and build up a reef of that thickness, which is fully as thick as most reefs we know anything about.

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[1] I cannot agree with Gardiner in his statement that the windward reefs of Fiji are of about the same breadth. (*Loc. cit.*, p. 492.) Compare the windward reefs of Mbengha, of the Great Astrolabe Reefs, and of the east coast of Viti Levu with the windward reefs of Wakaya, of Nairai, of Totoya, of the Budd Reef, of Kanathea, of the Exploring Isles, of the Argo Reefs, of Lakemba, of Aiwa, of Mothe, and of Ongea; the latter are certainly as a rule much narrower than the former.

[2] Nature, Vol. XLII. p. 31.

[3] Nature, October 12, 1893, p. 575.

Murray,[1] who visited Kandavu in the "Challenger," considers the banks of Fiji surrounding the extremities of volcanic islands as banks formed from the loose material of the islands spread out laterally by wave action, the extensive banks extending much farther seaward there in one direction than in another. Murray has also called attention to the North Astrolabe Reef, which, if its present condition with Solo Rock in the centre is due to subsidence, should have a very much deeper lagoon, instead of the comparatively shallow one characterizing that reef.

Great Astrolabe Reef.

Plates 11, 11^a, Figs. 10-13, and Plates 51, 52.

To the northward of the eastern extremity of Kandavu (Plate **11**) extends the Great Astrolabe Reef. Its eastern face is the extension of the reef to the eastward of Tomba ni Soso (Plate **10**), an irregularly shaped bay, the mouth of which is protected by a barrier reef. This barrier reef extends as a fringing reef along the southern coast as far as Kandavu Bay, where it becomes separated from the island and forms stretches of barrier reef patches, with passages leading into the bays protected by the reef.

West of the entrance to Ngoala Harbor a broad fringing reef extends along the southern coast nearly to the western spit of Kandavu. Several reef harbors are cut out from it, one of which, Tomba Yauravu, is of considerable size (Plate **10**). From Naingoro Pass the outer reef of the Great Astrolabe Reef runs unbroken in a northerly direction for a distance of 25 miles round its northern horn, as far as Usborne Pass, which is an entrance into the lagoon on the western side, about a mile from the apex of the Great Astrolabe Reef. Off Mbulia, the easternmost of the islands inside the Great Astrolabe Reef, the eastern encircling reef makes a sharp elbow, and then forms a double curve in a northwesterly direction to the narrow apex, from which the reef turns sharply south as far as Alacrity Rocks in a great narrow arc broken in many places. North of Ono Island there are three well defined passages, but south of Alacrity Pass the reef becomes much broken up into small patches, and finally, from Ono Island south the lagoon is open, and has a steep slope towards the 100 fathom line.

The depth of the lagoon north of Ono is not more than twenty-two fathoms; the bottom is most uneven, often passing rapidly from five

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[1] Nature, July 4, 1889, p. 222.

or eight fathoms to seventeen and eighteen fathoms, with a number of extensive patches, the remnants of former islands now covered with coral. (Plate 11.)

Within the Great Astrolabe Reef are included a number of islands and islets. They are all volcanic in structure, and all bear signs of the great denudation and erosion to which they have been subjected. Beginning at the north there is Vanua Kula, about 250 feet in height, covered by scanty vegetation; next comes Ndravuni, a much larger island, rising to a height of 350 feet. Yanu Yanu sau and Yanu Yanu eloma are small islets upon a spit which must have formed a part of Nmara Island; to the south of it is Ngasi Mbali. To the eastward are Yaukuve and Yaukuve lai lai (Plate 52), 400 and 200 feet respectively, connected by a spit, and off the south point of Yaukuve lai lai extends a long sunken shallow rocky spit. Mbulia and Yambu are to the north of Ono, the largest of the islands within the Great Astrolabe Lagoon (Plate 51). It has two peaks of over 1,100 feet, and is indented with deep bays forming finger-like spokes, which further disintegration would soon separate as distinct islands, similar to those of Vuro and Vuro lai lai off the northeastern point of the island. Between Ono and the eastern point of Kandavu Island the lagoon is dotted with numerous rocky and coral patches. Ono, and most of the islands of the Great Astrolabe Lagoon, are edged with fringing reefs. The eastern reef flat is quite broad (Plate 11); in some localities it is nearly a mile wide, besides being fringed along the inner edge by nearly continuous patches of rocks and corals. On the western face of Ono there are some fine cliffs, interesting as showing the progress of the denudation and erosion to which the island has been subjected. It seems comparatively simple to follow with the chart the changes which must have taken place in separating from Kandavu the islands enclosed within the Great Astrolabe Lagoon north of that island. They undoubtedly represent the fragments of the former northern extension of Kandavu itself, which

NMARA AND YANU YANU ELOMA.

probably covered the greater part of the area now enclosed by the Great Astrolabe Reef.

If we examine Kandavu Island itself (Plate **10**), we can easily see how far denudation and erosion, if continued, would cut it up into a number of larger or smaller islands; as, for instance, an island would be formed at the neck separating Tomba Kaivala from Koro Levu, a larger island, by the cutting of the neck separating Tomba ni Ndaku on the north side from Tomba ni Soso on the south of the island. Finally, the cutting of the Malatta Isthmus would make two islands of considerable size of the western half of Kandavu, while the many spits bounding the deep bays of the island would also become islands similar to Matanuku on the south side of Kandavu, and connected with it by the broad fringing reef. These would all be enclosed on the south by the southern extension of the Great Astrolabe Reef, which is now either a barrier or a fringing reef along the south coast of Kandavu, while on the north coast the island would merely be flanked by outlying reef patches separated by great stretches bare of reefs, as along the southwestern part of the Great Astrolabe Lagoon.

Skirting the northern shore of Kandavu from Tomba Kaivala to Levuka, we found the physiognomy of the larger island to be identical with that of the islands of the Astrolabe Lagoon, — high cliffs, formed by the crumbling of the faces of the shores, sloping to high mountains, deep bays extending far inland, and a vegetation identical with that of the adjoining islands. According to the position and proximity of the islands to the inner edge of the outer reef flat, we found the bottom of the Great Astrolabe Lagoon to consist of volcanic mud or of coral sand and coralline algæ, or of a mixture of the two.

North Astrolabe Reef.

Plates 11, 11^a, Fig. 14, and Plates 53, 54.

North Astrolabe Reef is separated from the northern point of the Great Astrolabe Reef by the D'Urville Channel, which is about a mile wide, and with 190 fathoms coralline bottom in the middle (Plate **11**).

North Astrolabe Reef encloses an oval egg-shaped lagoon about four miles in length by three and a half in breadth, with a small rocky islet, Solo, situated nearly in the centre of the lagoon (Plate **11**). The greatest depth of the lagoon is sixteen fathoms, with very undulating bottom full of rocky and of coral patches along the inner edge of the reef, and especially over the southern part of the lagoon. Solo is composed of volcanic rocks, and has been very much eroded by the action of the sea (Plate **54**). Corals grow upon its slopes, but they are not very flourishing, either there or upon the many patches found inside the lagoon, and which are separated by broad sand lanes, or by dark patches of nullipores and algæ, with a few scattered coral heads.

The reef enclosing the lagoon is continuous except on the north side, where there are two entrances into the lagoon, one with thirteen and the other with three fathoms in the channel. The inner side of the weather reef can be reached quite close to the breakers. There is from one and a half to two fathoms of water on the reef flat, which is covered by a great number of flourishing patches of coral, mainly Madrepores, Pociliopores, heads of Astreans and Mæandrinas, with a few Gorgonians. The patches are separated by wide areas of coral and coralline sand. Towards the inner part of the lagoon, as the water deepens, the coral patches are separated by masses of dead corals and of fragments. Dark patches of coralline Algæ become more abundant, and the coral patches less flourishing and more distant. On the outer edge of the reef, to the south of Beagle Passage, the reef flat is somewhat narrower than on the eastern face, where it varies from 1,000 to 1,800 feet in width; it is covered by one to two fathoms of water, and the coral patches appear to flourish upon its surface fully as luxuriantly as upon the eastern face. The corals descended in steps to ten or even eighteen fathoms, rising from the coral and coralline sand separating the heads. They were most flourishing in the belt of from six to ten fathoms in depth. The prevailing trades drive a strong current across the lagoon, and the water of the lagoon rushes out through the northern passages and over the western reef flats with considerable velocity. The bottom inside of the lagoon consists mainly of algæ, of coralline algæ, and of broken shells and fragments of coral.

It is quite probable that the North Astrolabe Reef represents an eroded peak adjacent to the former greater Kandavu, of which Solo Rock is the only witness left (Plate **53**).

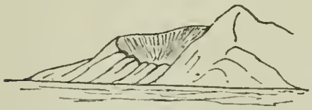
Budd Reef.

Plates 4, 18, 70.

Budd Reef (Plate **18**) has a narrow outer reef of irregular shape, broken into many separate patches. These become quite distant on the southern side, leaving the outline of the reef indistinct. The lagoon, as well as the channels separating the islands enclosed within the outer reef are quite deep, with the exception of that part of the lagoon which lies south of Yambu and Yanutha and between Thombia and the northwestern edge of the outer reef. The deepest part of the lagoon is 47 fathoms and the average depth is between 35 and 40 fathoms.

In addition to Thombia, which is on the northern horn of Budd's Reef, there are the islands of Yanutha, Yambu, Mungaiwa, Tai ni Mbeka, and Rara ni Tinka, which are in the central part of the lagoon. South of the central islands the lagoon is also studded with rocks, as well as in the southwestern horn of the lagoon. The islands and islets and rocks, as well as many of the patches, are of volcanic origin. Yanutha, the largest of the islands, about a mile long and half a mile wide, rises to a height of 480 feet. It is connected by a coral reef with Mungaiwa Island and Mbeka Rock.

The most interesting of the islands is Thombia (Plate 70), the crater of an extinct volcano, having an exterior circumference of about two miles. The crater is half a mile in diameter, with a greatest depth of twenty-four fathoms. The rim of the crater rises at its highest point in a dome of nearly 600 feet. On the northeast side the horns of the rim are connected by a flourishing fringing coral reef about a fifth of a mile in length, the extension on the ridge connecting the horns of the fringing reef surrounding the island. Both the inner and outer slopes of Thombia are steep, and, except on the northwest side, we find over thirty fathoms within a short distance of the shore.



WESTERN END OF THOMBIA.

One cannot fail, on seeing the coral reef growing on the denuded rim of Thombia with the enclosed deep lagoon having a depth of twenty-four fathoms, to revert to the old opinion that some of the lagoons of atolls represented the rim of extinct craters. There is, it seems to me, nothing unreasonable in the suggestion that many of the small round atolls, or others perhaps rising from great depths and isolated, represent the denuded rims of such extinct craters as Thombia, or it may be that, if of greater size, they may represent parts of such larger craters as Totoya, or of circular islands with interior lagoons resembling extinct craters, like the Sound of Fulanga. It seems simple to imagine that, when these small extinct craters have been levelled down, and corals have obtained a footing, they may have formed such atolls as Pitman's Reef, Motua Levu, Motua lai lai, Williamson Reef, Horseshoe Reef, and other similar atolls in Fiji. We must remember, however, that the formation of such atolls may also be accounted for as the result of the denudation and submarine erosion of a patch of elevated limestone, cut first into a sound, and then, with the disappearance of the outer rim, into a lagoon surrounded by a shallow reef flat; or the same result may be accomplished from the wearing away of islets of volcanic origin enclosed within the outer reef, as, for instance, from the disintegration of the islets now left in such atolls as the Kimbombo Islands, Komo, and others, or of islets consisting of elevated limestone like the Aiwa Islands, Katavanga, Vekai, and others. The structure of the negro-heads occurring upon the outer reef flats, or their position near either a volcanic or an elevated reef region being the only guide as to the category to which belong such atolls as Thakau Mata Thuthu, Thakau Vutho Vutho, the Adolphus Reef, Dibble's, Duff, and Bell Reefs, Thakau Tambu, Malevuvu, etc.

Such a cluster as Budd Reef suggests an explanation for the formation of interior atolls, like those described by Darwin as occurring in the Maldive Islands, very different from the one suggested by him. Were Thombia cut down by erosion to the water's edge or below, and changed into a small atoll, we should have a secondary atoll within the area enclosed by Budd Reef, and were the other small islands of the cluster summits of elevated limestone, and should they in their turn be cut down, they might form in such a large lagoon as that of Budd Reef other diminutive atolls, or small atolls enclosed within an atoll. Such interior atolls, if my view of the formation of atolls is correct, could only be formed in lagoons of considerable depth and size, so that the seas formed by the prevailing winds should have a long sweep and rise to a considerable height, and thus possess great disintegrating power. I shall refer again, when describing Vanua Mbalavu, to the probable origin of such great depths as forty-seven fathoms inside of the reef encircling the islands of Budd Reef.

Komo.

Plates 19^{a}, Figs. 9-11, and Plates 22, 63-65.

Komo Island is a narrow ridge of volcanic origin, about a mile and a half in length, rising to over two hundred feet. Its western extremity is connected by a coral reef full of volcanic negro heads, two of which are mushroom-shaped and of considerable size, with the islet of Komo Ndriti, itself about seventy feet high. Komo lies in the southeastern horn of the lagoon (Plate 22) close to the southern face of the outer reef flat, fro which it is only separated by a narrow boat passage full of negro-heads, especially numerous off the southeast point of the island. The lagoon enclosed by the outer reef flat is elliptical. There are two ship passages through the north face of the outer reef. The northern and eastern reef flats are narrow, edged on the outer side by masses of negro-heads; while the western and southern reef flats are fully half a mile broad, and edged by an inner belt of heads, the central part of the lagoon is quite clear of them. The rocks were composed of a volcanic puddingstone (Plate **64**), much like that of Mbengha, Levuka, and elsewhere. This disintegrates readily, is easily undercut, as we had ample proof in the undermining of the shore bluffs and the formation of so many negro-heads on the reef flats and off the spits of the island (Plate **63**). The aspect of the islands of volcanic origin and of elevated limestone is quite different as seen from the sea. The mode of disintegration and erosion of the two kinds of material can at once be distinguished from the peculiar physiognomy of the rounded bluffs when composed of rocks of volcanic origin, or of the vertical shore bluffs deeply grooved and streaked with red earth, or eroded into domes or conical hills when composed of elevated coralliferous limestone.

The reefs which encircle Mbengha, Komo, and Budd Reef, indicate approximately the land area once probably occupied by those islands. The islands must have been of considerably greater height; they have been reduced by denudation, and their area has been further diminished by extensive submarine erosion wearing away the ridges and spurs of the volcanic islands, and leaving submarine platforms of varying width, — dependent upon the nature of the material to be eroded, and the height of the land to be cut down, — upon the surface and outer edge of which corals established themselves. In the case of Komo and of Budd Reef, the islets which remain show the extent of the denudation and erosion. In the case of Mbengha the larger islands probably retain more of the character of the island which once covered Mbengha, representing its higher peaks, while the islets and rocks are all that remain of its lower ridges and slopes.

Olorua.

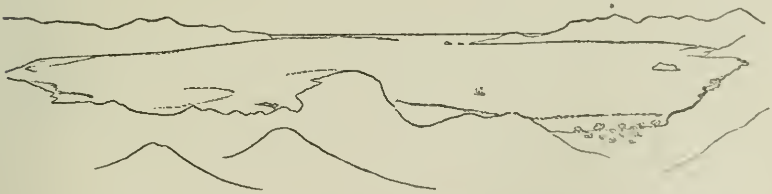
On our way into Komo we saw in the distance Olorua (Plate **22**), a small island with a ridge having three prominent humps, probably of elevated limestone, rising to a height of 250 feet. The island is surrounded by a fringing reef extending to a point for more than a mile off the south face. A small lagoon full of heads separates the north shore of the island from the narrow outer reef flat. We also passed the atoll of Thakau Vuite (Plate 22), separated from Komo by a channel of about one and a half miles in width, with a probable depth of about 150 fathoms. The lagoon is about two miles and three quarters long by two miles broad, with a greatest depth of sixteen fathoms; there is an opening for boats into the lagoon on the northwest side. The encircling reef flat is narrow, and there is a sand key on the northeast horn of the lagoon.

OLORUA.

Totoya.

Plates 19^3, Figs 4-7, and Plates 23, 66-69.

Before entering the western passage through the outer reef surrounding Totoya, we steamed round the eastern and northern edges of the outer reef to obtain a good idea of this interesting island. Totoya (Plate 23) is triangular in shape, enclosing an inner basin, nearly circular, of three miles in diameter, and with a greatest depth of 35 fathoms. The width of the rim varies from two miles to a low narrow isthmus on the western face (Plate 66), the highest points of the rim being 1,200 feet above sea level. The eastern part of the rim is the broadest and highest. The basin is open to the south (Plate 67), the horns of the rim being about two miles distant. Stretching across this opening is the extension of the outer reef, which connects at the extremities of the rim with the narrow fringing reef bordering the island. Between the edge of the fringing reef on the western horn and the outer reef there is a narrow but deep passage called the "Gullet" (25 fathoms), affording a good entrance into the basin filling the extinct crater of Totoya, in which we anchored close to the inner edge of the northern part of the rim. The outer reef extends unbroken from the entrance on the west side to its



BASIN OF TOTOYA CRATER, FROM THE SUMMIT OF THE NORTHERN RIM.

northeastern extremity; it follows irregularly the outline of the shore at a distance varying from one to over two miles. The outer reef off the north coast is broken into distant patches, leaving broad passages between them. North of the western passage the reef is also interrupted, leaving a boat passage. The outer reef flats are irregularly trapezoidal in outline, and quite narrow. The greatest depth in the outer lagoon is 27 fathoms. The eastern arm, and also the northern horn of the lagoon and the inner edge of the southern face of the outer reef, are studded with rocks and coral patches. The corals on the reef flats are thriving, and those on the patches inside of the lagoon are everywhere most flourishing. Many of the patches close to the outer shore line are in the extension of lateral spurs which have been eroded from the ridge of the rim. The general depth of the outer lagoon is over 20 fathoms along its central channel. Similar spurs run into the inner basin, and have formed extensive spits on which corals flourish, or islets and islands such as those figured on Plate **69**, near the inner edge of the northern rim of Totoya. Near the centre of the basin there is an extensive coral patch, Kini Kini (Plate **23**), formed upon the sides of a small islet rising from the bottom of the crater, as is so often the case in the craters of other volcanoes (see Plate **71**). The volcanic rocks forming its centre are exposed at low water. The outer rim of the crater of Totoya has a diameter of six miles; it slopes quite evenly from the crest of the ridge to the outer and inner shore line; the slopes are cut by comparatively shallow valleys, separated by ridges with rounded crests. (Plates **67**, **69**.)

The water which pours into the inner basin over the barrier stretching across the horns of the crater finds its only outlet through the "Gullet," where it rushes through with considerable velocity. The scouring effect of the waters rushing out of lagoons has been noticed by all who have navigated among coral reefs, and the strong currents flowing out of the lagoons through the encircling reefs or openings are constantly referred to in the sailing directions.

In the extension of the western horn of the crater on the west of the "Gullet," are two small islets (Plate **68**), the remnants of a part of the southern rim of the crater. Small islets also exist off the west coast, on the northern side of the isthmus. They are remnants of one of the spurs putting out from the west side of the outer rim. From what we have seen in Totoya, there is little doubt that the fringing reefs, the shore flats, the coral patches, and in different parts of the lagoon the outer reef flats are the remants of flats formed by the denudation and submarine erosion from the former extension of the slopes of the rim or of its spurs. These have been more or less connected together by the subsequent growth of the corals which have found a footing upon them. Kini Kini and the other islets about Totoya, as well as the negro-heads on the reef flats and patches, all show the volcanic substructure upon which has grown and is thriving now a thin crust of corals.

TOTOYA FROM THE NORTHEAST, DISTANT FIVE MILES.

It has been difficult to explain the great depth in some of the lagoons of some atolls (60 fathoms). It seems to me that the conditions occurring in an island like Totoya give us a simple explanation of what such depths mean in coral districts situated in volcanic regions. Provided that we assume that these lagoons are in a region of elevation, as are the Fiji Islands, and that its volcanic peaks or ridges and volcanoes have been denuded and eroded, and that nothing has been left to indicate their former existence beyond the reef flats upon which the corals of the present day are growing. Remembering also that the corals can form but an insignificant crust upon the slopes and flats which have been prepared for their growth by the processes of elevation and of subsequent erosion and denudation, and that the features characteristic of the existing state of things was not brought about by the growth of the coral reefs of to-day except in a very secondary manner. We are not discussing the question of the formation of great limestone banks by subsidence to attain the proper depth at which corals may begin to grow. We are only trying to give an explanation of the conditions which must have preceded and have led to the existing state of things.

The deepest water in the crater basin of Totoya is thirty-five fathoms, and it certainly cannot be held that a lagoon of such a depth has been formed by subsidence after the coral reefs have begun to grow. Let us now follow what would have become of Totoya had the denudation and submarine erosion which have brought it to its present state been continued during a longer period of time. A very few fathoms more, and we should have the rim divided into three large islands, — an eastern island with a ridge having a height of about 1,100 feet, a western island with a height of about 800 feet, and a northwestern island with a summit of the same height. These islands might thus be reduced to three separate ridges, giving no indication that they had formed part of the rim of the crater of an extinct volcano.

The denudation and erosion could be carried still further, leaving only islets, the summits of the higher peaks, to indicate the former position of the rim, the islets being joined by coral patches connecting their extremities, much as the present opening between the horns of the rim of the crater is closed by the outer reef. We may still further imagine it to be so far cut down as to form reef flats upon which coral would grow, thus forming a nearly circular atoll with a depth of 35 fathoms, — an atoll with the formation of which subsidence has had nothing to do. But this is not an imaginary atoll I am reconstructing. A number of such atolls are found in Fiji, the formation of which can be satisfactorily explained on the theory that the ring of coral patches represents the rim of an extinct volcano which has been cut away to below low water mark. Such atolls in the Fijis are probably Thakau Momo, Thakau Lasemarawa, Thakau Lekaleka, Motua Levu, Motua lai lai, Pitman and Williamson Reefs, and perhaps others.

The example of Thombia, one of the Ringgold Islands, in which there is only a distant outer reef, would also indicate the possibility of the rim of the crater of a small volcanic peak cut down to the surface and forming the circular flats upon which corals might grow. In the case of Thombia such a condition would result in forming a diminutive atoll not more than a third of a mile in diameter, enclosed within an encircling barrier reef.

We might also consider the "Boilers," the diminutive "Serpuline atolls" inside of the lagoon of the outer reef off the south shore of the main island of the Bermudas,[1] as a series of such interior atolls, though the mode of origin is very different from that of subordinate atolls, formed, as I have suggested, upon the rim of an extinct crater like Thombia. In either case, the explanation of the formation of such interior or subordinate atolls is radically different from that given by Darwin[2] for their growth in the Maldive atolls, an explanation also accepted by Dana.

It is becoming more and more apparent that each locality must be

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[1] Bull. Mus. Comp. Zoöl., XXVI. No. 2, 1895, Plates XXII.–XXVI., p. 253.

[2] Darwin's Coral Reefs, 3d ed., p. 44.

considered by itself, and that no sweeping generalization can take in the formation of all coral reefs. Such atolls as those of Alacran on the Yucatan Bank of the Hogsty Reef in the Bahamas owe their origin — I mean the conditions existing there now — to entirely different causes from those which have brought about the formation of some of the atolls of Fiji, and the atolls of Alacran and of Hogsty themselves again owe their origin to different causes. The barrier reef of Florida does not owe its origin to the same causes as those which have led to the formation of the Great Barrier Reef of Australia, or the barrier and fringing reef surrounding parts of Viti Levu, or some of the other islands of the Fiji group.

It is playing with words to call such atolls as I have mentioned above pseudo atolls, as is becoming the fashion, and to speak of the localities to which Darwin's theory of the formation of barrier reefs and of atolls does not apply as exceptions to the rule. These exceptions now cover a good deal of ground. They include nearly all the coral reefs which have been examined by recent investigators, — from Semper in the Pelew Islands, Rein in the Bermudas, Murray in Tahiti and elsewhere, of Forbes, and of Bourne, of Guppy in the Solomon Islands, Krämer in Samoa, and others, — down to my own in Florida, the Yucatan Bank, Cuba, Bermuda, the Bahamas, and the West India Islands, as well as in the Galapagos and Sandwich Islands, besides the exploration of the Great Barrier Reef of Australia, and of the Fiji Islands. Surely the list of investigators and of localities is long enough. The negative evidence is now becoming overwhelming, and the recent borings at Funafuti have not weakened the position of those who do not recognize the Darwinian theory as of universal application, and as not having been proved to exist in a single instance, either by a careful examination of the locality or by borings.

Taviuni.

Plates 4, 18, 60.

The islands of Taviuni (Plates **4**, **18**) and of Kandavu (Plates **10**, **11**) illustrate admirably the formation of reefs encircling denuded and eroded extremities of large islands, and readily explain the existence of very irregularly shaped reefs representing the former outline of the islands which they replace. Other characteristic points similar in their origin are the great spits forming the Namena Barrier Reef, which connects with the extensive reef platforms reaching towards Ovalau from the southeastern extremity of Vanua Levu (Plates **3**, **3**ᵃ) and the northeastern spit of Vanua Levu, which breaks up into Kioa and Rambe Islands and the reef-bound platform from which they rise (Plate 4).

On the platform of submarine denudation and erosion Namena and Vatu i thake Islands, as well as a few isolated rocks on the western edge of the southeastern horn of the Vanua Levu Barrier Reef are the only remnants of the former southern extension of Vanua Levu. To the southeast of this must have existed a dumbbell-shaped island of considerable height, of which only the summits of Makongai and of Wakaya are left (Plate 3ª).

The island of Taviuni is, with the exception of the shore fringing the northern half of the island and of the point of reefs off Vuna Point, destitute of reefs. The island is about 23 miles long, from five to eight broad, sloping uniformly to the shores from the backbone of the island. This rises to a height of over 4,000 feet. The main ridge sends off a few spurs towards the northeastern face of the island. The fringing reef attains its greatest width to the east of Naiselesele Point. It encloses a few small volcanic islets, varying in height from 60 to 90 feet, and the somewhat larger island of Mbuimbani (Plate 60), lying to the south, and which rises to a height of more than 400 feet. To the south the fringing reef becomes again quite narrow, and disappears at Laveine Point.

Immediately north of Somo Somo Strait the submarine platform widens. Koro Levu Islet and Phillips and McPherson Rocks are included within shallow soundings covered with reef patches running out from the west shore of Taviuni. At a somewhat greater distance from the west shore of Taviuni within the 50 fathom line are Champion, Breaknot, and Maté Rocks, and to the northeast of Naiselesele Point the submarine platform reaches its greatest width, the Gangway Rocks and the bank connected with them being the most distant of the outliers of Taviuni.

To the eastward of Taviuni lie the islands of Ngamia, Lauthala, and Matangi, separated from Taviuni by the Tasman Strait. The plateau from which these islands rise is really the extension of the shoal lying to the east of Taviuni and the outer reef which extends from Matangi east of Lauthala and south of Ngamia, stretching across Tasman Strait in disconnected patches and joining the fringing reef off Thurston Point. To the westward of Matangi the outer reef extends only in broken patches, and is seen also in the many disconnected patches found in the western part of Tasman Strait. Between Matangi and the northeastern horn of the outer reef there are two passages across it. The lagoon enclosing Ngamia and Lauthala has a greatest depth of forty fathoms and an average depth of over twenty, except to the east of Lauthala, where the outer reef joins the fringing reef which skirts Lauthala and Ngamia. There are a number of coral patches all through the lagoon, but they are most abundant along the inner edge of the southern line of the outer reef.

Ngamia and Lauthala are both volcanic; the former rises to a height of 1,000 feet. Both are indented with deep bays.

Along the shore of Thurston Point we found a conglomerate in course of formation, composed of rounded pebbles of lava cemented together with broken fragments of coral.

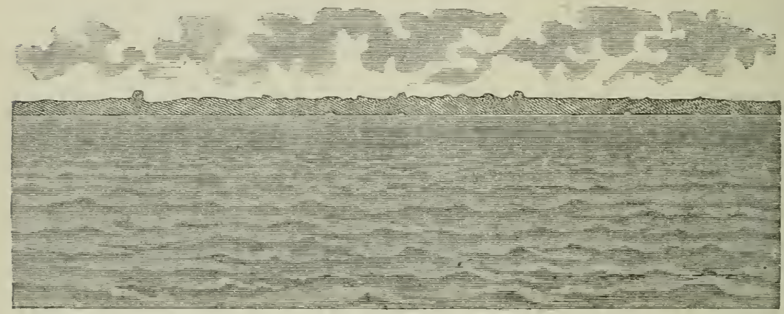
ELEVATED ISLANDS COMPOSED OF CORALLIFEROUS LIMESTONES.

Ngele Levu.

Plates 17, 17^a, Figs. 5-12, and Plates 95-99.

Ngele Levu is an elongated pear-shaped atoll, somewhat constricted at a few points (Plate **17**). Its length is fourteen miles and its greatest breadth seven. The lagoon is enclosed by a continuous outer reef, varying in width from a quarter of a mile to over a mile. The western face of the outer reef is broken into patches leaving excellent deep passages for ships. The depth in the lagoon is quite uniform, the bottom being very level, varying in depth from about five to nine fathoms at the eastern extremity, and sloping very gradually to fifteen or sixteen at the western entrance. The bottom is composed of coralline algæ, broken shells, and coral sand, as well as masses of dead corals derived from the disintegration of the former elevated coralliferous limestone which once covered the whole area of the lagoon. The lagoon is free from coral patches except at the eastern end, which is studded with heads of old coral and patches of living coral. These heads also form a belt of considerable width along the inner side of the outer reef flats.

The reef flats are made up of elevated coralliferous rock which has been planed off to the level of the sea, and scooped out below it to form the lagoon. At the southern of the western entrances there is a small sand key, and at the northeast end there are three islands, Ngele Levu, Tai ni Mbeka (Plate **96**), and Taulalia (Plate **95**). The outer faces of these islands form the sea face of the outer reef, there being no outside reef flats. These islands are entirely composed of elevated coralliferous limestones, rising on Ngele Levu to about sixty feet, on Tai ni Mbeka to forty feet, and on Taulalia to thirty feet. The process of disintegration which has taken place can still be seen going on at the extremities of the island of Ngele Levu. On the reef flat near it, as well as along the inner beach, crop out many negro-heads of elevated limestone rock, and between the smaller islands, which are now only connected by a reef flat, the islands themselves being undercut and their surface deeply pitted and honeycombed (Plates 95, 96). On Taulalia many large domes of harder material, somewhat conical, still exist, which have not been rounded off to the general level of the island.



TAULALIA, NGELE LEVU LAGOON.

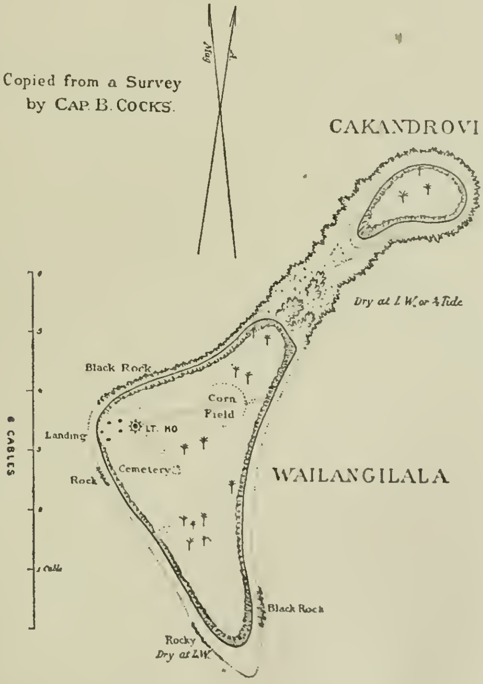
We walked a good part of the length of the island of Ngele Levu, and crossed it at right angles. The elevated tertiary limestome rock was found cropping out at all points (Plate 97), and towards the northeastern shore we came upon a belt of limestone nearly devoid of vegetation, which must have risen at points to fully sixty feet above the shore line. The surface of that part of the island was full of deep potholes and crevasses of all sizes and shapes, separated by ridges and columnar or conical masses, some of them fully fifteen feet alove the general level of the surrounding area (Plate 98). The rock surface in all directions was pitted and honeycombed, and eroded into thousands of sharp points and needles, the aspect of this island recalling a similar structure so common among the Bahamas. At Observatory Point, the southern extremity of the island, this very characteristic structure is quite well marked, and shows admirably the gradual passage of an island composed of elevated limestone rock into a reef flat identical in all respects with the reef flats surrounding the lagoon. Plate 99 shows the characteristic shore vegetation along the narrow cultivated strip of the island, while Plates **97** and **98** show the inland vegetation.

We found rather distant coral patches growing in the lagoon in from six to seven fathoms of water, close up to the inner edge of the outer reef, starting from an underlying base of tertiary limestones, fragments of which we brought up with the dredge. And upon the plane of the outer rim of the lagoon, composed of the same tertiary limestones, corals were growing to a depth of from six to ten fathoms, or more perhaps.

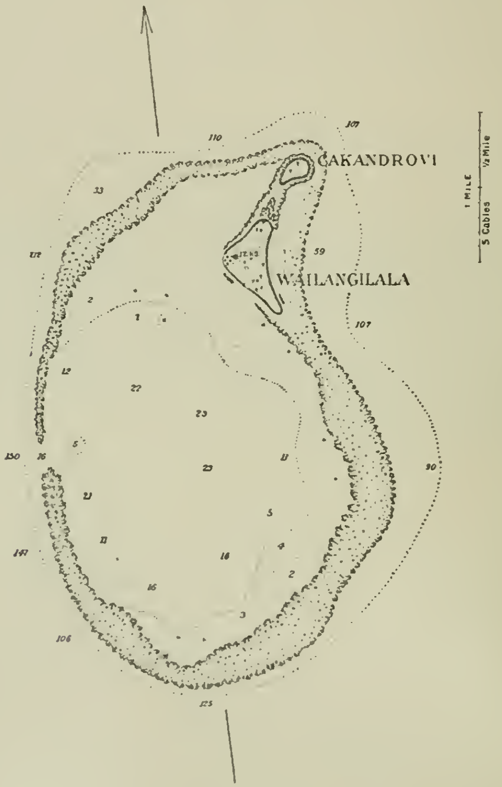
Wailangilala.

Plates 18, 109, 110.

The island of Wailangilala is somewhat triangular, and connected by a spit of coral beach rock with the small island of Cakandrovi to the northeast. The east side of the larger island is about fifteen feet above high water mark. Both islands are low, with sandy or beach rock



beaches, and covered with cocoanut trees and shrubs (Plate **110**). The islands are in the northeast angle of a nearly elliptical lagoon (Plate **18**), surrounded by a reef flat varying from a quarter of a mile to more than a mile in width. The outer reef is about nine miles in circumference. There is an entrance for ships into the lagoon in the western reef flats.



The depth of the central part of the lagoon is from 22 to 23 fathoms, and the bottom is mainly coralline and coral sand, with broken shells. The inner edge of the reef flat is flanked by a broad belt of coral patches, which extend upon the flat itself, with here and there an isolated patch in six or seven fathoms of water.

Wailangilala was selected, after consultation with inhabitants of the Fijis well acquainted with the group, as affording an isolated atoll with a steep submarine slope, and an island on the outer rim on which to establish the boring plant. Having a lighthouse on it, with a keeper and assistants, it afforded unusual facilities for establishing a comfortable camp for the boring crew, who were at work a couple of days after landing.

The following is the record of our boring at Wailangilala.[1]

From the surface —

To 20 feet, coral and coralline sand with broken shells, like that on the beach.
20–30 feet, coralline sand.
30–40 " coral and coralline sand, coarse.
40–50 " fine coralline sand.
49–51 " parts of core of yellow limestone (elev. limestone).
51–61 " " " " " " "
61–71 " " " " " " "
71–80 " " " " " " "
80–85 " " " " " " "

It was on the western inner edge of the island (Plate 109) that I established our boring apparatus, soon after arriving at Suva, and while under the impression conveyed by the newspapers, and from published reports, that the second Funafuti boring expedition had demonstrated that at the Funafuti atoll true coral reefs extended to a depth of 643 feet. This information seemed so positive that had it been received before the shipping of my outfit to Fiji via Australia, I should have remained at home, convinced that at any rate, whatever had been my experience in the West Indies, Australia, and the Sandwich Island reefs, yet that in a region of typical atolls in the Pacific the conditions of subsidence suggested by Darwin and Dana might exist, unless the boring at Funafuti proved eventually, on closer examination, to have been carried on in the sea face talus of a reef. But my outfit having left, I was not prepared to accept the preliminary conclusions of Professor David as recorded by the papers, and I started on my expedition ready to confirm by my own borings the truth of the great thickness of modern coral reefs in atolls of the Pacific, or to give some other explanation of this apparently overwhelming proof of the correctness of Darwin's theory.

From what we saw of the elevated coralliferous limestone at Ngele Levu, Vanua Mbalavu, Mango, and other points in Lau on our way to Ongea, it was very evident that these limestones attained a great thick-

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[1] The bore hole was about five feet above high water mark, and about thirty feet from the shore line, a few feet north of the Landing (figure on page 45).

ness, — 800 feet at Tuvuthá, 1,000 feet at Vatu Vara. Therefore as soon as the drill struck the limestones it might correspond to any height in the beds exposed elsewhere, beds which at Mango, Kambara, and Vanua Mbalavu we had observed to rest upon a volcanic substratum. It was natural that immediately on my return to Suva after our first trip round the Eastern Archipelago I should send to Wailangilala orders to stop further boring, and to bring the crew and machinery back to Suva. For it seemed a waste of both time and money to bore and obtain a core from an indefinite datum plane, when the same evidence could be obtained by the examination of any one of the bluffs of elevated coralliferous limestones with which we had become familiar in our first trip. But, unfortunately, we were not equipped to make a thorough exploration of such a section, not being provided with explosives or drills, and had to content ourselves with somewhat fragmentary collections at the more accessible points. However, this is a subject which I hope to attack again under more favorable conditions.

The boring at Wailangilala shows that the island is the fragment of an ancient island of larger size, which once covered the whole area of the lagoon. Being at the northern extremity of the atoll, it was less subject to the destructive agency of the sea due to the prevailing southeasterly winds, and thus there was left a wider reef flat, the last to be worn away by the action of the sea. It also shows that at a depth of forty feet we meet the underlying elevated limestone forming the substratum of the northern reef flat of the lagoon. As will be noticed from the Figure on page 46, the western reef flat is much narrower than the eastern and less exposed face of the lagoon.

The boring at Wailangilala is from the remains of an upheaved coral island, as has been suggested by Gardiner;[1] but it is also the remnant of an island which once occupied the whole of that part of the atoll. Aiwa shows a stage antecedent to that of Wailangilala, the island on the rim of the lagoon being still of considerable height. Many of the reef rocks (negro-heads), which Gardiner considers as having been thrown up by hurricanes, are the remnants of the elevated reef rock outliers left from the denudation of the flats on which they occur, and which once rose to a greater height but have gradually been eroded and planed down to their present elevation.

But Gardiner is wrong in assuming that the islands of the atolls are converted into land. Such is by no means necessarily the case. The islands on the rim of an atoll, as Ngele Levu, consist of elevated coral-

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[1] *Loc. cit.*, p. 445.

liferous limestone rock, and are the remnants of the former land mass once covering the area of the atoll of Ngele Levu.

Nuku Mbasanga.

Plates 18, 22^a, Fig. 18, and Plate 108.

We skirted along a part of the southwestern edge of Nuku Mbasanga atoll (Plate **18**). The atoll is oblong, a little over two miles long, open to the northwest, where the reef flats are broken up into numerous coral heads. Within the broad reef flats are a small sandy cay, Nuku Mbalate on the western face of the atoll, and the islet of Nuku Mbasanga (Plate **108**), the shores of which are covered with coral beach rock, or patches of elevated reef rock, judging from the character of the negroheads which crop out on the western side. Both the islands are covered with coacoanuts and shrubs.

There is every reason to believe that the islands of the Nuku Mbasanga group are the remnants of an island composed of elevated limestone, which has been denuded and eroded to its present condition, and partly covered, as Wailangilala has been, with coral sand.

Nukusemanu and Nanuku Reefs.

Plates 18, 103–107.

To the eastward of Budd Reef, and separated from it by a channel about nine miles wide, is situated an elongated, angular, irregularly shaped atoll, terminating at its southern extremity in a long ridge of reef flats called the Nanuku Reef. These send out spurs, the extension of which connects with the Nukusemanu Reef and encloses a lagoon fully twenty-four miles long and from two to six miles broad. The greater part of the eastern face of the reef is not awash, being made up of a long series of coral reef patches, with from one to six fathoms of water, with deeper water between it and the extension of the Nanuku Reef. A tongue of the ocean runs westward from 118 fathoms in the gap separating the extremities of the reefs, rising to a ridge with five to ten fathoms, separating it from a deep pool with as much as forty-six fathoms near the eastern face of the central part of the western reef flat of Nanuku Reef. Only an occasional reef patch rises to the surface on that face. On the northeast horn is situated Nukusemanu Island, a small sand key covered with cocoanuts. On the northwest face the Nukusemanu Reef flats are seen to be well covered with flourishing coral patches, but nearly the whole of the west face until it joins the western spur of Nanuku Reef consists, like the east face, of a long but narrow reef flat, with from two to seven fathoms, and studded with heads. The greatest depth in the lagoon is 52 fathoms, with an average depth of from 25 to 40 fathoms. The interior of the lagoon, especially the northern part, is studded with heads.

We examined the islets on the southern spits of the Nanuku Reef. The northern islet, Nanuku lai lai, has been nearly washed away during the hurricane of 1893 (Plate **107**). The southern islet is covered with shrubs and cocoanuts (Plate **104**). The eastern face of this islet, Nanuku Levu, is flanked with beach rock (Plate **106**). There were a large number of negro-heads of beach rock and of elevated coralliferous rock scattered upon the reef flats adjoining the island (Plate **103**), and both to the north and towards the southern extremity of the reef flat ridge (Plate **105**). Coral heads begin at about seventeen fathoms off the lee side of the reef, the patches increase in size and number at twelve fathoms, and form a very fine flourishing belt between six to one and a half or two fathoms. We could trace these coral patches on the narrow reef flat ridge extending northward. This ridge is at some points so narrow that the breakers form a long white mass of rollers as they fall from the windward to the leeward side of the reef flat. The leeward pitch is not as steep as the charts seem to indicate. We found a hundred fathoms on that side, hard bottom, at a distance of one and three quarters miles from the leeward edge of the reef flat, two and a quarter miles northerly from Nanuku lai lai (Plate **18**).

The island which once covered the tract extending from the northernmost horn of the Nukusemanu Reefs to the southwestern horn of the Nanuku Reefs (Plate **18**) was probably flanked by outer ridges of hills running into a long narrow ridge at the southern extremity, of which Nanuku lai lai and Nanuku Levu islets are the solitary remnants, while Nukusemanu Island is the only fragment of the northern extremity of the eastern ridge. There must have been a valley separating the ridges now indicated by the open lagoon, with a greatest depth of over forty-five fathoms, extending from Nanuku Reef to Nukusemanu Reef, which was cut into at many points all along the outer edges of the ridges, and connected the plateau of submarine erosion with the great sound of the interior.

Tuvuthá.

Plates 20, 88, 89.

Tuvuthá Island is triangular in shape; its northern face is about one and three quarters miles long; the island is nearly three and a half miles long, and trends in a northwesterly direction from the southern point to the northern face (Plate 20). It is surrounded by a barrier reef. The greatest width of the enclosed lagoon is about three quarters of a mile on the eastern side; it is somewhat narrower off the western face of the island. At two points on the northern side of the island the outer reef becomes a fringing reef for a short distance. There are a couple of boat passages into the lagoon through the outer reef flats, one on each side. The lagoon varies in depth from two to nine fathoms. With the exception of the central part of the eastern lagoon, it is studded with coral patches and negro-heads. The latter are especially numerous off the northern face of the island between those points where the outer reef becomes a fringing reef, and empounds a small distinct lagoon.

The central ridge, occupying the interior of the northern part of the island, runs parallel to the west coast, and as far as I could judge consists of coralliferous limestone elevated to a height of eight hundred feet. The central ridge is surrounded by a more or less continuous ridge, forming an outer rim and surrounding the inner depressed part of the island. This ridge consists entirely of elevated limestones, forming along the northern face a collar of steep bluffs (Plate 88). Other parts of the ridge, especially on the west side of the island, have been greatly denuded and eroded into rounded peaks and domes, while the southeast point is marked for its steep bluffs and sharp ridges (Plate 89). Where the bluffs rise from the shore of the lagoon, they are deeply undercut. The outer ridge not being low and broken at any point, no interior lagoon or sound has been formed with the exception of a small bight on the southern part of the eastern face of the island (Plate 20).

The central volcanic mass which has elevated Tuvuthá as well as Naiau has not broken through the elevated limestones, although it has assumed the appearance of the wide round rim of an extinct crater. But, as will be seen in the case of Naiau, the formation of the central basin is not due to volcanic agencies, but to atmospheric causes.

Naiau.

Plates 20, 22[3], Fig. 1.

Naiau Island is, like Tuvuthá, composed entirely of an elevated limestone ridge forming a continuous rim round a central depression stated to be about 200 feet lower than its highest points, which rise from 530 to 580 feet above the level of the sea. The sea face of the rim rises in nearly perpendicular bluffs round the island. At their base they are deeply undercut, and the larger fragments are eroded into dome-like heads. Off the southeastern point an islet has been isolated from the island. Naiau is surrounded by a fringing reef broadest on the eastern face, about half a mile wide, where at half tide boats can pass between it and the shore, forming an incipient lagoon, and enter through a narrow boat harbor passage, out of which, I am informed by our pilot, runs a strong current. There are numerous negro-heads all along the outer edge of the fringing reef, especially near the northwestern point of the island, where the fringing reef is narrowest.

NORTH POINT OF NAIAU.

Naiau,[1] Tuvuthá, Kambara, Wangava, and other elevated islands, consisting of coralliferous limestone, have been considered to be elevated atolls, owing to the existence of a depression in the summit, which is looked upon as representing the former lagoon. While that may be the

NAIAU, SEEN FROM THE EAST.

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[1] Moore, Nature, March 18, 1897, p. 463. Others have looked upon these islands as extinct craters.

case, I am inclined to consider these central basins as due to the action of atmospheric agencies, and to look upon them as similar to the gigantic banana holes, as they are called, occurring in the Bahamas, which are undoubtedly due to the solvent action of the rains overcharged with carbonic acid, which carry off the limestones, and, percolating through the mass, leave the saucer-shaped basins characteristic of the so called elevated atolls. In such islands as Naiau, Vanua Vatu, Tuvuthá, Kambara, and Wangava, the central depression has not extended very far towards the sea level. But in such islands as Mango the central depression has formed a small lagoon, in Namuka submarine erosion has carried off one side of the rim; in Fulanga (Plate **22**) the process has been carried still further by the direct action of the sea and of submarine erosion, forming a large lagoon; and the conditions existing at Ongea, Yangasá, Aiwa, and finally at Reid Haven, Wailangilala, Ngele Levu, etc., illustrate the different stages in the transformation by submarine erosion of a so called elevated atoll of tertiary age into an atoll of the present epoch.

The probable extent to which atmospheric agencies have contributed to shape such central basins is also shown from the presence of extensive caves in the elevated limestone islands of Vatu Leile, of Thithia, and of Ngillangillah, and in the numerous cracks, caverns, and cavities which characterize the faces of the vertical bluffs of elevated limestone wherever we have met them in the Fijis (see Plates **74**, **77**, **92**).

VATU VARA, SEEN FROM THE EAST.

Vatu Vara.

Plate 19.

On the last trip of the "Yaralla" from Suva to Wailangilala, Captain Thomson examined for me the islands of Vatu Vara, Yathata, Kaimbo, and Naitamba. The accompanying account is based upon his notes.

Vatu Vara or Hat Island (Plate **19**) is one mile and a quarter in diameter. Its summit is flat, and falls off on all sides in steep cliffs. It attains an altitude of 1,030 feet. The cliffs consist of elevated limestone standing out conspicuously through the dark foliage which covers the island from base to summit. Up to the very summit of the island the exposed rocks are seen to consist of limestone. The island is surrounded by a fringing reef nearly a mile in width on the west coast. On the east and north sides the sea breaks against the nearly vertical limestone cliffs. They are deeply undercut. On the northwest side two separate masses of limestone stand out midway between the base of the cliffs and the outer edge of the reef. An incipient lagoon, open to the north, is forming along a part of the west coast of the island.

Yathata and Kaimbo.

Plate 19.

The islands of Yathata and Kaimbo (Plate **19**), which rise respectively to the height of 840 and 150 feet, are composed of elevated limestone rock. A fringing reef encloses them both. It attains a width of over half a mile where it connects the islands, and is nearly a mile wide off the north of Yathata. Off that shore a number of small islets and heads stand out between the island and the outer edge of the reef. Elsewhere the fringing reef is narrow. Between the islands in the middle of the fringing reef stands out the islet of Nuku Levu, 90 feet in height, and a few heads. There appears to have been a secondary elevation on the south side of Kaimbo, where the undercut ledge has been raised about twenty feet above high water mark.

I am informed by Captain R. Cocks that Katavanga is composed of elevated limestones.

Aiwa.

Plates 21, 22^a, Figs. 13-15.

Aiwa consists of two small elongated islands, the western one of which is not quite a mile in length (Plate **21**). Both are composed of elevated limestone, pitted and honeycombed, forming low vertical bluffs along their southern faces. The highest points of the islands are respectively 210 and 200 feet. They are connected by a coral reef awash at low tide. The islands are in the middle of the southern face of the outer reef flat, which encloses an elongate narrow triangular lagoon nine miles in length. From the extremities of the islands off the south face projects a horn of the outer reef, forming a small enclosed lagoon separated from the principal lagoon and with a greatest depth of ten fathoms. The greatest depth of the principal lagoon is 23 fathoms. The northern face of the outer reef is much broken, and flanked by large patches of corals and heads, with a wide entrance into the northwestern end of the lagoon. The western face of the lagoon is three miles long. The inner edge of the western face is flanked by a broad belt of coral patches and heads. The coral patches are growing upon sunken heads of elevated reef rock, the remnants of the elevated reef once covering the area now occupied by the Aiwa lagoon. The reef flats consisted wherever we saw them of elevated reef rock planed off to a general level, upon which coral patches were growing.

This group is historically interesting, as Dana in his Corals and Coral Islands (p. 264) gives a section across the islands and lagoon, which according to him illustrates very forcibly the effect of subsidence in the formation of atolls. A more unfortunate selection could not have been made. But Dana did not visit this group, and took his information from the charts, or he would not have chosen as an illustration an island group which consists of elevated limestone rock, — islands which after their elevation have suffered most extensive denudation and erosion, and upon the outer edge of the surrounding platform the corals of the present epoch have found a footing and formed a sheet of very moderate thickness. The lagoon between the encircling reef and the islands has been hollowed out by mechanical causes similar to those which I have alluded to elsewhere, and which have in my opinion shaped the lagoons of all the atolls and barrier reefs of the Fijis.

Dana assumes the lagoon of Aiwa to have been formed during the slow subsidence of the island enclosed within its reef, while there is every evidence that the lagoon of Aiwa has been scooped out by submarine erosion, and the island, consisting of late tertiary limestones, has been lowered by denudation, and that the limestones after their elevation have remained at the present level, and that the corals now growing upon the outer rim and upon the reef flats, as well as the coral heads inside of the lagoon, have but little thickness, and that well within the greatest depth at which reef-building corals can grow.

Oneata.

Plates 21, 22^{a}, Figs. 10-12.

Oneata Island is a low ridge of elevated limestone, rising to a height of 160 feet, connected at its eastern extremity by a coral reef with the islet of Loa, of similar structure to Oneata, and rising to a height of 140 feet. Towards the eastern extremity of Oneata, on the northern side, the island is indented by deep bays, studded with mushroom-shaped islets and large heads barely cropping to the surface. The spit protecting the bay from the east rises vertically, is deeply pitted, full of potholes, and honeycombed and perforated by a large opening similar to the Hole in the Wall at Abaco in the Bahamas. Everywhere on the surface of the island we found the elevated limestone cropping out. The southern face of the island is also indented with bays, the beginning of shallow sounds which are now cutting Oneata into smaller islands by undermining the shore line and forming low vertical cliffs, probably by the same processes which disintegrated the area formerly occupied by the elevated limestones, and of which Oneata and Loa are the remnants.

ONEATA.

ISLET OFF ONEATA SHORE.

Oneata lies about a mile from the inner edge of the outer reef flat, enclosing a triangularly shaped lagoon, with a greatest depth of 21 fathoms. The length of the southern reef flat is a little over ten miles, that of the northern face about nine miles, and that of the western and northwestern faces connecting them is five miles. There are three passages on the western and northwestern faces, and one through the northern face. The bottom of the lagoon, between the reef patches and heads, is covered with coralline algæ and with coral sand. There are many large heads scattered along the inner edge of the northern reef flat, and on the extension of the western extremity of the island.

Namuka.

Plate 22.

We did not visit Namuka, but steamed near enough to the island to recognize its distinctive features. It is a narrow, undulating ridge, four miles long, rising to a height of 240 feet; it is composed of elevated limestone. On the southern and western faces there are deep bays, or incipient sounds, which, if extended, would divide the island into a number of islets. The island is surrounded by a fringing reef off the southwestern extremity, and off the eastern point of the island. Between these points an outer reef extends off the south coast, forming a narrow and shallow lagoon full of heads, with five fathoms at its deepest point. On the northern face the western part of the lagoon is deeper, having thirteen fathoms. The horns of the outer reef of the northern and western faces are connected by broken patches and heads which form the harbor of Namuka.

About three and a half miles northeast from the entrance to Namuka Harbor lies Wilkes Reef (Plate 22), a flat a little over half a mile in length, dry at low water, with outlying rocks and banks within the surrounding 100 fathom line.

Yangasá.

Plates 22, 22^a, Figs. 8, 9, and Plates 90-93.

The cluster of Yangasá (Plate 22) consists of four islands and numerous rocks and islets, all of which are composed of elevated limestone. The largest island of the group, Yangasá Levu, is nearly two miles in length and about half a mile wide. Its shores are formed of precipitous cliffs, which surround the whole island; they are deeply undercut at the base, perhaps more than any other island we have seen in Fiji. The crest of the highest ridge is flat, and runs at a general level of about 300 feet. The highest summit, toward the southern end of the island, is nearly 400 feet; off that point there are indications of a terrace at about one third the height of the island, as if the elevation of this group had taken place at two successive periods. Yangasá Levu seen from the west, on the way to Ongea, appears hat-shaped, with a high terrace forming the rim. The island of Yangasá Levu is from one to two miles distant from the inner edge of the outer reef flat forming the eastern horn of the lagoon. Along the western side of the lagoon are situated Navutuira, in the northwest angle of the lagoon, which rises to 270 feet; this is connected with the islet of Yuvutha (Plate **90**) by a long narrow reef studded with mushroom-shaped rocks rising above high water mark. The whole of the northwestern part of the lagoon to the west of the ship passage on the north face of the outer reef flat is also thickly studded with negro-heads and with mushroom-shaped rocks of all sizes and shapes, which cover the wide reef flat to the west and north of Navutuira. The large mushroom-shaped heads are generally on the extension of spits or headlands of the two islands named.

YANGASÁ LEVU.

The crest of Navutuira is undulating, and from its shores rise low undercut vertical bluffs. Yuvutha (Plate **90**), on the contrary, has a conical outline, its highest summit rising to 240 feet; its vertical shore bluffs are higher than those of Navutuira, deeply undercut; they are nothing but the rim of a sound left from the disintegration, denudation, and erosion of the adjoining land. Such rims are at a distance readily mistaken for the rims of extinct craters. We anchored off the west side of Navutuiloma, the most southern of the islands along the west side of the lagoon. The small bay on the north face of Navutuiloma resembles closely a part of the rim of an extinct crater. But that rim and those forming the eastern and western points are entirely composed of elevated limestone, full of caverns and caves, pits and potholes, many of them full of red earth, as is the case wherever elevated limestone is met with; it is deeply honeycombed and cut into ridges (Plate **92**), upon the edges of which rise endless sharp pinnacles and needles. This was also the structure and appearance of the inland slope of the island where we landed.

The little bay was studded with mushroom-shaped and conical islets and rocks, all deeply undercut (Plates **91**, **93**), and the bottom in from two to four fathoms was covered with sunken coral patches and heads rising at all depths.

Some of the islets were covered with bushes and cocoanut trees, like the main island. The highest point of Navutuiloma is 210 feet; it is a little over one mile in length, and is larger than Navutuira. The shape of the outer reef flats enclosing the lagoon of Yangasá (Plate **22**) is irregularly rectangular, with rounded angles; the faces are each about five miles long, the western face being the longer. On the eastern and northeastern side, the reef flat is quite narrow, but it is studded along the inner edge with a belt of heads and coral patches and negro-heads. Off the southeastern horn, the reef flat becomes very wide, projecting in a point fully two miles beyond its general line. The reef flats of the southern and western faces are also broad, fully a mile in width in some places, and at the northwestern horn the reef flat is more than a mile and a quarter wide.

On the northern face of the lagoon a tongue of deep water (145 fathoms) fully a mile wide runs towards the centre of the lagoon; this is the passage used for entering the lagoon. The slope of this part of the lagoon is very steep, and it is studded with coral patches and heads growing upon the remnants of the former island of Yangasá. This narrow and deep tongue of the ocean represents probably an original valley formed in the uplifting of the island, and has no connection with a subsidence of the island during the formation of the encircling reef, which has grown subsequently upon the platform of submarine erosion formed by the wearing away of the original land mass. The average depth of the northern part of the lagoon is from 14 to 19 fathoms. The southern part, between Yangasá Levu and Navutuiloma and the reef flat, is shallower, from six to twelve fathoms, with a still shallower belt along the inner edge of the southern reef flat.

Off the southeastern extremity of Navutuiloma extend a number of mushroom-shaped rocks and islets, deeply undercut and eroded into fantastic crests, pinnacles, and summits. The reef flat of the western face of the Yangasá lagoon is full of thriving coral patches, which extend along the inner edge, between and upon the negro-heads, down to seven or eight fathoms. The formation, by erosion and denudation, of diminutive or incipient sounds, as in the bay of Navutuiloma, is interesting as representing one stage in the action of such processes, of which others can be followed in the conditions which have been reached by such islands as Namuka, Mango, Ngele Levu, Fulanga, Oneata, Ongea, and others. It is quite probable that the islands and islets of this group represent the remnants of the submarine erosion and denudation which have cut the greater island of Yangasá, consisting of elevated limestone, which once occupied the area of the lagoon, into smaller islands by a process similar to that now going on to cut up the island of Navutuiloma, — a process which has left, as indicating its former greater extent, the islands of the cluster, its rocks and islets, and the numberless heads cropping out everywhere over the outer reef flats, and in the extension of the spits and points of its islands.

To the eastward of the Yangasá cluster, and separated from it by a narrow channel of about half a mile in width and a depth of a little over 100 fathoms, lies Thakau Levu (Plate **22**), an elongated horseshoe-shaped atoll, nearly four and a half miles in length, with a greatest breadth of less than two miles. The lagoon enclosed by the outer reef flat is open on the west face. The greatest depth in the lagoon is 11 fathoms; it is studded with heads and patches. The reef flat at the eastern point of the lagoon is fully a mile wide.

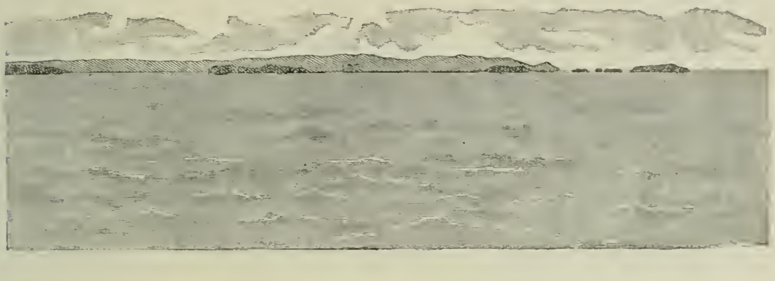
South of Thakau Levu (Plate **22**) lies the flat reef of Thakau Thikondua, and the small island Naiabo, of elevated limestone, rising to a height of forty feet, surrounded by a narrow encircling reef enclosing a shallow lagoon. Still farther south are the flat reefs of Thakau Reivareiva and Thakau Nasokesoke, both, according to the sailing directions, dry at low water and steep to all round. We did not visit either Thakau Levu or the last mentioned reefs.

Ongea.

Plates 22, 22ª, Figs. 6, 7, and Plate 94.

The Ongea group consists of two large islands, Ongea Levu and Ongea Ndriti, and numberless mushroom-shaped or conical or dome-shaped islets and rocks, studding both the passage between the two principal islands or fringing the shores or extending across the openings of the bays which indent the coast line of Ongea Levu and Ongea Ndriti (Plate **22**). The larger island, Ongea Levu, runs nearly north and south; it is four miles long, and varies from one to two miles in width; it rises to a height of 270 feet. This island lies in the centre of the northern part of the lagoon, about equidistant from the outer encircling reef flats, within a channel from three quarters of a mile to a mile in width, and varying in depth from seven to twelve fathoms. Off the southern end of Ongea Levu the lagoon expands, and attains a width of nearly six miles. The outer reef flat is narrow, but expands to a width of three quarters of a mile off the southern face of Ongea Ndriti, where it becomes a fringing reef. Ongea Ndriti is nearly two miles long and one mile broad, and rises to a height of 300 feet. The Barracouta Passage is the only ship channel leading into the lagoon. It opens through the western reef flat into the widest part of the pear-shaped lagoon, a little south of the extremity of Ongea Levu. The greatest length of the lagoon is about eight miles.

The Ongea Islands consist of elevated limestone, rising in nearly vertical cliffs along the shore line. This is deeply indented by broad and deep bays, forming small irregularly shaped sounds, which in the case of Ongea Levu have nearly cut that island into two (Plate 22). The openings of the bays and the shores of the islands themselves on the western and southern faces of Ongea Levu are studded with islets and rocks, which, like the ridges of the islands, consist of elevated limestone. They are most numerous off the wide and deep bay on the southern face of the larger island, and extend across the channel separating Ongea Levu and Ongea Ndriti (Plate 94). The outliers extending south from the former island connect with those stretching north from the opposite face of the smaller island.



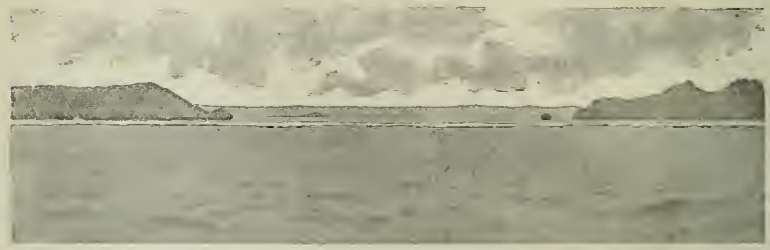
SOUTHWEST POINT OF ONGEA LEVU.

The mushroom-shaped rocks and islets also extend along the western face of Ongea Ndriti, but they are not as numerous as on the northern face. On many of the islets are found a few straggling palmettos, identical with those growing on the principal island. The islets and rocks as well as the shore cliffs are deeply undercut, and the surface is deeply pitted, honeycombed, and full of potholes and caverns, and presenting the appearance so characteristic of the weathered coralliferous limestone wherever we have found it in Fiji. It seems, however, as if the erosion and denudation, and the accompanying weathering, had been more intense as we proceeded southward along the windward islands of Fiji. The islets and rocks remaining as evidence of the former connection of the islands of this group are perhaps as good illustrations as any we have seen of the process which has been going on to reduce to its present proportions the original reef flat or island, which probably once covered the whole of the area of the Ongea Lagoon. The bottom of the lagoon is made up of coral and coralline sand. Half a mile from the northeastern horn of the outer reef of Ongea rises a sharp submarine peak, of which only the rock rising on the western edge remains, and on which has been formed the small circular reef of Thakau Teteika, about three quarters of a mile in diameter; while to the southeast, distant about three miles and a quarter, rises Nuku Songea, a triangularly shaped atoll enclosing a shallow lagoon with a low sand key at its northern extremity.

Fulanga.

Plates 22, 22^a, Figs. 4, 5, and Plates 80-84.

Fulanga is an elliptical island deeply indented on its southwestern face (Plate **22**), along which rises a ridge of elevated limestone to the height of 240 feet. This tertiary limestone rock has been elevated to a height of 260 feet at Quoin Hill, on the northeastern face of the island. The "Sailing Directions" (p. 214) represent Fulanga as "of volcanic and coral formation, and the circular shape of the island leads to the supposition that it is the rim of an extinct crater." What I have seen of Fulanga shows no trace of volcanic rocks, though they may exist on the southwest shore, which we did not see. Mr. Gardiner,[1] who visited Fulanga, classifies it among the limestone islands. It is quite natural



ENTRANCE TO FULANGA.

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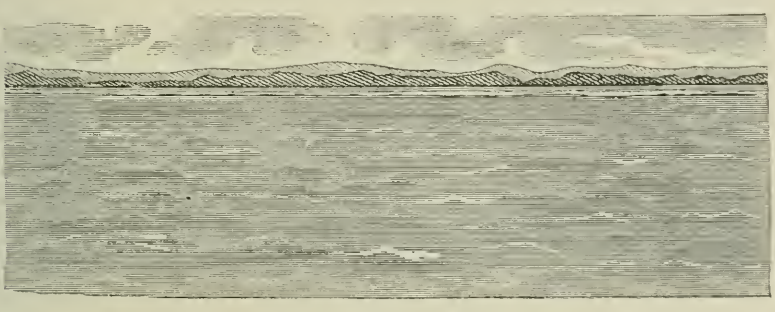
[1] Proc. Cambridge Phil. Soc., Vol. IX. Part VIII. p. 458 (1898).

that the honeycombed pitted pinnacles of hard ringing limestone should be mistaken by inexperienced observers for volcanic clinker-like rocks, and the locality described as volcanic, especially when taken in connection with the crater-like aspect of the sounds. The island is surrounded by a fringing reef nearly a mile in width in some places, and with a passage forming a shallow and very narrow lagoon with a depth of four to five fathoms between the outer reef flat and the shore line along parts of the eastern and of the western face of the island. There is a narrow passage (Plate **82**) on the northeastern face into the interior basin, but too shallow to have admitted the "Yaralla." In addition there are also a number of openings between the numerous islands and islets into which the elevated limestone ridge has been cut up (Plate **80**). Through all these the current flows with considerable velocity (three knots). The interior of the basin is full of islets and of rocks, mushroom-shaped or dome-shaped, all deeply undercut and all consisting of the same elevated limestone of which the outer ridges are composed (Plate **81**). These islets and rocks are of all sizes and shapes, some of them nearly half a mile in length; and they are found in every part of the basin (Plates **83**, **84**). The greatest depth of the interior basin is ten fathoms, with an average of five to six.



EAST SIDE OF FULANGA.

Although the general appearance of Fulanga is much like that of an extinct crater, yet its formation is due to other than volcanic agencies. The whole of the area of Fulanga must formerly have been covered by a bed of raised coralliferous limestone. The lower parts of the eastern face of this elevated flat became cut up into islands and islets, allowing the passage of the sea, and it has little by little eaten into the body of the elevated limestone, forming an extensive inner basin four miles in length by two miles wide, leaving the basin studded with innumerable islets and rocks (Plates **83**, **84**) such as I have already mentioned. These islands have usually vertical faces; many of them are conical, dome-shaped, or mushroom-shaped, like the islands and islets inside of the interior basin. A similar process has been going on off the northern point of Fulanga, south of Quoin Hill, where the conical and dome-shaped and mushroom-shaped islands and islets and rocks are seen to pass gradually from conical or dome-shaped bluffs along the shore line into the negro-heads of the outer reef flat off that point. This process of disintegration must have been similar in every respect to that which has formed the sounds in the Bermudas, eating small bays into the faces of bluffs inland, these becoming circular with time, with only a narrow opening, and finally leaving merely a narrow ridge or parts of ridges surrounding a central basin resembling an atoll.

FULANGA SOUTH OF QUOIN HILL.

If the process which has been shaping Fulanga had been going on longer the result would have been a low ridge on the southwestern face of an elliptical outer reef flat, with an enclosed lagoon full of islets or rocks or heads, and here and there perhaps an island or islet indicating the former existence of the elevated coralliferous limestone ridge; there being a passage into the lagoon where it now exists, the lagoon as enlarged including the true lagoon and the "Sound" basin, — a condition of things very similar to that found on Oneata, Ngele Levu, Yangasá, Nanuku, and on Vanua Mbalavu. On the faces of the islands and islets forming the eastern ridge of the basin of Fulanga rise vertical cliffs deeply undercut and weathered. The reef flats are full of negro-heads, some of which are of considerable size. The reef flats are everywhere covered with extensive stretches of flourishing corals.

This atoll-like basin has thus in reality been formed by the wearing action of the sea, and subsidence has played no part in its formation; on the contrary, the coralliferous limestone flat covering the basin has been elevated to nearly three hundred feet, and it has been subject for a long period to the action of the atmosphere and of the sea; the one wearing down the limestone land into an inner basin or cutting it out into valleys, and finally into islands and islets; the other encroaching into it from the outside, and eventually forming an interior basin studded with islets, which to all appearance would be a lagoon surrounded by an encircling reef with its heads and patches and islands and islets. And yet it would really be a crater-like basin, a "Sound," which by erosion had become connected with the true barrier reef lagoon, and finally even all trace of the Sound character of the inner basin might vanish with the disappearance of the old shore line, and the existence of only islets to indicate the former land area.

In the case of Fulanga, Gardiner[1] has well described the action of the sea both as a solvent and as a disintegrating factor in reducing the rocks and islets to mushroom-shaped structures, and in the great undercutting of the cliffs, of which he gives the same illustration as that I give here, which was kindly furnished me by the Hon. W. L. Allardyce. He says: "The final result should be a perfect atoll reef just awash, the land being dissolved away while the living reef round it continues to grow." So it does, but the reef has played no part in the shaping of the atoll, the lagoon of which owes its existence to the formation of the interior Sound by the decomposition of the elevated tertiary limestone reef mass, and has no connection with the recent coral reef growing upon the reef flats or external platform of submarine erosion.

SOUTHEAST POINT OF MARAMBO.

Marambo.

Plate 22.

Marambo is a small circular island about three quarters of a mile in diameter (Plate 22). It is composed of elevated limestone rising to 160 feet in height. It is surrounded by a fringing reef fully a mile in

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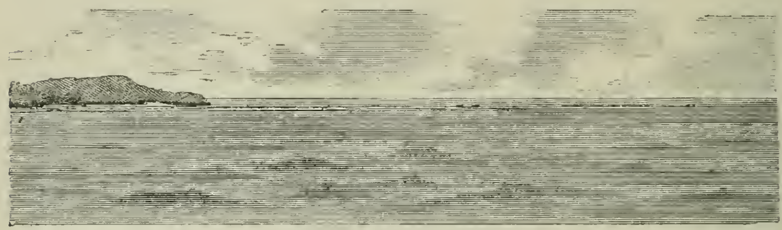
[1] *Loc. cit.*, p. 459.

width off the northern extremity of the island. Off the southwest face of the island there is a shallow incipient lagoon. There is a large crack running through the peak of the highest point of the island near the southern point, as if the sea face might scale off at any moment and form a vertical cliff. There is a fine vertical cliff along the northeast point of the island over 100 feet in height, deeply undercut. From the lower edge of this cliff numberless negro-heads extend over the surface of the fringing reef flat, which is covered by large patches of flourishing corals.



NORTH POINT OF MARAMBO.

Dana and Darwin both speak of fissures passing through the shore shelf reef. The fissure we saw at Marambo I attribute to the giving way of the shore bluffs from the undermining preparatory to its shaling off.

Wangava.

Plate 22.

Wangava, as seen from the passage between it and the northern extremity of Kambara, appears to be composed of two parallel ridges of limestone, elevated to a height of nearly 300 feet. The island is steep to on all sides, steep cliffs forming its eastern and western faces. It is surrounded by a wide fringing reef (Plate 22) except off the north face, where it becomes broken up into coral heads and patches.

Vatu Leile.

Plates 9, 17^a, Figs. 1-4, and Plates 100-102.

Vatu Leile, the westernmost island of the group we examined, is triangular in shape, with a small lagoon extending along the eastern and the northern faces of the island (Plate 9). The lagoon is comparatively shallow, not having anywhere a depth greater than five fathoms. Nearly the whole lagoon is covered with patches of corals and of reef rock, especially in the southern and western parts. The island of Vatu Leile is a mass of elevated limestone rock, rising at the southern extremity to bluffs of about 30 feet on the western side. The series of bluffs forming the western shore gradually increase in height as we go north, where at the most westerly point the bluffs are more than 100 feet in height (Plate 100).

WEST SIDE OF VATU LEILE.

The bluffs of the western coast are vertical faces with rounded summits full of cavities and alternate with short coral sand beaches. On many parts of the fringing reef edging the west coast there are still left small mushroom-shaped rocks, fragments of elevated limestone rock once forming a part of the main island. The northern extremity of the island is full of caves. Judging from the color of the water, the outer slope of the reef flat towards deep water appears to be very gradual. The whole island slopes gently to the eastward, having gradually been denuded and eroded so as to form a low east shore line, with extensive flats off the northeastern point. The west shore is protected by a fringing coast reef

NORTHWEST POINT OF VATU LEILE.

varying in width from a few yards to 300 or 500 yards, or even disappearing entirely along some of the beaches, with many areas of smooth impounded water within the fringing reef flats. The north side of the lagoon is protected by an outer reef flat fully half a mile wide in some places. On it corals are flourishing. There are two passages into the lagoon, with about ten feet of water in the channel. On the eastern side the outer reef runs parallel with the coast, gradually becoming wider towards the south, where it forms a wide coral flat connecting as a fringing reef the outer reef with the low southern part of the island.

To the west of the lee passage are the small island of Vatu Savu (Plate **101**), consisting of a larger low rock of elevated limestone deeply undercut and pitted and honeycombed, and of three other mushroom-shaped rocks of the same structure. Between the lee and the weather passage are the islands of Vatu Levu and the cluster of rocks Vatu lai lai (Plate **102**), similar in structure and in appearance to Vatu Savu. These islands and islets are all situated upon the flat of the outer reef. The whole reef flat is further studded with negro-heads, the remnants of former islands and islets of elevated limestone.

The presence of these islands, islets, and rocks, as well as the existence of the extensive flats off the east coast, clearly indicate the manner in which denudation and erosion have transformed the greater Vatu Leile which once may have covered the whole area of the lagoon, leaving only a part of the main island, with the islands and islets on the outer reef flats and the innumerable patches of corals flanking the inner edge of the outer reef. There is a strong current flowing out through the passages of the northern line of the outer reef.

THE SOUNDS OF FIJI.

Plate 22.

Fulanga is also interesting as illustrating the formation of an atoll by the same causes which have produced the Sounds in the Bermudas.[1] In the case of Fulanga we have a ring of elevated coralliferous limestone raised by volcanic agencies to a height of nearly two hundred feet. The whole area of Fulanga was probably once covered by coralliferous limestone, forming an island resembling Kambara or Mango. The island was, judging from its present condition, highest on the northern side, with

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[1] Bull. Mus. Comp. Zoöl., Vol. XXVI. No. 2, 1895, p. 231; also Bull. Mus. Comp. Zoöl., Vol. XXVIII. No. 2, 1896, p. 29.

summits nearly as high on the southwest coast, and sloping seaward towards the east (Plate 80). Atmospheric agencies gradually reduced its height, cutting out at the same time an interior basin, the eastern rim of which (Plate 81), being lowest, was soon denuded and eroded in part. One can readily see (Plate 22) how longer denudation and erosion would reduce the existing Fulanga land to a few large islands left isolated in the interior of an encircling reef and connected only by a few mushroom-shaped or conical islets, the interior of the lagoon being dotted with coral heads, the recent corals on the outer edge of the submarine flat forming a reef crust of moderate thickness. This coral rim has been broken through, and the action of the sea has gradually hollowed out in the interior a circular sound resembling an extinct crater (Plate 22), which has arisen solely from the disintegration of the inner part of the elevated limestone. Many parts of this still exist as small mushroom-shaped or conical islands (Plate 83).

It is also probable that some of the ancient elevated reef flats may have been converted into atolls by causes similar to those which have produced the crater-like Sound of Fulanga. This has perhaps been the case with such atolls as Ngele Levu, and the Oneata, Ongea, and Yangasá groups. In both Ongea Levu and Ongea Ndriti (Plate 22), incipient sounds are forming which will cut these islands into two or more components, each one of which will in its turn be dissected into smaller islands or islets, till finally the remaining land may be all reduced to insignificant islands and islets, as on Ngele Levu (Plate 17), or on Wailangilala (Plate 18), Reid Haven, Vanua Masi (Plate 20), Motua Levu and Motua lai lai, Duff and Adolphus Reefs (Plate 18), or the islets may have totally disappeared and no vestige of the former land area remain except the sunken coral heads and rocks of such atolls as Thakau Levu, Thakau Motu (Plate 22), Thakau Lekaleka (Plate 21), the Ongea Reefs (Plates 20, 21), Thakau Tambu (Plate 20), Thakau Mata Thuthu, and Thakau Vutho Vutho (Plate 17), with the reservation that some of these atolls may be the result of the denudation and submarine erosion of volcanic islets or peaks or ridges, and not necessarily of elevated coralliferous limestones.

Are not islands such as Phœnix, Birnie, Kean, Howland, Baker, and Enderbury, which have depressions in the centre and no lagoons, islands which are gradually being denuded to the level of the sea, and the next stage of which will be the formation of a lagoon (sound) by the cutting in of the sea across the rim at one or more points, forming islands or islets round the lagoon? We can thus explain the peculiar formation of these islands without having recourse to subsidence. Yet other writers upon coral reefs would look upon some of these islands as instances of raised atolls.

The gradual transformation of islands, composed either wholly or in part of elevated limestone, into islands with large interior sounds like Fulanga can be readily followed by examining such islands as Wangava (Plate 22), Tuvuthá, Naiau (Plate 20), or Vanua Vatu (Plate 21), in which the interior basin is still surrounded by a high rim. Next followed such islands as Mango (Plate 19), in which the interior basin has at one extremity been transformed into a diminutive sound; then follow such islands as Namuka (Plate 22), the rim of the basin of which has been eroded so as to leave only parts of it, and the outline of which has been deeply cut into by a large outer sound. We pass next to such a group as Ongea (Plate 22), and next to such groups as Yangasá (Plate 22), of which the rim of the basin is represented only by four small islands scattered within the encircling reef; next to Oneata and Aiwa, where a single island, comparatively small, represents the former extent of the elevated limestone area of those groups. And a still further stage of erosion and denudation is represented, as stated above, by Ngele Levu, Wailangilala, and other atolls in Lau.

Vatu Leile (Plate 9) must have sloped very rapidly eastward to have attained its present condition, and we can readily follow it to a time when it will be flanked on the west side by a line of narrow islets very similar to those now existing on the north side of the lagoon. When the island and islets in Vatu Leile, Ngele Levu, Wailangilala, Katavanga, Reid Reef, Aiwa, Oneata, Yangasá, and Ongea have disappeared by subsequent erosion, it will be wellnigh impossible to detect the nature of the substratum upon which the modern reef is growing. At that time the lagoon will probably have become gouged out much as Ngele Levu has been. A similar difficulty will naturally be encountered, though at a later period, in determining the geological composition of the substratum underlying the modern coral reef in the atolls of Wakaya, Makongai (Plate 15), Mbengha (Plate 8), North and Great Astrolabe Reefs (Plates 9, 10, 11), Budd Reef (Plate 18), Totoya (Plate 16), Kimbombo (Plate 19), Nairai (Plates 12, 14), Komo (Plate 22), and others, when the islands now existing on the edge or within the encircling reefs have disappeared from denudation and submarine erosion.

This is another instance of the great variety of causes which have been active in producing the present physiognomy of the reefs of the Fijis, and shows the impossibility of assigning any one factor, like subsidence, for instance, as is done by Dana and Darwin, as the single cause for the formation of the many different kinds of atolls and of barrier reef islands to be found in the Fijis.

THE TERTIARY ELEVATED LIMESTONES OF FIJI.

The existence throughout Fiji of numerous platforms of submarine erosion at average depths varying within very moderate limits seems to indicate a condition of approximate equilibrium as far as either elevation or subsidence is concerned. The elevation of the limestones of late tertiary age clearly indicates that the origin of the greater number of the Fiji Islands dates back approximately to that period. This is undoubtedly the case with the range of islands known as the Lau or Eastern Archipelago of Fiji. With them we should include the more northerly islands, the group to the east of Ngamia, and of Budd Reef, including Thikombia.

It is more difficult to determine the age of the larger islands. Viti Levu and Vanua Levu, as well as Taviuni, Kandavu, and the volcanic islands of the Koro Sea. We may assume with a certain degree of probability that the age of such islands as Nairai and Ngau corresponds with the age of the volcanic rocks which have lifted the islands of the Lau group to their present altitude. But in Viti Levu and Vanua Levu the problem is more complicated. While elevated coralliferous limestones of late tertiary age occur along the shores of Viti Levu evidently of the same age as the limestones of Lau,[1] yet there is evidence of the existence of older rocks as a nucleus of the larger Fiji Islands. So that until the geology of Viti Levu and of Vanua Levu has been more accurately studied, we must leave their age undetermined; but enough is known of the geology of the shore line to show that the existence of the great barrier and fringing reefs along the shores of Viti Levu and of Vanua Levu gives no evidence that the great barrier reefs of these islands owe their origin to the gradual subsidence, during our epoch, of the islands themselves.

The existence of the tertiary elevated coralliferous limestone at so many points in the Fiji Archipelago (Plate 2) seems to indicate a huge limestone bed of great thickness and extent, formed during tertiary times, along the flanks of ancient volcanic islands, and elevated by subsequent intermittent volcanic action during more recent times over areas of

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[1] Horne (A Year in Fiji, London, 1881, p. 165) says that in Viti Levu and Vanua Levu sedimentary or limestone rocks are found on all mountains.

varying dimensions, — areas which might be of considerable extent, like the Exploring Isles, the Argo Reefs, or smaller areas, like Yangasá, Oneata, Ongea, Fulanga, and the like, or smaller peaks forming atolls of very limited circumference, like Wailangilala, Nuku Mbasanga, or isolated limestone rocks of still smaller dimensions, like Vekai, Tavunasithi, and others.

Of course numerous soundings among the islands of the Eastern Archipelago of Fiji are needed to ascertain the existence of a more or less continuous plateau of coralliferous tertiary limestone deposited either by accretions upon its surface or formed during subsidence.

I brought to Suva a complete diamond-drill boring apparatus and a competent man to superintend the work, Mr. William Eyers, recommended to us by the Sullivan Machine Company of Chicago, from whom the apparatus was obtained. A comparatively small hand machine was sent, capable of drilling to a depth of from four to five hundred feet; an oil motor was also provided to expedite the work with increasing depth.[1] This machinery had been shipped when information reached the United States that Professor David of the University of Sydney had left for Funafuti in charge of an expedition to take up the work where it was left by Professor Sollas, the head of the expedition, assisted by the council of the Royal Society of London.[2] The day before leaving Cambridge for the Pacific, we heard that Professor David's party had succeeded in reaching a depth of nearly 600 feet, the bottom being still in coral. This information seemed to settle the coral question, and all I hoped to accomplish was merely to confirm the work of Professor David by boring in some other district. Subsequent information received from him leads me to think that the matter is not so simple as represented by the newspapers, and from what I have seen thus far in the Fiji Island reefs I can only conclude that the boring at Funafuti has settled nothing, and that we are still as far as ever from having a general theory of the formation of coral reefs. In fact, with the present information obtained in Fiji, I should never have thought of boring in the atolls of that group, for reasons which will be given presently.

This evidence shows that any result obtained would merely indicate the thickness of the former elevated limestones at any particular point; information which could have no bearing on the main question, if I am

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[1] I have to thank the Trustees of the Bache Fund of the National Academy of Science at Washington for an appropriation of $1,200 towards defraying a part of the expenses of the boring.

[2] Proceedings of the Royal Society of London, March, 1897, p. 502.

correct in my interpretation of what I have observed; information, in fact, which may be obtained as one steams along, without the trouble or cost of boring. Should I be correct in my inference, I am inclined to look upon the boring at Funafuti much in the same light, and to assume that that island is also in an area of elevation, as well as others in the Ellice group, and that the great thickness of coral obtained was reached in the base of an ancient limestone, and that the results obtained by the boring there do not assist us in any way in corroborating the theory of subsidence as essential to the formation of atolls.

The evidence which has been brought forward regarding the great thickness of modern reefs, as postulated by Darwin, from that of the fossil coral reefs existing during former geological periods, seems to me to be of little value. Langenbeck[1] and von Lendenfeld[2] have both urged this point. The former has given an excellent *résumé* of the subject of these ancient reefs, although he has no personal knowledge of recent reefs. All that can be said at present is that these so called fossil reefs are coralliferous limestones of great thickness, which first occur in the Devonian; they are little developed either in the Permian, or Trias, or Lias. They are again well developed in the Jurassic period, less so in the Cretaceous, and increase in Tertiary times. That parts of some of these coralliferous limestone masses represent reefs there can be little doubt, yet the observations we made in Fiji regarding the coralliferous elevated Tertiary limestones, which have been considered as elevated reefs of the present epoch, only show how guarded we should be in an expression of opinion as to what constitutes a fossil reef, — I mean a fossil fringing or barrier reef, or a fossil atoll, — when we are not able to decide that point in the reefs of to-day, and when one set of observers claims that the Tertiary elevated limestones represent elevated atolls, while the other set clearly shows that these elevated limestones have played no part in the formation of the recent atoll, or barrier reef, but have merely built up the substratum upon which the moderately thin crust of recent reefs has established itself.

Granting, even, as is very probable, that when these Tertiary limestones were formed they were formed in great part by subsidence, and in part by accretion from the carcasses of the invertebrates living upon their surface, this would in no way help us to a satisfactory

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[1] Langenbeck, R.: Die Theorien über die Entstehung der Koralleninseln und Korallenriffe und ihre Bedeutung für Physische Fragen. Leipzig. Abschnitt IV.

[2] Nature, May, 1890, p. 29. See also the interesting note by von Fritsch, quoted by Krämer, *loc. cit.*, p. 33.

explanation of the formation of atolls and of barrier reefs by the growth of the corals of the present epoch. Nor would the geological evidence of the great thickness of similar limestones in past periods be of any assistance in the solution of the problem if our explanation of the formation of atolls and of barrier reefs upon platforms of submarine erosion is correct.

Certainly the analogy of the association of volcanic rocks and so called reefs in the Devonian and Trias with similar association in the Pacific has no value, as is suggested by Frech [1] and Langenbeck. The substratum upon which corals may grow depends upon the geological structure of the country and its latitude. Such an analogy would throw out in great part the reefs of Australia, those of Florida, of the Bahamas, of Honduras, and of the northern coast of Brazil, which are not in volcanic regions, and where the substratum is either Cretaceous or Tertiary.

The only evidence we have of the great thickness of coral reefs, such as is required by the Darwinian theory of the formation of atolls and of barrier reefs, is based upon the great thickness of the so called elevated reefs observed in the Pacific by Dana, Darwin, and others, and upon similar observations in Cuba and other parts of the West Indies, and upon the evidence of the great thickness of the reefs of the Dolomite. That the latter are true coral reefs is more than doubtful. Those rocks are probably great masses of limestone similar to the huge deposits of so called elevated reefs of the West Indies and of the Pacific. The evidence obtained by boring, and from recent elevated reefs, shows that the modern coral reef attains but a moderate thickness well within that of the depth at which reef corals grow. The limestones form the basis or substratum upon which the recent reefs have obtained a footing. The elevated reefs of Cuba and of the West Indies have been shown to be Tertiary coralliferous limestones, and the same is the case with the elevated reefs of the Pacific, if we can judge of their age by that of the elevated coralliferous limestone reefs resembling them observed by me in Fiji.

The central depression, noted as characteristic of the summit of so many islands consisting of elevated coralliferous limestones does not show these islands to be elevated atolls as has been supposed. The summit basin representing the former lagoon of the island has been formed since the elevation of the island by atmospheric agencies. This basin is a gigantic banana-hole, as such depressions are called in the Bahamas,

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[1] Neues Jahrb. f. Mineral., 1892, Pt. II. p. 173.

formed by the carrying off the limestone in solution in the pools or ponds in the summit basins, — basins which with age become deeper and deeper, forming thus depressions which in some instances have been mistaken, in the one case for extinct craters, in the other for the lagoons of elevated atolls.

I would refer to the description of such islands in Fiji as Mango, Kambara, Tuvuthá, Naiau, Fulanga, and others, as evidence supporting the explanation here given of the formation of the so called elevated atolls. Of course I do not mean to assert that an atoll cannot be elevated as such, nor that such atolls may not exist. I merely wish to assert that the summit basins of islands formed of elevated coralliferous Tertiary limestones in Fiji are islands in the first stage of disintegration, passing gradually from such types as Naiau[1] and the like to islands like Mango, then to Fulanga, next to the Yangasá cluster, then to Ngele Levu, and finally to Motua lai lai and the like.

The steepness of the slopes of coral reefs has been assumed to be due to the growth of corals, and has generally been taken from old and unreliable soundings, as has been stated by Admiral Wharton[2] and others. The great depths are generally soundings so far off from the coral islands as not to give any accurate information.

The actual slopes of coral reefs which have been measured are very few, and the slopes given are invariably those of the underlying substratum, which may or may not be steep, and the inclination of which has no bearing on the angle of the steep outer slope of recent coral reefs, which usually reaches only to the very moderate depth of twelve to fifteen fathoms.

It seems to me that the calculations which have been made by Darwin in regard to the thickness of coral reefs, depending as they do upon the assumption that their great thickness has been formed by subsidence, and that this thick mass rests upon the continuation of the inner land slope under the coral reef, are assumptions which cannot be proved, or have not been proved. We should get a totally different result, that of a comparatively thin crust, if we assume that the land slope commences at or near the outer edge of the reef wherever the outermost negro-heads have been found. And in a great many cases, the steepness of the sea face is no greater than the slope of the mountains of the adjoining land. I have already called attention to the fact that

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[1] Naiau itself having become depressed in the centre by chemical and atmospheric erosion.

[2] Nature, June 19, 1890, p. 172.

off the south coast of Cuba we have along the sides of Bartlett Deep fully as steep a pitch as that of any coral reef.

Gardiner[1] has noticed the atoll-shaped shoals inside the great barrier reef of Fiji (Plate **23**^{a}), and compares them to the smaller atolls inside the large atolls of the Maldive group. See also the Serpuline atolls of the Bermudas,[2] which hold the same relation to the lagoon inside the outer barrier as the atoll-shaped shoals just mentioned hold in Fiji, and they certainly are not due to the effects of the débris of the outer reefs of the present day, as is claimed by Dana.

As long as it was taken for granted that the coral reefs of the present day were of great thickness, it was natural to compare them with the great beds of coralliferous limestones occurring in past ages from the time of the Devonian to the end of the Tertiary period. While there is abundant proof that some of these limestone beds have been formed during a period of subsidence, there is also ample proof that they must have greatly increased in thickness by accretion. But it does not follow from this that atolls and the lagoons of barrier reefs have been formed during a period of subsidence, now that we know that a great many of the coral reefs of the present day attain a comparatively moderate thickness, well within the bathymetrical limits at which reef building corals thrive. Nor is there anything to prove that these ancient limestones represent such modern structures as the atolls, or bordered the lagoons of barrier reefs, and even if they did it is more natural to suppose that the lagoons of these ancient atolls, as well as those within the ancient barrier reefs, must have been formed by the same agencies which have shaped the atolls and the lagoons of barrier reefs in our days. So that the analogy between ancient and modern reefs, such as is upheld by Dr. R. von Lendenfeld,[3] while undoubtedly true as far as it applies to the formation of beds of coralliferous limestones of great thickness, yet has no application to the actual formation of the lagoon of an atoll or of a barrier reef.

This still leaves open the question of the mode of formation of such thick masses of coralline and coralliferous limestone, which, though they may originally have been formed partly by subsidence, may also have been formed partly by the gradual pushing out to seaward of the outer edge of a reef increasing both in height (depth) and in width by the constant pushing out of the mass of débris and of blocks detached from the

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[1] *Loc. cit.*, p. 493.

[2] Bull. Mus. Comp. Zoöl., Vol. XXVI. No. 2, 1895, p. 253.

[3] Nature, No. 1071, May 8, 1890, p. 29.

outer edge upon which corals may flourish and spread seaward, when the talus has reached the depth at which corals can grow. I am inclined to think that the examination of such a reef will alone give us an idea of the way in which such thick masses of coralliferous limestones were formed, — most probably by a combination of subsidence, of accretion, and of lateral expansion.

What the exact age of the elevated limestones is, I am as yet unable to state. Their aspect and position show them to be of considerable age, and probably antecedent to the present period, and in many ways they resemble some of the late tertiary elevated limestones I have found on the north coast of Cuba. The great thickness which the elevated coralliferous limestones attain in this group, at least 800 feet, also shows that it may have been deposited during a period of subsidence, but not a period of subsidence in our epoch, or which could have had any effect in shaping the outline of the islands of the Fiji and their accompanying reefs.

Whether the elevation of the Fiji group corresponds in time with that of the northern part of Queensland, I am unable to state. I can only suggest that it is not improbable that the elevation of Queensland and of the islands to the east of the Solomon, New Hebrides, etc., including the Fijis and Samoa, may have been synchronous, and that these islands have, like northern Queensland, been subject to an immense denudation and erosion, reducing them to their present proportions. The elevation having probably, as in northern Australia, been preceded in still earlier geological times by a great depression, during which the thick beds of coralliferous limestone may have been formed. Judging from some photographs I have seen, I should feel inclined to consider the atolls of the Paumotus to have been formed by causes similar to those which have shaped those of the Fijis.

The Tonga Islands as described by Lister[1] are arranged by him in three divisions: (*a*) purely volcanic islands; (*b*) islands formed of volcanic materials laid out beneath the sea and since elevated, with or without a covering of reef limestones; and (*c*) islands formed entirely of reef limestones.

The islands of the Vavau group consist entirely of limestone, the formation of which must have been at least 300 feet thick. The islands are flat-topped, and the majority stand at one of three levels of elevation. Lister[2] figures the terraces of the islands to the south of Vavau. At

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[1] Notes on the Geology of the Tonga Islands. By J. J. Lister. Q. J. Geol. Soc. of London, Vol. XLVII. p. 590, 1891.

[2] *Loc cit.*, p. 608.

Fiji the only signs we saw of terraces were at Yangasá. The terraces in Fiji are most obscure, and what we find of elevation would seem to indicate sudden and rapid elevation without periods of rest such as occur in the Vavau Islands of the Tonga group, or in Cuba,[1] where the terraces are so well marked, especially in the vicinity of Cape Maysi.[2]

Lister speaks of the peculiar shape of the groups, penetrated by long, narrow, and deep inlets of the sea, a condition of things very similar to that of Ngillangillah, and of the north shore of Vanua Mbalavu in Fiji. Tongatabu is formed of coral limestone throughout, and one often meets with patches of coral, many feet in diameter, on which the lines of Astræoids or Madrepores are seen radiating from a common centre.

Lister calls attention to the basis for the growth of coral reefs which can be formed by such islands as Falcon Island.[3] He also shows that in the Tonga Islands, Tongatabu and Nanuku rest on shallow banks, and where the basis is exposed it is shown at Nanuku and Eua to consist of layers of volcanic material laid out under water.

Darwin and Dana both suggested that the formation of the Tonga Atolls was in a period of subsidence, yet it is asserted in the discussion of the subject[4] by Mr. J. W. Gregory that his theory (Darwin's) was not proposed for areas of coral formation in shallow or rising areas. Why then do Darwin and Dana quote them as examples of their theory? There is altogether too much of that kind of argument in the discussion of that theory. Are Darwin's supporters at liberty to carry on the process of selection till nothing is left of the original statement?

In Samoa and Tonga the volcanoes are still active, and we can, following Lister, actually trace the process of elevation and of erosion which has resulted in Tonga in elevating limestones and volcanic islands similar in every respect to those we have observed in Fiji. Islands in the last named group owe their existence to former volcanic action, the evidence of which is still visible in the existence of the extinct craters of Taviuni, of Thombia, of Moala, and of Totoya, and this volcanic action is to be traced throughout the larger islands of the group.

The description of Eua Island in the Tonga group given by Commander Oldham in Nature of May 22, 1890, p. 95, applies admirably to

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[1] A. Agassiz, A Reconnoissance of the Bahamas and the Elevated Reefs of Cuba. Bull. Mus. Comp. Zool., Vol. XXVI. No. 1, p. 110, 1894.

[2] R. T. Hill, Notes on the Geology of the Island of Cuba. Bull. Mus. Comp. Zoöl., Vol. XVI. No. 15, 1895.

[3] Falcon Island is stated to have disappeared during an eruption in August, 1898.

[4] Q. J. Geol. Soc. of London, Vol. XLVII. p. 590, 1891

the conditions which I imagine to have existed in the Fijis,[1] although the terraces indicate two periods of elevation, with one of rest, during which an interior basin similar to the central basin of islands like Kambara, Wangava, and the like, in Fiji, was formed by atmospheric agencies probably.

The rocks underlying the coralliferous limestones are stated by Professor Judd to be igneous rocks, but not modern volcanic material. He says, "They are suggestive of ancient volcanic masses that have been exposed at the surface by denudation, . . . and it is quite incorrect to quote examples like this as lending support to the view that all oceanic islands are of volcanic origin."

Speaking of Eua, which belongs to group (*b*), Murray according to Lister is of the opinion that the organic deposits of the island are old, yet there is no satisfactory evidence to refer them to the Tertiary period.

Niue or Savage Island is an elevated coralliferous limestone island, said to be 200 feet high;[2] the younger Foster considers that the central plain represents an ancient lagoon. It is skirted with enormous caverns.

The figure and description given by Dana[3] of Metia or Aurora Island, one of the Western Paumotus, recalls many of the raised limestone islands of Fiji. In the Hervey group at Atiu similar caverns exist, and they have also been noticed by Captain Beechey at Henderson Island. Its cliffs worn into caverns rise abruptly to about 230 feet on all sides except the south, where the island slopes very abruptly, much as Vatu Leile in Fiji. The surface of Metia, as described by Dana, resembles closely that of Ngele Levu, and he describes the wide shore platform, "resembling that of the low coral islands" and the modern reef about its margin.

It will be interesting to see if the great masses of coral blocks, figured and mentioned by Dana[4] may not throw some new light on the nature of the substratum of some of the Paumotus, where he observed them.

The sections of the small island of Masámashu in the Red Sea[5] do not seem to me to indicate subsidence, as is stated by Bonney (p. 312).

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[1] See also the account of Eua, by J. J. Lister, in Q. J. Geol. Soc. of London, Vol. XLVII. p. 590, 1891.

[2] Sailing Directions, Pacific Islands, Vol. II. p. 54.

[3] *Loc. cit.*, p. 193.

[4] *Loc. cit.*, pp. 179 and 203.

[5] Nature, Vol. XXXVI. p. 413.

On the contrary, judging from Fiji analogy, the section indicates the elevation of a submarine bank of coralliferous limestone and its subsequent denudation, and the forming of an enveloping reef on its summit having no relation with the nature of the deeper sea slope.

We collected a number of corals from the elevated limestone rock at several localities along the south and west coast of Viti Levu, at Suva, Ngele Levu, Kambara, Ongea, Ngillangillah, and Oneata. I found it impossible to determine whether the corals were *in situ*, or had been rolled or dropped along the sea face to form a talus. The difficulty of determining this without very considerable blasting at the base, the face, and along the exposed slopes of the elevated coralliferous limestones, is very great.

The collecting of corals from the exposed faces of the cliff was almost hopeless with our appliances. The faces have become extremely hard, a hammer produces no impression, and the corals are so well embedded as to make it impossible to cut them out.

It seems impracticable, except where one can actually see the corals grow along a slope, or on a patch or the sides of a head, to determine in the elevated reef rock if they are still in their natural attitudes. Madrepores and Pocillopores grow in all kinds of position; so do the heads of Astræans, Mæandrinas, and other massive corals. Furthermore, the spaces between coral patches and heads and individual masses of coral reef are filled either with sand, corallines, or fragments of dead corals. We can easily see the difficulty of recognizing the former condition of corals now embedded in a homogeneous mass of hard ringing limestone, in which the corals often exist as more or less indistinct solidified masses, barely indicating the genus to which they belong. The coral and coralline sand have become solidified into a close limestone ringing to the hammer. Large spaces have become impregnated with the red earth, characteristic of coral limestone formations, and the masses of coral fragments form a breccia or puddingstone of corals of the species which once flourished on the reef. Masses of Nullipores and Orbitolites are similarly cemented, or form the connection between the individual masses. The whole again is more or less cavernous, representing either spaces originally existing on the reef, or cavities which have been formed by the percolation of water through the mass. As far as I have examined the corals collected from the elevated limestones, they appear to belong to the same genera as those now living.

A careful and extended examination of one of the elevated coralliferous limestone reefs, as at Vanua Mbalavu or Kambara or Mango, for instance, where we can begin the study at the very base of the elevated limestone reef at its point of contact with the underlying volcanic rock, will teach us a great deal regarding the interior structure of a coral reef. This we can follow to the surface, or nearly so, by following the faces of exposed cliffs or the slopes of the ridges. Of course, the uppermost part of the reef rock, that which formed the original surface of the reef, will have been denuded and eroded to a considerable depth. But it ought to be possible from the study of an extensive area of an elevated reef, both vertical and horizontal, to settle the question of the growth of a reef seaward by its gradual extension upon a talus formed at a comparatively shallow depth (say twenty fathoms) from the fragments and masses which have dropped at the foot of the sea slope of the reef, after having been detached by the action of the breakers from the edge of the reef. It is natural to suppose that there must exist at the base of the reef a number of coral masses, judging from the multitude which are thrown upon the sea face of any modern reef when exposed to violent breakers.

Dr. William H. Dall[1] has been kind enough to examine the fossil mollusks which I collected from the elevated limestone reefs in the Fijis. He confirms the impression I had formed of their late tertiary age. Dr. Dall writes: "The fossils comprise Turbo, Cassis, Lithophaga, Macha, Tellina, Meretrix, Dosinia, Chama, Pholas, and fragments of Pecten. None of the genera are extinct. The rock, however, looks decidedly too old for Pleistocene. I should say the fossils were younger than Eocene, and might be either Miocene or Pliocene."

The boring which I started at Wailangilala Island in the atoll of the same name reached at forty feet a limestone similar in all respects to that composing the elevated reefs we had observed at Ngele Levu, at Vanua Mbalavu, at Mango, at Yangasá, at Oneata, at Ongea, at Kambara, at Vatu Leile, and at different points along the eastern, southern, and western shores of Viti Levu. At some points the elevated limestones attain a height of over 1,000 feet (Vatu Vara Island 1,030 feet), and the volcanic rocks underlying the elevated limestone reefs were observed at Vanua Mbalavu, at Mango, at Kambara, and at several points along the southern and western coast of Viti Levu. A renewed examination of the elevated reefs of the Paumotus, of the Friendly Islands, of the Gilbert, Ellice, and other groups of atolls in the Pacific will be needed to determine their age and correlation to the Fiji elevated limestones. At any rate, it is evident that the tertiary coralliferous limestones of Fiji have not played any part in the formation of

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[1] See Am. Journ. Science, Vol. VI. p. 165, 1898.

the atolls or islands encircled by recent coral reefs beyond forming the substratum upon which the recent corals have grown and established themselves as a comparatively thin crust.

The underlying limestones have performed exactly the same part as the volcanic substratum in other islands of Fiji, such as Totoya, Kimbombo, Wakaya, Makongai, Moala, Nairai, Ngau, and others. In both cases the platform upon the edge of which the corals grow has been prepared by extensive submarine erosion, dating from the time when the limestones were elevated by the volcanic rocks which crop out everywhere in Fiji, — an elevation which was not necessarily synchronous throughout Fiji and may have taken place at several distinct periods, so as to make it often difficult to determine the relative age of the limestones and of the volcanic masses.

Professor David, of the University of Sydney, has been kind enough to assist me in obtaining the services of one of his students, Mr. E. C. Andrews, to collect fossils from the elevated limestones of Fiji. Mr. Andrews has spent a part of the summer in Fiji, collecting material and exploring in detail some of the faces and slopes of the elevated reefs of the Archipelago, and has obtained ample material to determine the age of these elevated limestones.

In the earlier discussions of the thickness of recent coral reefs by Darwin and Dana, no attention was paid to the possibility of the substratum of recent reefs consisting of tertiary limestones. Elevated limestones containing corals of tertiary age were considered as of recent origin and as pointing to a great thickness of modern reefs. It has been shown in Florida that the modern reef is not more than about 50 feet thick, and is, according to the borings from the artesian well at Key West, succeeded by tertiary limestones, in which corals occur at intervals to a depth of 2,000 feet.

It has been stated by Dana and others that the borings from the artesian wells at Honolulu, to the rear of the shore line of the fringing reef of Oahu, indicate a great thickness of modern reef corals. These statements are based upon the examination of samples of finely ground particles of limestone accompanied by an occasional fragment of coral, the age of which has not been determined. The statements are further supported by the evidence of Mr. J. A. McCandless, the engineer in charge of the boring, who asserted to both Mr. Dana and myself that in boring all his wells the tool passed through a great thickness of corals, at various levels. During my recent visit at Honolulu, I was so fortunate as to be on the spot where Mr. McCandless was boring a ten-inch well, about

2,500 feet from the shore line, and perhaps seven feet above high water mark. Down to a depth of 80 feet nothing but recent reef coral rock was encountered, but from that point to a depth of over 300 feet the limestone passed through was of a very different character. It contained but few corals, being composed almost entirely of the shells of mollusks, mainly bivalves. The rock was white, chalky, and resembled in every way the rocks of the Vicksburg age of Florida and of Yucatan; but its age has not yet been accurately determined. Enough, however, is clear to show that the limestones which form the substratum upon which rests the recent fringing reef of Honolulu do not belong to the present period. Mr. McCandless assured me that limestones like those I had the opportunity of examining while the boring was going on are identical with those to which he called Mr. Dana's and my attention in 1888, and that until I pointed out to him that the white limestone was almost wholly made up of mollusks he had only paid attention to the occurrence of occasional corals, and supposed that the lower limestone formed the continuation of the recent modern reef. But, as I have stated, this lower limestone differs from reef rock both lithologically and in its being mainly made up of fossil mollusks.

It is very clear that when boring in a coral reef district in which it is difficult or impossible from other data to determine what geological changes may have taken place, or the probable age of any limestone we may pass through in boring, it may be very easy to draw wrong conclusions both as to the age of the limestones and regarding the position of the line of demarcation between the modern coral reef and the underlying older limestone substratum.

If my conclusion is correct, that such atolls in the Fiji Islands as Wailangilala, Ngele Levu, and many others to which I have referred in this report, are formed upon platforms of submarine erosion of elevated tertiary limestones, and if, further, in similar atolls in the Paumotus, the Gilbert, Ellice, and other groups, the substratum underlying the modern coral reef is likewise composed of tertiary limestones, it will become apparent that such borings as those carried on at Funafuti will not help us in any way to solve the problem of the formation of atolls by modern coral reefs. Such a boring, even should it reach the underlying volcanic substratum, will only give us the thickness of the tertiary coralliferous limestone beds forming the substratum upon which the modern coral reef has grown, — a thickness which in the Ellice group can only be ascertained by boring, while in Fiji it can be ascertained approximately from the height of the islands composed of elevated tertiary limestones.

I take it that the "cliffs" mentioned by Sollas,[1] and that the pinnacles described by Gardiner[2] which he calls "the remains of a part of an old raised reef," found on the inner rough zone of the outer reef, are just such masses of tertiary limestone as we found throughout the Fijis.

The shoals described by Gardiner[3] seem to me to be remnants of this elevated reef which have been isolated by submarine erosion, much as in Fulanga and Ngele Levu, and other groups of elevated tertiary limestone reefs in Fiji, upon which corals grow with greater or less luxuriance, the bottom of the lagoon between the patches and knolls being covered with sand.

Gardiner[4] supposed the atoll of Funafuti to have been formed before it was elevated. If I am correct in my interpretation of similar reefs in Fiji, I think, on the contrary, that the low limestone outer platform which now forms the ring of the atoll was once much higher, covered a greater area, and has been gradually denuded and eroded to its present stage, a process which according to Gardiner and my own observations is still going on.

Hedley,[5] as well as Sollas and Gardiner, assumes an elevation of four feet from the presence of dead subfossil corals in the position of life near high water mark. I do not see why the fact that the older limestones of Funafuti form a cone, and have no connection with the recent reef formed upon them, should have any bearing either in favor of or against any theory of coral reefs, even if the formation of the coralliferous limestones of Funafuti could only be explained on the subsidence theory. The lateral growth of the recent reef inwards and outwards is a feature depending, so far as the outer growth is concerned, wholly upon the exterior slope of the atoll, and the lateral expansion towards the interior of the lagoon depends upon a great variety of causes, such as the depth of the lagoon, the character of the islands on the outer edge of the atoll, the nature and depth of the shallower windward passages leading into the lagoon, the position of the outer reefs with reference to the prevailing winds and currents, the geological structure of the substratum upon which the recent reef is growing, and many other causes. As far as the filling of the lagoon of Funafuti is concerned, the views of Gardiner and Hedley are diametrically opposed. The islands may in-

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[1] Proc. Royal Society of London, March, 1897, p. 502. Nature, September 24, 1896, p. 517.

[2] Proc. Camb. Phil. Soc., Vol. IX. Pt. VIII., 1898, pp. 430, 431.

[3] *Loc. cit.*, p. 434. [4] *Loc. cit.*, p. 438.

[5] Memoir III., Australian Museum, Part I. Sydney, 1896.

crease in width, and encroach upon the lagoon, but that is a different proposition, as shown by Gardiner, from the filling up of the lagoon.

Gardiner[1] assumes that the limestones of the Fijis cannot have had any different origin from that of many of the atolls and barrier and fringing reefs of the present day.[2] But it seems to me that, inasmuch as these elevated limestones are of tertiary age and have been uplifted to heights varying from a few feet above the level of the sea to nearly a thousand feet to form subsequently platforms of submarine erosion upon which the recent reefs have grown, we cannot claim that they have been deposited, as recent corals have been, within comparatively narrow bathymetrical limits, the dolomitization of the elevated tertiary limestone having gone on to a considerable extent, while that of the recent reefs is insignificant.

Gardiner[3] looks upon Naiau, Tuvuthá, and other islands as perfect specimens of raised atolls. I have elsewhere given my reasons for not accepting such a view, and for considering the interior depressions of such "elevated atolls" as huge sinks similar to those formed in the Æolian hills of the Bahamas and Bermudas, and which eventually result in the formation of sounds or lagoon-like depressions. Gardiner[4] does not think it possible that denudation owing to climatic causes could have been of sufficient importance to have greatly affected the position of the summits. It seems to me that the gradation we can trace in the summits and outlines of such old island masses as Naiau, Kambara, Mango, Fulanga, Ongea, Aiwa, and others indicate, on the contrary, a most extraordinary denudation and accompanying submarine erosion. Gardiner[5] himself has given very much the same examples which I used in tracing the gradual changes hinted at above, only he attributes them wholly to the solvent action of the sea, while I am inclined to call into action in addition the effect of denudation and erosion, and to attribute to them a more important share than to the solvent action of the sea in the successive stages of the changes in the elevated limestone land masses, from an island with a fringing reef to a true atoll.

Under what conditions these tertiary coralliferous limestones of great thickness have been deposited is a distinct question from that of the formation of atolls through subsidence by the upward growth of corals during the present geological period. Neither the borings through a coral reef growing upon a substratum of tertiary limestone, nor the

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[1] *Loc. cit.*, p. 467.

[2] *Loc. cit.*, p. 467.

[3] *Loc. cit.*, p. 470.

[4] *Loc. cit.*, p. 470.

[5] *Loc. cit.*, p. 471.

examination of the outer edge of a coral reef formed upon a substratum of volcanic rocks, has given us in Fiji any evidence of the great thickness of a modern coral reef. On the contrary, all the evidence I have gathered there tends to prove that a coral reef forms only a comparatively thin crust upon the platform of submarine erosion, whatever be its geological structure, upon which it may have found a footing, — a crust of modern corals of no greater thickness than that within the bathymetrical range of which reef building corals can flourish.

The examination of the conditions under which beds of coralliferous limestone of great thickness have been laid down has little in common with the study of the conditions under which a modern reef is formed. The study of the conditions under which a modern reef — a reef of the present period — is formed and increases in thickness has yet to be made, and such a reef must be carefully selected. Probably a broad fringing reef resting upon a substratum readily distinguished from the reef rock, and one on which there existed a sand key close to the outer edge for boring until the substratum was encountered, would be the most suitable. But as it would be most difficult to judge from the core obtained at that or any other point where the growing reef ceased and the talus began to add to the thickness of the reef, it would be necessary to supplement this work with soundings taken close together, as well as with an examination of the bottom by dredging, either with large or small dredges or with trawls and tangles to obtain material in as many different ways as possible. Of course we can hardly expect to bring up in this way many specimens of reef building corals, but we can surely, by combining the information obtained from the nature of the soundings, the character of the bottom as shown in the larger samples secured by the dredge, and the occasional fragments of living corals we are sure to bring up, form some idea of the exact bathymetrical range to which reef building corals extend, and this is not so difficult a problem as is supposed by Professor Sollas. We should in determining this remember that in the interior of large lagoons in which there is an abundant circulation of pure sea water close to the inner edge of the outer reef flats we have very positive information as to the lower limit to which corals grow in abundance. We know that under these conditions the most flourishing belt of reef builders grows in depths of from three to eight fathoms, and beyond that the coral patches decrease very rapidly in number and size, that the patches are with increasing depth separated by wider lanes or greater areas of coral and coralline sand, or by masses of fragments of corals and of dead corals. We also know that on the sea face of the outer reef flats wherever they have been examined by means of the sounding lead, the dredge, the tangles, and the water glass, identical results have been obtained as regards the bathymetrical range of the reef growing corals, with the exception that the lower limit of depth seems to be somewhat greater, and extends in some instances to 17 or perhaps even 20 fathoms. We should also remember that there abound on all coral reefs numberless organisms whose only role seems to be to cement again the particles and fragments broken by the action of the sea or of boring animals, and they play a most important part in forming coralline limestone full of reef building corals, which yet have nothing to do with the increase of thickness of the reef from their own growth. Nullipores, Algæ, Corallines, Foraminifera, the minute fragments of corals or small particles of sand, all continue to act as great cementers at considerable depths far beyond that at which reef building corals have ceased to flourish. They act not only on the surface of the reef in the interior of the lagoons, but along its sea face and down to a considerable depth, and all along the outer slope they cement the fragments of corals which have fallen at the foot of the growing reef, and gradually transform the material of the talus into a hard limestone similar in its constitution to that of the reef building corals. But in this limestone formed of talus material, the corals no longer retain their natural attitude as when growing. It is a breccia of corals or a puddingstone, consisting sometimes of huge masses which have fallen from the growing face of the reef and rolled upon the talus along the sea slope where such a conglomerate breccia or puddingstone has been formed, and it reaches the depth of from 15 to 20 fathoms. Corals can again grow upon this buttress, and thus we may imagine the reefs of the present day to build outward and increase in thickness. This was the result which was hinted at from an examination of the sea face of the reef off Honolulu made in 1888.[1] Of course I do not deny that some reef builders may occasionally live at greater depths than those I have mentioned, but their casual occurrence at those greater depths would not materially affect the growth in height and increase in width of the great majority of coral reefs; and it is well known that Oculina, Lophohelia, and other genera, may cover extensive tracts at depths far beyond those at which so called reef builders flourish.[2]

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[1] Bull. Mus. Comp. Zoöl., Vol. XVII. No. 3, April, 1889, p. 121.

[2] Pourtalès, Mem. Mus. Comp. Zoöl., Vol. II. No. 2, 1871; Wyville Thomson, Depths of the Sea, 1873, p. 432; also The Voyage of the Challenger, the Atlantic, 1877, Vol. I. pp. 266–273.

ISLANDS PARTLY VOLCANIC, AND PARTLY COMPOSED OF ELEVATED LIMESTONES.

Kimbombo.

Plates 19, 61.

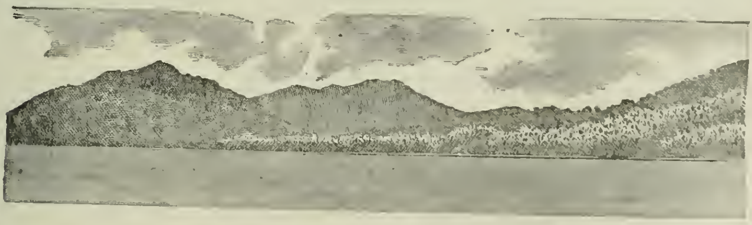
The Kimbombo Islets (Plate **61**) are a group of three small islands, one, the highest, of volcanic structure; the other two, the northern islets, are composed of elevated limestone, situated in the axis of a triangularly shaped lagoon, with twelve fathoms of water. The reef flat surrounding the lagoon is continuous, except at the northwestern point, where there is a passage into the lagoon (Plate **19**). In addition to the islands there are a number of coral patches and isolated rocks along the inner edge of the reef flat and in the western part of the lagoon. The atoll is nearly five miles in its greatest length, and the southern face is about three miles long. As we did not enter this lagoon, I could not satisfy myself regarding the structure of all the outlying rocks on the outer edge of the submarine platform, some of which were evidently volcanic, others of elevated limestone. This is an interesting group, showing how varied the structure of an atoll may be, and yet the record on the chart be most deceptive, the substructure of the Kimbombos being volcanic at one extremity, and consisting of elevated limestone at the other. Half way from Kimbombo to Ngillangillah Island rises the small peak of Trigger Rock to within four fathoms of the surface; to the east of the group lies Bell Reef, to the north Williamson and Dibble's Reefs, and Lookout Reef still farther to the east, all separated by deep channels and rising abruptly from deep water. The substructure of these reefs is of course unknown, and may be either volcanic or limestone elevated or eroded to within a few fathoms of the surface.

Exploring Isles.

Plates 19, 19^{a}, Figs. 1-3, and Plates 72-76.

We entered the atoll of Vanua Mbalavu, or the Exploring Isles, as it was called by the United States Exploring Expedition in 1840, through the Ngillangillah Passage. The reef enclosing the islands is triangular in shape; its greatest length is over 22 miles along the southeastern face; the breadth from the southeastern to the northwestern horn is 20 miles. The outer reef flats are comparatively narrow, except in a few places where, near the islands of Munia, Malatta, and Susui, they pass into the fringing reef flats. There are two important passes on the southeastern face,[1] the Tongan and the American Passages. The latter is a narrow tongue of the ocean cutting into the eastern face of the slope of the atoll with over 100 fathoms in depth, and opens into a wide deep submarine valley extending westward into the heart of the eastern lagoon. The Tongan Pass is a similar, but much shallower and shorter, tongue of the ocean. On the western side the Andiwathe Pass leads into a long deep lagoon formed by the outer reef and the west coast of Vanua Mbalavu. This western lagoon is connected on the south with the principal lagoon to the east of the island by a narrow and shallower passage over the fringing reef north of Malatta Island, and on the north by the passages leading round Ngillangillah Island into the passage of that name opening through the northwestern horn of the outer reef, and which extends, gradually widening eastward, along the northern shore of Vanua Mbalavu until it opens beyond Avea Island into the large eastern lagoon. Along the northern face of the lagoon are situated Avea and Sovu Islands. About two miles from the

NORTHEAST POINT OF VANUA MBALAVU.



VANUA MBALAVU, LOOKING WEST.

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[1] An exception to the usual rule, that entrances to lagoons are on the lee side.

eastern face is the island of Thikombia i lau. On the southern face are Ngillangillah, then follows the principal island of the group, Vanua Mbalavu, the western shore line of which is hollowed out by a deep indentation forming the western lagoon. Off its southern extremity is situated Malatta, next Susui, and finally the volcanic island of Munia. Vanua Mbalavu is fourteen miles long, forming a sharp angle at its highest and broadest point, where the island is nearly three miles wide and reaches a height of 930 feet.

The central and highest part of Vanua Mbalavu is volcanic, but towards the northeast and the south the volcanic rocks have lifted up an ancient elevated reef which extends from opposite Avea westward. The volcanic rocks (Plate **72**) dip very rapidly to the north, so that less than half way from Koro Mbasanga to Blackswan Point the bluffs are elevated limestones. These bluffs are deeply undercut, their surface pitted and thoroughly honeycombed, and full of potholes. The extent of the wearing of this coral rock is well shown by the deep bays and numberless indentations which characterize the northern coast of Vanua Mbalavu. When we come to the vicinity of Blackswan Point, the denudation and erosion of the elevated limestone has reached its maximum. Off the end of the large island lies the little island of Ngillangillah (Plate **73**), which is entirely composed of elevated limestone, which here attains a thickness of 510 feet. Beyond Ngillangillah there are numerous negro-heads and coral patches, some of them being of considerable size; they are of ancient coral rock. The coral heads and negro-heads extend along the whole length of the outer reef

ISLET OFF NGILLANGILLAH.

flat as far as we followed it to Avea. The bluffs forming the steep sides of the island are undercut and deeply indented, forming gorges and ravines (Plate **74**) which cut into the island or separate dome-like islets from the adjacent shores. The elevated limestone is full of species of coral, mainly large heads of species of Astræans, of Mæandrinas, and Pocillopores, which appear to be closely allied if not identical with those now living. One of the points of Ngillangillah was merely a thin shell covering a huge cavern some 50 feet in diameter and rising to a height of nearly 100 feet, and full of stalactites. The rock in the pool at its base was covered with Gorgonians and small corals, and abounded in Comatulæ.

The narrow channel lying between the north shore of the large island and the outer reef is full of flourishing coral patches. The many narrow deep cañons (Plate **74**) cut into the face of the island with the dome-shaped or mushroom-shaped heads of elevated reef rock projecting a few feet above the water line give to this shore line a very picturesque appearance. It is a simple matter to follow the extent of the elevated reef rock eastward, and to trace the gradual appearance of the central ridge of volcanic rocks until we come to the headland north of Koro Mbasanga (Plate **72**), where we find only a comparatively small outlier of the elevated limestone, and a similar one to the south of the village. Northeast of Koro Mbasanga lies the island of Avea (Plate **75**), which rises to a height of 600 feet, and which is wholly composed of elevated limestone. This island as well as Susui runs at an angle from the outer reef, and shows the great width of the former elevated reef. From Koro Mbasanga south and for some distance beyond Lomaloma the volcanic rocks occupy the whole width of the island, and the elevated limestone has disappeared to reappear again on the southern spit of the main island, and to extend eastward in the islands of Malatta and of Susui and their many outliers, as heads, rocks, and islets, both on the northern and off the eastern point of the latter island. The island of Munia consists, like the central part of Vanua Mbalavu, of volcanic rocks. The island of Thikombia i lau, on the contrary, is composed of elevated limestone rising to a height of 550 feet. Beyond Avea lie the Sovu Rocks, three small islets about two miles inside the outer reef, also of elevated limestone, one of which rises to a height of 230 feet. Between Avea and the Sovu Islets runs southerly for a distance of nearly five miles a series of narrow coral patches, which, so far as I can judge, are remnants of the ancient elevated limestones, as are probably the heads and patches of the eastern part of the lagoon beyond the Tongan Pass. On the contrary, many of the heads lying off the central parts of the east coast of Vanua Mbalavu are undoubtedly of volcanic origin, and are merely covered with a thin veneer of growing corals. Some of the small volcanic rocks and islets off the east central part of the east coast of Vanua Mbalavu are deeply undercut and eroded into mushroom-shape. By far the finest example of marine erosion of volcanic rocks is seen on Plate 62, which represents an eroded shore line with mushroom-shaped rocks off the shore, indicating a slight recent elevation. Plate 62 is taken from a photograph given us by Mr. E. G. Jones, and taken in Lau; unfortunately I am unable to state the exact locality. The islets of Yanu Yanu forming the harbor of Lomaloma consist of a yellow volcanic mud full of rounded pebbles, and some of the spits of the east coast of Vanua Mbalavu are composed of bedded volcanic mud (soapstone) similar to that found at Suva and its vicinity. The condition of the islands and islets and rocks, both of those composed of elevated coral reefs and of volcanic rock, clearly indicates the great denudation and erosion which have taken place, to leave only such fragmentary remains of the land which must have once occupied the area of the lagoon. It is possible that the age of the elevated limestone found at so many points in Fiji may be comparatively great, and that the ancient limestone forming the substructure of the reef of the present day may have been deposited in late tertiary times, immediately before the present epoch.[1]

VOLCANIC HILLS BACK OF LOMALOMA.

As has been observed, the dip of the lagoon is to the eastward, or rather, in a general way, toward the slopes of the deep tongue of water forming the American Passage (Plate 19). This would seem to be the natural result of the elevation of the great flat of tertiary limestones

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[1] See the report of Dr. Dall, referred to in another part of this Bulletin.

occupying the area of Vanua Mbalavu Lagoon, caused by the uplifting of the ridge forming the crest of Vanua Mbalavu, which has a short western slope and a long comparatively easy eastern slope, with the resulting deep valley leading to the American Passage, and perhaps a secondary elevation caused by the rising of Munia Island.

The depth of the western lagoon varies between 10 and 20 fathoms, that of the western part of the eastern lagoon from 6 to 30, while the eastern part of the lagoon slopes gradually from 20 or 25 fathoms toward the 100 fathom tongue in the eastern face of the outer reef. On sounding one mile north from the edge of the outer reef, off Blackswan Point, we found, at 203 fathoms, hard bottom. The character of the bottom of the lagoon varies greatly according to its proximity to shores or heads or patches composed of volcanic rocks or of elevated coralliferous limestone, or of a combination of both.

Nowhere in Fiji have we found the fringing corals growing in such profusion as in the Ngillangillah Channel. While steaming along the northern face of the reef, close to the outer edge, we had a good opportunity to note the appearance of the outer reef flat, of a yellowish green color covered with patches of violet, indicating the areas incrusted by living corals. Being on the lee side, there was scarcely a ripple along the outer edge, which was in sharp contrast to the very dark blue of the water covering the outer slope of the reef, while on the inner side there was a more or less wide light greenish belt bordering the reef flat and passing through light blue into the darker blue of the narrow continuation of the Ngillangillah Passage, itself dotted with greenish or yellowish patches of coral all along the reef flat, and on many of the inner patches were scattered negro-heads, consisting of elevated coralliferous limestone.

Mango.

Plates 19, 22^a, Fig. 3, and Plates 85-87.

Mango is a circular island, the southeastern and southern faces of which consist of a rim of volcanic rocks, through which rises to a height of 670 feet the central elevated ridge of the island (Plate 19). On the northern and northeastern faces an ancient coralliferous limestone has been elevated to a height of from 200 to 300 feet or more. That part of the elevated limestone which lies across the break of the rim of the island has been eroded and denuded to form a small lagoon or diminutive sound (Plate 85). The entrance is flanked by low conical or dome-shaped mounds and patches deeply undercut, some of which are mushroom-shaped. A passage has been cut for boats through the shallow opening connecting the lagoon with the inner sound, which receives the drainage of the interior of the depressed basin. The elevated limestone bluffs extend from the northern horn of the rim, along the coast line, towards the landing place on the north face of the island. To the east of this, on the north shore, are fine bluffs of elevated limestone, weathered into dome-like lamellar masses, with rounded masses and mushroom-shaped heads at the base (Plate 86). A little farther west, on the beach beyond the bluffs, the underlying volcanic rocks crop out again, and from there south the negro-heads on the western reef flats are all of volcanic origin.

MANGO, SEEN FROM THE NORTHEAST.

The island of Mango is almost circular, about three miles in diameter, surrounded by a barrier reef, which passes into a fringing reef off the northern coast near the landing, and off a part of the southeastern face of the island. The inner lagoon is very narrow, not more than a quarter of a mile in width, and also very shallow. Its greatest depth is about two fathoms, and it is further studded with negro-heads and coral patches, thus protecting the lagoon to a certain extent from the invasion of the sea. The ridge of elevated coralliferous limestones on the west side of the island extends as far as the first islet on the south face of Mango. There the central volcanic ridge which has raised the reef joins the western edge of the rim of the island. The ridge runs in a southerly direction, at a

MANGO LANDING, VOLCANIC SUBSTRATUM.

slight angle with the west coast ridge, and is separated from it by a deep valley. The three islets off the western part of the southern face of Mango are all on the outer edge of the reef flat (Plate 87). They consist of volcanic rocks. The central islet is the largest, and is composed in part of stratified volcanic mud underlaid by harder rocks. Between the islets, and extending over the outer reef flats to the north and to the east, stretch numerous negro-heads of a volcanic nature.

WEST OF MANGO LANDING, VOLCANIC SUBSTRATUM.

The island of Mango is of the same type as Fulanga, except that the erosion and denudation of the lagoon has not been carried on to so great an extent, Mango being composed so largely of harder volcanic rocks. The platform forming the reef flat is dug out into a very narrow and shallow lagoon, and both are studded with negro-heads, the remnants of the adjacent shore slopes. The inner sound, which in the case of Fulanga has been eroded and denuded to form a large inner basin, consists in Mango only of a diminutive basin studded with elevated limestone heads and rocks, and barely connecting with the exterior eastern lagoon; the sea has not found its way to any extent through the elevated limestone barrier lying across the break of the rim of the island.

Lakemba.

Plates 19, 21.

The island of Lakemba is elliptical, with a prominent spit extending off its southern face. Its greatest diameter is about five miles and a half. The central mass of the island, which rises to a height of 720 feet, is volcanic; on the flanks of this, on the northwestern and western sides, are found nearly vertical steep shore bluffs of coralliferous limestone elevated to a height of from 200 to 250 feet. The ridges extending along the south shore, separated by a spur from the central mass, also consist of elevated reef rock. Lakemba is surrounded by a fringing reef, narrowest off the northwestern point of the island; it widens towards the south off the west coast, and on the eastern face of the island it attains a width of nearly a mile. In continuation of the fringing reef off the northern face and off the southern spit of Lakemba extends a narrow outer reef, enclosing a lagoon, irregularly rectangular in shape, about five miles in length. The lagoon is thickly studded with patches and heads; its greatest depth is 14 fathoms; on the east face of the outer reef there is a passage for steamers. This is another exception of a lagoon entrance on the windward side. It should, however, be noted that the east face of the Lakemba atoll is protected to some extent by Aiwa and Oneata.

The resemblance in shape of Lakemba and Kanathea, the latter of which we did not visit, is very marked. The encircling reef of the latter surounds a larger lagoon; there is also a narrow extension of the lagoon on the south side of Kanathea, and a boat passage on the east face. One mile and a half south of Kanathea, and separated from it by a channel with a depth of 131 fathoms, lies the small summit of Morse Reef; and off the central part of the northern face of the encircling reef, Boehm Rock. At Lakemba Gardiner[1] has noticed the flat limestone hills which rise abruptly to a height of 60 to 70 feet on the west coast, the foundation being volcanic conglomerate, which forms the rest of the island. Captain Wilson states that on the reefs of the extreme south some of the islets are limestone, others volcanic, and he considers the three larger islands in the centre to be the remnants of an old crater.

Thithia.

Plate 20.

I am informed by Bishop Vidal of Levuka that the island of Thithia, which we did not visit, is also composed in part of elevated limestone, in which large caverns have been excavated similar to those we saw in Ngillangillah Island. It is also stated by others to be in part volcanic. It resembles Mango in outline, appearance, and structure, but is somewhat smaller; the fringing reef surrounding it is narrow. The central part of the island is probably a volcanic ridge, which has elevated the ancient limestone surrounding it.

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[1] *Loc. cit.*, p. 466.

Naitamba.

Plate 19.

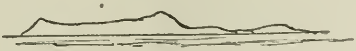
The cliffs of the southeast side of Naitamba consist of volcanic conglomerates or puddingstone, which extend along the highest points of the ridge on that side of the island. But on the northern side of the island the ridge, rising to a height of over 100 feet, is clearly seen to be composed of elevated limestone. Naitamba is surrounded by a narrow lagoon (Plate **19**), which is a little over half a mile wide off the north side of the island, where its greatest depth is seven fathoms. On the southwest side the lagoon is very shallow and narrow, the reef becoming practically a fringing reef. The highest point of Naitamba is 910 feet.

NAITAMBA, FROM THE EAST.

Mothe.

Plate 22.

The Mothe group is interesting, consisting of a volcanic island, Mothe, and of Karoni, a low island to the south of it, formed by a short ridge of elevated limestone rising to a height of 120 feet. An outer reef flat surrounds both the islands. It runs at a distance of a little over half a mile from the shore of Mothe itself, which is also surrounded by a very narrow fringing reef. In that part of the lagoon there is only from two to five fathoms of water, and the channel is studded with heads. The lagoon enclosed by the Mothe Reef is shaped like a boot, the foot reaching towards the east and the leg in a northwesterly direction. Mothe Island is elliptical in outline. Its greatest diameter, running north and south, is about two and a half miles, and it rises to a height of 590 feet. There are only boat passages into the lagoon through the eastern face. Although these passages are on the eastern face, yet they are practically to the lee, owing to the westerly trend of the lagoon and



KARONI.

the projection of Na Potu on the south. The deepest part of the lagoon is in the eastern point. It is only nine fathoms, and north of Karoni not more than seven. Na Potu, as the eastern point of the lagoon is called, is studded with rocks and heads. Off the northwestern point of Mothe we could distinctly see that the negro-heads rising upon the platform of the outer reef flats were of volcanic origin. Mothe resembles in shape Lakemba and Kanathea.

NORTHWEST POINT OF MOTHE.

Kambara.

Plates 22, 22^a, Fig. 2, and Plates 77-79.

Kambara Island is elliptical, nearly five miles in length, with a greatest breadth of three (Plate **22**). It is surrounded by a rim of elevated limestone enclosing a depressed basin. The rim has an average height of between 300 and 350 feet, with steep cliffs on the sea face (Plate **77**). On the northwest face of the island, near the village of Tokalau, the elevated limestone ridge is broken through by a conical hill 470 feet high, which is of volcanic origin, and the flanks of which underlie the elevated limestone ridge resting on its sides (Plate **78**). From this makes out a flat covered with negro-heads, all of volcanic origin, and of rocks similar to those of the high hill, while on each side the flats are covered with negro-heads composed of elevated limestone; on both grow very flourishing coral patches, and both are steep to, the reef flat, passing rapidly into deep water, plainly showing that the corals have had no share in shaping either of these slopes, the one composed of volcanic rocks, the other of elevated coralliferous limestone.[1] The island is

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[1] Throughout Fiji we found along the cliffs and sea face of limestone islands masses of the red earth so characteristic of the denuded limestones of the Bahamas and Bermudas, as at Kambara, Ngillangillah, Yangasá, Oneata, Ongea, and other islands.

surrounded by a fringing reef which ends beyond the northern point of the island along the base of the vertical cliffs between it and Tokalau village (Plate **78**), and becomes the merest thread to the south of it for a short distance. Along the rest of the west face there is a narrow incipient lagoon studded with coral patches, with from one to two fathoms of depth in places between the outer reef and the shore.

Gardiner[1] describes the interior plateau of Kambara as being about 100 feet above the level of the sea, and that "on the plateau itself are many small hills, rising nearly to the level of the rim, with very steep walls, and some springing almost like buttresses from the rim itself," and that on this plateau there are a number of deep holes in which salt water is found and tidal influences are felt. This description corresponds with what has been observed in the æolian hill basins of the Bahamas and Bermudas, in which atmospheric agencies are at work to form the incipient sounds, and finally the great sounds or lagoons of the islands of these groups.

Gardiner[2] reports that the hills of Thikombia i ra are certainly of limestone, and at a distance appear distinctly terraced.

SUNDRY ATOLLS.

Pitman Reef.

Plate 18.

Pitman Reef is an oval atoll about a mile in greatest length. We passed within a cable's length on the west side, and could see the outer edge of the reef flat uncovered at points, and patches of corals growing upon it. The reef flat seems to be 300 to 350 yards in width. It is widest at the northern extremity. The lagoon is marked on the chart as being eighteen fathoms deep.

Motua Levu and Motua lai lai.

Plate 18.

Motua Levu and Motua lai lai are two atolls to the eastward of Lauthala reef. The former is somewhat rectangular, about two miles in length, and encloses a lagoon with a greatest depth of twenty-five fathoms. On the northwest edge boats can cross into the lagoon. The latter is nearly circular, a mile in diameter, enclosing a small lagoon.

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[1] *Loc. cit.*, p. 464.

[2] *Loc. cit.*, p. 462.

The yellowish reef flat is widest at its two extremities ; the coral patches appear to be very flourishing, and a few large negro-heads of coral protruded upon the inner edge of the reef flat. From its diminutive size, the whole atoll can be taken in at a glance, and it forms an excellent specimen of its kind (Plate **112**), with its broad yellow reef flat edged on the outside by the white line of breakers separating it from the deep blue water, the inner edge passing from yellowish to light green, then to light blue, and finally to the darker blue of the central part of the lagoon.

Williamson Reef.

Plate 19.

We passed close to Williamson Reef, which is a somewhat rectangular reef flat widest at the eastern face. The greater part is dry at low water, and encloses a lagoon with thirteen fathoms. The greatest length of the reef is a mile and a quarter by nearly a mile at its greatest width.

Bell Reef.

Plate 19.

Bell Reef is separated from the Kimbombo cluster by a channel of nearly three quarters of a mile in width. It is irregularly triangular, with a reef flat of over half a mile in width. The reef flat of the western side is open. The sea breaks heavily on the eastern face, but there is little sea on the western face. The greatest depth in the lagoon is thirteen fathoms.

Adolphus Reef.

Plates 18, 22^a, Figs. 16, 17.

We steamed close to the eastern edge of Adolphus Reef. The outer rim is somewhat rectangular in outline, with rounded corners, and carries from one to four fathoms of water, enclosing a lagoon twenty fathoms in depth. It can be entered from the southwestern angle. We could not examine it, as the sea was breaking heavily upon it. We could, however, clearly distinguish the patches of corals growing inside of the breakers.

These atolls are excellent examples of the effects of submarine erosion upon areas of different dimensions, ranging in size from Pitman

Reef to Motua lai lai, Motua Levu, and to Adolphus Reef. They all owe their origin to the disappearance through atmospheric agencies of the peaks or ridges of greater or less heights which they represent, and to the formation of lagoons by submarine erosion, passing finally into such sunken banks as the Penguin, Alexa, and other banks discovered by Captain Field in the "Penguin," and figured in Admiralty Chart 1431 (see Plate **23^a**). Possibly, as I have suggested in the case of the smaller atolls, the lagoons may represent the extinct craters of small volcanoes of which the rim has been planed off by the action of the sea.

We did not visit Duff Reef (Plate **18**), which, judging from the chart, presents no points of special interest or of difference, except in shape, from such atolls as Wailangilala.

Thakau Momo.

Plates 3^a, 12, 14, 23^a, Fig. 6.

On our way from Nairai to Moturiki Channel we examined the Horseshoe Reef (Thakau Momo) about nine miles northwest of Nairai. Owing to the high stage of the tide we did not find it awash, and could only trace the very narrow ring of the yellowish green flat upon which violet patches of corals could be seen dotted over its surface. This flat being edged on the outside by the narrow white rim of breakers, and the dark blue water of the deeper soundings on the inner edge being fringed by a narrow belt of light green passing into light blue and into the somewhat darker blue water of the central part of the lagoon.

The plan of Thakau Momo (Plate **23^a**, Fig. 6) shows the narrow rim forming the outer edge of the lagoon awash, with a depth in the centre of twelve fathoms. The western edge is worn away, leaving the greater part of the rim of the lee edge more or less open to the outflow of the water pouring in over the weather edge.

Tova Reef.

Plate 23^a, Fig. 5.

The plan which is given of Tova Reef is more detailed, and shows a lagoon with a more complete rim than that of Thakau Momo, with boat passages on the lee side through the northern and western rim of the encircling reef. These two atolls are sharp peaks, the one, Thakau Momo, probably the summit of a volcanic ridge, the other, Tova, perhaps the summit of a peak of elevated coralliferous limestone, which have been denuded to the level of the sea and then subjected to submarine erosion, forming first a flat, then an incipient atoll of which the lagoon has been gouged out, in one case to twelve, in the other to sixteen fathoms. Upon the outer edge of the flats, corals have grown, protecting the rims to a great extent from further denudation and erosion.

The depth of the plateau from which Tova rises is probably very considerable. The depth of water at a distance of seven or eight miles is, judging from soundings to the eastward, perhaps as much as 1,200 or 1,500 fathoms; while Thakau Momo apparently rises from a shallower depth of less than 500 fathoms to the north, and about 900 fathoms at a distance of about five miles.

Such atolls as Thakau Momo, Tova, and a host of others occurring in Fiji, are identical in their mode of formation with such an atoll as the Hogsty in the Bahamas,[1] the lagoon of which I believe to be due to mechanical causes similar to those which have shaped the above named lagoons in Fiji. While the former are recognized by writers on coral reefs as true atolls, the latter are regarded as pseudo atolls. It is juggling with words to represent structures as different because the one is in the Pacific and the other in the Atlantic, and because the one is in an area recognized as stationary or as one of elevation, while the other is in an area formerly supposed to be one of subsidence and which is now found to be one of elevation. In both cases the coral rims of the atolls are shown to be of little thickness. The same authors refuse to recognize as true barrier reefs, and call them patch reefs, barrier reefs occurring in other districts than those examined by Dana and Darwin, because they have been shown to be of comparatively moderate thickness. We can now show, in the very districts which have been selected as typical, that neither the coral reefs of the atolls nor those of the barrier reefs have the thickness attributed to them.

Thakau Lekaleka.

Plates 21, 111.

On our way from Oneata to Mothe we steamed close to Thakau Lekaleka (Plate 21), a very narrow reef flat of polygonal outline, somewhat more than a mile in diameter, enclosing a shallow lagoon, judging from the light blue color of the impounded water. The reef flat rises

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[1] Bull. Mus. Comp. Zoöl., Vol. XXVI. No. 1, p. 103, 1894.

on the western edge of a bank sloping to the eastward, the 100 fathom line being more than half a mile from the eastern edge of the reef flat.

A number of negro-heads, apparently coral, could be seen on the western horn of the reef flat. Plate **111** gives a good idea of the appearance of the curve of the narrow reef flat of one of these smaller atolls, with the sea breaking over the rim.

LAGOONS OF ATOLLS.

Dana denies that there is any connection between the channels of lagoons and prevailing currents, and asserts that the channels tend to be closed by the increase of growing corals. Certainly our experience in Fiji could not indicate such a conclusion, nor are the lagoons in the smaller islands without channels except where a closed ring of coral sand islets has accumulated on the outer rim, — a rare occurrence, and one where the lagoon was formed while open to the influx of the sea. Some of the small islands, with lagoons which are dry, may be elevated islands reduced to that stage by atmospheric agencies.

While there may be a large amount of coral ooze and mud deposited in the lagoon, yet even in the lagoons mentioned by Dana he states that the sea has access to them, and that they are remarkable for the salinity of the water and the absence of growing corals within the lagoon at high water.[1]

Dana says [2] that nine tenths of the atolls under six miles in length, half of those between six and twenty miles, and the majority of all atolls in the Pacific Ocean, have no entrances to the lagoon a fathom deep, and the larger part of those included in each of these groups have no open entrances at all. He further says that nine, ranging from one and a half to three miles in the larger diameter of the reef, have no lagoon, only a small depression in its place; two of these take in water at high tide and the rest are dry (namely, seven), certainly a very small proportion, and that of diminutive atolls which give us little information regarding the formation of the larger ones. Surely we cannot reverse the process and let the formation of the large atolls precede that of the smaller, as is suggested by Dana,[3] for in that case we should have around the small atolls the platforms or slopes which have gradually been formed by the filling of the larger lagoon as sup-

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[1] Dana, Corals and Coral Islands, p. 182.

[2] *Loc. cit.*, p. 300.

[3] *Loc. cit.*, p. 302.

posed by him, and I know of no small atoll in which any such platform has been observed.

Neither Dana nor Lendenfeld seem to take into account the mass of water which is poured into a lagoon, even if it has no boat passage, over the reef flat at low tide, to say nothing of the period during which the reef remains covered between low and high water times.

A large atoll, like that of Ngele Levu, if it has been formed by subsidence, should be of greater depth. This has already been noticed by Admiral Wharton.[1] Ngele Levu is thirty-three miles round, gradually increasing in depth towards the western extremity from four to sixteen fathoms. It rises gradually from a ridge with a depth of about 145 fathoms, and from a plateau of less than 400 fathoms in depth. There is no filling up of that lagoon; it is well scoured, and a strong current is constantly deepening the entrance and outlets at the western end, to say nothing of the mass of water which finds its way out over the reef flat. The lagoon of an atoll is often referred to by writers on coral reefs as a sort of stagnant pool, which must of necessity be gradually filling. Such is certainly not the case in the atolls with which I am acquainted, and it is the exception. If any one will take the trouble to examine the hydrographic charts of the coral reef regions, both in the Pacific and the Atlantic, they will find it to be the exception when the atoll of a lagoon is really impounded, or that of a barrier reef is shut out from a most active circulation carried on by the breakers rolling over the rim of the one and the barrier of the other into the enclosed lagoon. In Fiji, the only atolls which are enclosed and surrounded by a reef allowing no circulation or access to the sea are small, and play no part in the physiognomy of the reefs of the group, and I know of no barrier reef in Fiji the lagoon of which is not well threshed by the breakers.

An examination of the charts accompanying this report will show on the rim of the larger atolls, both to windward and leeward, moderate depths, from one to three fathoms or less at innumerable places, forming a regular sieve of passages through which the breakers force their way. An examination of the charts will show the same results as regards the circulation across the barrier reefs of Fiji. Finally, we should remember that at high tide even fringing reefs are washed in every part and scoured, and that, while at low tide a certain amount of stagnation in pools may occur, it is only temporary, and not the natural state of things.

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[1] Nature, May 22, 1890, p. 81.

Lendenfeld[1] gives altogether too great prominence to the part played by dry atolls. They do not occur anywhere except as most diminutive atolls. The only atoll in Fiji which answers at all to the theoretic requisitions of Lendenfeld is that of Vuata Vatoa (Plate **23**^{a}, Fig. 4), near Turtle Island, in Lau. I have not visited the island, and my impression is taken from the chart[2] and the Sailing Directions where it is described. Yet even that atoll has outfalls on the northwest side, and the margin is awash at high water, evidently allowing large masses of water to be poured into the lagoon, so that further denudation and erosion must eventually so modify this atoll that there will be a larger and more open lagoon than formerly, and it will not fill up as is required from the other point of view.

EXTINCT CRATERS AND ATOLLS.

There is, however, still another phase in the formation of atolls which has received but little attention, and that is the influence of the denudation and erosion of volcanic summits or ridges, or of extinct craters, in the formation of atolls. There are in the Fijis two extinct craters which are most interesting. One of these is the small extinct crater of Thombia in the Ringgold Islands (Plates **18, 70**). The highest point of its rim, the exterior circumference of which is nearly two miles, is nearly 600 feet, and it is continuous with the exception of a small part of its eastern edge, about a fifth of a mile, across which a coral reef extends, the extension of the fringing reef surrounding the island closing the entrance to the crater; the enclosed basin has a depth of 24 fathoms. The other extinct crater is that of the island of Totoya (Plates **16, 22, 66–69**), an isolated peak in the southern part of the group. It is about six miles in diameter, with an inner basin of three miles in diameter and a depth of over thirty fathoms. The highest point of the rim is 1,200 feet, and at two points the rim is low, forming in one case a narrow isthmus separating the crater basin from the outer lagoon. The horns of the open rim are connected by a coral reef, over which thunders the Pacific swell, piling up the water into the great basin of the crater. This water finds its way out through an opening called the Gullet, which, though narrow, forms an excellent passage into the anchorage inside of the crater. This island has not only a fringing

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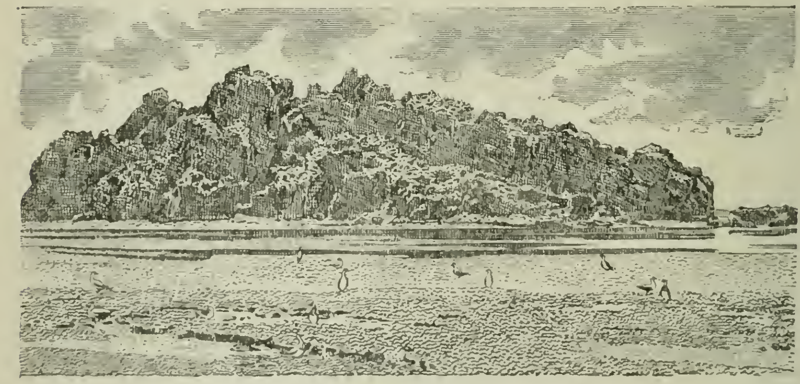
[1] Nature, June 12, 1890, p. 148.

[2] Admiralty Chart, Plan 742.

reef, but also a barrier reef of a triangular shape surrounding it. It is evident that this barrier has been formed upon the denuded and eroded spurs of Totoya, which once extended seaward from the outer rim of the volcano.

Supposing, now, that the erosion of both Thombia and Totoya had continued for a period of time long enough to have reduced the rims of these volcanoes to the level of the sea, we should have, as soon as corals had covered the flats thus formed indicating the former existence of the rim, atolls of nearly circular form; the one with a circumference of only two miles, and a depth of 24 fathoms, without patches in the central lagoon; the other much larger, more than 25 miles in circumference, having a depth of 34 fathoms inside the lagoon, which would be dotted with patches, some of them forming part of the rim, others being the remains of eroded spurs extending towards the centre of the extinct crater.

Admiral Wharton[1] has given a most interesting sketch of Clipperton Atoll, in which he confirms the trachytic nature of the "Rock" of Clipperton, as determined by Professor Wolff[2] from specimens collected by Mr. Jensen and kindly sent me by Professor Davidson. The photographs and specimens collected by Mr. J. T. Arundel, on which Admiral Wharton's notice is based, have enabled him to give what seems to me a natural explanation of the character of the atoll. As he says, it is



CLIPPERTON ROCK.
(From a Photograph by J. T. Arundel.)

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[1] Quart. Journ. Geol. Soc. of London, May, 1898, p. 228.

[2] Bull. Mus. Comp. Zoöl., Vol. XXVI. No. 1, p. 174, 1894.

"the rare case of coral forming on the lip of a volcanic crater, one part of which alone, perhaps the plug, has resisted the action of the sea, which has worn the rest of it down to the limits of wave action." The foregoing figure is a view of the rock (trachytic) rising to a height of sixty-two feet on the rim of the atoll. Admiral Wharton calls attention to the great depth of this lagoon, perhaps fifty fathoms, as a depth not improbable if it be the crater of an extinct volcano. It would be most interesting to have Clipperton carefully examined and mapped. In the mean time, from its analogy with Totoya and Thombia, it seems to me that Admiral Wharton's explanation is the only possible one. We may perhaps add that the old rim may have also been subject to atmospheric denudation and erosion, in addition to being blown away in part during some eruption.

There are in the Fijis a number of small atolls from one to three or more miles in circumference, the formation of which can also be satisfactorily explained on the theory that they have been formed upon the eroded summits of extinct craters, reducing the rim of the volcano either to a continuous flat or to flats separated by deeper passages, as in the case of the low parts of the rim of Totoya, forming entrances into the enclosed lagoons. Such atolls are Motua Levu, Motua lai lai, the Adolphus Reef (Plate **18**), Bell Reef, Pitman Reef, Williamson Reef (Plate **19**), Horseshoe Reef (Plate **14**), and Thakau Lekaleka (Plate **27**), although it is possible that some of these atolls may have been formed from the submarine erosion and denudation of volcanic peaks or of elevated limestone masses. It is also possible that some of the larger groups in which volcanic islands are found, like Vanua Mbalavu (Plate **19**), Komo, Mothe (Plate **22**), Lakemba (Plate **21**), and Mbengha (Plate **8**), may represent parts of the rims of extinct craters, the bulk of the volcanic peaks having disappeared from erosion, and left the outer flats upon which the barrier reefs have grown, while the deeper valleys and gorges of these volcanic islands represent the undulations of the lagoons, which vary greatly in depth, reaching in the case of the Vanua Mbalavu (Plate **19**) 72 fathoms in parts of the eastern slope of the lagoon. These great depths, far beyond any at which corals can grow, represent the elevated gorges of the slopes of the volcanic peak which probably once extended over the whole area enclosed by the outer reef, during the elevation of which the reef which once covered a part of the same area was lifted to its present or even a greater height.

Such large volcanic centres with extensive craters of considerable depths are not unknown.. Haleakala (Plate **71**) in the Sandwich

Islands has a crater with a depth of nearly 450 fathoms, while many smaller peaks, some of fully 1,200 feet rise from its bottom, and its diameter is fully as great as that of many of the larger atolls of the Fijis. So that, at any rate in a volcanic district, the great depth of some of the atolls cannot now be considered as a proof of the theory of subsidence.

A still larger extinct crater than Haleakala is that of Aso San in Japan, and in Java there are many craters of dimensions fully equal to those of a number of Fiji atolls.

In addition to Thombia and Totoya, we found at Moala the rim of an extinct crater forming the deep bay on the east side of the island (Plates **16**, **56**). The longest diameter of this crater must have been fully three miles, and had the denudation of the island been carried on somewhat further, so as to eat away the low western rim of the crater (Plate **56**) and connect the deep bay of the east face (the extinct crater) with the indentation on the west of the island, it would be difficult to detect the existence of a former extinct crater from the narrow ridge or island which would rise in the eastern part of the lagoon (Plates **16**, **56**).

Krämer[1] has attempted to account for the elongated outline of so many of the atolls of the Paumotu, Caroline, Marshall, Gilbert, and Ellice Islands, upon the theory that they owe their origin to submarine hot springs and volcanic eruptions, the material of which was distributed by the trend of the great oceanic currents in the general directions indicated by these island groups.

While granting that volcanic agencies have raised the coral islands of the Pacific, we must remember that the shape of the islands and their extent are due to the size of the plateaus of submarine erosion which form the banks upon which coral reefs have grown. Undoubtedly the substratum of many of the atolls may have been formed of volcanic ashes by eruptions similar to that which has thrown up Falcon Island, and which has been fully described by Lister.[2] Yet the great majority of the vol-

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[1] Bau d. Korallenriffe, p. 88.

[2] J. J. Lister, A Visit to the newly emerged Falcon Island, Tonga Group, South Pacific. Proc. Roy. Geog. Soc., 1890, Vol. XII. p. 157.

The island (Falcon) is composed of fine-grained dark grayish material, arranged in strata. "A bare brown heap of ashes round which the great rollers break and sweep the black shore in sheets of foam." The eruption occurred four years ago; its present height is 153 feet. "Considering how rapidly the island is being covered by the action of the waves, it is evident that in a few years . . . it will have disappeared beneath the surface of the ocean. . . . Some distance to the east of it lie two islands, Namuka iki and Mango, and these islands have been elevated before any canic islands which abound in the coral reef districts of the Pacific do not consist of such easily scattered material. In addition, it is well known that many of the islands are composed of elevated coralliferous limestones, and that is probably the composition of the substratum of many of the atolls of the Paumotu, Ellice, Gilbert, Tonga, and Fiji groups. They indicate the existence of more or less extensive submarine ridges composed either of limestone or of volcanic rocks, and not necessarily peaks or summits formed of volcanic ash and spread out by the action of the currents, as has been mapped out by Krämer.[1] Nor do we know enough of the configuration of the bottom to justify the statement that the atolls of a group are not separated by great depths such as separate the islands of the Samoan group. The soundings round Funafuti by the "Penguin," and others near Tonga and in Fiji (Plate 1), do not confirm Krämer's views.

The old view entertained by Chamisso regarding the mode of origin of the substratum upon which coral reefs are built does not greatly differ from that which we have applied to the formation of coral islands in Fiji. We have laid greater stress upon denudation and submarine erosion after elevation by volcanic agencies, while Chamisso[2] accepts the uplifting of the insular masses to the level at which coral begins to grow.

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considerable thickness of coral grew upon them. They are formed by stratified volcanic material deposited under water, and are now surrounded by broad coral reefs. In them we may read the possible future history of Falcon Island. If no elevation takes place, the stones and débris will give a resting place to a host of marine animals and plants, . . . and another fine island will be added to those summer seas." Recent volcanic action in Tonga and in Samoa does not seem to have prevented there the formation of extensive coral reefs, as has been suggested by Dana.

[1] *Loc. cit.*, pp. 95–97.

[2] "Wir denken uns eine Inselgruppe dieser Bildung als eine Felsenmasse, die sich mit senkrechten Wänden aus der unermesslichen Tiefe des Oceans erhebt und oben, nahe an dem Wasserspiegel, ein überflossenes Plateau bildet. Ein von der Natur rings um am Rande dieser Ebene aufgeführter breiter Damm, wandelt dieselbe in ein Becken um. . . . Er ist da Stellenweise unterbrochen und seine Lücken bieten oft selbst grösseren Schiffe Fahrenge dar. . . . Innerhalb dieser Thore liegen öfters einzelne Felsenbänke. . . . Andere ähnliche Bänke liegen hie und da im Innern des Becken zerstreut." Kotzebue, Reise, Bd. III., Bemerkungen und Ansichten, 1826, von Adelbert v. Chamisso, p. 106. Chamisso gives an admirable account of Radack Ralick, and of the fauna, flora, and general aspect of this low coral island.

VITI LEVU REEFS.

Plates 1, 3, 5, 6, 7, 20ᵃ, Figs. 9-12, and Plates 24-45.

The great barrier and fringing reef which follows the southern and part of the eastern coasts of Viti Levu may be said to begin off the northeastern extremity of the island of Ovalau (Plates 3, 7). Off that island a spur of the barrier reef extends in a northerly direction, terminating in deep water (Plate 3). From that point to off Tova Peak there is no barrier reef, the bottom being generally muddy, formed from the decomposition of the islets composed of soapstone, which are scattered in great number between Ovalau Island and the island of Viti Levu. Similar islands and islets abound along the shore of Viti Levu, and between it and the outer reef south of Moturiki towards Mbau and the Tomberua Passage (Plate 7).

The islands of Viwa (Plate 36) and Mbau are both composed of stratified volcanic mud resting upon harder volcanic rocks, and the whole shore line of the adjoining part of Viti Levu is made up of the same material, judging by what we could see of the shore bluffs as we steamed from the Moturiki Channel to Mbau. The soft rocks of the shores of that part of Viti Levu are readily disintegrated, and their erosion and denudation have supplied the material for the extensive mud flats (Plate 35) lying in the area just mentioned (Plate 7), leaving endless patches and small flats more or less covered with patches of growing corals. These softer rocks rest upon harder volcanic rocks, the extension of the rocks which attain a considerable height in Moturiki and a still greater one in the peaks of Ovalau.[1]

FRINGING REEF HARBOR, OFF KORO LEVU.

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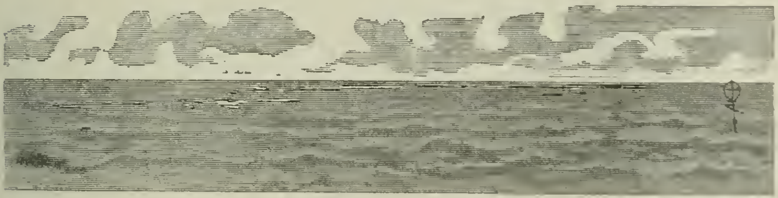
[1] Both Ovalau and Moturiki are surrounded by a fringing reef.

The formation of the great barrier reef of the southern shores of Viti Levu is due to causes very similar to those which have given its present physiognomy to the northern coast of Cuba between Nuevitas and Matanzas. Along those parts of the island where denudation and erosion proceed rapidly owing to the soft character of the shore rocks, very extensive flats have been formed like those south of Ovalau. When the reef barrier flats have been eroded from a harder base, like volcanic rocks, the flats are less prominent; they are somewhat more extensive where the old elevated coralliferous limestone formed the shore hills; or the reef flats may disappear altogether when the harder volcanic rocks have been only little affected by erosion or denudation. From the nature of the negro-heads scattered upon the reef flats it is generally a simple matter to ascertain the character of the base of the reef flats of an atoll or of a barrier reef.

MOTURIKI CHANNEL.

The islands of Ovalau and of Moturiki (Plate 7), which are enclosed by the northeastern extremity of the Viti Levu barrier reef, are both of



ENTRANCE TO LEVUKA.

volcanic formation, a kind of conglomerate or breccia similar to that found at Mbengha, Tavuki in Kandavu, and in many other places in Fiji. The highest peak of Ovalau rises to a height of nearly 2,100 feet, and the shape of its ridges, crests, and peaks (Plates 33, 34) shows the effect of extensive denudation and erosion. The island is elliptical, eight miles long, and about six wide. Moturiki flanks Ovalau on the southwest side, is low, about five miles long, and connected with the southern face of Ovalau by an extensive fringing reef flat surrounding its eastern face and the islands of Yanutha Levu and Yanutha lai lai. The Moturiki fringing reef is separated from the barrier reef by a narrow channel, and the northern extension, forming the barrier reef off the east coast of Ovalau (Plate 20^a), is broken by a number of deep openings (Plate 7). The bottom of the lagoon is made up of coral and coralline sand, comparatively little mud being washed down from the hill slopes, the water inside the lagoon being quite clear. From the inner edge of the barrier reef run out a large number of very flourishing coral patches in from two to three fathoms, and extending to seven or eight. The reef flat is in some places more than half a mile wide (Plate 20^a, Figs. 1–5). A good many negro-heads are scattered upon the reef flats, some of them of considerable size. The average depth of the narrow lagoon separating Ovalau from the barrier reef is from nine to fifteen fathoms, but in some places there are short stretches with a depth of from sixteen to twenty fathoms.

NEGRO-HEAD, LEVUKA BARRIER REEF.

Between the Na lulu and the Ngava Passages (Plate 7) an extensive flat connects the barrier reef with Ovalau, much as the fringing reef of

Moturiki is connected with the barrier reef stretch opposite its eastern face. There is also a similar connection between the fringing reef off Bololo Point and the barrier north of Na lulu entrance. The southeastern part of the reef off Ovalau and Moturiki being strictly neither a barrier nor a fringing reef, but a combination of the two, the Ngava and Na lulu entrances forming reef harbors similar to those characteristic of fringing reefs, indicating how the offshore platform of Óvalau has been eroded and how corals have gradually obtained a footing on the underlying volcanic substructure, remnants of which are visible at many points of the barrier reef flats. One may judge of the extent of the denudation and erosion which have taken place from the shape of the peaks and bluffs and ridges which give to Ovalau so characteristic a profile when seen from the sea (Plates **33**, **34**). Compare the sharp peak of Tumuna, the rounded elevations forming the ridge of Ndelai and of Koro Levu, the sugar loaf of Craig, and the bluffs near Levuka.

LEVUKA.

The spur which has formed the island of Moturiki is covered by low conical hills, culminating on the eastern summit at Ului Mboa, which is but little higher than the rest of the island.

To the westward and northward of Ovalau reach the extensive flats full of patches which connect the west shore of Ovalau with the mainland, and reach on the northwest to Tova and south towards Mbau (Plate **7**): flats which are formed by the disintegration of the low bluffs, consisting of bedded volcanic mud ("soapstone"), which must once have extended eastward close to Ovalau and Moturiki. The patches on the flats are covered with growing corals.

The stretch of strata of volcanic mud constituting the east shore of Viti Levu north of Mbau undoubtedly once extended farther east, connecting the main island with the islands of Moturiki and of Ovalau. This readily explains the changeable character of the barrier reef at different points along the coast of Viti Levu. Off Ovalau and Moturiki the substructure of the barrier reef is volcanic, and the negro-heads which crop out upon its surface at various points plainly indicate this. One of the most striking of these protrusions being a small mushroom-shaped volcanic rock on the barrier reef to the south of Moturiki, immediately west of Thangalai Island (Plate 7). This island and Leluvia, and one or two keys on the northern part of the great reef south of Moturiki, are small islets of coral sand thrown up on some of the shallower parts of the reef flats. The larger islands are thickly covered with cocoanuts and shrubs. On the southern part of the reef flats immediately north of the Tomberua Passage near the exterior edge is the island of Mumbualau. It is about thirty feet high, and is composed of elevated coralliferous limestone deeply undercut, pitted, and honeycombed, while the islands farther inland off Kamba Point consist of stratified volcanic mud.

Another very striking fragment of elevated coralliferous limestone is that of Na Vunivatu (Plate 37), on the reef flats to the south of Nasilai Mouth. The remnants of the elevated reef can be traced south of Tomberua Passage on the Nasilai reef flats, and extend on both sides of the lighthouse. There are numerous heads of elevated limestone, fragments of former large stretches of the same material. Still farther south the elevated coralliferous limestone is seen to underlie the island of Nukulau (Plates 38–41) at the mouth of Lauthala Harbor (Plate 25), as well as the flats to the eastward and the island of Mokaluva with its flat (Plate 38). The extensive mud flats forming the mouth of the Rewa River have to a great extent encroached upon the inner edge of the coral reef flats underlaid by the elevated coralliferous limestone which everywhere crops to the surface to the south of Tomberua Passage. As far as the Nukulau mouth of the Rewa, the reefs are in reality fringing reefs growing upon flats of elevated coralliferous limestone, intersected by deep indentations forming reef harbors. The great extent of the flats skirting the shore of Viti Levu eastward from Suva Point shows the amount of denudation and erosion to which this part of the island has been subjected (Plates 24, 25). From off Lauthala Bay (Plate 25) to Suva, the reefs are extensive barrier reef flats separated by passages leading into the channel running between the barrier and the shore (Plate 7). Some parts of the barrier flats are more than a mile wide.

The barrier reef flat north of Tomberua Passage and south of Rat Passage is in many places nearly three miles wide, with an average width of about two miles. The wide reefs of Serua and of Rovondrau Bays (Plate 5) are covered with flourishing patches of corals; what their substratum is I am unable to determine from the absence of negro-heads on the outer reef flats. Judging however from the nature of the headlands and of the rocks cropping out all along the shore between Serua and Suva, it is probably of the "soapstone,"—the bedded volcanic mud so characteristic of the shores of Viti Levu both east and west of Suva, with the exception of a small key probably of elevated limestone on the end of Rovondrau Reefs (Plate 5).

To the east of Namuka Harbor, a small reef harbor formed like the Navua and the Tongoro pass through the outer reef flats, and the elevated limestone again forms the substratum of the reef flats. The reef is here a fringing reef, which can be navigated by boats near the shore after half tide, and the outer face is covered with large negro-heads consisting of elevated coralliferous limestone. West of the entrance to Suva Harbor (Plate 5) the reef occurs in successive stretches of fringing or of barrier reef outside of fringing reefs, forming in some cases small reef harbors, like Namuka, Nanggara, Vatuloa, Navua, Serua, or, opposite the mouth of the Navua River, a large open bight, Rovondrau Bay.

The passages through the Viti Levu barrier reef and its principal reef harbors, Suva among others, are generally opposite the mouth of some river or creek, through which considerable fresh water carrying silt flows; this is especially the case of the Rewa River, which brings through its many mouths an immense amount of silt and detritus, and has formed a great delta. Both Darwin and Dana have attributed the formation of reef harbors largely to local currents, to the presence of fresh water, and to the action of silt. The bringing down of detritus, especially in the rainy season, and its deposition in channels will keep the bottom clear of corals, and thus form passages or reef harbors. The extensive reef which protects the harbor of Rewa has been formed in part by the erosion of the softer volcanic beds, and in part by the deposition of the silt brought down by the Rewa and the cutting out of a barrier channel behind the reef.

To the west of Serua the barrier reef disappears (Plates 5, 6), and the shore line is now composed of hard volcanic rocks which are not easily decomposed, or consists of the soft and easily disintegrated volcanic mud strata extending as a general thing from Mbau to Serua. Although here and there the harder rocks push out to the shore, where they are edged with a fringing reef, or we may find the remnants of the elevated coralliferous limestone, which is less easily eroded than the volcanic mud strata, as in the elevated reef in a valley to the north of Suva. This reef rises to a height of 120 feet above high water mark, and is fully fifty feet thick (Plate 31). Its extension can be traced in outliers on the north shore of Suva Harbor and on islands composed of elevated limestone at the mouth of the inner harbor of Suva, — islands which are from sixty to ninety feet in height, and rest directly upon beds of stratified volcanic mud and capped by similar strata. On the northwest shore of the inner harbor there is a bluff of the same elevated limestone rising to about sixty feet. The continuation of the reef can be traced inland and along the shore for a considerable distance.

The character of the islands within the barrier reef patches of Namuka and of Serua indicate that the corals growing upon the flats rest upon beds of stratified volcanic mud (Plate 5). Here and there we find a negro-head of the harder volcanic rock upon which the volcanic muds rest. From Serua westward the fringing reef varies in width from a mile to a mere narrow fringe of corals close to the shore (Plate 42). Negro-heads of volcanic rock stud the reef flats, which are here and there hollowed out into small boat harbors (Plate 6). At the Singatoka River the fringing reef has disappeared (Plate 6), and the heavy breakers roll upon a coral sand beach for a distance of about three miles. Immediately behind the beach rises a line of huge coral sand dunes, one of which attains a height of 190 feet (Plate 44). At this point the character of the fringing reef changes again. It is built upon the remnants of the ancient elevated limestone reef (Plate 43), small bluffs of which occur all the way between the Singatoka River and Nandronga Harbor (Plate 45). Some of the bluffs on the shore attain a height of more than seventy feet. Negro-heads consisting of elevated limestone fragments now abound upon the whole line of the fringing reef, and the two islands which protect the harbor of Nandronga on the east, and on the west are outliers of the ancient elevated reef (Plate 45). The height (thickness) of that reef must have been very considerable, judging from the height of an extensive bluff, consisting of limestone to the north of the sand dunes at the mouth of the Singatoka, which must be fully 250 feet. The fringing reef extends to the west of Nandronga as far as Likuri Harbor, where it gradually passes again into a barrier reef with a gradually widening shore passage (Plate 6) as we approach the Nandi waters.

The elevated limestone reef must have extended west as far as Viwa, and north again as far as Asawa i lau, both of which islands, as I am informed by Dr. Corney, consist of elevated limestone (Plate 2). Viwa is 100 feet in height.[1]

Plateau off Nandi and Yasawa.

To the westward of Nandi waters (Plate 3), off the northwest coast of Viti Levu, extends a wide plateau, the result of the denudation and submarine erosion of that side of the island. The depth of this plateau is most irregular, varying from ten to forty fathoms. The plateau is studded with sunken patches, and with rocks and islets and islands. The southwestern line of islands from the Mololo Islands to Mana is flanked by an outer line of reef flats, which gradually become smaller and disappear off Tartar Reef (Plate 3). From these the edge of the plateau crosses toward the north, and the outer reefs reappear again to the westward of the long chain of the Yasawa group.

The Viwa Island reef is separated by a narrow, deep channel, with 137 fathoms in mid-channel, from the western edge of the Yasawa plateau. To the northward of the Malolo Islands are scattered a few islands, — Kandavu, Lovuka, Tavua, and Vomo. The last is of volcanic origin, while Kandavu is flanked by beach rock, as is also Tavarua at the entrance of Navula Passage. All the islands which Captain Thomson examined on his way from the Malolo Islands to Waia he found to be of volcanic origin, — Mana, Tavua, Monu, and others. As I have

VOMO LAI LAI.

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[1] The elevated limestone patches which begin at Singatoka extend to the patches and reef flats north of Navula Passage (Plates 2, 3). Captain Thomson collected some pieces of a negro-head on the edge of the reef flat near Tavarua Island which consisted of elevated limestone.

already stated, Viwa and Asawa i lau are said to consist of elevated limestone.

The Malolo Islands rise to more than 700 feet. Mana is 240 feet high, Mondriki and Monu respectively 590 and 730 feet, and Waia more than 1,800 feet. The extension northward of the Yasawa group forms a chain of sixteen high islands for a length of fifty miles, which terminates in the reef of the Kinsilk Islands on the south of Round Island Passage, the principal entrance through the Great Sea Reef off Vanua Levu. The Yasawa Islands, as well as the islands to the westward of the Nandi Waters, are surrounded by fringing reefs. As will be seen from the charts, the reefs are on the western face of the plateau (Plate 3); so that the outer reef flats and the chain of inner islands intercept the full access of the sea, and corals grow but sparingly inside of that line.

NORTHERN END OF MANA.

Suva Reef Flats.

Plates 5, 24–30, 65, 76.

Perhaps no reef flats illustrate better the grinding and wearing action of the sea than those of the barrier reef, both to the east and west of the entrance to Suva Harbor. All the inequalities of surface seem to have been levelled off as with a plane, leaving only the shallow pools formed by the interstices of the large masses of coral (Plates 28–30). The fauna of the surface of these reef flats is comparatively poor in species, but abundant in individuals. A large black Ophiothrix, with its disk hidden in some crack or corner, trails its arms in all directions, and they literally swarm in all parts of the reef. Towards the outer edge they are replaced by Echinometra lucunter, the holes and hollow ways of which, often over two inches deep, honeycomb the surface, leaving narrow walls to separate them (Plate 30); and finally, near the outermost edge begins the belt of Madrepores and Pocillopores (Plates 28, 29) which extends into the line of breakers and beyond. There are few of the massive type of corals, like Porites, Astræa, and the like, and these are of diminutive size.

The surface of the reef is kept from too rapid wearing by the growth of marine algæ and of corallines which carpet it. The algæ are mainly species of Udotea, of Caulerpa, and of Turbinaria, which in sheltered pools grow to a considerable size. One finds also on the surface an occasional large black Holothurian, a blue Linckia, a green Goniaster, a Muræna darting from a pool, a large Cancer trying to hide under a shelving piece of coral, or a Squilla, or a few specimens of small fish of a brilliant blue color. There are few Mollusks under the negro-heads and dead masses of coral scattered upon the reef; the lower surface of these is often carpeted with many species of brilliantly colored Sponges, in which small Mollusks, Crustacea, and Annelids find refuge. The coral masses themselves are perforated in all directions by boring Mollusks and Annelids.

The substratum of the eastern and the western reef is made up of elevated limestone, extending from the shore close to the outer edge of the reef, independently of the thin crust of corals which grows upon the outer edge of the reef flat. So it is also with the mushroom-shaped heads which are found upon the outer edge of the reef flats of Vatu Leile, Mango, and other islands consisting wholly or in part of older limestones. They are all composed of the same rock as that of the shores and of the substructure. The outer sea face of the reef flats is steep in all cases, irrespective of the increase due to the corals growing upon them, or of the character of the underlying rock, which is only an unimportant factor in determining the thickness of the sea face edge of the outer reef flats.

We also examined the outer face of the barrier reef forming the eastern edge of the passage leading into Suva Harbor. This reef flat, like that of the western side of the passage, is entirely made up of ancient elevated limestone planed down by the sea to a level flat, with small shallow pools scattered over the surface. Negro-heads and fragments of the ancient limestone are scattered over considerable areas on the reef flat: many of them have been thrown up by the sea from the undermining of the outer edge, others have been torn off from the reef flat itself, and both are gradually wearing away, leaving fragments of branches of corals and of coral heads scattered over the reef. The belt of the reef flat close to the line of breakers is riddled with holes and channels gouged out by the Echinometra common on the reef. These channels look like short winding drill holes extending in all directions, or merely small potholes in which the Echinometræ live protected from the action of the breakers (Plate 30). In the same belt corals begin to grow in greater profusion, mainly Pocillopores, Madrepores, and small heads of Astræans and of Goniastræans or Mæandrinas, a few of these are also found scattered on the inner part of the reef flat. The corals living upon the outer edge of the reef flat form merely a thin crust, between the patches of which the substratum of elevated limestone crops out. Similarly, at a great many other points in Fiji, the outer edge of the reef flat, when exposed at the very lowest stages of tide, is seen to be edged with a belt of rocks identical in structure to that which forms the substratum of the reef flat platform. I may mention Mango, Vatu Leile, and a number of the islands of Fiji which have been described. The slope of the outer edge of the reef flat falling off more or less rapidly has little to do with the recent reef crust growing upon it; that only modifies its slope, possibly to twenty fathoms. The general slope of the sea face of the reef is due to conditions which antedate the formation of the coral reefs of the present day.

Dana[1] says that beneath the channels (basins) lies in general the coral rock of the reef region, the inferior part of the great reef formation, whose upper portions constitute the so called barrier and fringing reefs. This certainly is not generally the case: see the description of the flats between Ovalau and Mbau. Dana himself cites a number of examples which do not accord with his views when describing great admixtures of coral and of material derived from the mountains adjoining, and as he well says: "When the materials from both sources, the shore and the reef, are mingled, the proportion will necessarily depend on the proximity to the mouths of streams, the breadth of the inner waters or channels, and the direction and force of the currents."

As has already been observed by Dana, "At low tide the breakers often cease, or nearly so."[2] It is frequently possible a short time before the turn of the tide to examine the corals growing on the outer face of a reef. At Komo we had an opportunity to photograph coral reef flats where the corals were growing upon a substratum of volcanic rocks (Plate 65) just as they are growing upon a basement of tertiary limestone at the entrance of Suva Harbor. At Ngillangillah we came upon

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[1] Corals and Coral Islands, p. 149.

[2] *Loc. cit.*, p. 131.

a fringing reef flat covered with Alcyonarians (Plate 76), similar to those figured by Kent.

Gardiner[1] has observed the important part which incrusting coralline algæ perform in Fiji in supplying the material for a reef rock of compact homogeneous structure; they undoubtedly assist materially in preventing the disintegration of dead corals, and their subsequent comminution by the action of the waves. In an interesting article on the calcareous algæ of the Gulf of Naples,[2] Walther has given an excellent account of the part which coralline algæ like Lithothamnium play in building up amorphous limestone deposits of considerable thickness from the obliteration of its structure.[3] But he has confused the theory of the formation of reefs with the theory of the formation of limestone deposits of great thickness, one of which is based on an assumption, the other which is not in the least open to doubt. It is evident, however, that those who have examined coral reefs have not attributed to coralline algæ the share which they have in building up recent amorphous limestone deposits of considerable thickness.

The following list of algæ collected I owe to the kindness of Professor Farlow: Amphiroa fragilissima Lam'x; Galaxaura·fragilis Lam'x, var. fastigiata Decaisne; Liagora Preissii Louder, var. pacifica Grunow; Padina Pavonia (L.) Gaillon; Dictyata ciliata J. Ag. sterile; Turbinaria conoides Kg.; Hydroclathrus cancellatus Borg.; Sphacelaria furcigera Kg.? sterile; Caulerpa Freycenetii C. Ag.; C. clavifera (Turn.) C. Ag.; C. complanata J. Ag.; Halimeda macroloba Decaisne; H. Opuntia (L.) Lam'x; H. polydactylis J. Ag.; Aurainvillea comosa (Harv.) Murray & Boodle; Aur. papuana Murray & Boodle; Dictyosphæria favulosa Decaisne; Valonia ægagropila (Roth) J. Ag.; Valonia utricularis J. Ag.

ISLANDS AND CORAL REEFS DESCRIBED FROM THE CHARTS.

With the exception of the Argo Reefs (Plates 19, 20), the islands and reefs we did not visit were insignificant in size, or, judging from the charts, presented no point of interest not included in those we examined. I may mention among these Vanua Vatu (Plate 21), a small circular island with a depressed central summit, about a mile and a half long. It is composed of elevated coralliferous limestone rising to 310

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[1] *Loc. cit.*, p. 477.

[2] Zeitsch. d. deutschen geol. Gesell., Heft 2, Bd. XXXVII., 1885, p. 329.

[3] See also an article by Fresh, Neues Jahrbuch f. Mineral., 1892, II. 169.

feet. It resembles Naiau on a smaller scale. It is surrounded as is Tuvuthá by a narrow outer reef flat, becoming a fringing reef at several points of the shore, and enclosing a narrow and shallow lagoon full of rocks and patches.

There are also a number of atolls presenting no special features. To the westward of Ngele Levu are two reefs, Thakau Vutho Vutho and Thakau Mata Thuthu (Plate **17**). The former is separated from Ngele Levu by a channel eight miles wide, with 145 fathoms in mid-channel. The latter is separated from Thakau Vutho Vutho by a channel 171 fathoms deep and three miles wide. The lagoons have respectively a greatest depth of 15 and 19 fathoms. They both have navigable entrances, and the outer reef flats are studded with negro-heads and coral patches, and there are no islands on the rim. These atolls resemble Ngele Levu, but are not more than one third of its size.

It is interesting to note that to the westward of Thakau Mata Thuthu (Plate **17**) there is an isolated bank with 74 and 76 fathoms of water, but separated from it by a narrow channel; it may be a spur of the bank upon which the atoll of Thakau Mata Thuthu is situated, similar to Cock's Bank, which is close to the southwestern edge of the 100 fathom line.

Similar atolls and varying greatly in shape are Duff's Reef (Plate **18**) to the west of Wailangilala, and to the south Dibble's Reef (Plate **19**), to the east of Vanua Mbalavu, Nuku Thikombia (Plate **19**), and Malevuvu Reef (Plate **19**); farther south Thakau Tambu, Yaroua, and the smaller reefs Thakau Nokeva and Thakau Lasemarawa (Plate **20**). As we steamed from Tuvuthá to Naiau we saw the sandbank in the centre of Tavanuku i vanua Reef surrounded by a fringing reef somewhat more than a third of a mile in width (Plate **20**). To the southwest of Tuvuthá is also situated a small circular atoll, Tavanuku i wai, with an outer reef of about half a mile in diameter enclosing a small shallow lagoon.

To the east of Mothe are Thakau Motu (Plate **22**), a large atoll open to the west, with 24 fathoms in the deepest part of the lagoon (Plate **23**^{a}, Fig. 6), and Thakau Vau (Plate 22), a small circular reef with a shallow lagoon of impounded water. Neither of these did we visit. West of Komo, Thakau Vuite (Plate **22**), in a line running north and south, east of the Yangasá cluster, lies Thakau Levu, and southwest of Vanua Vatu and to the northeast of Totoya the Tova or Na Vatu Reef (Plate **23**^{a}, Fig. 5, and Plate **20**^{a}, Figs. 13, 14). Tova has been well surveyed (Plate **20**^{a}, Figs. 13, 14, and Plate **23**^{a}, Fig. 5); unfortunately we were not able to visit it, but, as will be seen, it closely resembles the Horseshoe Reef (Thakau Momo, Plate 23ª, Fig. 6), which we examined. All these islands are atolls with an outer reef flat and a lagoon of moderate depth, varying from ten to about twenty fathoms as the greatest depth, with entrances into the lagoon, and with only rocks and patches and no islands on the outer reef flats.

Thakau Vau, Thakau Lasemarawa (Plate 20), and Thakau Nawa enclose impounded water. South of Thakau Levu (Plate 22) are Thakau Thikondua, Thakau Reivareiva, Thakau Nasokesoke, and Thakau Teteika, representing probably as well as Wilkes Reef north of Namuka, and the two reefs Tavanuku i wai and Tavanuku i vanua and Frost Reef, the summits of small peaks or of crests, now covered only by heads on which corals have found a footing. In the case of Tavunasithi (Plate 22), Nuku Songea, Yaroua, Maafu Rock, and the Nukutolu Islets west of Yathata, the summits are still visible. Naiabo Islet is the remnant of a small island now surrounded by a very narrow outer reef flat enclosing a lagoon.

We did not visit the Nukutolu Islets (Plate 19), which seem to be the summits of a former narrow ridge. Frost Reef, to the west of Mango (Plate 19), is a flat circular reef of about a mile in diameter, with a rock at its northern edge.

Neither did we examine the following islands and reefs to the south of the Exploring Isles (Plate 19): Malevuvu Reef, an atoll nearly three miles long by half that in width, and a lagoon with thirteen fathoms greatest depth, accessible to boats on the west side; Katavanga, a small island, consisting, according to Captain Cocks, of elevated coralliferous limestone rising to a height of 180 feet, situated in the western part of the elliptical lagoon encircled by a reef flat widest at the eastern face, and over three miles in greatest diameter, with a greatest depth of thirteen fathoms, and an opening for small vessels on the northern side of the lagoon; and Vekai, an elevated limestone rock nearly thirty feet high on the inner edge of a circular reef about two miles in diameter, with a boat passage on the northwest side leading into a lagoon with a greatest depth of eighteen fathoms. The Malima Reef resembles Kimbombo Reef. The islets are near the centre of a lagoon about two miles in diameter.

It would not be difficult in most cases to determine how these smaller reefs have been formed. They are either in part volcanic and in part elevated coralliferous limestone, or wholly volcanic, or elevated limestone alone. The result would in either case be the same. The volcanic islets disintegrating more slowly than the tertiary limestone, it is probable that the reefs, which show no signs of volcanic rocks, have a substratum of ancient limestone of greater or less thickness, according to the height to which the particular reef has been elevated.

An atoll formed from the disintegration, erosion, and denudation of an island of volcanic structure, like Komo, for instance, would not differ in structure from an atoll like Oneata, formed from the disintegration of an island composed of elevated coralliferous limestone; but their origin would at once be detected, if the islands had disappeared, from the existence in one case of negro-heads and rocks of volcanic origin, in the other of coralliferous limestone scattered within the lagoon and on the surface of the outer reef flats. The steep slopes of these two lagoons, of different geological structure, being in no way due to the thin veneer of coral patches growing upon their respective flats and slopes, but to the fact that they are a continuation of the slopes of the islands once covering the areas of Komo and of Oneata Islands, which have been elevated and since their elevation have disappeared in great part, and have been denuded and eroded to form the platform surrounding the islands now remaining to attest their former greater extent. The denudation and erosion of these islands, being accompanied by the scouring out of the lagoons from the submarine platform through the action of the sea, caused by the incessant pouring into the lagoon of a mass of water which can only find its way out through the entrances into the lagoon or over the reef flats, where it passes out with considerable velocity, a velocity obtained in part from the hydraulic head, and in great part also from the drift due to the constant driving of the trade winds in a westerly direction.

North of the Exploring Isles there are some small banks, in from eight to twelve fathoms least water. They are Alacrity, Jeffreys, and Lewis Banks. Reid Reef (Plate 20, 20ª, Figs. 1–4) is a narrow encircling reef, enclosing a large lagoon with three islets, rising respectively to a height of sixty, ten, and twenty feet, probably of elevated limestone. The outer reef flat is narrow on the western side, bordered by a belt of heads along the inner edge. There are two passages into the lagoon on the western face. The length of the lagoon is about eight miles, and its width five. The greatest depth is twenty fathoms.

Mbukata tanoa or Argo Reefs.

Plates 20, 20ª, Figs. 5-8, and Plate 21.

These reefs are irregularly triangular, about twenty miles in greatest length. A narrow continuous outer reef flat extends along the eastern and southern faces, but the western and northern faces are bordered by disconnected reef patches (Plate **21**), and towards the northeastern face from the central part in from twenty fathoms the lagoon slopes gradually to the 100 fathom line. The western part of the lagoon is full of separate patches and clusters of rocks and coral patches. Off the west face lie two small banks, one of which is awash, the other with two fathoms of least water and covered with heads. Off the east face are three similar small banks, all of which probably represent the remnants of isolated peaks or spurs of the former land covering the Argo Lagoon. The Argo Reef is separated from the Vanua Masi (Plates **21**, **22**) atoll by a narrow channel with a depth of 115 fathoms.

The island of Vanua Masi is not quite half a mile long, eighty feet high, and is composed of elevated coralliferous limestone. Bacon Islet, sixty feet in height, is stated to be of volcanic origin; it lies on the eastern face of the narrow outer reef flat facing the lagoon. This is open on the southwest, where the lagoon is studded with heads and coral patches. The greatest depth of the lagoon of Vanua Masi is twenty fathoms, the average from twelve to sixteen. The southern part of the lagoon of Argo Reef has a depth of thirty-four fathoms, and an average depth of from twenty to thirty.

We may look upon the Argo Reef (including Vanua Masi) as vastly more denuded and eroded than that of Vanua Mbalavu, which it resembles in many respects. The islands which probably once covered the whole area of the Argo Reefs have been disintegrated, and there remain of them only the islets in Vanua Masi and the innumerable heads and patches which stud the slope of the Argo Reefs. The slope of the Argo Reefs corresponds to that of Vanua Mbalavu, and represents the slope of the volcanic island which thrust up the elevated limestones now eroded which once covered the great part of the Argo Reef Lagoon as at Vanua Mbalavu. The great open stretch on the northern face of the Argo Reefs represents a tongue of the ocean which encroached upon the northern slope of the land and has left in the shallower parts only heads and patches of corals, while in the deeper parts corals have not obtained a footing.

Thikombia.

Plate 17.

We did not visit Thikombia, the northernmost island of the group, which I am informed is composed in part of elevated coralliferous limestone rising to a height of four hundred feet. The island is a narrow undulating elongated ridge with conspicuous summits (volcanic?), one of which is over six hundred feet high; it is a little over six miles in length, and situated at the northwestern extremity of an elongated plateau extending fifteen miles in a southeasterly direction, with an average depth of thirty to over forty fathoms. The western extremity of Thikombia, as well as the southern half of the island, is bordered by a fringing reef, which extends in a long spit made up of patches and detached rocks for two and a half miles in a southeasterly direction. Gardiner states that parts of Thikombia are terraced.

Ono i lau.

Plate 17ª, Figs. 13-16, and Plate 23ª, Figs. 1-4.

We did not visit the islands to the south of Ongea. Among them are the Ono i lau Islands (Plate 1), of which some are volcanic and others composed of elevated coralliferous limestone, the highest island being 370 feet high. These islands are surrounded by an outer reef flat, elliptical in outline, about seven miles by four, which is dotted with islets, rocks, and coral patches. To the south of these islands are the small islands of Tuvana i tholo and Tuvana i ra (Plate 17ª, Fig. 13, and Plate 23ª, Fig. 27), situated on the northern edges of the circular barrier reef which surrounds them. To the southwest of the Ono cluster lies Vuata Ono (Plate 17ª, Fig. 14, and Plate 23ª, Fig. 3), an oblong reef nearly three miles long and always awash. Turtle Island to the northeast of Ono is a narrow ridge of elevated limestone, rising to over two hundred feet, with a barrier reef about four miles long off the west face, enclosing a narrow lagoon with six fathoms of water and passing into a barrier reef on the east face. Vuata Vatoa (Plate 23ª, Fig. 4) is a detached reef somewhat over two miles in its greatest length, enclosing a tidal basin into which there is a boat passage through the reef. This reef lies about two miles to the south of Vatoa, with two hundred and forty-six fathoms in mid-channel. Vatoa and Vuata Vatoa are probably the summits of a short ridge. The presence of elevated coralliferous limestone in this part of Fiji shows that the area of elevation of the group extended to the southernmost islands.

Viti Levu and Vanua Levu.

Plates 3, 3ª, 4, 18.

Although there are large stretches of the shores of Viti Levu and of Vanua Levu (Plates 3, 3ª, 4) which I have not examined, we may perhaps assume from the information I have gathered and from an examination of the charts, that neither they nor the smaller islands and reefs in the Lau Archipelago, which have been passed by, present any features which are likely to throw much additional light on the results obtained from the examination made by the "Yaralla." The area between the Yasawa group and the north shore of Viti Levu (Plate 3) has not been systematically surveyed. All we know is that it is full of coral patches, undoubtedly the eastern extension of the patches to the northwest of Nandi waters towards the Yasawa group. How far west of Charybdis Reef the extension of the deep water bay north of Vatu i ra Channel reaches is not known. Its northern and eastern limits off Vanua Levu are well defined on the charts (Plate 3). It is interesting to note that a very steep slope — fully as steep as any of the sea faces off the reefs or smaller islands of Fiji, or as steep as the sea faces of the great barrier reef off the south coast of Viti Levu — runs off the west side of Vanua Levu from the Makongai Channel beyond Yendua Island (Plate 3), and off the east side of Viti Levu from the horn of the reef north of Ovalau to opposite Charybdis Reef. Yet on this steep face the corals form only scattered patches over the surface of the flats, extending between the shore lines toward the 100 fathom line, — patches and stretches which are separated by wide areas in which the bottom is full of heads of rocks similar to those of the adjoining shores.

Charybdis Reef and the extensive reef on the southwest side of Vatu i ra Channel (Vatu i ra Reef), represent probably the eroded summits of a more or less circular island and of an elongated ridge, on the outer edges of which coral patches have found a footing, and of which Vatu i ra Islet (one hundred feet high) is the only remnant. The lagoon varies in depth from twenty-two to twenty-seven fathoms, "with several passages into it through which the tide runs strongly." Charybdis Lagoon is full of rocks and patches its average depth is about twenty fathoms; its western edge is open, with rocks scattered along its face.

An extensive fringing reef skirts the north shore of Viti Levu, which disappears within reach of the influence of Ba River. There is a wide navigable channel between it and the broad outer barrier reef patches, which resemble those off the east coast of Viti Levu, south of Moturiki Channel.

I have not examined the shores of Vanua Levu, but according to Horne[1] and from some verbal information relating to the barrier

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[1] John Horne, "A Year in Fiji," London, 1881, pp. 167, 168. Horne says that on the southwest side of Rambe a reef has been elevated twenty feet, and that the

reef, its character is similar to that of Viti Levu, the substratum of the reef flats being either hard volcanic rocks, or stratified volcanic mud, or remnants of elevated limestone. The northern shore of Vanua Levu from Cape Undu (Plate 4) west is flanked by wide extensive stretches of barrier reef patches; between them and the shore exists a broad navigable channel full of islands and islets, and the whole of the shore is also indented by deep bays separated by prominent promontories almost isolated from the larger island; plainly indicating that the flats and patches occupy areas formerly covered by large islands or by former slopes of spurs from Vanua Levu itself, which have been eroded and denuded and separated from the larger island. The outer flats and patches of the barrier reef, which as it extends westward beyond the Mali Passage forms the Great Sea Reef, and is nearly thirty miles distant off the western point of Vanua Levu. The islands and islets off the north coast of Vanua Levu form a broad belt of islands separated by islets, rocks, and patches; on the western extremity of the belt is Yendua Island and the islets extending westward.

The existence of fringing reefs inside of barrier reefs is a very striking feature of the Fiji coral islands. Their absence in some localities has been explained by Dana[1] on the supposition that the conditions are more favorable to the growth of corals on a barrier than on an interior fringing reef. Yet in some of the wide lagoons of Fiji the corals of the fringing reef grow quite as luxuriantly and to the same depth as those on the outer edge of the barrier reef, and are often more abundant than those of the lagoon slope of the barrier reef. Depths of five to six or seven fathoms are those of the most vigorous growth of corals on the outer face of such barrier reefs or encircling reefs as I have examined in Fiji, a depth corresponding to that observed in the Bahamas in similar positions.

Some of the reefs on the northwestern face of Vanua Levu (Plate 4) apparently illustrate admirably the formation by denudation and erosion of small reef flats awash, and of reef flats destitute of islands or with islands encircling a shallow lagoon. It will be noticed that these flats and pseudo atolls rise from a comparatively shallow platform, — nine to twenty fathoms, — and evidently represent the different stages of denudation and of erosion of islands which have been left on one side of the reef flat, or have disappeared, leaving an irregular enclosing reef, or have

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beach along Savu Savu, as well as Waikava and the adjacent islands, consists of coral upheaved to a height of thirty feet.

[1] Corals and Coral Islands, pp. 138, 278.

merely been denuded so as to be just awash; the scouring of the sea on the diminutive platform of submarine erosion having formed a shallow lagoon in the first instances mentioned, or a series of disconnected pools. These flats and atolls are in every way identical with similar reef flats or atolls formed from peaks or islands rising from great depths: Na Ndongu, Nuku i ra, Thakau Moi, Laukoto, and Thakau Levu Reefs (Plates **3**, **4**, **23**^{a}, Figs. 8–19). See the similar structures of Thakau Nalolo, Thakau Utulei, and Nuku i ra, on the eastern part of the north shore of Vanua Levu (Plate **4**, Figs. 8–12).

From the eastern point of Savu Savu Bay and the western point of Vanua Levu the island is bordered by a fringing reef (Plates **3**^{a}, **14**). Savu Savu Bay is protected by an extensive fringing reef off Savu Savu Point on the east, and by a series of wide barrier reef patches lying off Kumbalau Point on the west, and stretching in smaller disconnected patches across the southern face of the opening of the bay. To the west of Kumbalau Point runs an extensive plateau, the outer edge of which is from ten to twenty miles off shore, and varying in depth up to about thirty fathoms. On the outer edge of the plateau are narrow disconnected patches of corals and islets and rocks (Plates **3**^{a}, **4**). The plateau makes out in two prominent points, one, Namena Reef, elliptical in shape, about twelve miles long and three miles wide, to the south of Kumbalau Point. The reef patches enclose an irregular lagoon, in the southern horn of which lies the island of Namena, about 320 feet in height (Plate **3**^{a}). The other spit of the plateau is triangular in shape, and extends towards Makongai, from which it is separated by a channel 140 fathoms in depth. The western face of the plateau is bordered by a line of rocks and narrow coral patches, often widely separated, and extending in an undulating line.

The outline of the plateau as it forms the eastern side of Vatu i ra Channel is rounded, forming a deep bight off Solevu Point, and extending in a northeasterly direction towards Yendua Island. North of Passage Island (Plate **3**), 104 feet high, the coral patches lose their character of barrier reef flats; they become small, and are often very widely separated. The edge of the plateau is bordered with rocks, and the slope as we go north becomes less steep, passing off Solevu Point gradually into the deeper waters north of Vatu i ra Channel. But south of Nai Thombo thombo Point there are extensive reef flats, probably formed upon eroded flats of such detached spits as Lecupi Point on the south of Mbua Bay, and Lamut Islet north of Solevu Point. The principal one of these reef flats is Thakau Levu, on which some rocks are still awash at high water.

It is very probable that this plateau off the southwest coast of Vanua Levu represents the denuded and eroded slope of its western coast when it once extended near to the 100 fathom line. The only remnants of this former extension are the islands of Namena, Passage Island, and the numberless rocks and coral patches studded over the surface of the plateau and found along its edge.

The reefs of Makongai and Wakaya represent a stage of denudation and erosion less advanced than that of the Namena Reef, and of the reefs extending towards Vatu i ra Channel north of Makongai Channel.

From Cape Undu south the shores of Vanua Levu on both sides of Nateva Bay (Plate 4) are bordered by a fringing reef. From Savu Savu Bay the south shore is also protected by a fringing reef, which extends as far as Fawn Harbor; from there the fringing reef becomes a narrow barrier reef at a short distance from the shore, passing round Vienne Bay, and forming the Kioa Reefs, and the Florida and Texas reefs on the outer edge of the plateau upon which are the islands of Kioa and Rambe (Plates 4, 18). The horn of the Texas reef extends about five miles beyond Rambe, and returns to form a fringing and barrier reef on the north shore of that island, and connects with the barrier reefs off Kumbalau Point.

The Rambe Plateau (Plates 4, 18), as we may call the eroded eastern extension of Navukau Promontory, is another admirable example of the mode of formation by submarine erosion of such plateaus as those off the southwest coast of Vanua Levu, off the eastern point of Kandavu, and off the east face of Taviuni. The island of Rambe rises to a height of over 1,500 feet; it is nearly nine miles long, and about four and a half broad (Plate 18). Like Kioa, the other large island on the plateau, which is over 900 feet high, it is of volcanic structure. The plateau upon which these islands rise, and the accompanying islets, rocks, and patches, has a greatest depth of thirty-five fathoms, and an average depth of about twenty.

The Rambe plateau and the one to the east of Taviuni (Plates 4, 18), from which rise Ngamia and Lauthala, show more plainly than either Makongai or Wakaya the former connection with the larger islands of Vanua Levu and Taviuni. The promontory of which Cape Undu is the termination would, if denuded and eroded, have resulted in the formation of a plateau spit similar in all respects to that constituting the Namena barrier reef off the south coast of Vanua Levu. And finally the further disintegration of such irregularly shaped islands with encircling reefs as those of Makongai and Wakaya (Plate 15) would give us a ready explanation of the formation of such remarkably shaped reefs as the Nanuku and Nukusemanu Reefs (Plate 18), from the denudation and erosion of an extended ridge or line of the summits of independent islands, elevated at the time when the great masses of ancient limestones were raised to various heights perhaps up to one thousand feet.

The Great Sea Reef (Plate 1) appears on the chart as the continuation of the chain of which the Yasawa group of islands are the only remnants, and it may be that it represents its eastern continuation after its denudation and erosion, and transformation into a submarine platform for the growth of corals. Similarly the reefs extending to the east of Vanua Levu towards the Yasawa group may be the western extension of a range of which Sesaleka Peak and Yendua Islands formed prominent points.

GENERAL SKETCH OF THE FIJI ISLANDS AND CORAL REEFS.

I went to the Fijis under the impression that I was to visit a characteristic area of subsidence; for according to Dana and Darwin there is no coral reef region in which it is a simpler matter to follow the various steps of the subsidence which has taken place. Dana, in his last discussion [1] of the coral reef question, states that it is impossible to find a better series of islands than the Fijis to illustrate the gradual changes (brought about by subsidence) which take place in transforming a volcanic island with a fringing reef to one with a barrier reef, or to one with an encircling reef ring, and finally to one in which the interior island has disappeared and has left only a more or less circular reef ring. For these reasons one of the Fiji atolls promised to be an admirable location for boring and settling the question of the thickness of the coral reef of an atoll.

My surprise was great, therefore, to find within a mile from Suva an elevated reef about 50 feet thick, and 120 feet above the level of the sea, the base being underlaid by what is locally called "soapstone," [2] a kind of volcanic mud. The western extension of this reef can be traced at

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[1] Am. Journ. of Science, Vol. XXX., August and September, 1885. Dana says: "The large Feejee group bears abundant evidence of subsidence in its very broad reef grounds, barrier islands, and atolls."

[2] The "soapstone" is largely composed of volcanic débris, mixed with tests of Foraminifera, Pteropods, and Mollusks. Brady (Q. J. Geol. Soc. London, 1888, Vol. XLIV. p. 1) considers the Rhizopod fauna such as one would expect from a depth of 150 to 200 fathoms.

points along the north side of the harbor of Suva (Plate 7), the islands of Lambeko, Vuo, and Dra-ni mbotu, which are respectively sixty to seventy feet in height, being parts of an elevated reef extending to low water mark, and now planed off. It was this elevated reef or its extension westward which we traced from the Singatoka River to the Nandi Waters (Plate 6). A short distance inland from the mouth of the Singatoka there is a bluff of about 250 feet in height, composed of coralliferous limestone. This bluff is the inner extension of the elevated patches and limestone bluffs visible on the shore of Viti Levu. I am informed by Dr. Corney that the islands of Viwa and Asawa i lau (Plate 3), to the northward of the Nandi Waters, are also remnants of this elevated limestone.

But the traces of extensive elevation are not limited to the island of Viti Levu. I found that the islands on the rim of the atoll of Ngele Levu (Plate 17) consisted entirely of coralliferous limestone rock, elevated to a height of over sixty feet on the larger island. The northern sides of the smaller islands Taulalia and Tai ni mbeka, as well as the north shore of Ngele Levu, were on the outer edge of the rim of the lagoon, deep water running up to the shore line. We next found that at Vanua Mbalavu (Plate 19) the northern line of islands were parts of an elevated reef, forming vertical bluffs of coralliferous limestone rock which had been raised by the central volcanic mass of the main island to a height of 510 feet at Ngillangillah, at Avea to 600 feet, at the Sovu Islands to 230 feet, and on the main island to a height of nearly 600 feet, while on the south of the main island the coralliferous limestone bluffs are very much lower, and those of Malatta and of Susui reach a height of 420 to 430 feet. Going farther west and south we find at Mango vertical bluffs of an elevated coralliferous limestone of over 600 feet underlaid by volcanic rocks at the sea level. At Tuvuthá the limestone bluffs are probably nearly 800 feet high. At Naiau they are more than 500 feet. At Lakemba (Plate 21) they reach a height of about 250 feet on the southwest side of the island, the greater part of the rest of the island being of volcanic origin. On the island of Aiwa (Plate 21) the elevated limestone is fully 200 feet thick. In the Oneata group the highest point of the elevated bluffs is about 160 feet (Plate 21). South of the volcanic island of Mothe and enclosed within the same barrier on the island of Karoni (Plate 22), the reef is about 120 feet thick.

On the three islands of the Yangasá group (Plate 22) the elevated limestone attains a thickness of 240, 300, and 390 feet, and on Ongea, the most southeasterly cluster we visited, it attains a thickness of nearly 300 feet. At Fulanga (Plate **22**) the elevated limestone attains a thickness of 360 feet, at Kambara (Plate **22**) it is about 200 feet thick, and at Wangava (Plate **22**) it is perhaps over 300 feet; these islands may be in part volcanic. Finally, at Vatu Leile, the most westerly island we examined, the elevated reef forming the island is fully 110 feet thick.

All this plainly shows that the western and southern part of Viti Levu, as far south as Vatu Leile, and the whole length of the windward islands of the Fiji group, from Ngele Levu on the north to Ongea on the south (Plate **2**), have been subject to an elevation of at least 800 feet; and there is abundant proof that the greater part of the thickness of the elevated coralliferous limestone has been eroded so as to reduce it in certain localities to the level of the sea, or in others to leave the bluffs and islands and islets of limestone which we have traced at so many points.

Unfortunately there are as yet but few soundings among the islands of Fiji (Plate **2**). There is a line extending from Nanuku Passage to the Kandavu Passage, and a number of soundings to the north of Wailangilala and towards Thikombia, which have developed the existence of an extensive plateau with a depth of between 300 and 400 fathoms, from which rise all the islands forming the northeastern extremity of Fiji (Plate **2**). The soundings between Ngau and Viti Levu (Plate **2**) also indicate shallower water to the west of that island than is found either east or south of it. The deep water extends northwesterly in the passage, parallel with Kandavu. Deep water (1,200–1,700 fathoms) is found in the triangle formed by Moala, Totoya, and Matuku (Plates **2, 16**), showing the steep slope of Moala, from 1,200 fathoms at a distance of six miles, and of Matuku of 1,400 fathoms at a distance of five miles.

The deep channel passing through the centre of the Koro Sea (Plate **2**) gradually deepens towards the south until it attains a maximum depth of over 1,400 fathoms east of Nairai and Ngau, becoming shallower towards Viti Levu (Plate **12**). The water gradually deepens also in the Kandavu Passage from over 1,100 fathoms north of North Astrolabe Reef to over 1,900 fathoms southwest of Kandavu. The soundings to the north of Naitamba indicate a ridge with somewhat over 500 fathoms in depth connecting the plateaus on the two sides of Nanuku Passage (Plates **2, 18**). There are no soundings showing the depths between the larger clusters composing the Lau or eastern group of Fiji. It would add greatly to our knowledge of the connection of these groups to have lines of soundings connecting the different island clusters of Lau.

All the evidence to be gathered in Fiji tends to prove that preceding the present epoch there was an extensive elevation, which lifted the great masses of coralliferous limestone resting upon the flanks of the islands to a considerable height, in some cases as high as 1,000 feet. The base of the limestone masses rests upon volcanic rocks, as can be seen at Suva, at Kambara (Plate **78**), at Mango, at Lakemba, at Naitamba, and at Vanua Mbalavu (Plate **72**) it shows the thickness of the elevated reefs to have been over 800 feet. During this period of uplift the physiognomy of the islands of the group must have been greatly changed, and still further modified by the denudation and erosion which have taken place since the elevation of the ancient limestones. It is to the changes brought about by the elevation and the subsequent erosion and denudation that we must look for the causes which have fashioned the steep slopes of the islands and reefs, and not to the growth of the thin crust of corals which thrive upon the reef flats forming the substratum of the modern reef, — a substratum which in Fiji may be of volcanic origin or composed of elevated limestone, the sea face of which is the extension of the former land mass and follows its ancient slope, being only slightly modified by the growth of the crust of recent corals found upon it.

Similar elevated reefs (probably composed of the same tertiary limestone as those of Fiji) have been described by Clark[1] at the Loyalty Islands, and also by Chambeyron (L.),[2] and Pelatan (L.).[3] Chambeyron gives figures of the elevated terraces of Lifou and Ouvea composed of coralliferous limestone, and there is an excellent photograph taken by Pelatan of the elevated coral reefs of Lifou, and reproduced in Bernard's[4] Nouvelle Calédonie, p. 45. While Maré is said by Pelatan to have five terraces of elevated coralliferous limestone, and to be riddled with caverns,[5] Clark considers the elevated coralliferous limestones of the Loyalty Islands probably to be Pleistocene.

In the Solomon Islands, Guppy[6] has traced extensive elevated reefs,

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[1] Q. J. Geol. Soc. London, 1847, Vol. III. p. 61.

[2] Bull. Soc. Géogr., 1875, p. 566, and Bull. Soc. Géogr., 1876, p. 634.

[3] Les Mines de la Nouvelle Calédonie.

[4] L'Archipel de la Nouvelle Calédonie, par Augustin Bernard. Paris, 1895.

[5] See also De Rochas, La Nouvelle Calédonie, p. 90. Grundman, Die Loyalty Inseln, Peterm. Mittheil., 1870, p. 365.

[6] Guppy, The Solomon Islands, 1887, p. 126, and Scott, Geog. Mag., 1888, p. 121, a criticism of the theory of subsidence as affecting coral reefs. Geol. of the New Hebrides, Friedrick, Q. J. Geol. Soc. London, 1893, XLIX. 227. Campbell, R., Geol. Soc. of Australasia, Melbourne, 1889, VI. 19. Strehl, Zeit. f. Wiss. Geog. Ergänz., No. 3, 1890. J. Walther, Bau d. Flexuren, Jena Zeits. f. Nat., 1886, p. 243. J. Garnier, Ann. d. Mines, 1867, p. 59. Walther, Adamsbrücke, Peterm. Ergänz., No. 102.

which however he considers as belonging to the present epoch. Elevated coralliferous limestones also exist in the New Hebrides as well as on the southern shore of New Guinea.

The time of this Fijian elevation we cannot at present ascertain. It is not unnatural to assume that it was coincident with the elevation of Northern Queensland, and that the area of elevation included New Guinea, the islands to the east of it as far south as New Caledonia, and as far east as the most distant of the Paumotus (Gambier Islands), and extended northward of that line to include the Gilbert, Ellice, Marshall, and Caroline Islands; and that since this epoch of elevation the islands within that area have been, like Northern Australia, subject to an extensive denudation and erosion, many of them being reduced to mere flats but a few feet above the surface of the sea, others worn away to represent to-day but a small portion of their former extent. It is upon the reef flats thus eroded, or around the islands and islets which are the remnants of a former period, that the corals of to-day have obtained a foothold. And further, by the mechanical action of the sea combined with that of the trade winds, channels have been excavated out of the substratum underlying the coral reefs to form the lagoons of the barrier reefs and atolls of Fiji.

So that, as far as we can judge from the case of the Fiji Islands, the shape of the atolls and of the barrier reefs is due to causes which have acted during a period preceding our own. The islands of the whole group have been elevated, and since their elevation have, like the northern part of Queensland, remained nearly stationary, and exposed to a great and prolonged process of denudation and of aerial and submarine erosion, which has reduced them to their present height. The submarine platforms upon which the barrier reefs have grown being merely the flats left by the denudation and erosion of the central island, while the atolls are similar flats from the surface of which the islands have at first disappeared and the interior parts of which have next been removed by the incessant scouring of the action of the sea, the ceaseless rollers pouring a huge mass of water into the lagoon, which finds its way out of the passages leading into it or over the low outer edges of the lagoon. These atolls and islands, surrounded in part or wholly by encircling and barrier reefs, have not been built (as is claimed by Dana and Darwin) by the subsidence of the islands they enclose. They are not situated in an area of subsidence, but on the contrary in an area of elevation. The theory of Darwin and Dana is therefore not applicable to the Fiji Islands.

The evidence of elevation is not limited to that furnished by the remains of the elevated coralliferous limestone just mentioned, and it is natural to assume that the elevation we have just traced was but a part of a more general elevation, which perhaps took place in late tertiary times, and in which the whole group was involved. It is plain that there must have been most extensive denudation and submarine erosion going on throughout the group for a very considerable time, geologically speaking. The outlines of the islands, deeply furrowed by gorges and valleys, the sharp or serrated ridges separating the valleys, the fantastic outlines of the peaks and chains of Viti Levu, Vanua Levu, and Ovalau, all attest to the great work of atmospheric agency which must have been going on for so long a period.

The extent of the separation of the islands, islets, or isolated rocks from the points or spurs of the larger islands also bears witness to the great length of time during which submarine erosion and denudation have been at work.

The platforms of submarine erosion constitute the characteristic features of the islands of Fiji. A glance at the sketch map of Fiji (Plate 1) and at the detailed charts of different portions of the group cannot fail to show how extensive this action has been. I need only call special attention to the northwestern extremity of Viti Levu, the eastern face of the same island (Plates 3, 7), the southern coast of Viti Levu (Plate 5), the southwestern and northeastern shores of Vanua Levu (Plates 3, 4, 18), the extensive platform of Kandavu (Plate 11), that of the northern extremity of Taviuni, Budd Reef (Plates 4, 18), Thikombia (Plate 11), the platforms of submarine erosion of Mbengha (Plate 8), of Nairai, Ngau (Plates 12, 13, 14), of Makongai and Wakaya (Plate 15), of Moala and Totoya (Plates 16, 23), of the Exploring Isles (Plate 19), and of the smaller islands like Kimbombo and Kanathea (Plate 19), Lakemba and Oneata (Plate 21), Mothe, Komo, Yangasá, and Ongea (Plate 22), and a host of other smaller platforms. Finally, platforms of submarine erosion which have reached the stage of atolls of greater size, like the Argo Reefs (Plate 21), Reid (Plate 20) and Nanuku Reefs (Plate 18), Ngele Levu (Plate 17), or those of smaller dimensions, like Adolphus Reef (Plate 18), Thakau Mata Thuthu, Thakau Vutho Vutho (Plate 17), Duff (Plate 18), Dibble's Reef (Plate 19), Motua Levu, Motua lai lai (Plate 18), Thakau Tambu (Plate 20), Thakau Lekaleka (Plate 21), Thakau Motu (Plate 22), Thakau Levu (Plate 22), and others.

Add to this the fact that we are in a region of a former powerful and extensive volcanic activity, the traces of which can still be seen in all directions, and which has undoubtedly played a great part in the lifting of the island masses and their subsequent shaping to their present outlines. From this evidence I am inclined to think that the corals of to-day have actually played no part in the shaping of the circular or irregular atolls scattered among the Fiji Islands, that they have had nothing to do in our time with the building up of the substructure of the barrier reefs encircling either wholly or in part some of the islands, that their modifying influence has been entirely limited in the present epoch to the formation of fringing reefs, and that the recent corals living upon the outer margin of the reefs, either of the atolls or of the barriers, form only a crust of very moderate thickness upon the underlying base. This base may be either the edge of a submarine flat, or of an eroded elevated limestone, or of a similar substructure composed of volcanic rocks, the nature of that base depending absolutely upon its character when elevated in a former period to a greater height than it now has; denudation and erosion acting of course more rapidly upon the elevated coralliferous limestones than upon those of a volcanic character. It is therefore natural to find that the larger islands, like Kandavu, Ovalau, and Taviuni (Plates **1**, **3**, **4**, **7**, **10**, **11**), are of volcanic origin, while the islands which once occupied the area of the lagoons of Ngele Levu, Nanuku Reefs, Vanua Mbalavu, the Argo Reefs, the Oneata, Yangasá, Aiwa, Ongea, and Vatu Leile clusters, were composed of elevated coralliferous limestones. They have disappeared almost entirely, leaving only here and there a small island to attest to the former existence of a more extensive elevated limestone, once covering the whole area of what is now an atoll (Plates **1**, **17**, **18**, **19–21**). Smaller volcanic islands, like Matuku, Moala, Ngau, Nairai, and Koro (Plates **1**, **12**, **13**, **14**, **16**), also show the greater or smaller extent to which each has been eroded after its elevation, being least in Koro (Plate **3**^{a}) and Matuku (Plate **16**). and somewhat more in Moala (Plate **16**) and Ngau (Plate **13**), and still more in Nairai (Plate **14**), while in such volcanic islands with atolls as Mbengha (Plate **8**), Wakaya, and Makongai (Plate **15**) the denudation and submarine erosion[1] has been still greater, the islands covering but a comparatively

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[1] Dana (p. 230) accounts for the formation of the shore platform by the action of the sea. We go a little further, and assign to the action of the breakers and of the currents in carrying loose material to sea the formation of channels between the outer reefs and the shore; these become lagoons inside of barriers or encircling reefs, and finally scoop out the lagoons of atolls. Dana (p. 181) insists fully as strongly as Darwin upon the identity of origin of the encircling atoll reef and the outer reefs enclosing high or low islands: "The lagoons are similar in character and position

small area of that once covered by the island originally occupying the area of the lagoon; this denudation having been carried to a still greater extent in the Kimbombo cluster (Plate **19**), in Komo (Plate **22**), and the islands of Duff Reef (Plate **18**). This process of denudation and submarine erosion may have gone so far as to leave no trace in an atoll of its volcanic or of its limestone (elevated) origin, its shape to-day being entirely due to mechanical action, and having nothing to do with the growth of the corals which have found a footing upon the flats due to submarine erosion and to denudation and to the action of the atmosphere and of the sea.

It seems to me as if the position of an island left on the western or lee edge of a lagoon depended upon the original position of its highest point. This appears in the case of Makongai and Wakaya. The crest of the former was probably near the eastern edge, while the highest point of Wakaya was perhaps nearest the western side of the original island (Plate **15**). Similarly the highest summit and ridge of Vatu Leile, if our views are correct (Plate **9**), was on the western face of the original land mass. The highest ridge of Rambe lies on the northwestern side of the submarine plateau; the islands of Budd Reef indicate its highest land to have been on the northern part of the plateau (Plate **18**). In Mbengha (Plate **8**), on the contrary, the highest land mass is found on the east face of the lagoon. In the Great Astrolabe Lagoon it was in the central line of the plateau (Plate **10**). In Ngau (Plate **13**) the highest land lies to the east, in Nairai (Plate **14**) somewhat nearer the centre, in Moala in the northern part of the lagoon. In Totoya (Plate **23**) the highest part of the rim is the eastern edge.

The northeastern part of Ngele Levu must have been the highest extremity of the Ngele Levu land mass (Plate **17**). The islet at the northeastern extremity of Wailangilala (Plate **18**) indicates the position of the highest part of that atoll. The highest land of Naitamba, Kanathea, Vanua Mbalavu, and Katavanga lies on the western part of the plateau (Plate **19**), and also that of Lakemba (Plate **21**).

The highest of the land masses of Aiwa, of Oneata (Plate **21**), and of Komo (Plate **22**) was on the southern edge of these plateaus. In Mothe it lay near the northern extremity (Plate **22**). In Namuka and Ongea it ran through the central parts of the group (Plate **22**). In Fulanga the land seems to have been equally high on the northern and

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to the inner channels within barrier reefs. . . . The reefs within the lagoons correspond very exactly in mode of growth and other characters to the inner reefs under the lee of a barrier."

southern edges of the land mass (Plate **22**). In Yangasá the south-eastern and western faces were probably the highest land of the group (Plate **22**).

Admiral Wharton[1] has suggested "the cutting down of volcanic islands by the action of the sea, and that this action has a far greater share in furnishing coral foundations than has been generally admitted." From our experience in Fiji we may safely modify this to the cutting down, not only of volcanic islands, but also of other elevated islands, and their cutting down not only by submarine erosion but also by denudation and atmospheric agencies, and thus preparing the foundations upon which recent corals have established themselves. Add to this the elevation of banks composed of volcanic rocks or of sedimentary rocks up to heights at which corals or corallines can begin to grow, and we have in addition to their increment in height from the increase due to pelagic organisms and the decay of other calcareous invertebrates living upon their surface all the elements needed for the preparation of a set of foundations from very different causes.

I have already on other occasions called attention to the powerful scouring effect produced upon the interior of an atoll or lagoon, or the channel of a barrier reef, by the mass of water poured into it from all sides as the huge ocean swells break over the outer rim. This mass of water can find no outlet against the incessant swell; it must escape to leeward through the openings in the outer reef flats, or laterally over the low parts of their outer edges. It will be noticed that the openings are usually on the west face of the atoll, the direction in which the prevailing trades drive the water of the lagoon. The water becomes charged with particles of lime or of other material, and we soon have all the elements of a modified gigantic pothole, from which the churned material[2] is carried out by the currents flowing through the entrances into the lagoon. It has long been known that there is a violent rush of water out of the lagoons, the velocity attained reaching sometimes four to five knots. In Fiji I have noticed these powerful currents flowing out of the passages leading into the lagoons of Fulanga (Plate **22**), of Ngele Levu (Plate **17**), of Wailangilala (Plate **18**), of Vatu Leile (Plate **9**), of Totoya (Plate **23**), and racing along the interior channels of the great

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[1] "The Foundation of Atolls," Nature, February 25, 1897, p. 391.

[2] Material derived mainly from the mechanical disintegration of the corals or substratum forming the surface of the reef, and also in part from the chemical disintegration due to the sea water at work to rot and dissolve the limestones of the reef.

barrier reef stretching along the south coast of Viti Levu, especially at Lauthala Bay, Suva (Plate **7**), and the reef harbors and passages between Suva and Serua (Plate **5**), and out of the smaller atolls like Motua lai lai, Thakau Leka leka, Thakau Momo, and others (Plates **12**, **18**, **21**).

The strength of the currents in the channel separating the barrier reef and the shore has been noticed by Semper[1] and by Möbius[2] as bearing an important part in Mauritius. There is in the Biologisches Centralblatt, 1889–90, Bd. IX. p. 564, a short review of the third edition of Darwin's "Coral Reefs," showing the principal points in the discussion of the reefs to which Bonney has called attention. But this discussion is mainly theoretical, and adds no new factors in the problem. I would refer to what Gardiner[3] says regarding the conditions affecting the growth of coral reefs in Fiji, where he shows the effect of tidal currents in the passages of reefs and inside of reefs. Strong currents prevent the coral larvæ from fixing themselves in localities which they scour, while the corals will thrive off the passages where the currents have lost their strength. The navigators and naturalists of the U. S. Exploring Expedition[4] frequently speak of the rapid outward current passing through the openings of the reefs, especially during the ebbing tide. Dana[5] had noticed the great strength of the tidal currents, and he well explains by their action the great diversity of distribution of material over the bottom of a lagoon or of a barrier reef channel.

There seems to be no question that the action of the sea can cut out the lagoons of barrier reefs and of atolls at the depths at which they have been observed in the Fijis. Although there are individual atolls which show depths of thirty-five to fifty fathoms and even more, these are exceptional depths, which are readily explained as due to other causes than the scouring action of the sea.

Admiral Wharton[6] has given an excellent summary of cases showing to what depths the action of the sea in motion may be felt to a sufficient extent to move material at depths of fifty to sixty fathoms. As he justly says, "The effect [of the action of the waves in an otherwise deep sea over which strong winds are continually blowing] will be to cut down an island more or less rapidly, according to its constitution, to a very considerable depth below the surface, the final result being a perfectly flat bank."

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[1] Naturl. Existenzbeding. d. Thiere, Bd. II. (1880), chapters 7, 8.

[2] Beiträge z. Meeres Fauna der Insel Mauritius, Berlin, 1880, p. 29.

[3] *Loc. cit.*, p. 481.

[4] Dana, p. 170.

[5] *Loc. cit.*, p. 151.

[6] Nature, Vol. LV. p. 392.

On Plate **22**^{b} I have a series of hypothetical figures to illustrate the changes I imagine the islands of Fiji to have undergone from the time of their elevation to the present day. The only type which is not represented is that of Koro, which is however sufficiently well shown on Plate **19**^{a}, Fig. 8. The highest point of Koro occupies a nearly central position, the eastern platform of submarine denudation being only slightly wider than the western. Koro occupies a position intermediate between Makongai and Wakaya (Plate **22**^{b}, Figs. 2, 3), where in the one case the widest platform of submarine erosion is situated on the west side, and in the other on the eastern face of the island.

The dotted lines surmounting the Figures of Plate **22**^{b} indicate the hypothetical islands as they may have appeared after their elevation to the highest point; the solid lines indicate the heights of the islands as they are at the present day, and the lower dotted lines in Figures 7 to 12 indicate the position of the underlying volcanic rocks which have elevated the overlying coralliferous limestones in Figures 7 to 11, while in Figure 12 the volcanic rocks of Vanua Mbalavu are seen to pass under the elevated limestones of Thikombia i lau.

In Plate **20**^{a}, Figures 1 to 5, the dotted lines represent the position of the volcanic rocks underlying the recent coral reefs forming the barrier of the harbor of Levuka, upon the platform of submarine erosion consisting of volcanic rocks, as represented by the dotted lines in those Figures.

Figures 1 to 5 represent the hypothetical outlines of volcanic islands.

Figure 1, that of Nairai, with a narrow barrier reef off the east coast and a wide platform of submarine erosion on the western face, with heads and patches which probably represent higher points of the original Nairai as indicated by the dotted lines. Figures 2 and 3 represent modifications of a volcanic island having probably in one case its highest point nearest the eastern edge of the lagoon, and in the other nearest the western side of the lagoon (Makongai and Wakaya).

Figure 4 represents Mbengha, in which there must have been a western ridge, and perhaps also a central ridge, more or less parallel with the two main ridges of Mbengha near the eastern edge of the lagoon.

Figure 5 represents the continuation of a former great ridge northward from Kandavu towards the North Astrolabe Reef, which has been denuded and eroded into a series of islands now existing in the Great Astrolabe Lagoon.

Figures 6 to 11 represent the former outlines of islands composed of elevated coralliferous limestone. In the case of Figure 6, Tuvana i ra, the central limestone hill is flanked by two nearly equal platforms of submarine erosion which are scarcely more than reef flats. In Figures 8 and 10 are represented conditions in which, as in Vatu Leile, we have a very shallow lagoon with reef flats both on the east and west, and the remnant of the original island rising to a hundred feet at the western face. In Figure 10 we have the eastern end of the Ngele Levu Lagoon, with the islet of Taulalia on the north side of a shallow lagoon. Immediately beyond Taulalia all trace of the former elevated island composed of limestone disappears; the lagoon becomes deeper as we pass to the western entrances, and the only traces left of the original Ngele Levu Island are the extensive reef flats on the north and south side of the deeper lagoon.

Figures 9 and 11, Ongea and Oneata, indicate the amount of erosion and denudation which probably has taken place to reduce the islands as originally elevated to their present condition.

Figure 7 represents the manner in which the great central Sound of Fulanga, with its narrow outer lagoons, has probably been formed by the denudation and erosion of the central part of the limestones composing the island, aided by the solvent action both of the fresh water finding its way through the central limestone mass, and that of the salt sea after it had once gained access to the inner Sound of Fulanga.

Figure 12 gives a hypothetical section across Vanua Mbalavu, showing the extension westward of the volcanic rocks which have raised the island of Thikombia i lau, near the central part of the lagoon, composed of elevated limestone. The elevated limestone to the westward of Thikombia either having all been denuded and eroded or broken up into masses readily decomposed, the fragments of which still exist to the northeast towards Ngillangillah and south towards Malatta Island.

The sections which I have given (Plates **11^a**, **17^a**, **19^a**, **20^a**, **22^a**, **22^b**) plainly indicate the general flatness of the lagoons, with a slight inclination in the direction of the flow of the water in the lagoon toward the ship passages leading into the lagoon, and the outline of the islands which have first been cut down by atmospheric agencies show irregularities which disappear finally when they have come within the scope of submarine erosion, resulting in such "sunken" banks as the Penguin Bank (Plate **23^a**, Figs. 7, 13). By "sunken" we do not mean in any way to refer to subsidence as a factor in producing such a bank. The mass of water which is poured into a lagoon on the windward face of a reef, and transforms it into a gigantic pothole, is something enormous. The breakers follow one another incessantly, and the hydraulic head obtained is amply sufficient to account for the scouring of the lagoons after the reef has once established itself as a bank, and amply sufficient to wear away from the slope of the islands the platform upon which the coral reef is built. The topography of this platform is naturally much varied, depending upon the character of the shore line, the direction of the valleys of the shore hills, and their composition. A glance at the charts accompanying this Bulletin will show all possible conditions of submarine erosion in the cutting down of the submarine platforms of the islands of Fiji, and in the manner in which islands, islets, and rocks have been left, attesting their former greater extension in the various clusters of the Archipelago.

When the principal openings are not on the lee side of the lagoons, as is the case with Vanua Mbalavu (Plate **19**), and the Argo Reef or Totoya (Plate **23**), Fulanga (Plate **22**), and a few others, there is usually a simple reason, such as the lower elevation of the island once covering the area of the lagoon at some point not on the lee side, or the fact that the lagoon has been formed on a steep volcanic slope looking eastward or northward, so that deep ravines or tongues of deep water cut into the lagoons, and intercept the coral patches forming its rim on the weather side, and thus leave a windward passage. It is by some such orogenic condition that we must explain the existence of deep soundings within atolls, — soundings which in no way indicate a subsidence, as has been assumed by Darwin, and which according to him were not to be explained by any other hypothesis. Such deep ravines are of course also to be traced on the slopes of the larger islands where we find, crossing the shallow plateaus on which coral patches grow, valleys of considerable depth, which appear as deep soundings within the area of an outer reef flat such as in the great plateau off Viti Levu and Vanua Levu (Plates **3**^{a}, **4**), or of Kandavu (Plates **10, 11**) and Taviuni (Plate **4**), which according to Darwin would indicate a subsidence, while, on the contrary, they are a part of the results of the elevation and lifting up of that region of Fiji.

Nor are the great depths found close to narrow lines of corals an indication that the corals have grown up as a nearly vertical wall from a depth of two to three hundred fathoms or more. It merely indicates that the corals form a thin crust, at most 120 feet in thickness, over a sharp volcanic ridge, the summits or crest of which have either reached by elevation the depths at which corals can grow, or have been denuded by submarine erosion to form a platform below the level of the sea, where corals have found a footing upon them.

My observations in Fiji only emphasize what has been said so often, that there is no general theory of the formation of coral reefs, either of barrier reefs or atolls, applicable to all districts, and that each district must be examined by itself. At least such has been my experience in the Bermudas, the Bahamas, Cuba, Florida, the West Indies, the Sandwich Islands, and Australia. The results of this trip show plainly that Darwin's theory is not applicable to the Fiji Islands, notwithstanding the borings at Funafuti, and that, in all the cases I have examined, the reefs form but a thin crust upon the underlying base, the shape and composition of which is not in any way due to the growth of corals of the existing period.

CAMBRIDGE, MASSACHUSETTS,
October 1st, 1898.

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PLATE 74.

Cañon, east shore of Ngillangillah Island, Vanua Mbalavu Lagoon. Elevated limestone.

PLATE 75.

Avea Island (600 feet). Vanua Mbalavu Lagoon. Elevated limestone.

PLATE 76.

Alcyonarian Flat, Ngillangillah Island.

PLATE 77.

Limestone Bluff north of Tokolau Beach, Kambara, Wangava in the distance.

PLATE 78.

Volcanic Hill south of Tokolau, Kambara. The elevated limestone extends to the valley on left of hill. The negro-heads and shore platform underlying the limestone are volcanic.

PLATE 79.

Elevated Limestone Cliffs, Northwest Shore of Kambara. Neither fringing nor barrier reefs along this part of the coast.

PLATE 80.

Southeast Side of Fulanga. High hills in the southeast corner; shore line of low limestone hills in the foreground, seen from outside of barrier reef.

PLATE 81.

Looking into Fulanga Lagoon and Sound. Limestone islets across the rim of the Sound. Limestone islets and hills in the distance.

PLATE 82.

Entrance into Fulanga Lagoon and Sound, seen from the east.

PLATE 83.

Limestone Islets in Fulanga Sound, and Islets across eastern Margin of Sound. From a Photograph by Mr. Hathaway. Limestone Bluffs of Inner Rim of Sound looking east.

PLATE 84.

Undercut Limestone Islets in Fulanga Sound. From a Photograph by the Hon. W. L. Allardyce.

PLATE 85.

Low Gap, looking across Barrier Reef, into closed Sound of Northeast Coast, Mango.

PLATE 86.

Elevated Limestone Bluffs, East Coast of Mango. To the right along the beach the volcanic rocks underlying the limestone crop out.

PLATE 87.

Volcanic Islets on the southwest side of Mango, on the edge of the Barrier Reef.

PLATE 88.

Northwest Point of Tuvuthá. Elevated limestone (800 ft.).

PLATE 89.

Southeast Point of Tuvuthá. Elevated limestone.

PLATE 90.

Yavutha Island (240 ft.). Elevated limestone, distant 1¼ miles from the southeast inside of Yangasá Lagoon.

PLATE 91.

Looking into Bay on north side of Navutuiloma Island, Yangasá Lagoon. Elevated limestone.

PLATE 92.

Point (elevated limestone) on North Shore of Navutuiloma, Yangasá Lagoon. Yavutha Island in the distance.

PLATE 93.

Islets (elevated limestone) in Bay of Navutuiloma, Yangasá Lagoon.

PLATE 94.

North Shore of Ongea Ndriti (elevated limestone).

PLATE 95.

Taulalia Islet, distant two miles, northern edge of Ngele Levu Lagoon. Seen from Anchorage inside of Lagoon. The cones are composed of elevated limestone.

PLATE 96.

Northern Point of Tai ni Mbeka Island, elevated limestone, northern edge of Ngele Levu Lagoon.

PLATE 97.

Pitted and Honeycombed Surface of central part of Ngele Levu Island, with typical inland vegetation.

PLATE 98.

Pitted and Honeycombed and Denuded Surface of Ngele Levu Island near eastern shore, with conical mounds and deep crevasses.

PLATE 99.

Vegetation, West Shore of Ngele Levu Island.

PLATE 100.

Elevated Limestone Bluffs, Northwest Shore of Vatu Leile, seen across barrier reef line.

PLATE 101.

Vatu Savu Islets (elevated limestone) on northern edge of Vatu Leile Lagoon. The low eastern shore of the island of Vatu Leile (elevated limestone) in the background.

PLATE 102.

Vatu lai lai Islets (elevated limestone) northern rim of the Vatu Leile Lagoon.

PLATE 103.

Southern Horn of Nanuku Levu, seen from the south. Nanuku Levu Island in the distance.

PLATE 104.

Nanuku Levu Island, seen from the west across the Western Reef.

PLATE 105.

Southern Reef Flat of Nanuku Levu Island.

PLATE 106.

Beach Rock on East Shore of Nanuku Levu Island.

PLATE 107.

Negro-Heads (elevated limestone) occupying Position of Nanuka lai lai Island.

PLATE 108.

The Islands of Nuku Mbalate and Nuku Mbasanga, seen from the west across the encircling reef.

PLATE 109.

Western Point of Wailangilala Island, distant one third of a mile from anchorage inside the Lagoon.

PLATE 110.

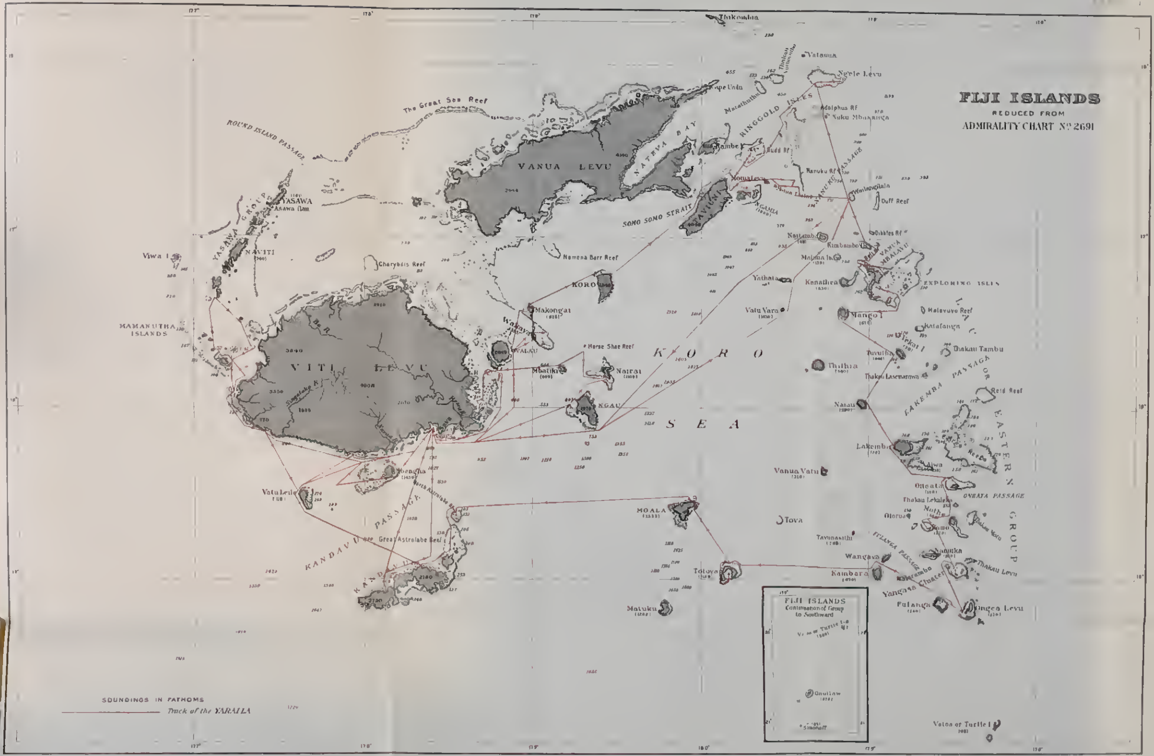
Northeast Point of Wailangilala Island, seen from Lighthouse Tower.

PLATE 111.

Southeast Horn of Thakau Lekaleka, Oneata Passage.

PLATE 112.

Northeast Horn of Motua lai lai, seen from the east.



FIJI ISLANDS
REDUCED FROM
ADMIRALITY CHART Nº 2691


FIJI ISLANDS
REDUCED FROM
ADMIRALTY CHART Nº 2691
SOUNDINGS IN FATHOMS
Elevated limestone coloured
Thikombia
Valanua
Ngele Levu
Cape Undu
Adolphus Rf
Nuku Mbasanga
RINGGOLD ISLES
Mbatuthuthu
Rambe I
Budd Rfs
Ranuku Rf
NANUKU PASSAGE
Nomalevu
Wailangilala
Duff Reef
The Great Sea Reef
ROUND ISLAND PASSAGE
VANUA LEVU
NATEWA BAY
SOMO SOMO STRAIT
TAVIUNI
YASAWA GROUP
YASAWA
Asawa Ilau
NAVITI
Viwa I
Charybdis Reef
Namena Barr Reef
KORO
MAMANUTHA ISLANDS
VITI LEVU
Makongai
Wakaya
OVALAU
Horse Shoe Reef
Mbatiki
Nairai
NGAU
KORO SEA
Naitamba
Dibbles Rf
Kimbombo
VANUA MBALAVU
Mothma I
Yathata
Kanathea
EXPLORING ISLES
Vatu Vara
Mango I
Malevuvu Reef
Katafanga
Tuvutha
Thakau Tambu
Thithia
Thakau Lasemarawa
LAKEMBA PASSAGE
Reid Reef
Naian
Lakemba
Aiwa
EASTERN OR LAU GROUP
Vanua Vatu
Oneata
ONEATA PASSAGE
Thakau Lekaleka
Mothe
Oloruá
Komo
Vatu Leile
Mbengha
North Astrolabe Reef
Great Astrolabe Reef
KANDAVU PASSAGE
KANDAVU
MOALA
Tova
Tavanasithi
Wangava
TULANGA PASSAGE
Namuka
Kambara
Marambo
Yangasa Cluster
Thakau Levu
Totoya
Matuku
Fulanga
Ongea Levu
FIJI ISLANDS
Continuation of Group to Southward
Vatoa or Turtle I
Onailau
Vatoa or Turtle I
177°
178°
179°
180°
179°
178°
16°
17°
18°
19°

FIJI ISLANDS AND CORAL REEFS. PL. 3.


Soundings in fathoms.

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Soundings in fathoms

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THE HELIOTYPE PRINTING CO., BOSTON

THE HELIOTYPE PRINTING CO., BOSTON

SERUA TO MALOLO.

Soundings in fathoms

5 MILES

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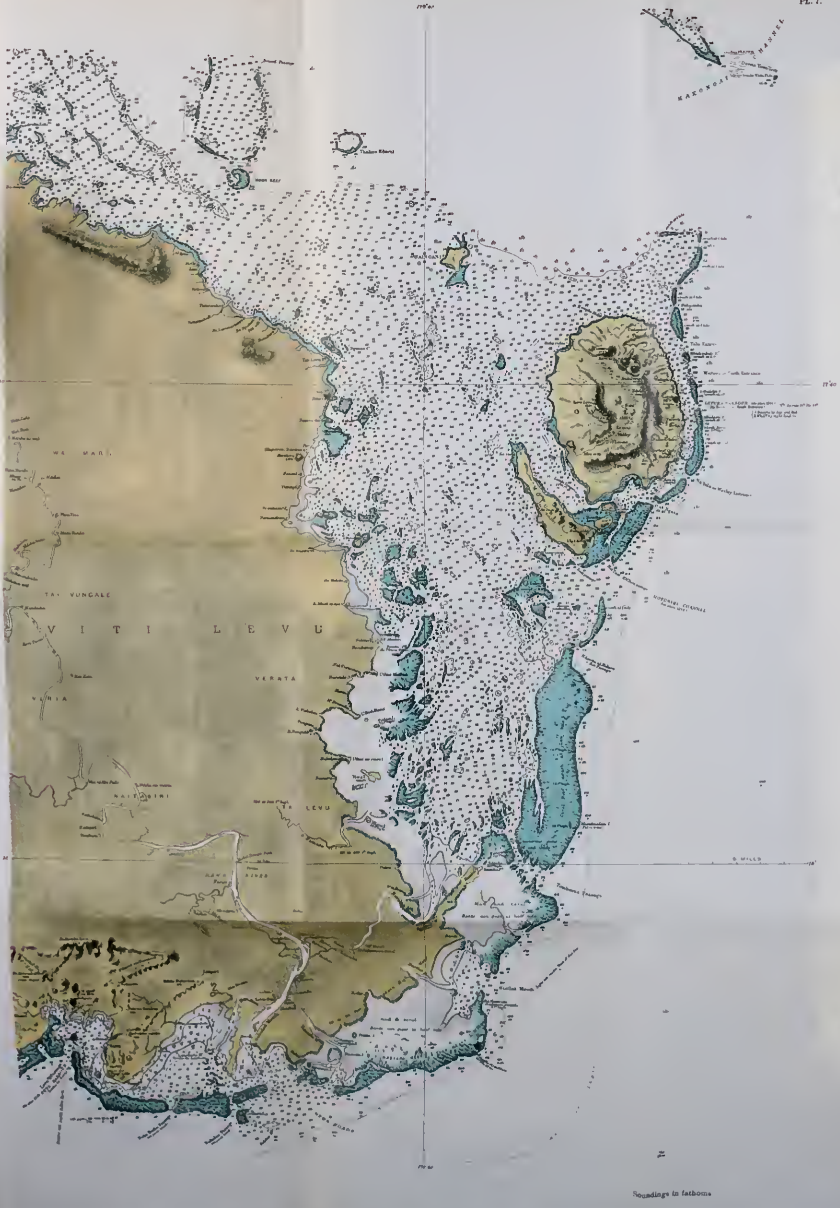

Soundings in fathoms

THE HELIOTYPE PRINTING CO. BOSTON

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THE HELIOTYPE PRINTING CO., BOSTON

Soundings in fathoms.

THE HELIOTYPE PRINTING CO., BOSTON

PL. 10.

Soundings in fathoms.

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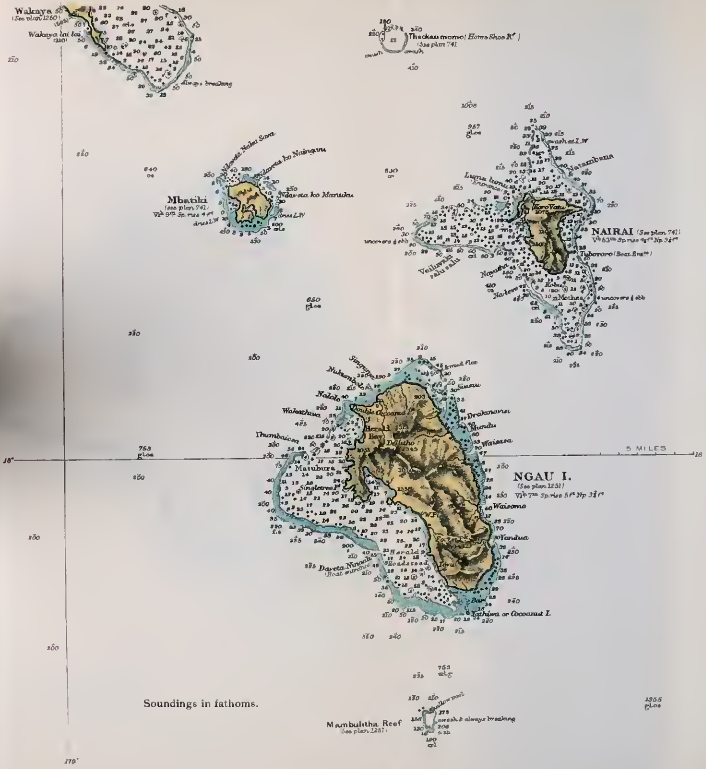
THE HELIOTYPE PRINTING CO., BOSTON

B Meisel lith Bo


Wakaya
(See plan 1250)
Wakaya lai lai
always breaking
Thackau momo (Horse Shoe Rf.)
(See plan 741)
awash
Mbatiki
(See plan 741)
Ndaveta Nalea Sava
Ndaveta ko Nainguru
Ndaveta ko Manuku
dries L.W.
NAIRAI (See plan 741)
Koro Vatu
Natambana
awash at L.W.
Luma lumu
Tuboroco (Boat Ent.ce)
Veiluvah salu salu
Nayaba
Na leve
Kobu
Mothea
uncovers ½ ebb
NGAU I.
(See plan 1251)
Singuru
Nukambola
Nalolo
Wakathuva
Thumbaicon
Matubura
Single tree Pt.
Double Cocoanut Pt.
Herald Bay
Dellutho
Drakanana
Mundu
Waisasa
Waisomo
Yandua
Herald Roadstead
Daveta Ninochi (Boat entrance)
Bari
Yathiwa or Cocoanut I.
5 MILES
18°
179°
Mambulitha Reef
(See plan 1251)
shallow pool
awash & always breaking
Soundings in fathoms.

Soundings in fathoms.

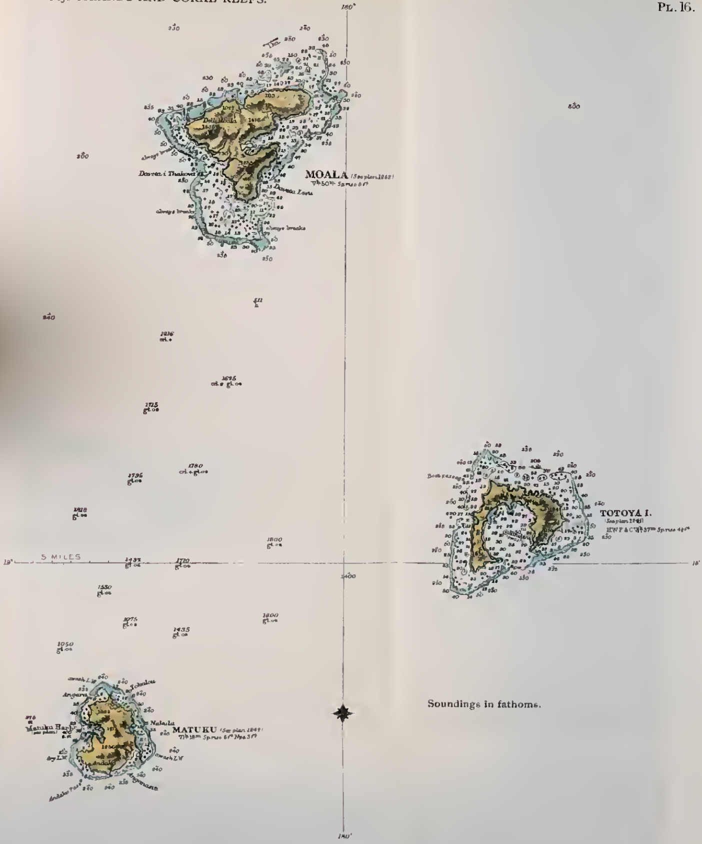
5 MILES

THE HELIOTYPE PRINTING CO., BOSTON

Soundings in fathoms.

THE HELIOTYPE PRINTING CO., BOSTON

THE HELIOTYPE PRINTING CO., BOSTON



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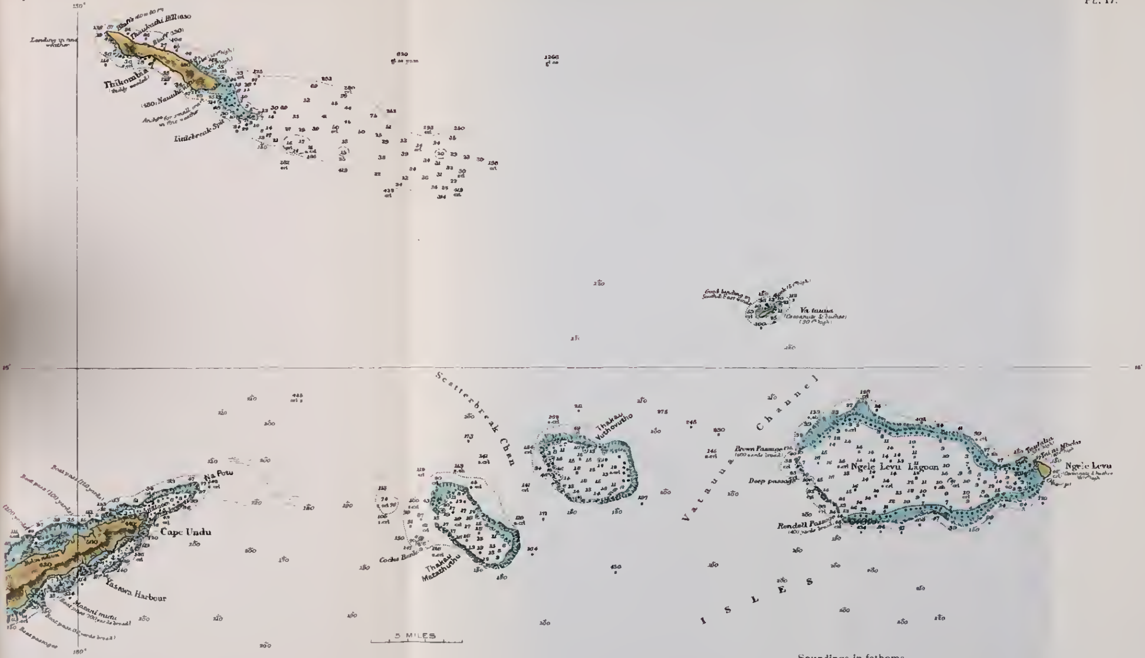

Soundings in fathoms.

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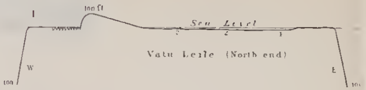

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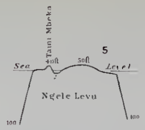

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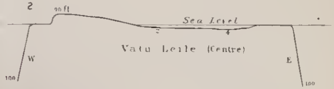

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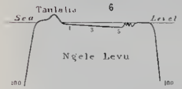

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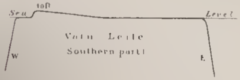

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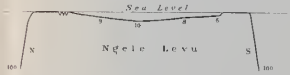

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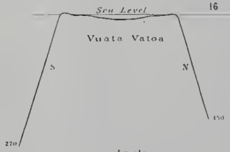

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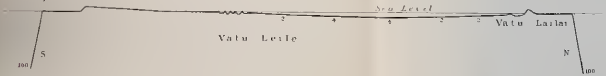
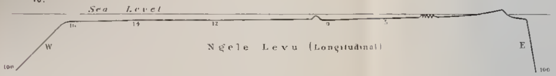


1 mile
Figs 13-16

10.



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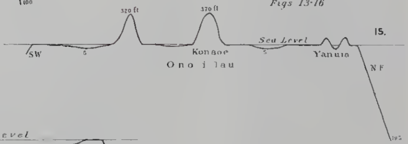

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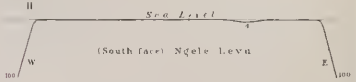

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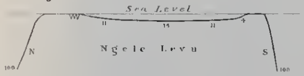
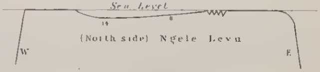


3 mile
Figs 1-12

12



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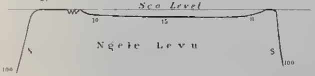
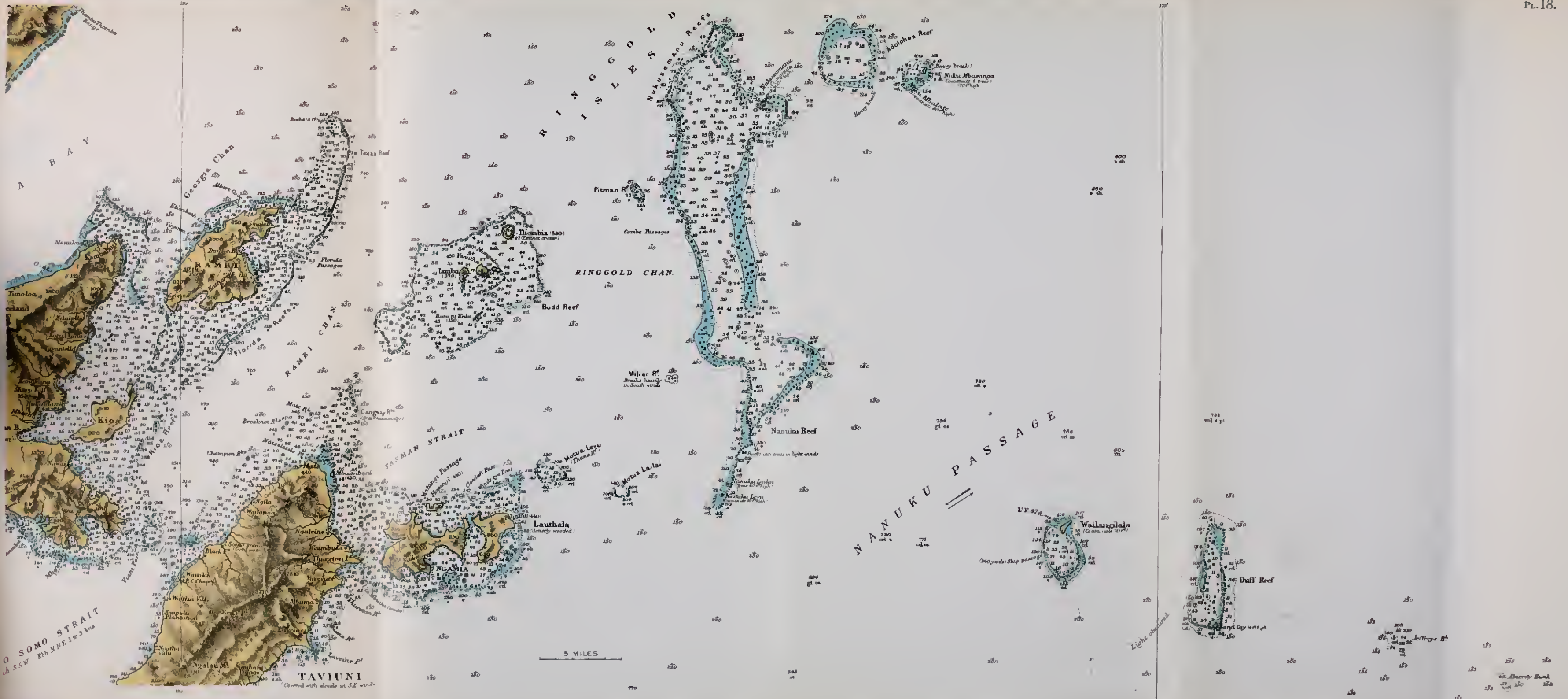


Soundings in fathoms
Heights in feet



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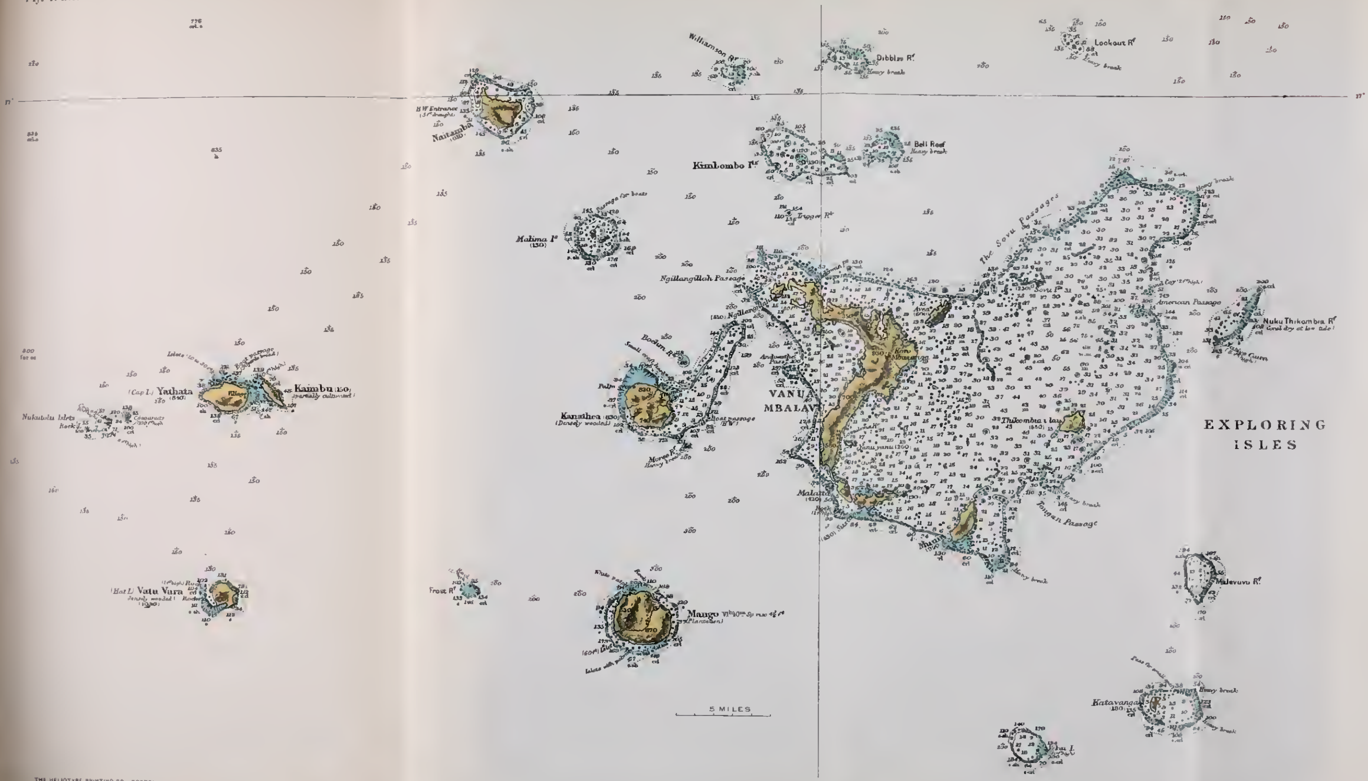
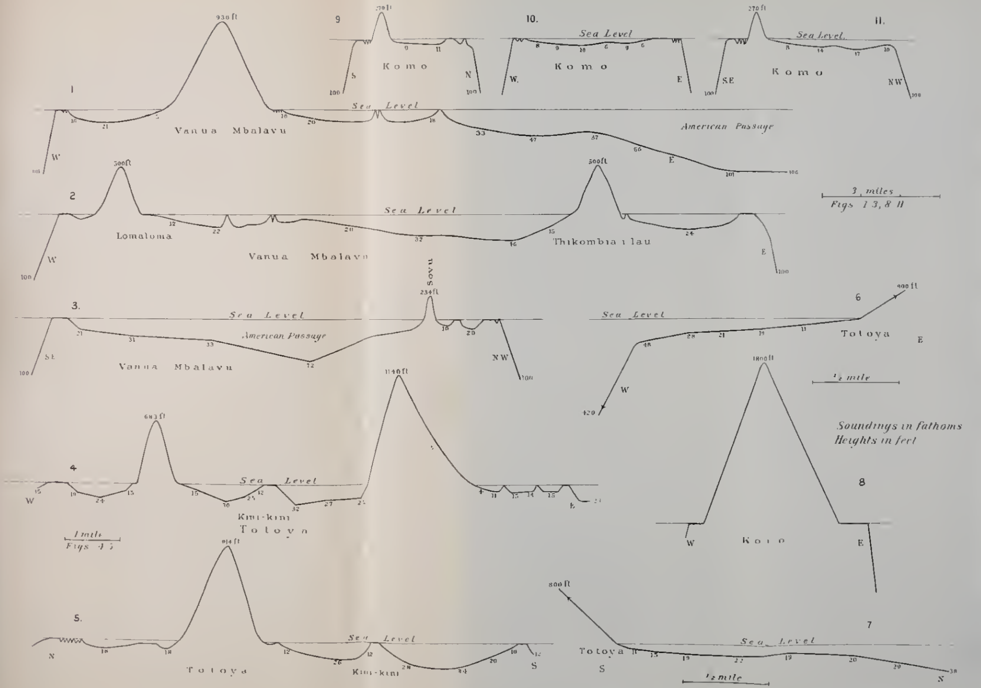
Soundings in fathoms.

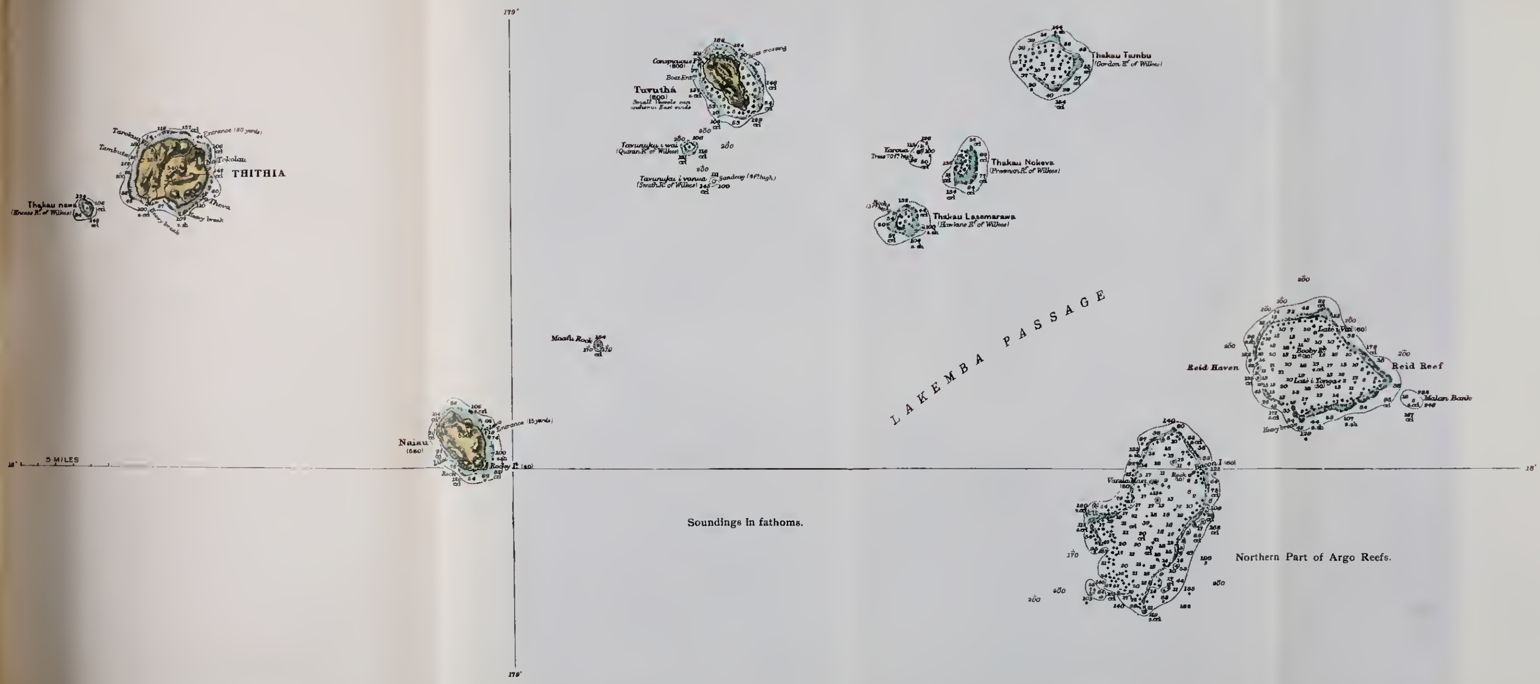


Soundings in fathoms.

THE HELIOTYPE PRINTING CO., BOSTON



B Meisel lith Boston



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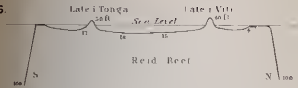

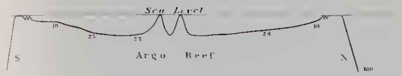

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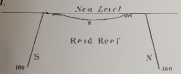

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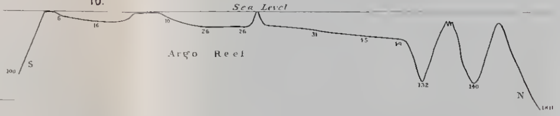

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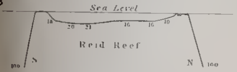

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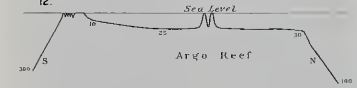

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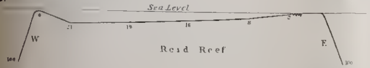

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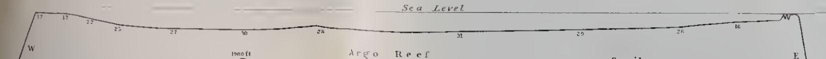
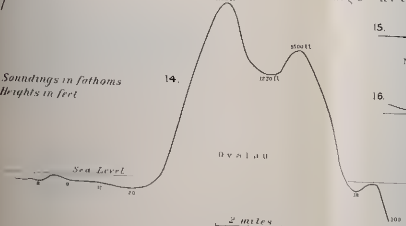


3 miles
Figs. 6-13.

Soundings in fathoms
Heights in feet

14.



2 miles
Figs 14-17

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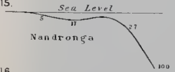

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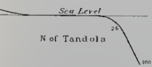

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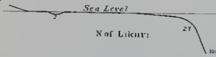

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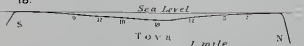
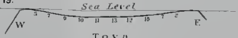
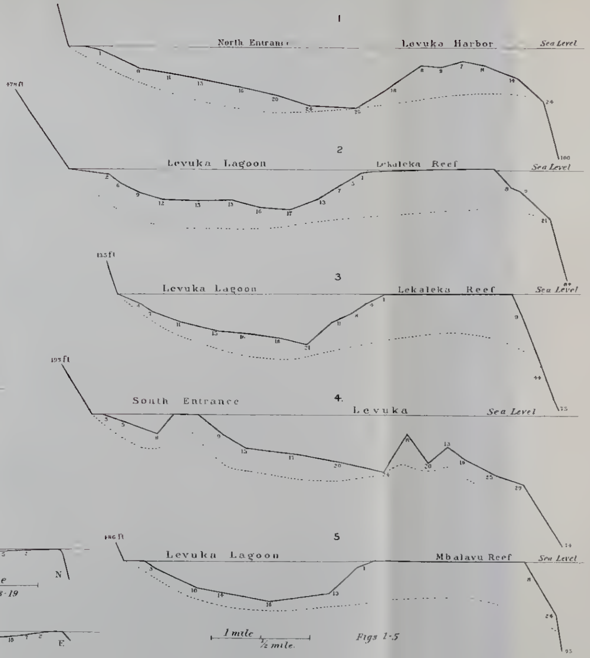


1 mile
Figs 18-19

19.





Figs 1-5

F. Meisel lith Boston

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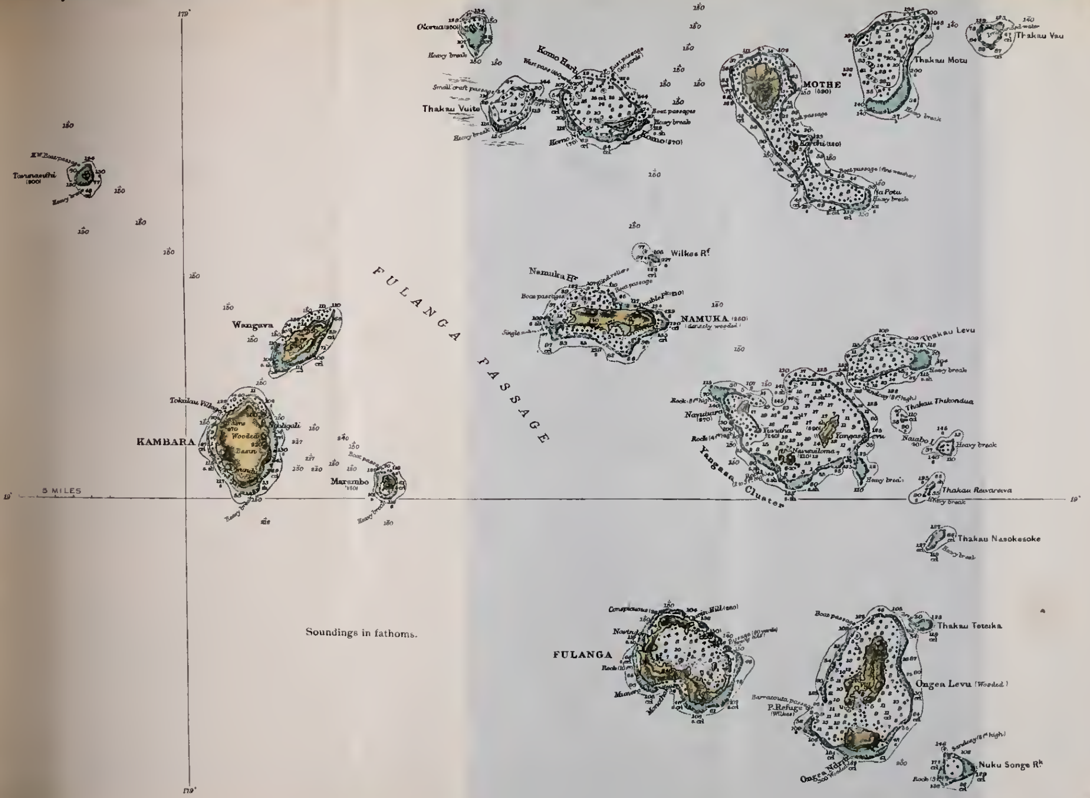

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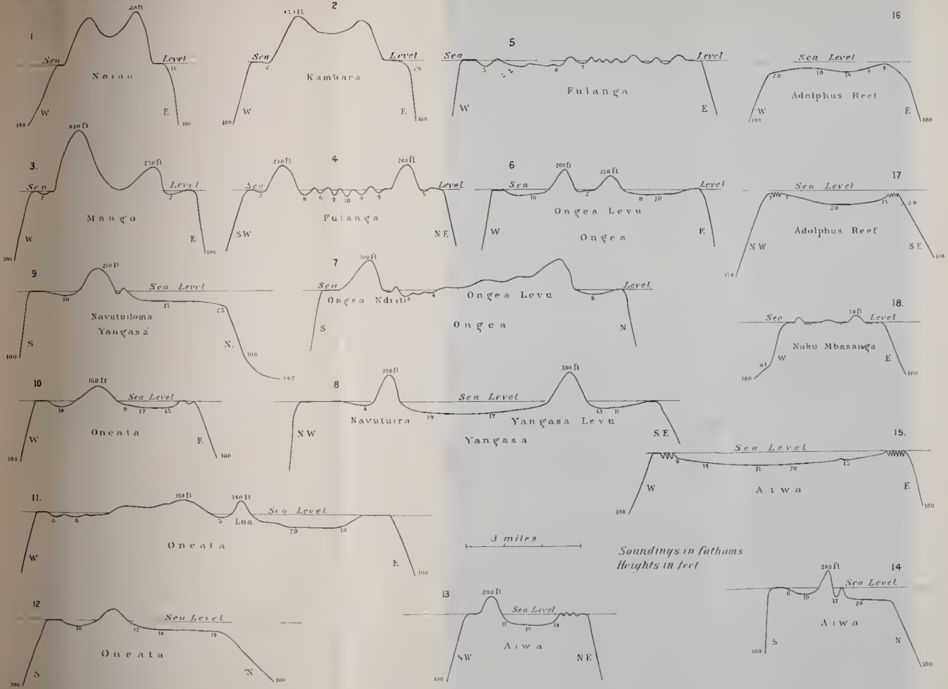
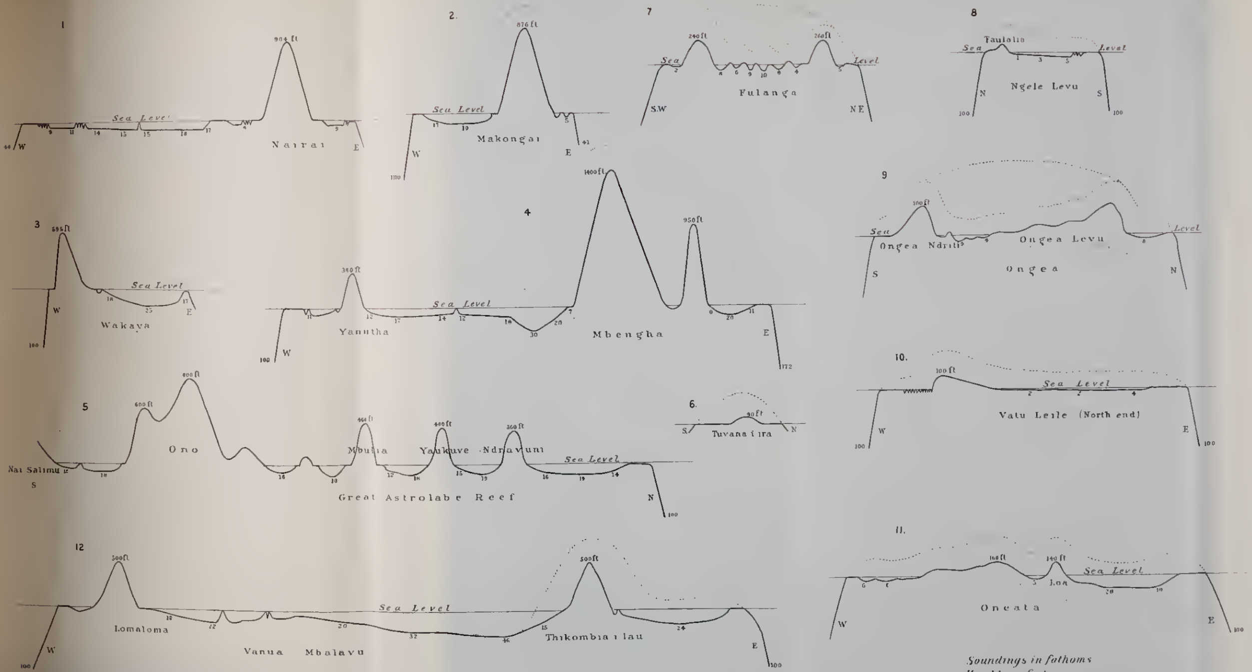


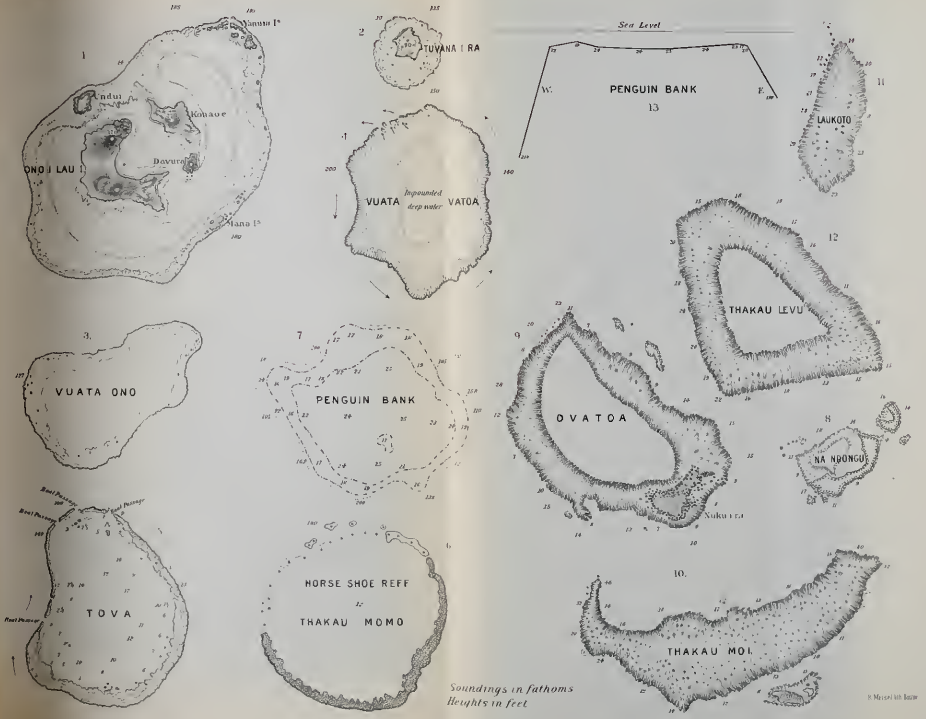
B Meisel lith Berlin



Soundings in fathoms
Heights in feet

B. Meisel Lith Boston


HERALD
SOUND
Navesi
Keleika
Kini-kini
Dalvoleka
TOTOYA
SOUNDINGS IN FATHOMS
HEIGHTS IN FEET
1 MILE



Soundings in fathoms
Heights in feet

R. Meisel lith Boston

M. A. PHOTO.

ARTOTYPE, E. BIERSTADT N. Y.

ENTRANCE TO SUVA HARBOUR THROUGH BARRIER REEF.

M. A. PHOTO

ARTOTYPE. E. BIERSTADT, N. Y.

BARRIER REEF, ACROSS LAUTHALA BAY.

PLATE 26.

W. McM. W. PHOTO.

ARTOTYPE E. BIERSTADT, N. Y.

REEF FLAT, WEST SIDE OF ENTRANCE TO SUVA.

W. McM. W. PHOT.

ARTOTYPE, E. BIERSTADT, N. Y.

REEF FLAT, WEST SIDE OF ENTRANCE TO SUVA.

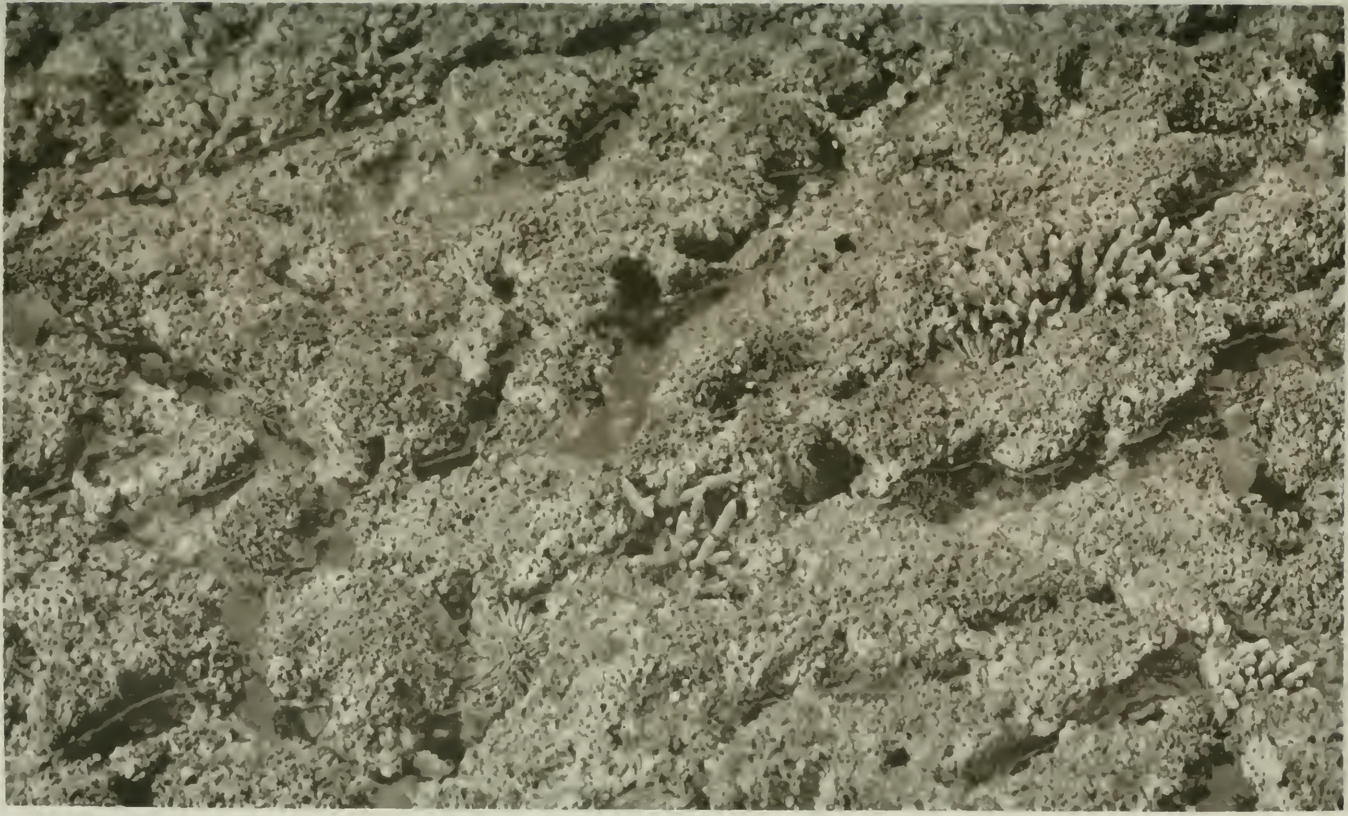
W. McM. W., PHOTO
ARTOTYPE. E. BIERSTADT, N. Y.

POCILLOPORA FLAT, EAST SIDE OF ENTRANCE TO SUVA.

W. McM. W. PHOTO

ARTOTYPE E. BIERSTADT, N.Y

POCILLOPORA FLAT, EAST SIDE OF SUVA ENTRANCE.



WOODWORTH PHOTO

ARTOTYPE, E. BIERSTADT, N Y

CHANNELS DUG BY ECHINOMETRA.

M. A., PHOTO

ARTOTYPE E. BIERSTADT, N.Y.

ELEVATED LIMESTONE BLUFF. NORTH OF SUVA.

PLATE 32.

MAX AGASSIZ PHOTO

THE HELIOTYPE PRINTING CO. BOSTON

ELEVATED LIMESTONE ISLET, INNER HARBOR OF SUVA

WOODWORTH PHOTO

ARTOTYPE, E. BIERSTADT, N.Y.

OVALAU FROM THE EAST.

PLATE 34.

WOODWORTH PHOTO

ARTOTYPE. E. BIERSTADT, N. Y.

LEVUKA FROM THE EAST.

W. MCM. W. PHOTO

ARTOTYPE E. BIERSTADT, N. Y.

FLATS LOOKING SOUTH WEST FROM MBAU.

MAX AGASSIZ, PHOTO.

THE HELIOTYPE PRINTING CO. BOSTON.

VIWA ISLAND. MBAU WATERS

W McM W PHOTO

ARTROTYPE. E. BIERSTADT, N. Y

NASILAI REEF, SEEN FROM THE EAST.

WOODWORTH, PHOTO

ARTOTYPE, E. BIERSTADT, N. Y.

NUKULAU AND MOKALUVA ISLANDS.

MAX AGASSIZ, PHOTO.

THE HELIOTYPE PRINTING CO. BOSTON

NORTH SHORE OF NUKULAU ISLAND

MAX AGASSIZ, PHOTO.

THE HELIOTYPE PRINTING CO. BOSTON

NUKULAU ISLAND FLAT

MAX [illegible] Z PHOTO

THE HELIOTYPE PRINTING CO. BOSTON

NUKULAU ISLAND FLAT

PLATE 42.

MAX AGASSIZ PHOTO

THE HELIOTYPE PRINTING CO. BOSTON

FRINGING REEF FLAT, OFF KORO LEVU

PLATE 43.

M. A. PHOTO

ARTOTYPE, E. BIERSTADT, N. Y.

FRINGING REEF. SOUTH OF SINGATOKA RIVER.

M. A. PHOTO

ARTOTYPE, E. BIERSTADT, N.Y.

SAND DUNES NORTH OF SINGATOKA RIVER.

MAX AGASSIZ PHOTO

THE HELIOTYPE PRINTING CO. BOSTON

SOUTH POINT OF THUVA HARBOR

MAX AGASSIZ, PHOTO.

THE HELIOTYPE PRINTING CO. BOSTON

CLIFFS, EAST SIDE OF MBENGHA

WOODWORTH, PHOTO.

ARTOTYPE, E. BIERSTADT, N. Y.

SHORE BLUFF RUKUA, MBENGHA.

M. A., PHOTO.

ARTOTYPE, E. BIERSTADT, N.Y.

MBENGHA SEEN FROM MOTURIKI BAY.

WOODWORTH, PHOTO.

ARTOTYPE, E. BIERSTADT, N. Y.

WESTERN POINT OF STORM ISLAND.

MAX AGASSIZ, PHOTO

THE HELIOTYPE PRINTING CO. BOSTON

JOHN WESLEY BLUFFS, KANDAVU.

MAX A. AGASSIZ, PHOTO

THE HELIOTYPE PRINTING CO. BOSTON

NORTHWEST SIDE ONO ISLAND, GREAT ASTROLABE REEF LAGOON

MAX AGASSIZ

THE HELIOTYPE PRINTING CO. BOSTON

YAUKUVE LAI LAI. GREAT ASTROLABE REEF LAGOON

MAX AGASSIZ PHOTO.

THE HELIOTYPE PRINTING CO. BOSTON

SOLO ROCK LIGHT-HOUSE. NORTH ASTROLABE REEF LAGOON

WOODWORTH PHOTO

ARTOTYPE, E. BIERSTADT, N. Y.

SOLO ROCK, NORTH ASTROLABE REEF LAGOON.

M. A., PHOTO.

ARTOTYPE. E. BIERSTADT N. Y.

WEST FACE OF WAKAYA ISLAND.

WOODWORTH, PHOTO

ARTOTYPE, E. BIERSTADT, N. Y.

SOUTH SIDE OF PASSAGE INTO WAKAYA LAGOON.

WOODWORTH, PHOTO

ARTOTYPE, E. BIERSTADT, N. Y.

EAST SIDE OF MOALA.

M. A. PHOTO

ARTOTYPE. E. BIERSTADT N. Y.

SOUTH WEST SIDE OF NAIRAI.

WOODWORTH, PHOTO

ARTOTYPE, E. BIERSTADT, N. Y.

KOBU ISLAND. NAIRAI LAGOON.

M A., PHOTO

ARTOTYPE, E. BIERSTADT N. Y.

ISLETS OFF NORTH POINT OF TAVIUNI.

WOODWORTH PHOTO

ARTOTYPE, E. BIERSTADT, N. Y.

KIMBOMBO ISLANDS.

E. G. JONES, PHOTO.

ARTOTYPE, E. BIERSTADT N. Y.

ERODED SHORE, LAU.

PLATE 63.

MAX AGASSIZ [illegible]

THE HELIOTYPE PRINTING CO. BOSTON

NORTHEAST POINT OF KOMO

WOODWORTH, PHOTO

ARTOTYPE, E. BIERSTADT, N. Y.

BEACH, NORTH SHORE OF KOMO

WOODWORTH PHOTO

ARTOTYPE E. BIERSTADT, N. Y.

POCILLOPORA FLAT, KOMO.

M. A., PHOTO

ARTOTYPE, E. BIERSTADT, N.Y.

EAST RIM OF TOTOYA, SEEN ACROSS THE ISTHMUS.

PLATE 67.

MAX AGASSIZ, PHOTO.

THE HELIOTYPE PRINTING CO. BOSTON

OPENING INTO TOTOYA CRATER BASIN.

MAX AGASSIZ, PHOT.

THE HELIOTYPE PRINTING CO BOSTON

LOOKING INTO CRATER OF TOTOYA FROM GULLET

A. AGASSIZ PHOT.

THE HELIOTYPE PRINTING CO. BOSTON

NORTHEAST RIM OF TOTOYA CRATER BASIN.

WOODWORTH, PHOTO

ARTOTYPE, E. BIERSTADT, N. Y.

ERODED RIM OF CRATER BASIN OF THOMBIA.

ARTOTYPE, E. BIERSTADT, N. Y.

CRATER OF HALEAKALA

WOODWORTH PHOTO

ARTOTYPE. E. BIERSTADT, N. Y.

NORTH EAST SIDE OF VANUA MBALAVU INSIDE OF LAGOON.

W. WOODWORTH PHOTO

ARTOTYPE, E. BIERSTADT, N. Y.

NORTH EAST POINT OF NGILLANGILLAH ISLAND

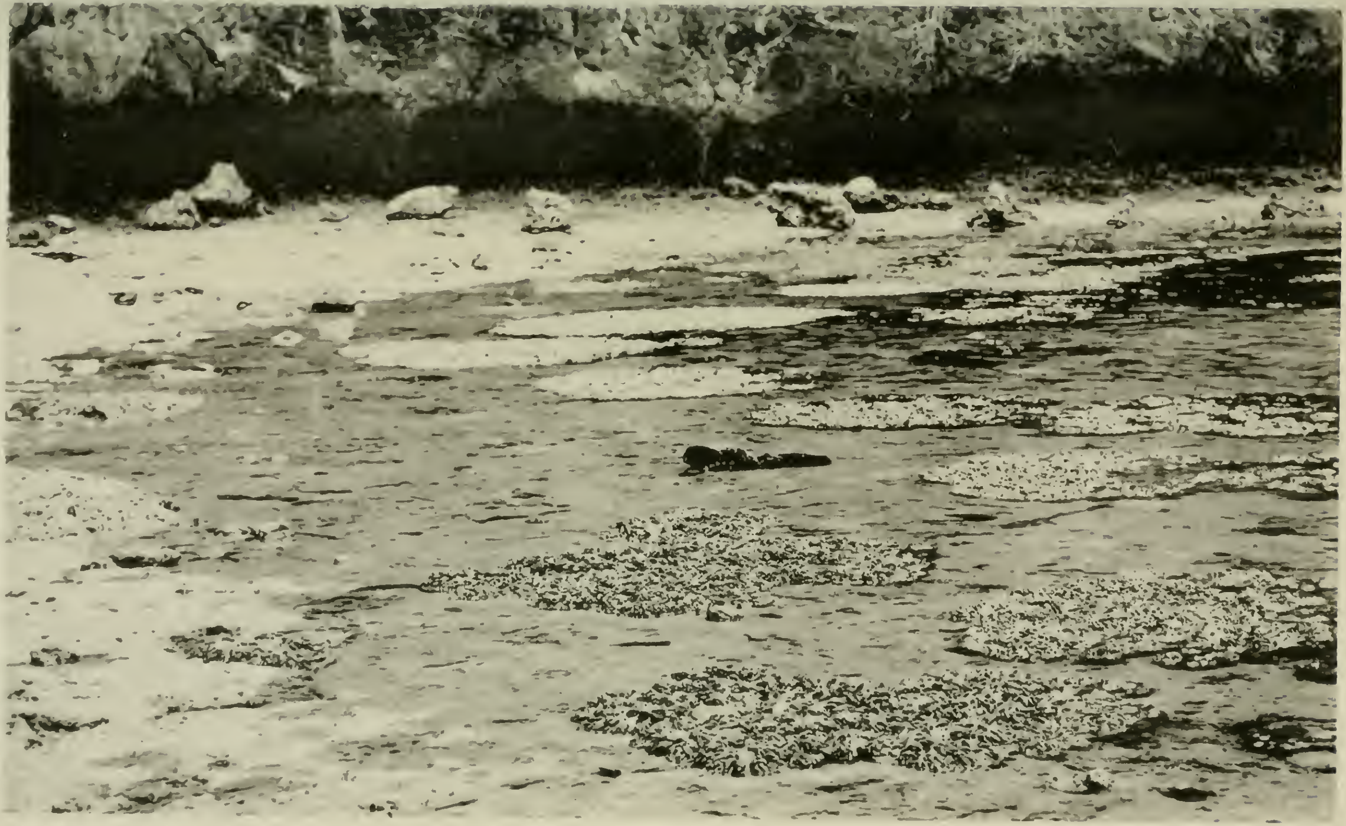
WOODWORTH PHOTO ARTOTYPE. E. BIERSTADT, N. Y

CAÑON, EAST SHORE OF NGILLANGILLAH ISLAND.

WOODWORTH, PHOTO

ARTOTYPE, E. BIERSTADT, N. Y.

AVEA ISLAND. VANUA MBALAVU LAGOON.



MAX AGASSIZ, PHOTO.

THE HELIOTYPE PRINTING CO. BOSTON

ALCYONARIAN FLAT. NGILLANGILLAH ISLAND.

NET NORTH PHOT.

ARTOTYPE, E. BIERSTADT, N. Y.

LIMESTONE BLUFF, NORTH OF TOKALAU BEACH, KAMBARA.

M. A., PHOTO

ARTOTYPE, E. BIERSTADT N. Y.

VOLCANIC HILL, SOUTH OF TOKOLAU, KAMBARA.

MAX AGASSIZ PHOTO.

THE HELIOTYPE PRINTING CO. BOSTON

ELEVATED LIMESTONE CLIFFS, NORTHWEST SHORE OF KAMBARA

WOODWORTH, PHOTO

ARTOTYPE E. BIERSTADT, N. Y.

SOUTHEAST SIDE OF FULANGA

MAX AGASSIZ PHOT.

THE HELIOTYPE PRINTING CO. BOSTON

LOOKING INTO FULANGA SOUND AND LAGOON FROM THE EAST

WOODWORTH, PHOTO

ARTOTYPE, E. BIERSTADT, N. Y

ENTRANCE INTO FULANGA LAGOON AND SOUND.

MRS. HATHAWAY PHOTO.

ARTOTYPE. E. BIERSTADT, N. Y.

ISLETS IN FULANGA SOUND.

PLATE 84.

W. T. ALLARDYCE, PHOTO.

ARTOTYPE, E. BIERSTADT, N. Y.

ISLETS IN FULANGA SOUND.

PLATE 85.

LOW GAP, NORTH EAST COAST OF MANGO.

WOODWORTH PHOTO   ARTOTYPE, E. BIERSTADT, N. Y.

ELEVATED LIMESTONE BLUFFS, EAST COAST OF MANGO.

WOODWORTH, PHOTO

ARTOTYPE, E. BIERSTADT, N. Y.

VOLCANIC ISLETS ON SOUTH WEST SIDE OF MANGO

WOODWORTH PHOTO.

ARTOTYPE, F. BIERSTADT, N. Y

NORTHWEST POINT OF TUVUTHA.

WOODWORTH, PHOTO.

ARTOTYPE, E. BIERSTADT, N. Y.

SOUTHEAST POINT OF TUVUTHA.

WOODWORTH, PHOTO.

ARTOTYPE, E. BIERSTADT, N. Y

YAVUTHA FROM THE SOUTHEAST, INSIDE YANGASÁ LAGOON.

WOODWORTH, PHOTO
ARTOTYPE, E. BIERSTADT, N. Y

BAY ON NORTH SIDE OF NAVUTUILOMA. YANGASA.

MAX AGASSIZ, PHOTO

THE HELIOTYPE PRINTING CO. BOSTON

POINT ON NORTH SHORE OF NAVUTUILOMA, YANGASA.

MAX AGASSIZ, PHOTO

THE HELIOTYPE PRINTING CO BOSTON

ISLET IN BAY OF NAVUTUILOMA, YANGASÁ.

MAX AGASSIZ, PHOTO

THE HELIOTYPE PRINTING CO. BOSTON

NORTH SHORE OF ONGEA NDRIKI.

MAX AGASSIZ PHOT.

THE HELIOTYPE PRINTING CO. BOSTON

TAULALIA ISLET. NGELE LEVU LAGOON

MAX AGASSIZ PHOT.

THE HELIOTYPE PRINTING CO. BOSTON

NORTHERN POINT OF TAINI MBEKA ISLAND, NGELE LEVU LAGOON.

WOODWORTH PHOTO

ARTOTYPE. E. BIERSTADT, N. Y.

CENTRAL PART OF NGELE LEVU.

MAX AGASSIZ, PHOTO.
THE HELIOTYPE PRINTING CO. BOSTON

HONEYCOMBED SURFACE OF NGELE LEVU ISLAND.

WOODWORTH, PHOTO

ARTOTYPE E. BIERSTADT, N. Y.

VEGETATION. WEST SHORE OF NGELE LEVU.

M A., PHOTO.

ARTOTYPE. E. BIERSTADT N. Y.

BLUFF, NORTH WEST SHORE OF VATU LEILE

MAX AGASSIZ PHOTO

THE HELIOTYPE PRINTING CO. BOSTON

VATU SAVU ISLETS, VATU LEILE LAGOON

WOODWORTH, PHOTO

ARTOTYPE, E. BIERSTADT, N Y

VATU LAILAI ISLETS. VATU LEILE.

WOODWORTH, PHOTO

ARTOTYPE, E. BIERSTADT, N Y

SOUTHERN HORN OF NANUKU LEVU.

MAX AGASSIZ PHOT.

THE HELIOTYPE PRINTING CO. BOSTON

NANUKU LEVU, SEEN FROM THE WEST.

M. A., PHOTO
ARTOTYPE. E. BIERSTADT N. Y.

SOUTHERN REEF FLAT OF NANUKU LEVU.

WOODWORTH, PHOTO

ARTOTYPE, E. BIERSTADT, N. Y.

ON EAST SHORE OF NANUKU LEVU.

MAX AGASSIZ PHOTO

THE HELIOTYPE PRINTING CO. BOSTON

NEGRO HEADS, OCCUPYING POSITION OF NANUKU LAI LAI ISLAND.

W. MCM. W. PHOTO.

ARTOTYPE E. BIERSTADT, N.Y.

NUKU MBALATE AND NUKU MBASANGA.

MAX AGASSIZ, PHOTO

THE HELIOTYPE PRINTING CO. BOSTON

WESTERN POINT OF WEILANGILALA.

WOODWORTH, PHOTO

ARTOTYPE, E. BIERSTADT N. Y.

NORTHEAST POINT OF WEILANGILALA ISLAND.

WOODWORTH PHOTO

ARTOTYPE. E. BIERSTADT, N. Y.

SOUTH EAST HORN OF THAKAU LEKALEKA.

PLATE 112.

MAX AGASSIZ PHOTO
THE HELIOTYPE PRINTING CO BOSTON

NORTHEAST HORN OF MOTUA LAI LAI.

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