SCIENTIFIC RESULTS OF EXPLORATIONS BY THE U. S. FISH COMMISSION STEAMER ALBATROSS.

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No. XXVI.—REPORT ON THE PTEROPODS AND HETEROPODS COLLECTED BY THE U. S. FISH COMMISSION STEAMER ALBATROSS DURING THE VOYAGE FROM NORFOLK, VA., TO SAN FRANCISCO, CAL., 1887–'88.

BY

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(With Plates LIII–LV.)

I.—THE THECOSOMATOUS PTEROPODS.

In the course of the steamer *Albatross*, south from Norfolk, representatives of this group of the Mollusca were dredged at a series of seven stations, off the West Indies Islands and along the eastern coast of South America, as follows:

Sta.	Lat.	Long.	Depth.	Temp.	Character of bottom.	Date.
	° ′	° ′ ″	*Fath.*	°*F.*		1887.
2750	18 30 N.	63 31 00 W.	496	44.5	fine gray sand	Nov. 27
2751	16 54 N.	63 12 00 W.	687	40.0	blue glob. ooze	Nov. 28
2754	11 40 N.	58 33 00 W.	880	38.0	glob. ooze	Dec. 5
2756	3 22 S.	37 49 00 W.	417	40.5	gray sand bank	Dec. 14
2760	12 7 S.	37 17 00 W.	1,019	39.5	brown clay (ooze)	Dec. 18
2761	15 39 S.	38 32 54 W.	818	39.0	pteropod ooze	Dec. 26
2763	24 17 S.	42 48 30 W.	671	37.9	brown glob. ooze	Dec. 30

They were also taken in a series of surface collections extending over regions as follows:

Sta.	Lat.	Long.	Temp.	Sea.	Sky.	Date.
	° ′	° ′ ″	°*F.*			
1	34 13 N.	74 13 30 W.	75	smooth	clear	Nov. 22, 5 p. m.
2	31 16 N.	71 50 00 W.	70	smooth	slightly cloudy	Nov. 23, 6:15 p. m.
16	4 21 S.	81 59 00 W.	74	very smooth.	moonlight	Mar. 1, 1888, 4:45 a. m.
19	7 37 N.	78 46 30 W.	78	light swell	hazy	Mar. 3, 2:15 p. m.
26	0 30 N.	88 37 30 W.	80	light swell	light clouds	Apr. 3, 7:35 p. m.
31	0 08 S.	90 06 00 W.	82	smooth	light clouds	Apr. 15, 7:30 p. m.

Of these, it will be seen that they do not in any way coincide with the dredging stations, since only the first two in which live pteropods were taken are located in the Atlantic, off Cape Hatteras, and farther east off northern Florida, while the four others are located in the Pacific, one off Cape Blanco of Peru, one in Bay of Panama, and two east from the Galapagos Islands. The vessel having in the mean time passed around South America into the Pacific, and sailing northward reached in her course the Galapagos Islands. Hence it is that a comparison of the foregoing tables of stations will show that the empty shells, taken with the dredge, do not conform in locality to the existence of live animals at the surface taken by the two nets. This is partly due to the fact that surface collecting was not always done at the same time and place as the bottom collecting, and even when that was the case the result was the same. In the deep-sea dredgings of the open waters where the pteropods are found, the surface and bottom collections for one station may not agree closely, whereas the averages of the surface and bottom from a number of stations of the same region may agree quite closely. Corresponding to dredging station 2756, only 117 fathoms, the surface net took heteropods but no pteropods; while corresponding to a surface station 7, at which also heteropods only were taken, was a dredging station 2755 in which shells of neither were taken at 720 fathoms. So that from the individual position of the stations no inferences can be drawn as to correlative existence between live pteropoda at the surface and the presence of their dead shells at the bottom, over the same area. Surface collections of pteropods may be present without the occurrence of like shells in collections of deposit at that point, as shown at surface station 26, as also deposit shells may be taken without the corresponding presence of live shells at surface, as at station 2756. But these dredgings would of themselves undoubtedly show that at some seasons of the year and at some zonary depths, if not at the surface, these mollusks exist in greater or less abundance throughout the regions traversed in the course of the *Albatross*

Of the three families of Thecosomatous Pteropoda, Limacinidæ, Cavoliniidæ, and Cymbuliidæ, the first is represented in these collections only by two live specimens of Limacina inflata, which were taken at station 2754, by the dredge, at a depth of 880 fathoms associated with six different species of Cavoliniidæ, all of which latter, however, were represented only by empty shells. This would agree with Haeckel's statement* that this particular species is one of those belonging to zonary and bathybic faunæ. The temperature at the bottom at this point was 38° F., 46 degrees colder than that recorded for the surface water, amounting almost to arctic temperature.

The Cymbuliidæ are not represented in the collections in any way. The Cavoliniidæ, on the other hand, considering the fact that the collecting points at which they occur are so few, are quite completely represented both at surface and bottom At the dredging stations all the eight species of *Cavolinia*, except one (*globulosa*) the one species of *Cuvierina* (*columella*) and six of the fourteen species of *Clio*, nearly one-half are represented. Cavoliniidæ, in fact, were taken at everyone of the dredging stations as well as at each of the surface stations where any pteropods were taken. Under this family of the eight spe-

* Jenaische Zeitschrift für Naturwissenschaft, Fünf und zwanzigste Bands, p. 277 (Pteropoden und Heteropoden).

cies of the genus *Carolinia*, *uncinata* occurred at two of the dredging stations 2750, 2760, and at one of the surface stations, surface 16. The species *longirostris* was found at two dredging stations 2754, 2760, and two surface stations 26, 31; *tridentata* was taken at four of the dredging stations 2750, 2756, 2760, 2763, but at none of the surface collections; *gibbosa* occurred at two of the dredging stations 2750, 2760, and at one surface station, 19; *trispinosa* was found at four of the dredging stations, 2750, 2751, 2754, 2760, and at one surface station, 2; *inflexa* was taken at two dredging stations 2754, 2760; *quadridentata* occurred once only, as a deposit shell at 2760.

Of the species of *Clio* represented in the collections from these points, *Clio* (*Creseis*) *virgula* has been included in the study, although it was taken at a point farther north in the Gulf Stream (hereafter described). *Clio* (*Creseis*) *conica* was taken at surface station 1; *Clio* (*Hyalocylix*) *striata* was taken at surface station 16; *Clio* (*Styliola*) *subulata* was taken at surface station 1, also at dredging station 2754; *Clio* (*s. str.*) *balantium* was taken at dredging station 2754; *Clio* (*s. str.*) *pyramidata* was taken at dredging stations 2750, 2751, 2760.

Lastly, of the genus *Cuvierina*, the species *columella* was taken at two dredging stations 2754, 2760, and at surface station 2.

Of the data of the distribution of these families here given, results indicate that areas of deposit and the surface habitat of these mollusks in these particular temperate and tropical regions, are rich in Cavoliniidæ, especially so in *Carolinia*, while *Clio* and *Cuvierina* are very well represented; *Clio* occupying the more northern latitudes in so far as these collections give evidence. Results also show that there are no marked distinctions between the kinds and distribution in the Atlantic and the Pacific waters upon either side of northern South America. The shells in deposit confirm the evidence of the surface collections, so far as there is any evidence from deposits upon the floor of the ocean. As has been said, there is no material dredged from the Pacific side, where surface collections were present, but these latter, from the Pacific, were entirely similar to the relative kind and abundance of the pteropods, both surface material and deposit shells, of the Atlantic side. The few Limacinidæ taken, either as dead shells or in the low temperatures of bathybic collections, were obtained from the deep-water dredgings in the Atlantic.

I have given in Plate I an outline map of the region to which this account applies, reference to which will show the line of transit along which the stations are laid.

Some of the dredging stations are apparently near in-shore for the occurrence of pteropod deposits, but all are drawn in at least 500 fathoms.

After leaving station 2763, the course of the steamer lay south for 26 degrees of latitude in the shallow waters along the eastern coast of South America, the depth ranging only from 10 to about 80 fathoms.

No shells of pteropods are recorded from the dredgings in these waters. Twelve deep-water stations are also recorded along the western coast of South America in the course of the vessel northward through 15 degrees of latitude, the depth ranging from 100 to 1,200 fathoms, but no pteropods are reported.

No dredging stations were made between 38° 08′ south and the equator. In fact, all the other forty-seven dredging stations in the Pacific waters, except nine, were made in shallow waters ranging from 6 to about 75 fathoms; in none of these are pteropods recorded.* But the surface collections secured them, as is shown in the outline map, between the mainland and the Galapagos Islands, as described heretofore in this article for the various genera and species of *Carolinia* and *Clio*. No dredging stations are recorded at exactly these bearings except one at surface 26 in 1,379 fathoms.

I have given thus a sketch of the course of the *Albatross* and the depths and, in some cases, the temperature of the waters traversed, in the hope of arriving at some reasons for the meeting with pteropods in the dredging points in the south temperate zone, upon both eastern and western coasts of the southern part of South America, in the same measure as they are found in the northern parts in the torrid zone. Not belonging to litoral faunæ, we should not expect them in the shallow dredgings along the coast. But some other causes must operate to prevent their occurring in the deeper waters of the more open sea along those coasts; and why, therefore, should they not appear from the deeper dredging stations on the western coast of southern South America? The dredging stations made below latitude 38° were, as has been stated, taken upon the eastern side in shallow waters, but upon the western side in much deeper waters, so that bathybic or zonary faunæ would be very different from that of the shallower seas; the surface temperatures, however, agree very closely. A series of thirteen consecutive stations of the east side below latitude 38° averaged, at surface, 54.3° F. in the latter half of the month of January; a similar consecutive series of thirteen stations in about the same latitude along the west side averaged 55° in the first half of the month of February. But no pteropods are recorded at any surface stations in the Pacific except those indicated upon the outline map in Plate I, while deposit shells were not taken in the Pacific by this expedition.

Thus it falls out that pteropod collections of this voyage are, in origin, for the most part from the Caribean and Panamaic provinces,—that the two regions furnish material entirely similar in make-up—which material belongs almost exclusively to the family Cavoliniidæ, representing all the species except one of the genus *Carolinia*, the spe-

*See "table of trawling and dredging stations" made by *Albatross* during the year and a half ending June 30, 1888, in the Report of the Work of the U. S. Fish Commission Steamer *Albatross* from January 1, 1887, to June 30, 1888, by Lieut. Commander Z. L. Tanner, U. S. Navy, commanding. Fish Commission Report of 1887."

cies of *Cuvierina*, as also six of the fourteen species of *Clio*, counting, however, *virgula* from farther north; and lastly that from none of the deeper water dredgings in the Pacific are reported deposit shells, although at times dredgings were there taken in the same region with the surface collections which secured them; also that *Limacina* occurred only at considerable depths both alive and as deposit shells.

From the work of the steamer *Blake* Alexander Agassiz concludes that bottom distribution is largely determined by the course of the ocean currents, so that by means of pelagic faunæ and their bottom distribution, light may be thrown upon the course of the currents.* To this cause he ascribes the presence of Arctic pteropods along the New England coast, from the course of the Labrador currents. In this way also an explanation is found why surface collections of pteropods may be abundant over deep waters while the bottom distribution must be looked for elsewhere along the ocean current which sweeps the region; such doubtless is the case with regard to the surface collections of the *Albatross* on this voyage in the Gulf of Panama and at the Galapagos Islands. As has also been stated from the evidence of these collections, forms of *Clio* are more abundant in the more northern stations than representatives of *Carolinia*. If therefore we regard the equatorial seas of the West Indian and Caribbean regions as offering the most favorable conditions for the growth of these pelagic molluscs, it may be readily seen that they would be largely distributed from these areas to the northward upon the surface of the Gulf Stream; while in the new conditions thus encountered the abundance of the *Carolinia* forms might succumb first, and that the species of *Clio* might be enabled to hold their own longer in the struggle and so be carried farther into the temperate waters of the Northern Atlantic.

So also in the distribution of these molluscs south from these equatorial areas named, the Brazil current and the other currents running southward along the coast of South America doubtless carry quantities of pteropod shells far from the habitat of the animals when living before their final deposition upon the bottom; but the bottom accumulations may at the same time be augmented by the shells of the same species borne alive upon the surface of the current until such conditions were entered as to cause their wholesale destruction, producing a comparatively sudden precipitation, as it were, of some of the classes of living organisms as soon as they are swept into the regions in question.

At any rate from these or other causes large deposits of pteropod ooze were encountered by the *Albatross* in her course along the South American waters. Such an ooze was discovered at station 2760, the study of which has some evidence for a distribution of the family *Caroliniidæ* as heretofore outlined; that is to say, the accumulation of mollusc shells upon the floor of the ocean is some evidence of the relative kind and abundance of the molluscan life inhabiting the

*Three cruises of the *Blake*, by Alexander Agassiz. Vol. I, pp. 120–121.

waters above, and, if the greater part of the ooze is made up of Cavoliniidæ deposited through constant and successive seasons in the same region, its composition must bear some relation not only to the pelagic but also to the zonary and bathybic faunæ by which it is laid down in this region.

This "pteropod ooze" in question was dredged in 1,019 fathoms depth, and when dried it proved to be a mass made up almost entirely of pteropod shells in various states of entirety, in which condition it was submitted for study. In order to compare the genera and species, as shown by deposit, with those of the same genera and species taken alive at the surface, the specimen of ooze reported was separated into its component parts and weighed. A comparison by weight, of course, expresses only the amount of material contributed to the general mass of the deposit by each group, and bears no exact relation to the number of individuals in each of the various groups, because of the great difference in individual size; one of the largest, *C. tridentata* for instance, will outweigh many of the small *Clio subulata*; one large *Clio balantium* will contain more material than several of the much smaller *Clio pyramidata*, and yet a table of comparative werghts shows very clearly, I think, the relative activity of the sources from which these great deposits are laid down, both as regards individual numbers as well as the mass of material contributed by each kind. Such a table of relative weight of the principal constituents in their order runs thus:

	Grams.	
Carolinia longirostris, tridentata, uncinata, quadridentata	6.177	
Carolinia inflexa	.084	
Carolinia trispinosa	.500	
Cuvierina columella	.808	
Clio (*s. str.*) *pyramidata*	.861	
Clio (*Styliola*) *subulata*	.276	
Total Cavoliniidæ		9.006
Limacinidæ (fragments)	.151	
Limacina inflata	.006	
Total Limacinidæ		.157
Atlanta peronii	.116	
Total Heteropoda		.116
Cyclammina	.170	
Triloculina (?)	.282	
Globigerina (etc.)	.082	
Total Rhizopoda		.534
Débris		7.808
Total oöze		17.651

The species under the genus *Carolinia* were weighed together, because the specific place of so many of the fragments of shells could not be distinguished owing to their fragmentary state, although their place in this genus was perfectly evident. But by far the greatest number of individuals, and the largest relative weight, belonged to the species *longirostris;* of the total 9.006 grams of *Carolinia*, 5.513 grams, nearly two-thirds, were from this species. Then come in the order named, *uncinata*, *tridentata*, and *quadridentata*. The material afforded by the Limacinidæ is relatively light, and it is probable that even this estimate of these coiled pteropods was somewhat exaggerated by some fragments of spiral shells (of which only the central spire remained), which belonged to other spiral gastropods than Limacinidæ; although weighed in this connection because they had possibly belonged to characteristic species of this group, Limacina was not even numerically abundant.

The Heteropoda are represented in the ooze only by medium-sized *Atlanta peronii*, which were quite common. The three principal genera of Rhizopoda which characterized this deposit were *Triloculina* (?), *Cyclammina*, and *Globigerina*, with a few *Orbitulina* and *Orbitoides* (?). These forms could easily be separated from the general mass on account of their large size; but there are doubtless others that remain mixed with the fine débris of the sample, which, if they could be separated out, would add somewhat, but not very materially, to the total weight of the Rhizopoda of the ooze. It is worthy of remark that this pteropod ooze was associated with a globigerina ooze, but so stratified as to be quite distinct. This appears from the account of Capt. Tanner,* who describes the trawl as being buried in mud, so as to be landed with difficulty, when the main mud bag of the net was filled with one deposit while the smaller ring nets were filled with a very different one—the deposits being a fine globigerina ooze, "with only here and there a pteropod shell," and a coarse pteropod ooze, but which was uppermost is not stated; the latter is the one here considered.

This débris, finally, is that which remained after all was separated that could be readily identified; it therefore comprises a good deal of very finely ground shells as of some very fine dried silt. But there were also weighed with it other forms of life, such as several kinds of gastropods, two kinds of lamellibranchs, and also small sea-urchin shells in considerable numbers—all the material, in fact, that was not quite plainly pteropod, heteropod, and rhizopod. It is largely made up of triturated shells as the unaided eye may readily determine, which triturated shells, however, represent the scattered remains of *Carolinia*, *Clio*, *Cuvierina*, *Limacina*, etc., in about the same ratio, I am strongly led to believe, as above given for the rest of the ooze.

Of course there are many sources of error in such a reduction of this sample of ooze; I have no means of judging what of the smaller constituents might not have been taken away in the preparation and

*Report on the work of the U. S. Fish Commission steamer *Albatross* from January 1, 1887, to June 30, 1888, by Lieut. Commander Z. L. Tanner, U. S. Navy.

drying of it, and it is by no means intended that these careful weights imply the mathematical accuracy of a chemical analysis, but I am very certain that they do represent very faithfully the relative proportions of the kinds and abundance of the forms actually living in the surrounding waters, at least as far as the pteropods and heteropods are concerned, because the evidence of the surface collections from regions to the north leads to this same view. At the depth of a thousand fathoms not many, even of the more delicate shells, would be lost immediately by solution; at least they would all disappear at a uniform rate, since the majority of the shells are so nearly alike in thickness and material.

This analysis of the work was entered into with the purpose of getting some check upon the sum total of the work done both at the surface and at other parts of this section of the equatorial Atlantic, and with the result that from the ooze at this point also we draw the same conclusions as to the relative kind and abundance of Cavoliniidæ and Limaciniidæ inhabiting these latitudes upon both sides of the northern part of the South American continent, as were drawn from the comparison of the other dredging and surface collecting stations. The Cavoliniidæ predominate largely, and of these the genus *Cavolinia* is more abundant, although the various subgenera of *Clio* are well represented.

In the sample of pteropod ooze, the species *longirostris* was the most abundant of any individual form, which is also true of the surface collecting, although the *uncinata* is very abundant. Such is accordingly the systematic composition and distribution of the pteropods of this expedition. The mere fact that they are pelagic forms prevents their being divided off into distinct regions, except very broadly speaking, but it is doubtless true that a corresponding number of consecutive collecting points, taken in arctic or even in temperate climates, would produce a series of pteropods agreeing among themselves as these do, but of a different general type which should represent the majority of individuals and species.

Some of the thecosomatous pteropods have been figured many times, showing their anatomy as well as the form of the empty shell, and in the figures upon Plates II and III it is not so much intended to bring out new points in the form of the individual genera or species as to bring together in a series the representative species taken by the *Albatross*, in order that their relative size and homologies may be better indicated, and thus their pelagic association with each other when living the better appreciated. In order to do this, the shells of the various groups are figured, drawn to the same scale—five times enlarged—as showing properly enough many of the points in which the genera of the family Cavoliniidæ stand related to each other, and the species to the genera. The outlines were drawn with an embryograph, showing lateral, ventral, and, in some cases, front views of the shells, in order to obtain the proportions of the organisms with their specific qualities. The classification was made in accordance with the radical revision of the group as proposed in the Reports of H. M. S. *Challenger*,* and it was the purpose of the figures to arrange the system graphically as far as could be done, for the pteropods of those regions covered by the *Albatross*.

Plate II is devoted to the genus *Cavolinia*, excepting Figure 8, which outlines in different positions shells of the only coiled pteropods taken, specimens of the family Limacinidæ, *Limacina inflata*. It has already been stated that two live specimens were taken at 880 fathoms, and when preserved the parts were withdrawn largely into the large opening of the shell. These minute empty shells were present also in the ooze examined. The other figures on the plates are drawn with ventral face upward, the position usually assumed by the living animal, so that the dorsal part of the shell is below in the side views of outline drawings. Figs. 1–7 present seven of the eight species of the genus *Cavolinia*, the small *globulosa* not having been obtained by these collections. Figs. 1 and 2 represent the species "with dorsal lip thickened into a pad." That is to say, *trispinosa* and *quadridentata*. The thickened dorsal lip—in the drawing represented by the heavy line—is in the living animal deeply brown pigmented, and so contrasts strongly with the translucent color of the rest of the shell. Fig. 1 represents *trispinosa*, *a* from ventral view, *b* from side view, and *c* from front view. The drawing is incomplete with respect to the long, posterior spine (not truthfully represented by the dotted lines of the figure), which bears upon its end the embryonic shell, and relatively is very long, as may be seen in figures of the living specimen.† This figure does show, however, the relative size of this species, its greater lateral extent as compared with its dorso-ventral thickness. In the arrangement of its projecting points, the aperture and various proportions of the parts, *trispinosa* compares with *inflexa* (Fig. 7.), but on account of the thickened dorsal lip it stands in the scheme of classification of the *Challenger* Reports, next to *quadridentata*.

Cavolinia quadridentata is represented in Fig. 2, from *a* ventral view, *b* lateral, and *c* dorsal view. It is the smallest representative of all the species of this genus in the collections, is very much rounded, very compact in shape, with small aperture, and without any lateral or posterior projections to the shell. All the other Cavolinidæ are without the thickened anterior edge of the dorsal lip. Of these *longirostris*—Fig. 6 *a* ventral and *b* lateral view—has a distinguishing feature in the fact that the ventral lip projects beyond the dorsal, so that in *a* the extreme points in the posterior contour of the shell belong to the ventral lip alone, since they project beyond the edge of the dorsal lip, which ends at the two small projections at the hind end of the shell, interior to the other extreme tips, and so nearer the middle line. The

* By Paul Pelseneer, Vol. XXIII of those Reports.

† Rang et Souleyet, Monographie des Ptéropodes, Paris, 1852.

side view of *longirostris* (*b*) shows also the great development of the dorsal (lower in the figure) lip of the shell, prolonged into the long hood which runs far out beneath the overlying fins, and sculptured with the deep notch in its anterior part. This little shell is, in many respects, the most highly developed, as it is also the most abundant in the collections.

C. gibbosa—Fig. 4, *a* ventral, *b* lateral view—is characterized by the prominent transverse keel into which the anterior surface of the ventral lip is developed. This feature appears in lateral view, Fig. 4 *b*, and is evidently due to an accelerated growth of the shell in this part, as is shown by the strong ridges and width between the lines of deposit, giving it a markedly serrated contour at this point. The dorsal (lower in the drawing) lip of this species is also relatively large at its anterior part, forming a deep hood underneath the fins. On these accounts the posterior aspect of gibbosa is comparatively narrower than the anterior part (see *a* of Fig. 4) which is one of the points used in giving it its systematic position.

Fig. 5 shows in outline a representative of the species *tridentata; a* from ventral, *b* from lateral view. All the members of this species taken on this trip of the *Albatross* were quite large, and the one figured was one of the largest specimens; they were not very abundant. It might well be chosen as a typical Cavolinian pteropod shell; none of the parts are exaggerated, all are symmetrically developed. The lateral view *b*, however, imperfectly represents the measure of the dorsal lip of the shell, the anterior hoodlike projection of which was broken off in the specimen figured; in a complete specimen it is more nearly like the same structure in *C. gibbosa* (Fig. 4 *b*), although not quite so well developed.

The two specimens of *Carolinia* which have the posterior and lateral parts of the shell drawn out into points (but with their anterior margin of dorsal lip) are *uncinata* and *inflexa*. The former of these is represented in Fig. 3 in *a* dorsal and *b* lateral view. The posterior spine of the shell is relatively quite long and strongly curved backwards, while the lateral points of the shell give a considerable increase to the expanse of the aperture between the two lips. The dorsal lip also is very strongly curved and compressed antero-posteriorly, while the ventral lip is very much rounded, showing upon its anterior face the lines of growth of the shell deposit. Finally, Fig. 7 represents the form of *Carolinia inflexa*, *a* from ventral, and *b* from lateral view. The shell is much more tubular than that of *uncinata*, the lateral points giving width to the aperture of the shell, which does not, however, extend the whole length of the shell, thus leaving a very long curved posterior part. The dorsal lip, moreover, runs straight forward and does not curve up into a hood below the fins, as is more or less the case in the other species.

Such are the relations of these species as indicated in Figs. 1–7. In every case the anterior of the drawings of the shells is toward the right (except the front view in Fig. 1*c*) and the ventral face of the shell turned uppermost, as when occupied by the living animal. *a* is in each case the outline from the ventral face and *b* from the side, while Fig. 8 represents the species *Limacina inflata*.

The representatives of the genus *Clio* are given upon Plate III. Of these the one species *virgula* (Figs. 9 and 10) was not taken upon this trip of the *Albatross*, but belongs farther north, having been taken abundantly by the Fish Commission Schooner *Grampus* in her investigations of the Gulf Stream, southeast from Marthas Vineyard, at the surface in the summer of 1889. Two forms of it were found—the species *virgula* proper (represented in Fig. 9) from lateral view, also an optical section from front, showing its circular shape, and a variety of the same, *corniformis*, which differs from the former only in the length of the shell, the size of its opening and the curve of the posterior point being relatively about the same.

The one other pteropod taken with shell quite unsculptured and of circular section is *Clio (Creseis) conica*, represented in Fig. 11, which thus shows its straightness in all positions, its great length, and slenderness also as compared with any of the others. In Fig. 12 is represented *Clio* (*Styliola*) *subulata*, which is distinguished from the other straight-shelled pteropods by the possession of a dorsal longitudinal groove which runs somewhat obliquely along the shell out into a projection, which on its account better resists fracture perhaps, or else is a normal feature of the shell. This groove gives a very evident asymmetry to the shell—as if it were the axis of the animal and the posterior part of the shell were bent away from this axis.

In the optical section the groove is seen to be caused by a folding up of a ridge of the shell; there is also to be noticed some dorso-ventral flattening of the animal. Whether this groove bears any relation to any anatomical peculiarities of the animal, I have, as yet, not ascertained.

The course of longitudinal groove is represented by the dotted lines in the figure. The three other species of *Clio* represented have certain peculiarities common to all, and in a way they stand in a series. Thus in Fig. 13 are given outline drawings of two fragments of *Clio* (*Hyalocylix*) *striata*, showing an individual variation in size, *a* being a small and *b* one of the largest specimens; for although quite a large vial full of the mollusks was taken at one of the surface stations, it was very difficult to get very many of the shells, and none perfect; they, being so delicate and covering loosely only the posterior part of the animal, are easily detached and lost in collecting. The side views given in *a* and *b* of Fig. 13 show how the outline of the shell is thrown into a series of transverse grooves shown here in the profile of the figure, while the view into the anterior end of the shell gives a dorso-ventrally flattened optical section, as indicated in *c*. In Fig, 14 (*a* lateral of the posterior part only, *b* ventral, and *c* frontal view of *Clio* (*s. str.*) *balantium*) the same features are emphasized as far as the dorso ventral flattening is concerned, so that the sides of the shell are produced into well defined "keels," while the dorsal (lower in the Fig. 14c) side of the mollusk shows the median groove, which also characterizes the dorsal lip of the shell of the Cavoliniidæ (see also the same Fig. 1c). The shell of the individual here figured was one of the largest of the collections. It is not uniformly grooved over its entire length, since the transverse markings tend to disappear at the most posterior part of the shell, as seen in the dorsal (left hand) face of the lateral view, *a* of Fig. 14. The exact form of the most anterior edge of the shell could not be determined on account of the breaking off of the delicate material, so that the dotted lines in *b* represent only the broken edge as it existed in the shell as preserved in the collections—not in nature. In *Clio* (*s. str.*) *pyramidata*, Fig. 15 (*a* lateral, *b* ventral, and *c* front, view) the anterior part of the shell is the most exaggerated into the lateral "keels" and the depth of the dorsal groove, as can best be seen in the optical section of the shell shown in *c*; the very wide keels are bent ventralwards and the dorsal groove (below in the drawing) appears deep and narrow in like manner. A lateral view, *a*, shows the extent of the aperture and the straightness of the posterior part of the shell and the length of the projection of the dorsal part into a grooved tongue which underlies the fins. The dotted lines in *a* and *b* show the condition of the shell when figured, but it was apparently not complete, and so may not truthfully represent the real outline of the anterior edge of a perfect shell.

Finally, in Fig. 16 are represented two views of *Cuvierina columella*, *a* from lateral and *b* from ventral view. Ordinarily, in the living specimens, one can find a good many with the embryonic shell still attached to the posterior end of the shell of the adult animal,* but they were not present in these collected by the *Albatross*, and so have the posterior end bluntly rounded, although compressed somewhat on the ventral edge, as is shown in the lateral view *a*, of which the dorsal face of the figure is toward the left. The anterior end of the shell also shows a difference in the two lips of the shell. *Cuvierina columella*, therefore, thus differs from the others; while the various species of *Clio* measure thus with each other as outlined for the figures of Pl. III.

It was purposed in entering upon the study of these collections to deal especially with the comparative anatomy of the group to be brought out by the method of serial sections, as employed in a former paper for one of the Cymbuliidæ,† but as some of the species were here represented only by empty shells, and since so many tissues of living animals were treated only with strong alcohol as they were collected, it seemed advisable to deal in this section of the work only with the distribution of the pteropods as indicated by this voyage of the vessel, to

*See figure in Tryon's "Introduction to Systematic Conchology," Pl. 42, Fig. 9.

†On the Anatomy and Histology of Cymbuliopsis calceola. Studies from Bio. Lab., Johns Hopkins University, Vol. IV, No. 6.

gether with such relationships as may be denoted by a study of the shells themselves; and to leave for another section the completion of the study of the comparative anatomy as it may be supplemented by more material for such a study of this interesting group.

The long delay of this paper has been quite unavoidable, and I owe many thanks to Commissioner McDonald of the U. S. Fish Commission, for the generous kindness with which he has treated all matters pertaining to this and all other points of my association with him. Also the most grateful remembrances are due Dr. W. K. Brooks of the Johns Hopkins University—at whose suggestion the study of the Pteropoda and Heteropoda by serial sections was entered upon—for the countless advantages enjoyed in his laboratory at the time this subject was undertaken four years ago as one of his students.

II. THE HETEROPODA.

These collections were taken together with the Pteropoda as discussed in the preceding part of this report, and as illustrated upon Plate I, where the positions of the various collecting stations are indicated in the outline map.

Heteropods, accordingly, either alive or represented by their empty shells, were taken at two dredging stations as follows:

Sta.	Lat.	Long.	Depth.	Temp.	Character of bottom	Date.
	° ′	° ′	*Feet.*	° F.		1887.
2751	16 34 N.	63 12 W.	687	40	Blue glob. ooze	Nov. 28
2754	11 40 N.	58 33 W.	880	38	Glob. ooze	Dec. 5

And at a series of four surface collections described as follows:

Sta.	Lat.	Long.	Temp.	Sea.	Sky.	Date.
	° ′	° ′	° F.			
7	8 04 N.	52 47 W.	81	Smooth	Showery	Dec. 7, 1887, 1:45 p. m.
8	3 22 S.	37 49 W.	79	Rough	Light clouds	Dec. 14, 1887, 11:30 a. m.
18	1 03 N.	80 15 W.	78	Very smooth	Overcast	Mar. 3, 1888, 8:20 p. m.
24	6 14 N.	80 27 W.	81	Light swell	Clear, starlight	Mar. 31, 1888, 7:30 p. m.

The collections contain but little material, but the individual specimens are, in nearly every instance, beautiful representatives of the various genera of this widely distributed group. Three genera are represented: *Atlanta*, *Carinaria*, and *Ianthina*.* Of these *Atlanta* is represented by about thirty large shells of the species *peronii*, found in deposit at dredging station 2751, associated with four of the delicate shells of some species of *Carinaria* (besides the Pteropoda taken there). These *Carinaria* shells also were uniformly of good size and must have belonged to large specimens of the living molluscs of the overlying

*Ianthina is merely a specialized Gastropod, but here considered with the pelagic Heteropods for convenience.

habitat. At dredging station 2751 there was also taken one small broken *Carinaria* shell. Beyond these two collecting points east from the West India islands, no heteropod shells are recorded until station 2760 was reached (see the former section of this report, "Thecosomatous Pteropoda," p. 36), while the *Atlanta* shells dredged in the ooze at this latter point are much smaller than the specimens of the same species taken farther north at station 2751 as just described. None of the *Atlanta* were alive. One shriveled specimen of a *Carinaria*, however, is reported from station 2751. I am unable satisfactorily to determine its origin, but from appearances conclude that it may have sunk to the bottom already dead and there have been taken with the dredge. At any rate it bears little resemblance to a specimen taken alive at the surface and is so distorted as to hide its specific distinction.

All the other material from this group of molluscs was taken alive at the surface collections as heretofore located.

I regret very much not having had opportunities of identifying all the species of these surface collections. A large specimen of *Carinaria* was taken at surface station 24, the species of which I do not know. Its body is 5.85 centimeters in length, is rather more slender than *Carinaria mediterranea*. The part of the body anterior to the prominent eyes is markedly bent ventralwards; the nucleus, situated directly opposite the foot, or fin, is long and cylindrical and stands vertically up from the surface of the body to a comparatively great height. No shell was present accompanying the specimen. The posterior part of the body extends behind the nucleus and foot about one third the length of the animal; the eyes, also, are situated about one-third the length of the animal back from the mouth end.

The remaining material of the collections consists of Gastropods of the genus *Ianthina*, which were thus distributed at the following points: At surface station 7, two young specimens of an *Ianthina*, the species of which could not be yet determined accurately because of their immature state; at surface station 8, three specimens of an *Ianthina*, two of which are of the species *globosa*, I think, and the other undetermined; they are all rather small specimens. At surface station 18 were taken four large specimens of *Ianthina globosa* (?) and one large representative of the species *communis*; finally, at surface station 21, there was taken another specimen of the species just mentioned as undetermined.

It will be readily seen that the Ianthinidæ taken in this expedition of the *Albatross* all come from regions within a few degrees of the equator, and are not markedly distinct from each other, although separated by the South American continent. Prof. A. E. Verrill, of Yale University, did me the great kindness to go over these specimens and to compare them with the Ianthinidæ in the museum of that institution. From such a comparison, moreover, it was impossible to give the specific position to the representatives taken by the *Albatross*, since no close agreement between them could be made; and this was doubtless due to the difference in locality; for specimens in the museum at Yale were of Ianthinidæ from the region of the Sandwich Islands, in the Pacific side, and from the Arctic regions of the Atlantic side; while these from the *Albatross* collections of the equatorial regions belonged to different species which possessed intermediate qualities of different kinds, such as a different compression of the spiral, shape of aperture, etc. From the fact, therefore, that they do show distinctions from material collected at other points, the representatives of this group illustrate also the segregation and the localization of pelagic mollusca in given areas, broadly speaking. Although Ianthinidæ were so widely distributed, no empty shells were taken from bottom collecting.

BIOLOGICAL LABORATORY

WILLIAMS COLLEGE, *April, 1893.*

Explanation of Plate LIII.

Plate 1 is an outline tracing of a Mercator projection map of South America, with a part of North America, illustrating the course of the *Albatross* south from Norfolk. The line of dredging stations, where pteropods and heteropods were taken, bears the numbers 2750–2763 according to the records of the steamer. So also the surface collecting stations where these molluscs were taken are likewise numbered 1–31.

Plate LIV.

All the outlines are drawn to the same scale—five times enlarged—with an embryograph. *a* ventral, *b* lateral, *c* front view, in each case.

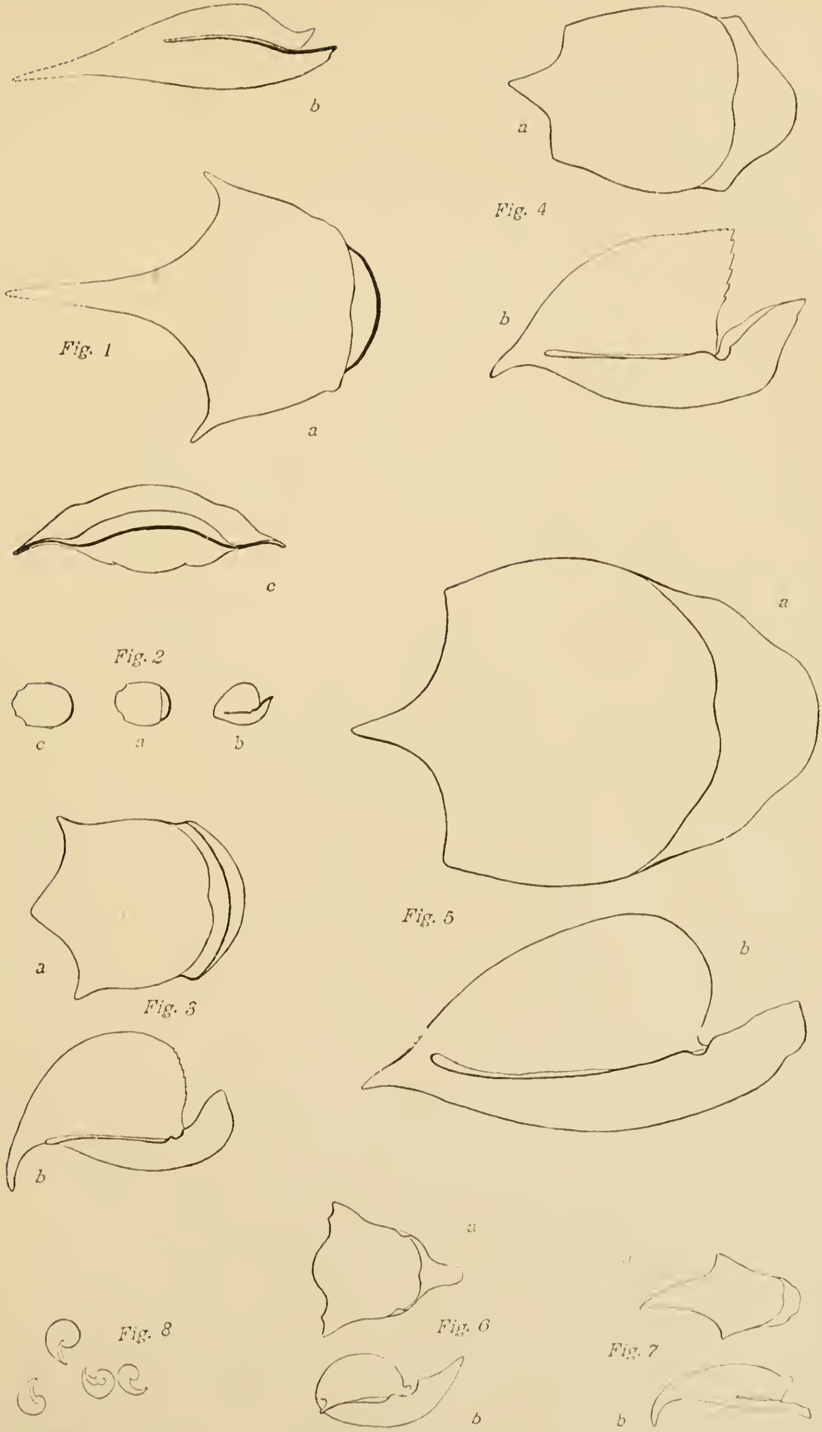
Fig. 1. Cavolinia *trispinosa*.
2. Cavolinia *quadridentata*.
3. Cavolinia *uncinata*.
4. Cavolinia *gibbosa*.
5. Cavolinia *tridentata*.
6. Cavolinia *longirostris*.
7. Cavolinia *inflexa*.
8. Limacina *inflata*.

Plate LV.

Letters as before.

Fig. 9. Clio (Creseis) *virgula*.
10. The same, variation *corniformis*.
11. Clio (Creseis) *conica*.
12. Clio (Styliola) *subulata*.
13. Clio (Hyalocylix) *striata*.
14. Clio (s. str.) *balantium*.
15. Clio (s. str.) *pyramidata*.
16. Cuvierina *columella*.

COLLECTING STATIONS OF STEAMER ALBATROSS.



PTEROPODA.


Fig. 9

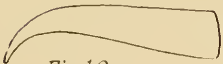


Fig. 10


Fig. 11

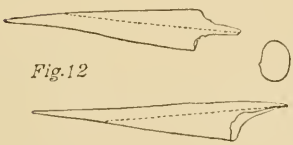


Fig. 12

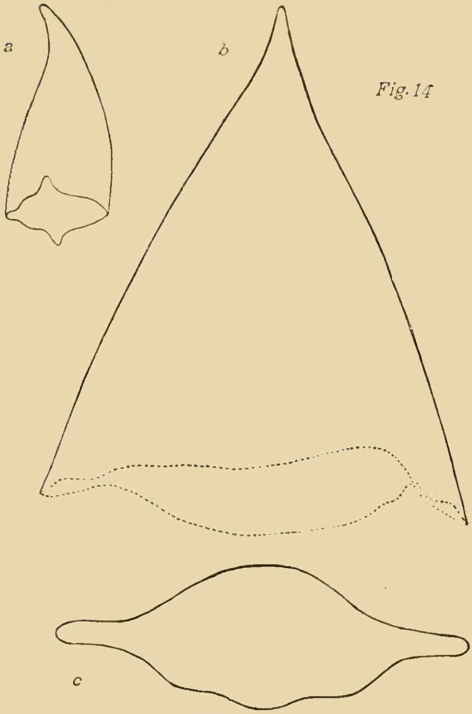


Fig. 14

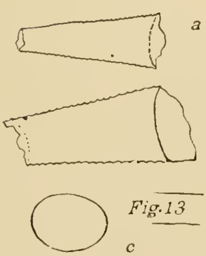


Fig. 13

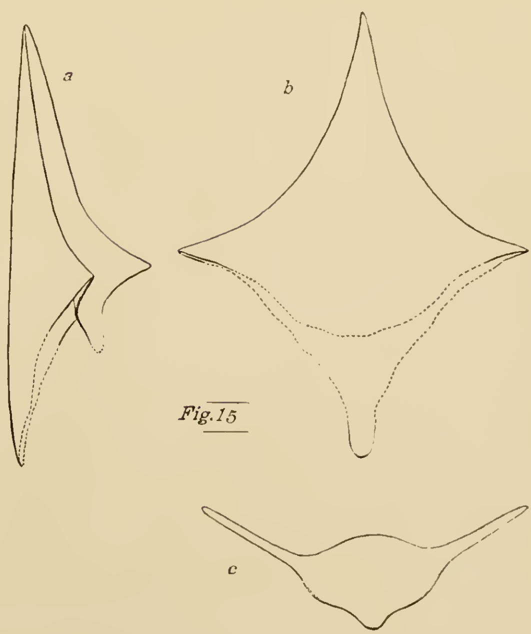


Fig. 15

Fig. 16

PTEROPODA.