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CONTENTS.

No. 1. — *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,"* LIEUT. COMMANDER Z. L. TANNER, U. S. N., *Commanding.*

II.*

General Sketch of the Expedition of the "Albatross," from February to May, 1891. By ALEXANDER AGASSIZ.

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ROUTE OF THE EXPEDITION.

WE left Panama on the 22d of February, and returned there after an absence of twenty days. During our first trip, the route extended from Panama to Point Mala, and next to Cocos Island ; from there we ran in a southerly direction, then northwesterly to Malpelo Island, and back to the hundred fathom line off the Bay of Panama, where we spent several days trawling off the continental plateau of the Bay.

After coaling, we left Panama, and reached Galera Point, where we began our second line, across the Humbolt Current to the southern face of the Galapagos. We spent a few days at the Galapagos visiting Chatham, Charles, Duncan, and James Islands, and then steamed for Acapulco, making casts of the trawl, and of the surface and the submarine townets, at various points.

After a few days' delay at Acapulco to coal the ship, we left that port on the 15th of April for our third cruise, into the Gulf of California, and steamed as far as Cape Corrientes without attempting to do any trawling. The character of the bottom, as indicated on the charts, promised nothing different from what we had dredged off Acapulco, and on the line from there to the Galapagos Islands. We made one haul off Cape

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* I. Calamocrinus Diomedæ, a new Stalked Crinoid. Memoirs Mus. Comp. Zoöl., Vol. XVII. No. 2, 1892. 96 pp. With 32 plates.

Corrientes, bringing up nothing but mud and decomposed vegetable matter. This induced us to keep up the Gulf of California, till we were off the Tres Marias. From that point until we reached Guaymas, on the 23d of April, we carried on our usual operations with the trawl, the townet, and the Tanner net.

In the afternoon of the same day I parted from the ship with great regret, but more than satisfied with the results of this expedition.

The more I saw of the "Albatross," the more I became convinced that her true field is that of exploration. She is a remarkably fine sea boat, and has ample accommodation for a staff of working specialists such as would be needed on a distant expedition. The time will soon come when the Fish Commission will hardly care to continue to run her, and I can conceive of no better use for so fine a vessel than to explore a belt of 20° of latitude north and south of the equator in the Pacific, from the west coast of Central America to the East Indian Archipelago.

The success of the "Albatross" thus far has depended entirely upon the zeal, energy, intelligence, forethought, and devotion of Captain Tanner, if I may judge of the past by the present. He never spares himself, and he is always ready to make the most of the time at his disposal for the benefit of the special object he has in charge. He looks after every haul of the trawl himself, and will not allow any one else to jeopard in any way the material of the vessel, or the time it requires to make a haul. That responsibility he assumes himself, and it constitutes his daily work. In looking over the records of the "Albatross" during her voyage from New York to San Francisco, I am struck with the amount of work which has been accomplished. It would be but a just return to Captain Tanner, if Congress would make the necessary appropriations to work up and publish, not only all that he has brought together on that cruise, but also what has been left untouched thus far of the immense collections made from the time he first commanded the "Albatross." In his cruises off the east coast of the United States and in the Caribbean, to say nothing of his explorations in the Gulf of California, on the coast of California, on the coast of Alaska, and in the Bering Sea, he has accumulated in the "Albatross" endless most interesting material, which no other ship could have got together unless she had another Tanner in command.

My cordial thanks are due to Colonel Marshall McDonald, the United States Fish Commissioner, for having given me the opportunity to join the "Albatross" on this extended cruise, and for his kindness in urging the President to allow the vessel to be detailed for this work. To Mr.

Richard Rathbun, of the United States Fish Commission, I must also express my thanks for the care, interest, and patience with which he attended to the endless details connected with the fitting out of the "Albatross" for her voyage. Since the arrival of the collections at Washington, he has taken full charge of their care and distribution to the specialists who will write reports on the results of the expedition.

I can hardly express my satisfaction at having had the opportunity to carry on this deep-sea work on the "Albatross." While of course I knew in a general way the great facilities the ship afforded, I did not fully realize the capacity of the equipment until I came to make use of it myself. I could not but contrast the luxurious and thoroughly convenient appointments of the laboratory of the "Albatross" for work by day and by night with my previous experiences. The constant assistance of Messrs. C. H. Townsend and N. B. Miller in the care of the specimens was most welcome, giving me ample time to examine the specimens during the process of assorting them, and to make such notes as I could between successive hauls, while paying some attention also to the work of the artist, Mr. Magnus Westergren. He found his time fully occupied, and we have in this trip brought together a considerable number of colored drawings, giving an excellent general idea of the appearance of the inhabitants of the deep waters as they first come up. These drawings can be used to great advantage with the specimens in making the final illustrations intended to accompany the reports of the specialists who have kindly undertaken the task of working up the different groups.

Stations occupied by the "Albatross," February to May, 1891.

During this cruise of the "Albatross," we occupied in all eighty-four Stations where the trawl, tangles, and tow-nets were used, and in addition five Stations at which the surface and submarine tow-nets alone were in use. Forty-four Stations, Nos. 3353 to 3397, with three tow-net Stations, were occupied on our first trip. Stations Nos. 3398 to 3423, as well as three others, were occupied during our second trip, from Panama to Acapulco via the Galapagos, and in the Gulf of California we occupied Stations Nos. 3424 to 3437, and three tow-net Stations.

The following record gives the work done at each Station: —

RECORD OF SUBMARINE TOW-NET STATIONS OF THE UNITED STATES FISH COMMISSION STEAMER "ALBATROSS."*

March and April, 1891.

Serial Number.	DATE.	TIME.	POSITION.		TEMPERATURES.		Depth in Fathoms.	Character of Bottom.	Depth at which towed, in Fathoms.	Time in Minutes.	REMARKS.
			Latitude North.	Longitude West.	Surface.	Bottom.					
	1891.	h. m.	° ′ ″	° ′ ″	°	°					
3282 Dr.	March 7	8 50 A.M.	6 21 0	80 41 0	75	35.8	1793	gn. M.	200	15	
"	" 7	9 53 A.M.	6 21 0	80 41 0	75	35.8	1793	gn. M.	200		Hauled up straight from 200 fathoms in 10 minutes; from 100 fathoms, in about 5 minutes. About 60 miles from the 100 fathom line.
"	" 7	10 23 A.M.	6 21 0	80 41 0	75	35.8	1793	gn. M.	100		
3388 Dr.	" 9	10 31 A.M.	7 6 0	79 48 0	73	36.2	1168	gn. glob. Oz.	400	17	Young Eryoneicus in upper part of net. 15 miles from 100 f. line, and 25 miles from nearest land.
2619 Hyd.	" 11	8 25 A.M.	7 31 0	78 42 30	68	36.5	1100	gn. glob. Oz.	300	19	
"	" 11	9 44 A.M.	7 31 0	78 42 30	68	36.5	1100	gn. glob. Oz.	1000 1482 †	16	Drifted into 1482 f. Atolla in upper part of net.
2627 Hyd.	" 25	6 49 A.M.	0 36 0	82 45 0	81	36.0	1832	gy. glob. Oz.	1770 1739 †	20	
2628 Hyd.	" 26	9 14 A.M.	South. 0 13 0	84 52 0	81	—	—	——	204	20	Towed awhile from 200 f. to surface, to fill upper part of net. About 250 m. from the Galapagos.
3414 Dr.	April 8	6 57 A.M.	North. 10 14 0	96 28 0	82	35.8	2232	gn. M.	100	20	350 miles from land.
"	" 8	7 47 A.M.	10 14 0	96 28 0	82	35.8	2232	gn. M.	200	10	
"	" 8	8 49 A.M.	10 14 0	96 28 0	82	35.8	2232	gn. M.	300	20	
"	" 8	10 30 A.M.	10 14 0	96 28 0	82	35.8	2232	gn. M.	300	15	
——	" 9	10 4 A.M.	12 34 0	97 21 0	82	—	—	——	175	8	About 300 miles S. E. of Acapulco. Depth.‡
——	" 9	8 3 P.M.	13 33 30	97 57 30	83	—	—	——	175	10	About 250 miles S. E. of Acapulco. Depth.‡
——	" 11	8 45 A.M.	16 32 0	99 42 0	80	—	—	——	300	20	About 30 miles S. E. of Acapulco. Depth §
——	" 16	10 10 A.M.	17 39 30	102 11 30	76	—	—	——	175	15	About 120 m. N. W. of Acapulco. Depth over 2,000 f.
3436 Dr.	" 22	1 22 P.M.	27 3 40	110 53 40	72	37.2	905	bn. M. bk. Sp.	800	15	Surface about 75 miles S. W. of Guaymas, half-way across Gulf of California. New Bougainvillia, Periphylla.
2637 Hyd.	" 22	7 21 P.M.	27 20 0	110 54 0	71	38.0	773	bn. M. bk. Sp.	700	15	About 50 miles S. W. of Guaymas. Nettastoma.
3437 Dr.	" 23	5 31 A.M.	27 39 40	111 0 30	70	40.0	628	bn. M. bk. Sp.	600	15	Shoaled water and dragged on bottom.
2638 Hyd.	" 23	7 26 A.M.	27 38 0	111 4 0	72	39.2	622	bn. M. bk. Sp.	500 570 †	15	

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* Tanner tow-net at all Stations except Station 3282, March 7.

† Depth varying between these points.

‡ Between two Stations, over 2,000 fathoms.

§ Between two Stations, about 500 fathoms.

RECORD OF DREDGING AND TRAWLING STATIONS OF THE UNITED STATES FISH COMMISSION STEAMER "ALBATROSS."

Serial Number.	DATE.	TIME.	POSITION.		TEMPERATURES		Depth in Fathoms.	Character of Bottom.	REMARKS.
			Latitude North.	Longitude West.	Surface.	Bottom.			
	1891.	h. m.	° ′ ″	° ′ ″	°	°			
	Feb. 22	8 0 P.M.	—	—	—	—	—	—	
3353	Feb. 23	8 56 A.M.	7 6 15	80 34 0	73	39.0	695	gn. M.	Surface tow-net.
3354	" 23	1 25 P.M.	7 9 45	80 50 0	78	46.0	322	gn. M.	
3355	" 23	3 1 P.M.	7 12 20	80 55 0	81	54.1	182	bk. G. Sh.	
3356	" 23	7 30 P.M.	7 9 30	81 8 30	83	40.1	546	sft. bl. M.	Surface tow-net. 15 miles from Mariato Point.
3357	" 24	6 17 A.M.	6 35 0	81 44 0	83	38.5	782	Modern Greensand.	Surface tow-net.
3358	" 24	11 38 A.M.	6 30 0	81 44 0	83	40.2	555	Modern Greensand.	
3359	" 24	2 4 P.M.	6 22 20	81 52 0	83	42.0	465	Rky.	
3360	" 24	5 20 P.M.	6 17 0	82 5 0	83	36.4	1672	fne. bk. dk. gn. S.	Surface tow-net.
3361	" 25	7 33 A.M.	6 10 0	83 6 0	82	36.6	1471	gn. Oz.	
3362	" 26	7 20 A.M.	5 56 0	85 10 30	84	36.8	1175	gn. M. S. rky.	Intermediate net of Chun and Peterson.
3363	" 26	4 37 P.M.	5 43 0	85 50 0	83	37.5	978	wh. glob. Oz.	Surface tow-net.
3364	" 27	6 58 A.M.	5 30 0	86 8 30	81	38.0	902	yl. glob. Oz.	
3365	" 27	1 30 P.M.	5 31 0	86 31 0	85	37.0	1010	yl. glob. Oz.	Surface tow-net.
3366	" 27	8 4 P.M.	5 30 0	86 45 0	84	37.0	1067	yl. glob. Oz.	
3367	" 28	6 38 A.M.	5 31 30	86 52 30	82	57.1	100	Rky.	
3368	" 28	7 21 A.M.	5 32 45	86 54 30	82	58.4	66	Rky.	Surface tow-net.
3369	" 28	8 7 A.M.	5 32 45	86 55 20	82	62.2	52	Nullipore or rky.	
3370	" 28	10 3 A.M.	5 36 40	86 56 50	84	54.8	134	Rks. & S.	At Cocos Island. Surface tow-net at night.
3371	March 1	7 49 A.M.	5 26 20	86 55 0	82	39.0	770	glob. Oz.	
3372	" 1	5 51 P.M.	4 49 0	86 11 20	84	38.8	761	gy. glob. Oz.	8 P. M. Surface tow-net.
3373	" 2	10 33 A.M.	4 2 0	84 58 0	82	36.6	1877	br. M. bk. sp.	
3374	" 3	10 35 A.M.	2 35 0	83 53 0	80	36.4	1823	gn. Oz.	

RECORD OF DREDGING AND TRAWLING STATIONS OF THE UNITED STATES FISH COMMISSION STEAMER "ALBATROSS." — *Continued.*

Serial Number.	DATE.		TIME.	POSITION.		TEMPERATURES.		Depth in Fathoms.	Character of Bottom	REMARKS.
				Latitude North.	Longitude West.	Surface.	Bottom.			
	1891.		h. m.	° ′ ″	° ′ ″	°	°			
3375	March	4	6 36 A.M.	2 34 0	82 29 0	77	36.6	1201	gy. glob. Oz.	Surface tow-net. In trawl swimming Holothurian, Periphylla, Atolla, and Eryoneicus.
3376	"	4	4 27 P.M.	3 9 0	82 8 0	78	36.3	1132	gy. glob. Oz.	
3377	"	5	8 38 A.M.	3 56 0	81 40 15	77	38.0	764	M.	
3378	"	5	11 45 A.M.	3 58 20	81 36 0	78	55.9	112	brk. sh.	
3379	"	5	2 15 P.M.	3 59 40	81 35 0	78	—	52	Rks.	
3380	"	5	4 51 P.M.	4 3 0	81 31 0	79	37.2	899	Rks.	In trawl, Periphylla, Atolla.
3381	"	6	8 38 A.M.	4 56 0	80 52 30	77	35.8	1772	gn. M.	Siphonophore clinging to wire rope.
3382	"	7	10 46 A.M.	6 21 0	80 41 0	75	35.8	1793	gn. M.	Submarine tow-net. 8:30 P.M., Surface tow-net.
3383	"	8	6 51 A.M.	7 21 0	79 2 0	74	36.0	1832	gr. glob. Oz.	Atolla in trawl, Periphylla, Nauphanta, fragments of Drymonema.
3384	"	8	1 20 P.M.	7 31 30	79 14 0	74	42.0	458	gn. S.	Stomobrachium in trawl.
3385	"	8	3 7 P.M.	7 32 36	79 16 0	72	45.9	286	gn. M.	
3386	"	8	4 51 P.M.	7 33 12	79 17 15	73	48.0	242	fne. gy. S.	
3387	"	8	7 21 P.M.	7 40 0	79 17 50	74	56.4	127	fne. gy. S.	Surface tow-net.
3388	"	9	6 41 A.M.	7 6 0	79 48 0	73	36.2	1168	gn. glob. Oz.	Submarine tow-net. In trawl, Stomobrachium. In tow-net, open part, Periphylla.
3389	"	9	2 10 P.M.	7 16 45	79 56 30	74	48.8	210	gn. M.	
3390	"	9	4 25 P.M.	7 26 10	79 53 50	74	62.6	56	fne. gy. S. G.	
3391	"	9	7 15 P.M.	7 33 40	79 43 20	73	55.8	153	gn. M.	
3392	"	10	6 30 A.M.	7 5 30	79 40 0	73	36.4	1270	hard.	Rhabdamina bottom.
3393	"	10	1 21 P.M.	7 15 0	79 36 0	74	36.8	1020	gn. M.	
3394	"	10	5 43 P.M.	7 21 0	79 35 0	73	41.8	511	dk. gn. M.	

RECORD OF DREDGING AND TRAWLING STATIONS OF THE UNITED STATES FISH COMMISSION STEAMER "ALBATROSS. — *Continued.*

Serial Number.	DATE.		TIME.	POSITION.		TEMPERATURES.		Depth in Fathoms	Character of Bottom.	REMARKS.
				Latitude North.	Longitude West.	Surface.	Bottom.			
	1891.		h. m.	° ′ ″	° ′ ″	°	°			
3395	March	11	2 20 P.M.	7 30 36	78 39 0	70	38.5	730	Rky.	
3396	"	11	5 15 P.M.	7 32 0	78 36 30	70	47.4	259	hrd. gy. M. S.	
3397	"	11	6 32 P.M.	7 33 0	78 34 20	71	57.3	85	stf. gn. M. brk.	Surface tow-net.
3398	"	23	3 16 P.M.	1 7 0	80 21 0	84	36.0	1573	gn. Oz.	Surface tow-net, off Galera Point.
3399	"	24	6 37 A.M.	1 7 0	81 4 0	80	36.0	1740	gn. Oz.	Siphonophore on wire. Phæodaria fragments. Surface tow-net.
3400	"	27	6 10 A.M.	*South.* 0 36 0	86 46 0	81	36.0	1322	lt. gy. glob. Oz.	Surface tow-net, March 25, pelagic Holothurian.
3401	"	28	4 45 A.M.	0 59 0	88 58 30	82	44.0	395	glob. Oz.	
3402	"	28	7 13 A.M.	0 57 30	89 3 30	82	42.3	421	R. glob. Oz.	
3403	"	28	10 19 A.M.	0 58 30	89 17 0	82	43.3	384	fne. gy. S. bk. Sp.	
3404	"	28	1 16 P.M.	1 3 0	89 28 0	83	43.2	385	R.	Tangles.
3405	"	28	3 42 P.M	0 57 0	89 38 0	83	60.0	53	P. Co. Sh.	
3406	April	3	6 47 A.M.	0 16 0	90 21 30	81	41.3	551	R.	
3407	"	3	10 48 A.M.	0 4 0	90 24 30	81	37.2	885	glob. Oz.	Tangles.
3408	"	3	4 7 P.M.	*North.* 0 12 30	90 32 30	83	39.5	684	glob. Oz.	Tangles.
3409	"	3	7 24 P.M.	0 18 40	90 34 0	82	42.3	327	bk. S.	Tangles. Surface tow-net. Off Bindloe Island, 4 miles west.
3410	"	3	8 48 P.M	0 19 0	90 34 0	82	44.2	331	bk. S.	
3411	"	4	7 35 A.M.	0 54 0	91 9 0	82	36.2	1189	yl. glob. Oz.	
3412	"	4	6 11 P.M	1 23 0	91 43 0	82	38.0	918	R.	9 P. M., surface tow-net, 5 m. off Wenman Islands.
3413	"	5	8 34 A.M.	2 34 0	92 6 0	82	36.0	1360	glob. Oz. dk. Sp.	At noon, surface tow-net.
3414	"	8	11 14 A.M.	10 14 0	96 28 0	82	35.8	2232	gn. M.	Submarine tow-net and surface tow-net.
3415	"	10	9 39 A.M.	14 46 0	98 40 0	82	36.0	1879	br. M. glob. Oz.	

RECORD OF DREDGING AND TRAWLING STATIONS OF THE UNITED STATES FISH COMMISSION STEAMER "ALBATROSS." — *Continued.*

Serial Number.	DATE.		TIME	POSITION.		TEMPERATURES.		Depth in Fathoms.	Character of Bottom.	REMARKS.
				Latitude North.	Longitude West.	Surface.	Bottom.			
	1891.		h. m.	° ′ ″	° ′ ″	°	°			
3416	April	11	9 46 A.M.	16 32 30	99 42 40	81	40.5	419	fne. br. M.	
3417	"	11	11 44 A.M.	16 32 0	99 48 0	82	40.6	493	gn. M.	
3418	"	11	2 57 A.M.	16 33 0	99 52 30	82	39.0	660	br. S. bk. Sp.	
3419	"	11	5 59 P.M.	16 34 30	100 3 0	81	39.0	772	gn. M. bk. Sp.	Surface tow-net.
3420	"	12	7 48 A.M.	16 46 0	100 8 20	82	39.6	664	dk. gn. M.	
3421	"	12	11 32 A.M.	16 47 20	100 0 10	82	42.9	388	dk. gn. M.	
3422	"	12	12 35 P.M.	16 47 30	99 59 30	83	53.5	141	gn. M.	
3423	"	12	1 31 P.M.	16 47 30	99 59 20	83	56.0	94	gn. M.	
3424	"	18	11 18 A.M.	21 15 0	106 23 0	76	38.0	676	gy. S. bk. Sp. Glob.	
3425	"	18	2 14 P.M.	21 19 0	106 24 0	76	39.0	680	gn. M. & S.	
3426	"	18	3 45 P.M.	21 21 0	106 25 0	76	51.2	146	Rky.	
3427	"	18	4 3 P.M.	21 22 15	106 25 0	75	51.2	80	Rky.	
3428	"	18	6 40 P.M.	21 36 30	106 25 0	76	48.1	238	dk. gy. S. Glob.	
3429	"	19	5 39 A.M.	22 30 30	107 1 0	73	37.0	919	gn. M. Glob. Oz.	
3430	"	19	3 27 P.M.	23 16 0	107 31 0	73	37.9	852	bk. S.	
3431	"	20	6 33 A.M.	23 59 0	108 40 0	70	37.0	995	lt. bro. M. Glob.	
3432	"	20	2 38 P.M.	24 22 30	109 3 20	70	37.8	1421	br. M. bk. Sp.	
3433	"	21	6 34 A.M.	25 26 15	109 48 0	69	36.5	1218	br. M. bk. Sp.	Surface tow-net.
3434	"	21	10 14 A.M.	25 29 30	109 48 0	70	36.4	1588	br. M. bk. Sp.	
3435	"	22	8 56 A.M.	26 48 0	110 45 20	70	37.3	859	br. M. bk. Sp.	
3436	"	22	3 10 P.M.	27 34 0	110 53 40	72	37.2	905	br. M. bk. Sp.	Submarine tow-net and surface tow-net.
3437	"	23	5 4 A.M.			70	40.0	628	br. M. bk. Sp.	Submarine tow-net dragged on the bottom. About 50 miles south of Guaymas.

Topography of the Bottom in the Panamic Region.

There can be no more striking contrast than exists between the topography of the two sides of Central America. The Atlantic side[1] with the great inland seas of the Gulf of Mexico and Caribbean, and the great submarine banks extending from Yucatan, Honduras, and Venezuela, while on the Pacific side (Plate III.) the continental slope is steep, the 2,000 fathom line often coming within 100 miles of the coast line. (See Plates V. to IX.) The 100 fathom line, with the exception of the stretch forming the Bay of Panama, and a comparatively narrow continental shelf along a part of the shore from Costa Rica to Tehuantepec, is within a few miles of the shore as far as the southern entrance of the Gulf of California, where it broadens out again to take in the Tres Marias group of islands. The 500 and 1,000 fathom lines are parallel with the 100 fathom line, forming a very abrupt slope from Ecuador to the Gulf of California, except along the stretch between Cape Mala and Tehuantepec, where the distance between those curves is somewhat greater (Plate III.), but still so slight as not to alter materially the prevailing steepness of the continental slope. In this same stretch the 1,500 fathom line is from three to four times as distant from the 1,000 fathom curve as it is off the coast line extending from Panama to Ecuador, and from Tehuantepec to Cape Corrientes; at the mouth of the Gulf of California, the 1,500 fathom line extends across the opening of the Gulf of California, coming in again close to Cape San Lucas.

The rise upon which Malpelo (Plate VI.) is situated is bounded by the 1,500 fathom line (Plate III.), and separated by a channel with over 1,700 fathoms of water from the Columbian and Ecuadorian coasts. And again the same curve forms a gigantic comma-shaped figure, taking in Cocos Island (Plates III. and V.) and the Galapagos group; it is separated from the 1,500 fathom line off Mariato Point by over 1,600 fathoms, and from the Malpelo Bank and Ecuadorian coast by over 1,800 fathoms. (See Plate III.) The course of the 2,000 fathom line shows how very uniform is the depth of the floor of the Pacific beyond the 1,500 fathom curve. The rise to the Galapagos is most gradual close to the islands, and the different islands of the Revilla Gigedo group, varying in distance from 300 to 500 miles from Cape San Lucas, form steep peaks suddenly rising from a comparatively level oceanic floor of an average depth of about 2,000 fathoms (see Plate III.), which is nearly the

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[1] See Figs. 55–59, Three Cruises of the "Blake."

general depth between them and the mainland. This flat floor also extends farther to the southeast towards the 1,500 fathom line from which the Galapagos rise begins, and in the direction of the Costa Rica coast. The slope from the 1,000 fathom line to the 1,500 and 2,000 fathom line is much more gradual between Costa Rica and Tehuantepec than farther north along the coast of Mexico as far as the Gulf of California (Plate III.).

Our knowledge of the hydrography of the Galapagos is still quite incomplete. (See Plates IV. and VIII. to XII.) There are unfortunately no soundings between James and Albemarle, or between Indefatigable and Albemarle, to indicate the probable depth of the ridges connecting them.

Nothing likewise is known of the depth of the channels between Abingdon and Bindloe and Tower, and no soundings exist to show how far to the westward the deep valley (of over 800 fathoms) separating Bindloe from Indefatigable extends (Plate X. Fig. 2), as there are no soundings between either Bindloe or Abingdon and Albemarle. There seems little doubt that the northernmost islands, the isolated rocks of Culpepper and Wenman, are themselves separated by comparatively deep water (Plate XII. Figs. 1, 2), and in turn separated from the northeastern group of islands, Abingdon, Bindloe, and Tower, by a tongue of the ocean of at least 1,000 fathoms in depth, and from sixty to seventy miles in width. From a careful examination of the soundings thus far made, it seems probable that the 100 fathom line connects Indefatigable, Duncan, Barrington, and Charles, (see Plate IV., as well as the line between Charles and Indefatigable, Plate XI. Fig. 1,) and that there is also a connecting ridge inside that same depth between those islands and Albemarle to the southeast of Cape Woodford on Albemarle, or a wider plateau of which Duncan Island is one of the culminating summits.

A comparatively shallow connection may also exist between Cape Nepean on James Island and Albemarle in the direction of Cowley Island, Narborough itself being only separated from Albemarle by a channel less than 75 fathoms in depth (Plate IV.). The soundings between Chatham, Barrington, and Hood are so few in number that we are not yet able to decide whether these southeastern islands, Chatham and Hood (Plate XI. Figs. 2, 3), are not perhaps connected by a ridge connecting Hood and Macgowen Reef (Plate IV.), and also uniting them with the great plateau which the islands of Barrington, Charles, Indefatigable, Duncan, Albemarle, Narborough, and perhaps James, have gradually built up. But it may be that the tongue of deeper water extending between Hood and Chatham (287 fathoms) runs towards Barrington, and also separates that island from Chatham (Plate XI. Fig. 2).

On account of the small number of soundings, no attempt has been made to draw curves of depth on the chart of the Galapagos (Plate IV.).

The structure of Albemarle, made up of a series of at least five volcanic centres, with the adjacent Narborough, gives us an indication of the probable appearance of the central and western group of islands were they still active so as finally to become connected and form a huge island, with James, Indefatigable, Jarvis, Duncan, Barrington, and Charles as the culminating points of the plateau formed by the 100 fathom line. We may therefore look upon the Galapagos Islands as a group of volcanic islands, gradually built up by successive flows of lava upon a huge mound, itself perhaps raised by the same agencies from the floor of the ocean; more active local flows in the same region having at special points built up more rapidly the northern group of islands, Wenman and Culpepper, and the two other groups of islands we have recognized.

Character of the Bottom Deposits.

We dredged frequently in most characteristic Globigerina ooze. On one occasion the trawl came up literally filled with masses of a species of Rhabdamina closely allied to R. lineata.

It is interesting to note that, at two localities not far from the coast off Mariato Point, we came across patches of modern greensand similar in formation to the patches discovered off the east coast of the United States by the earlier dredgings of the Coast Survey, of Pourtalès, and of the "Blake." (See page 5, Stations 3357, 3358.)

Nearly everywhere along our second line of exploration, except on the face of the Galapagos slope, we trawled upon a bottom either muddy or composed of Globigerina ooze, more or less contaminated with terrigenous deposits, and frequently covered with a great amount of decayed vegetable matter. We scarcely made a single haul of the trawl which did not bring up a considerable amount of decayed vegetable matter, and frequently logs, branches, twigs, seeds, leaves, fruits, much as during our first cruise.

I was struck, while trawling on our second line between the Galapagos and Acapulco, to observe the great distance from shore to which true terrigenous deposits were carried. There was not a station there occupied of which the bottom could be characterized as strictly oceanic.

At our most distant points from shore, the bottom specimens invariably showed some trace of admixture of terrigenous material. A very fine mud was the characteristic bottom we brought up, often very sticky, and enough of it usually remained in the trawl, even when coming up from depths of over 2,000 fathoms, materially to interfere with the assorting of the specimens contained in our hauls. This mud continued all the way from the Galapagos to Acapulco, and up to the mouth of the Gulf of California, where it became still more of an impediment to dredging, so that little work was done until we passed the Tres Marias. Even then the trawl was ordinarily well filled with mud, and with it came up the usual supply of logs, branches, twigs, and decayed vegetable matter.

On going farther north, into the Gulf of California, the nature of the bottom did not change materially from what it had been along the coast from Acapulco to Cape Corrientes; it was the same viscid mud, mixed occasionally with Globigerinæ and masses of vegetable matter. So we found the trawling most difficult from the weight of the mud brought up, but occasionally a haul was made which more than repaid us for the time spent on the less productive ones.

In the dredgings of the "Blake" in the Gulf of Mexico, off the West Indies, and in the Caribbean, my attention had already been called to the immense amount of vegetable matter dredged up from a depth of over 1,500 fathoms on the lee side of the West India Islands. But in none of the dredgings we made on the Atlantic side of the Isthmus did we come upon such masses of decomposed vegetable matter as we found on this expedition. There was hardly a haul taken which did not supply a large quantity of water-logged wood, and more or less fresh twigs, leaves, seeds, and fruits, in all possible stages of decomposition.

Temperature Sections in the Panamic District.

The temperature sections taken by the "Albatross" during this cruise give us a fair sketch of the temperature of the currents running north parallel with the Mexican coast, of the counter current running towards the Gulf of Panama, of a branch of the Humboldt Current running from the coast of Peru and deflected by the Galapagos to the northward, the main branch of the current running south of the Galapagos and forming a great westerly current running nearly at right angles from the coast of Central America past the Galapagos, and becoming the Equatorial Current of the Pacific.[1]

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[1] The Peruvian stream, the bulk of which flows westerly south of the Galapa-

A transverse section of the Mexican Current from Mariato Point to Cocos Island (Plate V.) shows the water to be considerably warmer near the mainland than about half-way across to Cocos Island. At the 1,000 fathom line, the 60° curve is found at a depth of more than 100 fathoms, while at Station 3361, at a depth of 1,471 fathoms, nearly the half-way point, the 60° curve has risen to a depth of 50 fathoms from the surface, to sink to 75 fathoms and rise to 25 fathoms again at Station 3362 at a depth of 1,175 fathoms, and at Station 3364 in 902 fathoms, towards Cocos Island, the surface belt becoming again decidedly warmer near the island. The curve of 45° temperature corresponds nearly with the 300 fathom line, rising near the mainland and falling somewhat at Cocos Island. The 40° curve in its turn corresponds practically with the 600 fathom line except near the mainland, where there seems to have been a colder body of water.

The bottom temperature of 36°.4 between 1,600 and 1,700 fathoms shows a free connection with the oceanic floor, and the temperatures on the ridges indicated by the soundings, the one near the mainland (42°), the other near Cocos Island (38°), show that they are not parts of an oceanic barrier, but are probably short ridges parallel with the mainland and the general trend of Cocos Island.

A temperature section run across the westerly Panamic current in a southeasterly direction from Cocos Island (Plate VI. Fig. 1) shows remarkably uniform temperature curves of 60°, 45°, and 40°. The 60° curve, after leaving the shores of Cocos Island, rises to about the 45 fathom line, the water as we go south gradually becoming warmer, and at Station 3375, about 100 miles southwest of Malpelo, the 60° curve is down to the 75 fathom line. The 45° curve barely rises above the 300 fathom line near Cocos, and at Station 3375 falls somewhat below it. The 40° curve is nearly parallel with the 520 fathom line; so that going south from Cocos Island the body of water above the 500 fathom line is considerably warmer than in the section from Cocos Island to the mainland.

gos, divides off Ecuador, one branch, the westerly, extending to the eastward of the Galapagos, the other flowing into the Bay of Panama. The westerly branch meets the eastern equatorial set, and the eastern branch meets north of the Bay of Panama both the easterly equatorial set and the Mexican branch of the California Current. There is thus found off the Bay of Panama, from the coast of Costa Rica and in a southerly direction, and northerly in the triangle between the Galapagos, Point Mala, and Acapulco, a most complicated system of currents and counter currents. These currents had a marked effect on the ship's course, and frequently set us one day thirty or forty miles east, the next day as many miles in a westerly direction.

In the section from Station 3375 towards Malpelo and to the Pearl Islands in the Bay of Panama (Plate VI. Fig. 2), the water becomes somewhat colder as we approach Malpelo and as far as Station 3,381 in 1,772 fathoms, where the temperature gradually rises again (the 40°, 45°, and 60° curves) towards the Bay of Panama, although the surface temperature has been gradually diminishing from 84° off Cocos Island to 77° off Malpelo, to become as low as 73° off the mouth of the Bay of Panama in 1,168 fathoms, to rise again to 75° in the shallow water of the bay itself.

The three temperature sections of Plate VII. Figs. 1, 2, 3, from Station 3392 to Caracoles Point, on the east shore of the Bay of Panama, and to Point Mala, and from Station 3383, fifty miles to the south of Caracoles Point, to Panama, show an increase of temperature as we rise above the continental slope to the heated waters of the bay, and close to Point Mala on its western face.

In the temperature section from Galera Point to Chatham Island (Plate VIII.) we find the 60° curve but little below the 50 fathom line, showing plainly that it is from the southern current that the cold water comes which occupies the upper strata of the Bay of Panama. The 45° curve rises above the 300 fathom line close to the mainland, to fall nearly 50 fathoms below it on the slope of Chatham Island. The 40° curve is below the 600 fathom line near the mainland, but rises to that line off Galera Point, to fall again nearly to 675 fathoms on the Galapagos slope.

It will be noticed that the upper belt of 50 fathoms varies considerably in temperature, ranging near Galera Point fully 20° in less than 50 fathoms, and in comparatively short distances more than 17°, the surface temperature varying from 80° to 84° on the way to Chatham, and the temperature at the 50 fathom line from 59°.1 to 64°.3.

The bottom temperature is fully half a degree colder below 1,300 fathoms than it is in the sections from Mariato Point to Cocos, and southerly from that island the colder water of the bottom, 36°, extends to the western face of the continental slope off the Bay of Panama as far as Point Mala, as is seen in the sections of Plate VII. Figs. 1 and 2.

The temperature of the upper strata rises somewhat as we approach the Galapagos, the 60° curve being found at a depth of 75 fathoms (Plate VIII.) off Chatham Island.

In the temperature section run in a northwesterly direction from the Galapagos to Acapulco (Plate IX.) we obtained the deepest soundings of our cruise, the temperature at a depth of 2,232 fathoms, somewhat more than half-way between Culpepper and Acapulco, falling to 35°.8, the temperature being below 36° in the whole of the great basin extending between the northerly slope of the Galapagos and the continental slope off Acapulco. The surface temperature was 83° off Chatham, it fell to 81° off James, and varied between 81° and 83° to fall to 81° again about half-way to Acapulco, to rise to 84° and fall to 80° off Acapulco. The 60° curve rises among some of the Galapagos Islands almost to the 50 fathom line, but falls rapidly below the 100 fathom line between Abingdon and Wenman, retaining that depth nearly to Station 3414 in 2,232 fathoms (Plate IX.), showing the presence of a large mass of warm water flowing eastwardly. From that point it rises rapidly above the 50 fathom line to a short distance off Acapulco, where the water close to the shore becomes warmer again. The 45° curve follows nearly the line of the 60° curve, reaching for a great part of its length the line of 350 fathoms. But the 40° curve shows more markedly than the 45° curve the influence of the warmer body of water moving eastward, and again as markedly that of the colder belt close to the Mexican mainland. It reaches well below the 600 fathom line for more than two thirds its length, extending for a considerable distance to 630, and even to 650 fathoms.

A comparison of the temperature curves of Plates VIII. and IX. will show in the one case the large belt of warmer water flowing east in the greater part of the oceanic basin extending between the Galapagos and Acapulco, and the comparatively colder water flowing north in the oceanic valley extending between Cape San Francisco (Galera Point) and the Galapagos.

The few temperatures taken between the different islands of the Galapagos are interesting as showing the southern islands, Chatham, Hood, and Charles, to be somewhat within the influence of the colder Humboldt Current (Plate XI. Figs. 2, 3, 5), while that which sweeps north of Chatham across the central islands is somewhat warmer (see Plate X. Figs. 1–4), and the upper belt of temperatures is still warmer between Abingdon and Wenman Islands (Plate XII.).

The mixing of the cold and warmer currents flowing between the different islands is plainly indicated by the temperature section from Indefatigable Island to Bindloe (Plate X. Fig. 2), where the 60° curve is at about the 50 fathom line, the 45° at the 300 fathom line, and the 40° curve at the 600 fathom line, while between Abingdon and Wenman the 60° curve is below the 100 fathom line, the

45° curve at about the 350 fathom line, and the 40° curve at the 650 fathom line, indicating a much larger body of warm water between Abingdon and Wenman (Plate XII. Fig. 1) than between Indefatigable and Bindloe, while farther south, near Chatham (Plate XI. Figs. 2, 3, 4), the upper belt of temperatures indicated are the coldest, the 60° curve being above the 50 fathom line.

The temperatures were all taken during February, March, and April of 1891. The sections of the first lines, Panama to Cocos, to Malpelo, and back again to Panama, were taken during the last of February and the beginning of March; those from Galera Point and the Galapagos during the latter part of March and beginning of April; and the line from the Galapagos to Acapulco from the 3d of April to the 12th.

The soundings and temperatures taken during our trip up the Gulf of California indicate free connection with the Pacific, (see the bottom temperatures of Stations 3424 to 3437 in the Gulf of California, page 8, and Hy. 2635, page 17, the deeper stations having practically the same temperature as the oceanic temperatures off Acapulco,) the 1,500 fathom line sweeping across the opening of the gulf with a rapid rise to the 1,000 fathom line running parallel to the two coasts, and a very flat bottom along the central part of the Gulf of California to the line where the 1,000 fathom curve cuts across the gulf off Topolobampo, the bottom rising again gradually along the centre of the gulf to the 500 fathom line, which extends north of Guaymas. The rapid decrease of the surface temperatures as well as that of the upper belt of water to 100 fathoms, within the Gulf of California, is very marked. See the record, on page 8, of Stations 3424 to 3437, and Hy. 2635, page 17.

The accompanying table shows the serial temperatures taken at the different Stations. The position is given in the list of Stations occupied, on pages 4 to 8.

Serial Number.	TEMPERATURE. Of the Air	At the Surface.	At Fathoms. 25	50	100	200	300	400	500	600	700	800	900	1000	At Bottom.	Depth in Fathoms.
	° F.	°	°	°	°	°	°	°	°	°	°	°	°	°	° F.	
Hy. 2609	79	81	67.2	63.2											57.7	127
Dr. 3356	80	83	68.4	65.9	58.5	52.9	44.9	48.7							40.1	546
" 3357	80	83	74.4			51.8	46.1	43.0	41.0						38.5	782
" 3361	81	82	76.9	59.0	55.0	50.5	46.8	43.6	41.9	40.2	38.3	38.9	37.5	36.5	36.6	1471
" 3362	80	84	71.8		55.8	51.3	46.7				39.1		37.3	36.8	36.8	1175
" 3364	79	81	71.4	58.9	54.4 *	48.8 *	44.9 *	42.8 *	41.0 *						38.0	902
" 3366	83	84	73.7	58.9	55.8	50.9	45.9	44.7	41.5	40.4	38.8				37.0	1067
" 3367	81	82	72.4	69.0											57.1	100
" 3372	85	84	74.4	58.8	55.0	49.1	44.9	42.5	41.0						38.8	761
" 3373	83	82	77.7	60.9	55.9	49.7	44.4	41.9		38.9	38.0	37.5	37.1	37.0	36.6	1877
" 3374	81	80	74.8	61.1	56.6	51.3	45.8	42.3	40.9	39.4					36.4	1823
" 3375	76	77	66.7		58.0	54.2	46.6	43.8	40.9	39.9	38.9	38.0	37.6	37.2	36.6	1201
Hy. 2613	77	77	69.9	59.9	57.7	50.8	45.6	43.3	40.9	39.7	38.8		37.3		36.5	1181
Dr. 3381	78	77	70.9	59.3	55.4	51.5	46.7	42.8	40.5	39.4	38.6	37.7	36.4	36.0	36.0	1772
" 3382	77	75	67.7	61.1	55.3	49.9	45.8	42.8	41.1	39.4	38.8	38.1	36.7	36.3	36.0	1793
" 3383	75	74	63.2	63.4	56.4	49.1	45.0	43.3	41.3	39.6	39.4	39.0	37.4	37.0	36.0	1832
" 3387	77	75	65.8	64.0											56.4	127
" 3388	75	73	64.0	60.9	56.1	49.0	45.5	43.4	43.1	39.8	39.2	38.1	37.7	37.2	36.2	1168
" 3392	76	73	63.0		55.9	49.8	45.0	43.2	40.5	39.7	38.6		37.3	36.8	36.4	1270
Hy. 2619	72	68	65.0	61.8		48.9	45.5	42.6	41.1	40.1	38.7	37.8			36.5	1100
Dr. 3396	77	70	64.5	62.4	55.9										47.4	259
Hy. 2624	77	80		59.1	58.1	56.4	45.6	43.1	41.9	41.0					39.0	724
" 2626	79	80	68.9	60.7											57.5	90
Dr. 3398	84	84	68.8	61.4	59.0	53.8	45.1	42.9	42.0	40.3	39.5	39.0	38.4	37.0	36.0	1573
" 3399	79	80	72.7	65.7	56.1	50.0	44.9	43.0	41.4	40.1	38.9	38.0	37.6	36.7	36.0	1740
Hy. 2627	80	81	71.4	64.3	56.8	49.2	44.8	42.5	41.9	40.2	38.7	38.2	37.7	37.1	36.0	1832
" 2629	85	83	69.9	63.7	56.2	50.1	45.0	42.4	41.8	40.3	39.2	38.6	37.8	36.8	36.0	1488
Dr. 3401	81	82	70.1	63.7	56.6	50.0	46.1								44.0	395
" 3406	79	81	73.5	59.9	57.9	53.9	45.0	42.3							41.3	551
" 3411	79	82	71.8	67.8	61.5	54.0	46.8	43.0	41.3	40.8	39.8	38.9	38.1	37.5	36.2	1189
" 3414	81	82	81.9	72.1	59.5	51.8	47.8	44.4	42.0	40.8	39.6	38.8	38.1	37.8	35.8	2232
" 3415	84	82	77.4	56.8	54.3	49.4	45.3	43.1	41.0	39.5	38.8	37.9	37.0	36.8	36.0	1879
Hy. 2631	79	80	72.5	59.6	54.2	49.5	44.5	42.6	41.1	39.8	38.7	38.2	37.9	37.2	35.8	1823
" 2635	72	74	65.4	59.0	54.6	49.8	44.8	42.2	41.1	39.8	38.7	38.1	37.6	37.0	36.0	2022
Dr. 3435	72	70	65.6	59.2	54.1	49.8		41.8	40.3	39.3	38.5				37.3	859

* These stations are all 50 fathoms deeper than the column in which they are placed.

SPECIFIC GRAVITY OF THE OCEAN IN THE PANAMIC DISTRICT.

During the present cruise of the "Albatross," a few observations of the specific gravity of the water were taken.

On February 23, at a depth of 546 fathoms, the specific gravity was as high as	1.027300
While on the surface it was only	1.025700
On February 24, at the surface, Station 3357	1.024700
" " at 600 fathoms " "	1.026912
" 25, at the surface, Station 3361	1.024712
" " at 1,000 fathoms, " "	1.027512
" 26, at the surface, Station 3362	1.024726
" " at 1,000 fathoms " "	1.027120
" 27, at the surface, Station 3365	1.024900
" " at 900 fathoms " "	1.027100
March 1, at the surface, Station 3371	1.024568
" 7, at the surface, Station 3382	1.026160
Cocos Island, at the surface	1.024600
Off Malpelo " "	1.025960
At the Galapagos, off Chatham, at the surface	1.025726
" " Wreck Bay, " "	1.025926
" " at Charles Island, at the surface	1.026126
" " at Duncan Island, " "	1.026126
" " at Indefatigable Island, at the surface	1.025926
" " off Wenman, at the surface	1.025926
April 6, at the surface	1.026912
" 8, at the surface, Station 3414	1.026112
" 11, off Acapulco, at the surface	1.026712
On the trip of the "Albatross" to these waters from San Francisco, the specific gravity of the sea water at the surface, reduced to 60°, off San Francisco, was	1.026160
It gradually increased to	1.026960
And diminished again, near Acapulco, to	1.026520
From Acapulco towards Panama, it gradually decreased to	1.025920
And off Panama passed through streaks as low as	1.024600
On a former trip from Panama to the Galapagos and to Acapulco, the specific gravity in Panama Bay was	1.026160
March 6, 1888, in Lat. 3° 22′ N., Long. 86° 5′ W., on the way to the Galapagos, the surface water had a specific gravity of	1.025726
Off Hood's Island, " " " " " "	1.028316
Off James Island, " " " " " "	1.027916
In Lat. 8° 10′ N., Long. 95° 9′ W., the surface water had a specific gravity of	1.026316
Off Acapulco, the surface water had a specific gravity of	1.026924

The lines limiting the areas of specific gravities given on the chart by Buchanan in the narrative of the "Challenger" will have to be modified as far as they relate to the Panamic District. According to the observations of the "Albatross," the specific gravities are too high off Panama.

Observations on the Pelagic Fauna by the "Challenger," and by Th. Studer in the "Gazelle."

Having always been more or less interested in pelagic faunæ, and having paid considerable attention to its vertical distribution during my earlier cruises in the "Blake," I was naturally anxious to reconcile the conflicting statements and experiences of the naturalists of the "Challenger" and "Gazelle" on one side, and my own observations on the other.

The subsequent observations of Chierchia, of Chun, and of Hensen, and their discussion, have only increased the interest in the problem of the bathymetrical range of the pelagic fauna. Before giving an account of the work accomplished towards the solution of the problem by the present trip of the "Albatross," I will rapidly give the results obtained since the "Blake" experiments.

It should be remembered that Studer's[1] statements were based entirely upon the assumption that the deep-sea Siphonophores, or their fragments, collected by him while in the "Gazelle" from the sounding line, actually came from the depths to which they were attached when the line reached the deck; so that, for instance, a fragment of Siphonophore coming up to the surface at the 650 fathom mark, or any other depth, indicated to Studer that the specimen was collected at that depth. From these observations Studer concluded that "auch die tiefen Wasserschichten nicht unbewohnt sind," and that they did not come from higher levels, the tow-nets of the "Gazelle" having frequently been lowered to a depth of 200 fathoms without bringing up any Siphonophores. He considers that the depth at which the Siphonophores occurred was a definite one, limited by the temperature, — a depth of from 800 to 1,500 fathoms, with a temperature of 2° or 3° Centigrade. The experiments of the "Challenger," on the other hand, consisted in sending open tow-nets down to various depths, and by a differentiation of the contents of the nets at different depths assuming that the changes in the catches were due to the several bathymetrical ranges of the species obtained. As the nets used by the "Challenger" were open tow-nets, all of which, on their way to the surface, passed through the upper and most

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[1] Zeitschr. f. Wiss. Zool., XXXI., p. 1, 1878.

populous stratum of the ocean, it is evident that no great degree of accuracy in determining the bathymetrical range of the pelagic fauna could be claimed for this method of towing. From the mode of making the observations, the catch of all the hauls must have contained representatives of the fauna of the upper belts of water, regarding the geographical range and the composition of which we know as yet but little.

Observations on the Pelagic Fauna by the "Blake."

In spite, however, of the objections urged above, both Murray and Studer contended that, in addition to the deep-sea and pelagic faunæ, there was what might be called an intermediate fauna with characteristic species, having nothing in common with the other two; while I maintained, on the other hand, from my experiments in the "Blake," that there was no such intermediate fauna, but that the pelagic fauna might descend to a considerable depth during the daytime to escape the effects of light, heat, and the disturbing influence of surface winds, and that this surface fauna on the Atlantic side of the United States, off shore in deep water, did not descend much deeper than 150 to 200 fathoms, or some point not far distant from that level, depending of course to some extent upon the latitude of the observation; the lower bathymetrical limits of the pelagic fauna very probably coinciding with the limits to which the action of the heat of the sun, of light, and of other disturbing elements of the surface extended.

The experiments I made on the "Blake"[1] were carried on with the Sigsbee gravitating trap, which worked successfully, and tested the contents of a vertical column of water of any desired height. The only drawback of the original apparatus was its small size. The machine subsequently used by Hensen for his quantitative experiments worked on the same principle, of filtering the whole of a vertical column of water, and examining the results.

Observations on the Pelagic Fauna by the "Vettor Pisani."

The next observations made were those of the "Vettor Pisani."[2] Lieutenant Chierchia devised a net which he asserted could be sent down

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[1] Bull. Mus. Comp. Zoöl., Vol. VI. Nos. 8 and 9, and Three Cruises of the Blake, Vol. I. p. 36.

[2] G. Chierchia, Collezioni per Studi di Scienze Naturali fatte nel Viaggio intorno al Mondo dalla R. Corvetta Vettor Pisani, Commandante G. Palumbo. 1885.

closed, then opened when it had reached the requisite depth, and after towing horizontally for a time closed by means of a propeller similar to the one adopted by Commander C. D. Sigsbee, U. S. N., for closing the water cups in use on the "Blake." Unfortunately, as experience has shown, all the experiments made by the "Vettor Pisani" are vitiated by the imperfect method of closure of the rim of the net, and the danger that it may open or close again and again on its way up to the surface should the hoisting be in the least irregular.

On the 31st of May, at a depth of 1,800 meters, a small net was attached below the thermometer, and tripped at the same time as the thermometer turned free of the propeller; but on examination of the figures of the net in use given on Plate X. by Chierchia, there is no doubt that he is correct in stating, "Anche in questo caso non si può asserire che tutta la quantità di animali trovati appartenga agli ultimi strati ove pescò il retino." So that this experiment at least proves nothing, the partly open net having passed through the upper 250 or 200 fathoms, where there is abundant life.

On the 5th of June the same experiment was again made on the "Vettor Pisani," at a depth of 1,000 meters; but there is nothing to show that, in the surging of the ship and the hauling up, the valves of the net have not opened and closed many times on its way to the surface. The same objection may be made to the haul of the 12th of June, at a depth of 2,300 meters.

The experience which all have had who have dredged at sea, of bringing up fragments of so called deep-sea Siphonophores, was of course also that of the "Vettor Pisani." Chierchia on the 24th of January, 1884, at a depth of 900 meters, let down the wire only, and brought up tentacles of Siphonophores. To insist, as he and Studer have done, that the depth at which these animals lived may be inferred from the length of the rope let out by which they reached the surface, is simply to ignore the fact that the wire rope on its passage upward through the pelagic belt of the fauna may catch anything within those limits. It will be seen that Hensen fully concurs with me in considering the bathymetrical data obtained by collections from the wire rope or the sounding line as of no value.

The fact that the "Albatross" on her last expedition brought up these so called deep-sea Siphonophores, from depths of less than 200 fathoms, in the open tow-net, which had not been sunk below that depth, ought to dispose of the argument of the wire rope catches as meaningless.

The two charts of Zootalassographia given by Chierchia for the Atlantic and Pacific show at a glance the general character of the surface fauna at the various localities at which the "Vettor Pisani" used the tow-net, and also in the Pacific chart the contents of the deep-sea net, and the depths to which it was lowered. But, as I have stated above, there is no proof as yet that the fauna and flora reported by the "Vettor Pisani" as living at the depths indicated by the record did actually live at those depths. We may leave out of consideration the catches of Siphonophores on the dredging and sounding wires, as well as a large number of hauls at depths of 100 to 400 meters, depths which are not in question; and as regards the contents of the self-closing net in use on the "Vettor Pisani," sent to depths in one case as great as 4,000 meters, it would add nothing to the discussion of the greatest depth at which pelagic animals are found, owing to the untrustworthiness of the working of the net. Of course, the same objections hold equally good to the results claimed from the contents of tow-nets sent to depths varying from 1,000 to 2,300 meters.

OBSERVATIONS ON THE PELAGIC FAUNA BY THE PRINCE OF MONACO.

In a German translation by Marenzeller[1] of the notices of the pelagic work of the yacht "Hirondelle" scattered through the Comptes Rendus, will be found an account of the experiments of the Prince of Monaco. Off Monaco he lowered a trap to a depth of 1,200 meters from the surface and 300 meters from the bottom, and obtained a species of Paralepis.

The Prince of Monaco has invented a number of most ingenious pieces of apparatus for collecting the surface fauna and that which may live at intermediate depths, but neither his apparatus nor that of Fol, who has experimented in the same locality, has been sufficiently tested to enable us to judge of its value.[2] Fol's apparatus, from his own account in "La Nature," is very sensitive to the rising and falling of the ship. The Prince of Monaco discarded the use of the Chun-Petersen net, as he found more or less gaping of the mouth frame, after it was supposed to have closed, during the whole of its ascent to the surface.

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[1] Zur Erforschung der Meere und ihrer Bewohner, gesammelte Schriften des Fürsten Albert I. von Monaco, von E. v. Marenzeller, 1891.

[2] His large pelagic beam-trawl, if I may so call it, in use on the "Hirondelle," should prove a valuable machine for collecting surface animals.

The closing net of the "Hirondelle" for deep-sea pelagic work is a somewhat complicated and expensive piece of apparatus,[1] but appears to have worked well, although special data are not at hand regarding the exact depths of its working; and as is sufficiently clear, results obtained in the Mediterranean, or any closed sea like it, as the Baltic, or close to the shores of any mainland, cannot be correlated with those of the open sea, far from the disturbing factors at those localities.

Observations on the Pelagic Fauna by Dr. C. Chun.

The next experiments were those of Dr. Chun, who, under the auspices of the Naples Zoölogical Station, made an expedition to the Ponza Islands. Dr. Chun and the engineer Petersen applied to a tow-net an apparatus for closing it, similar to the propeller in use on our thermometers and water cups. Chun towed to a depth of 1,300 to 1,400 meters, but never at any great distance from the mainland or from the islands of the Gulf of Naples, and came to the conclusion that the pelagic fauna existed all the way to the bottom.[2]

In a notice of Chun's memoir on the results of this expedition, I questioned the conclusions to which he had arrived, and quote the following *résumé* from the American Journal of Science[3]: —

"Unfortunately, this expedition, interesting as its results are, does little towards settling the subjects under discussion, because neither the distance from shore nor the depths investigated were great enough to eliminate the disturbing effects of close proximity to land, as it was near the continental slope, on the very edge of which Dr. Chun trawled with the tow-net. The results are further vitiated from the fact that they have been carried on in a closed sea where the conditions of temperature are strikingly different from those of the Atlantic, and where at a depth of about 500 fathoms we find already the lowest temperatures of the deepest part of the Mediterranean. The minimum seasonal differences of temperature between that and the surface cannot be contrasted to oceanic conditions."

On his trip to the Canary Islands, his second pelagic fishing expedi-

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[1] Compte-Rendu des Séances du Congrès Internat. de Zoologie, Paris, 1889, pp. 133–159.

[2] Bibliotheca Zoologica. I. Die pelagische Thierwelt in grösseren Meerestiefen und ihre Beziehungen zu der Oberflächenfauna, 1887.

[3] A. Agassiz, in Am. Jour. of Science, Vol. XXXV. p. 421, May, 1888.

tion,[1] Chun was provided, as he says, with a line for pelagic fishing of a length of 1,600 meters.

During the journey Chun made seven casts, at depths varying from 500 to 1,600 meters. The casts are certainly not numerous enough to furnish a basis for a general theory. Two of the casts were at depths of 500 and 1,000 meters, not very distant from Cape Finistère, while another cast of 500 meters was made off Funchal, and the cast of 1,600 meters was made between Teneriffe and Gran Canaria, where he speaks of making a pelagic haul at a depth of 1,600 meters with a line only 1,600 meters long. He must, of course, have lowered his net vertically, and Chun can hardly expect any one practised in dredging or towing to accept the depth he gives as the correct bathymetrical limit at which the two specimens he brought up were collected. Furthermore, all of these casts except one, perhaps, are open to the objection of having been made at comparatively small distances from land; and, taking Chun's own account, the casts of 500 meters, say 250 fathoms, contain, judging from his list, about the same amount (somewhat less) of pelagic material as was found in our "Albatross" hauls with the tow-nets at depths of about 200 fathoms.

Furthermore, he says: "kam es bei den früherhin im Mittelmeer angestellten Versuchen gelegentlich vor dass durch den starken seitlichen Druck, welche die sich auslösenden Drähte auf den mit einem Schraubengewinde versehenen Messingstab ausübten, ein Öffnen und Schliessen des Netzes nicht erfolgte, anderseits blieb nach dem Schluss des Netzes gelegentlich ein schmaler, etwa fingerbreiter Spalt zwischen den beweglichen Hälften des Rahmens frei."

I need not say that an opening of half an inch wide and nearly two feet long at the mouth of the net will, in its ascent through a distance of 200 fathoms of the upper belt of the pelagic fauna, suffice to sift into the bag enough material to vitiate all accurate conception of what lives *below* that belt. In his expedition to the Canary Islands, these defects were said to be remedied by Chun, and the modified net was used by him during his voyage at depths of 500, 1,000, and 1,600 meters. But Hensen is of the opinion that the modified net is still defective, and that its results cannot be relied on. There seems to be no reason why these self-closing nets should not be placed serially on a line, as are thermometers, and then we may expect to get accurate results. If this be impracticable, we can, at any rate, use the nets at the same locality at

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[1] Untersuchungen über die pelagische Fauna der Canarischen Inseln, von Carl Chun, Sitzungsb. d. König. Preuss. Akad. d. Wiss. zu Berlin, XXX., 1889, p. 519.

different depths, as I attempted to do on the "Blake," and have done more successfully on the present trip on the "Albatross." It is important to give at the same time the depth of the bottom and the distance from land, both most essential factors, to which neither Chun nor Hensen has paid sufficient attention.

In discussing the value of Chun's observations made on his way to the Canaries, we should remember that of the three casts with the closing net one was taken at a moderate distance off shore from Cape Finistère. The only strictly oceanic cast was his No. V., Lat. 34° 18′ N., Long. 15° 34′ W., and even that, if plotted, will be found remarkably close to the bank extending in a northeasterly trend from Madeira. This bank as marked is inside the 1,500 fathom line, and has many points the depths of which are near 500 fathoms. But leaving this out of consideration, his catch at that point consisted only of a single Copepod[1] and a Phaeodaria, and even these may have come from near the bottom. At any rate, we can hardly consider such a catch as indicating the presence at that depth of an abundant pelagic fauna.

As for the work accomplished by Chun at the Canaries, that strikes me as vitiated by the same disturbing factors to which I have already alluded. It can certainly not be called oceanic. The most distant of the Canary Islands is not more than 225 nautical miles from the coast, and the nearest less than forty, so that the pelagic fauna is under the influence, of all the disturbing elements of a coast line within a short distance. The very fact that so much surface pelagic material accumulates around the islands is the best evidence of this. We are therefore still left, so far as the distribution in depth of the pelagic fauna is concerned, to the few observations I made on the "Blake" (*pace* Haeckel), to that one of Chun mentioned above, to those of Hensen in the "National" expedition, and to those of the last expedition on the "Albatross." I am leaving out as not conclusive those of the "Vettor Pisani." The positive results of all these hauls clearly indicate that the bulk of the pelagic fauna is limited to a depth not exceeding 200–250 fathoms, and that then it rapidly decreases.

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[1] The material collected by Chun was worked up by Claus in Arbeiten aus dem Zoöl. Inst. d. Univ. Wien, IX., 1890, I. p. 1. Of the new species described, "Die Gattungen und Arten der mediterranen und atlantischen Halocypriden," six said to have been collected at 1,500 and 1,000 meters were also collected at the surface. No less than nine species have a wide geographical distribution, and those brought up from deep water in the proximity of land or near the Canaries of course add nothing to our knowledge of their oceanic bathymetrical distribution.

But until our reports give us the exact depth of the bottom, together with the results of the tow-nets from the so called intermediate deep-sea pelagic life, there is nothing to show that the contents of the nets may not have come from a belt of water close to the bottom, about which there has as yet been no discussion.

The occurrence of animal life within a moderate distance of the bottom is a question which is not to be confounded with that of the lower limit in depth of the pelagic fauna. These two zones may meet at depths of 500 to 700 fathoms, under favorable conditions of distance from shore, and give the impression of a continuous fauna from the surface to the very bottom. Undoubtedly a great deal of the confusion which has arisen regarding the lower limits of the pelagic fauna is due to differences in our understanding of what we call deep water. To a deep-sea dredger the limits of the bulk of the pelagic fauna, whether it turn out to be 200, or 250, or even 300 fathoms, is naturally shallow water. To one who has been accustomed to tow merely on the surface, 50 to 100 fathoms are already deep water, and depths below that seem enormous.

This last expedition of Chun — which made one oceanic cast! — marks, so Haeckel states, the greatest progress in marine biology since the "Challenger" expedition.[1] Yet he discards the results obtained from the oceanic hauls of the "Blake," which are the only accurate ones made up to the time when Hensen entered the field. He also considers Hensen's work worthless, probably because for over three months he explored the surface of the Northern Atlantic as it had not been done before. Unfortunately, Hensen's results do not chime with Haeckel's preconceived ideas, and they are naturally condemned because they do not show below 200 fathoms the existence of a populous pelagic fauna, which Haeckel had decided ought to exist down to great depths, and which he assumes the catches made by the defective net in use in the "Vettor Pisani" and those of the open nets of the "Challenger" to have conclusively proved. Taking all these positive results, as Haeckel is pleased to call them, and adding to them the equally fictitious statements regarding the presence of an intermediate pelagic fauna, based upon the fact that the so called deep-sea Siphonophores were found on the sounding wire and dredging rope of various expeditions, he gets a formidable array of incomplete data, brought together by defective methods. Upon these grounds he bases results for which more recent investigations, carried on with improved machinery, furnish as yet no

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[1] I need not say that Chun makes no such ridiculous claim for his few experiments as are put forth by Haeckel.

proof. The later results are of course, as Haeckel says, in absolute contradiction to former experiences. Hence their great value, and the burden of proof is not upon the recent explorers, but upon those who build castles in the air based on the incorrect data obtained by the earlier expeditions. They have got to show that what they obtained from these great depths did not come from the upper belt of the pelagic fauna, from 250 or 300 fathoms in depth, up to the surface.

The Pelagic Fauna and the "National" Expedition.

It is a great merit of Hensen's [1] explorations, that he was the first to see that the quantitative measurements of the pelagic fauna could only be reached by the examination of the contents of a vertical column of water. This, if examined from the point of its minimum density upwards to the surface, will very nearly represent the total amount of life which lives in any given locality. We may by thus fishing upwards get at any locality practically all that is characteristic of it, whether the fauna has congregated at the surface or near it, or at any other part of the pelagic faunal belt, owing to the peculiar conditions of light, heat, wind, and weather.

In the "National" expedition in charge of Hensen,[2] the Plankton fishing hauls were limited to depths of 200 to 400 meters, and, if I understand the statements of Dr. Brandt[3] correctly, several hauls were made at the same spots to determine the vertical distribution of the pelagic organisms. A modification of the Petersen-Chun net was also used in the "National" expedition, and according to Hensen and Brandt there are still found in very considerable depths between the surface and the bottom "noch Organismen leben allerdings sehr viel weniger als in den oberen, von Licht durchstrahlten Wasserschichten." The number of indviduals decreased very materially the deeper the net was sunk, and there was also a rapid decrease in the number of species. Only Copepods and certain Radiolarians (Phaeodariæ) were found living at depths of 3,500 meters. Five casts from 3,500 to 2,000 meters contained nothing except Copepods and Phaeodariæ. Nearer the surface, from 2,000 to 1,000 metres, Sagittæ were added to the above groups, besides

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[1] Hensen, V., Ueber die Bestimmung des Plankton's. Fünfter Bericht der Kommission zur wiss. Untersuchung der deutschen Meere in Kiel. 1887.

[2] Die Plankton Expedition von Victor Hensen, 1891.

[3] K. Brandt, Verhandl. d. Gesell. f. Erdkunde, Berlin, 1889, p. 515. Ueber die biologischen Untersuchungen der Plankton-Expedition.

single individuals of Siphonophores, Craspedote Medusæ, Ostracods, Amphipods, Decapods, Salpæ, Doliolum, and young fishes. Eleven casts from 1,000 to 600 meters gave similar results, only the diversity was still further increased by the presence of Schizopods, Pteropods, Alciopidæ, and Tomopteridæ. How far these animals were the dead or recently dead carcasses of the mass of pelagic life living nearer the surface is of course not known, and, while hauling up from great depths through the column of water lying below the 200 fathom pelagic belt, we might expect a goodly number of such finds among the presumed inhabitants of the depths at which the self-closing net was operated.[1]

It must be remembered that, while many of the pelagic animals are most delicate, and decompose after death with great rapidity, yet when sinking from the surface towards the bottom these dead or dying organisms, soon reach a belt of water in which the low temperature as compared to the surface would prevent any very active decomposition, and the cold itself of the lower belts may be one of the causes of the limitation in depth of the bathymetrical range of the pelagic fauna. Moseley has found by experiment that a Salpa would take about four days to reach the bottom in a depth of 2,000 fathoms.

A few Velellæ, no Physalia, but a few Porpitæ, were met with, while Diphyes occurred in nearly all the hauls, either with the surface or with the vertical net. About twenty casts were made to determine the occurrence of organisms near the bottom, but owing to the failure of the sounding machine and its uselessness it was impossible to tell what the depth was, as the Sigsbee machine was not, according to Krümmel and Brandt, constructed according to specification, and gave out after the fifth trial; and hence no data of the depth of the bottom accompany the casts for the determination of the intermediate fauna.

To those of us who have been accustomed to fish for the pelagic fauna along the course of the Gulf Stream and off the east coast of the United States, it seems incredible, as is asserted by Hensen, that the pelagic fauna of the Atlantic is much poorer than that of the North Sea or the Baltic.

The success of the Plankton expedition in making their best surface hauls on the lee side of the ship is not a new experience to old fishermen. In all our dredging expeditions the lee side of the ship naturally has invariably been used to catch floating pelagic stuff, and the tow-net is always placed on that side. The floating tow-net of the "Hirondelle,"

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[1] There being no description of Hensen's self-closing net, we cannot judge of the value of his results as settling the existence of a deep-sea intermediate fauna.

a pelagic trawl, seems to have escaped the notice of Brandt and Hensen, and a huge tow-net has been in use by the "Albatross" for many years.

I find it difficult to agree with Hensen's statement that it "is nonsense to think one can run the tow-net at a given depth horizontally, and that it is therefore mere waste of money to equip for this object." Certainly no one will claim to have towed along a mathematical line. All the variables which enter into the question as to the depth at which the net has been towed, — the speed of the vessel, the weight of the rope, its resistance as well as that of the net, and the shot which loads the extremity of the line, — undoubtedly make it a most intricate mathematical problem. But practically there is no such impossibility in keeping the tow-net within a very moderate distance of the required depth, and making constantly a careful record of the angle at which the line tends from the dredging boom. In our practice the net is first lowered vertically to the required depth, then the line is let out gradually, so that its length plus a small amount, taken from logarithmic tables, will represent the hypotenuse and catenary of the triangle along the base of which the net moves with a given speed which is carefully regulated by the angle of the rope. The shot used to sink the rope and net is a 200 pound shot, and a 60 pound shot at the end of the net halyards. This is about the weight of the wire rope to a vertical depth of 300 fathoms. The Tanner dredging quadrant angle-indicator[1] is in constant use to regulate the speed, and we feel satisfied from our extended practice that the difficulty of keeping the tow-net, say for fifteen or twenty minutes, at or near a given depth is comparatively slight, although the constant mathematical calculation of the exact position of the net is wellnigh impossible. The elements of error in estimating the height of the column of water passed through by the tow-net while towing vertically are equally great, and the same variables which Hensen enumerates as impossible of satisfactory reduction apply equally well to the rigid mathematical calculation of the height of the column through which the tow-net has passed. And yet he must be perfectly satisfied with his approximate measurement of that vertical column.

Hensen evidently does not think it of importance to limit the towing to a short column; his net closes after travelling 250 meters, and of course everything in that column is filtered through his net. Hensen has called attention to the danger of Chun's net opening on its way down, and also closing so that it would bring up nothing, leaving it

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[1] Plate XXVIII., Appendix A, Report of the Commissioner of Fish and Fisheries for 1883, Washington, 1885.

uncertain whether the result was due to there being nothing at certain depths or to the action of the net itself.

While it is true that we made no volumetric or quantitative measurements of the material obtained by the tow-net, yet as we invariably used the same large pan, filled to about the same height, for the washing out of the contents of the tow, and as this water was then carefully examined in smaller dishes, it was not a difficult matter to make comparisons, which, though not quantitatively accurate as those of Hensen, yet differed sufficiently to show us a degree of variation in the quantity of pelagic animals far greater than that admitted by him. Hensen very justly says (p. 71): "Da sich die Massen im Ocean bei zu dieser Tiefe (400 m.), wenngleich mit abnehmender Dichte vertheilen, so ist es unzweifelhaft, dass dort selbst bei grossen Fängen die Dichte des Planktons nur gering ist." He adds in a note: "Die Bestimmung, wie die Massen nach der Tiefe zu abnehmen, erfordert genauere Analyse der gemachten Fänge, als bisher ausgefürt werden konnte; *die Hauptmasse findet sich meistens an der Oberfläche.*" The italics are mine.

It seems to me as if Hensen had himself given here an excellent reason for the value of fishing horizontally or in limited vertical ranges, neither of which he considers of any value.

Hensen's views regarding the depth at which the so called deep-sea Siphonophores exist are as follows: "Das Vorkommen von Fangfäden an Lothleinen [or also dredging wires] ist an und für sich überhaupt kein Beweis, den diese Leine geht zweimal durch die Oberfläche und kann hier alles fangen."

The discussion of Hensen regarding the accumulation of pelagic animals along extended rows I cannot understand. That such winrows exist near the shores he himself admits; that they are due near the coast to the greater or less interference of the complicated shore tidal currents seems to me self-evident. The action of counter currents and eddies complicated by the action of the prevailing winds is so well known to collectors at special localities that at certain stages of tide and wind one may feel sure of finding these accumulations at given points. That such winrows also occur on the track of great oceanic currents has been my experience in the Caribbean and Gulf of Mexico, in the Gulf Stream from 150, 200, or 250 miles from the coast, and that there they are also probably due to similar eddies and counter currents acted upon by the prevailing winds.

The Gulf Stream, with its ever fluctuating belts of currents, its rips, and the great Equatorial Current off Panama, with its bands of colder and warmer water, its velocities from little or nothing to five or six knots, and its endless counter currents and eddies, did produce such winrows on several occasions at great distances from the shore, — over 600 miles. That these accumulations of pelagic animals on the surface are intensified on calm, brilliant days, goes without saying. How far they retreat below the surface when they disappear, we do not yet know. Such accumulations continue sometimes for a whole season on the surface. We have had at Newport Salpæ rendering surface fishing absolutely useless for more than six weeks, and again Ctenophores have been as great pests for as long a period, later in the fall.

The most extraordinary winrows I have met were off the Tortugas, about 150 miles to the northward, where the surface of the Gulf of Mexico for a whole day's steaming swarmed with Globigerinæ. It was a dead calm. Again, steaming from the Tortugas to Key West, a distance of sixty miles, outside the reef, we kept in sight a long comparatively narrow line of Linerges all the way from one locality to the other, and it extended eastward as far as the eye could reach beyond the entrance to Key West harbor.

Again, in the track of the Gulf Stream we passed for a quarter of a mile through a stretch of Trichodesmiæ of a width of about a hundred yards judging from the discoloration of the water. And in this last cruise, when about half-way from Cape San Francisco to the Galapagos, we remained for a whole day within the belt of a swarm of Nautilograpsus, the current running at the rate of nearly four knots in twenty-four hours. Again, for more than seven hours we steamed against a current of about three miles through a field of gigantic Salpæ, which extended on each side of the ship as far as one could see. Finally, we passed through winrows of a new species of Siphonophore, a gigantic species allied to Praya, which filled the water in compact masses on all sides of us as we slowly forced our way through it between our dredging stations on the way to Cocos Island from Point Mala.

Hensen, in his quantitative analysis of the pelagic fauna, does not seem to have given sufficient weight to the changes due to seasons, to currents and winds, and to local influences, and in his earliest experiments, dating back to 1882, and carried on from Kiel to the Danish islands, he has disregarded many important variables noticed by other observers.

He himself mentions the sudden occurrence, on the Scottish coast,[1] of

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[1] We should remember that all observations made on the Scottish coast, the North Sea, and Baltic are within the area of the 100 fathom line, and at no great distance from land.

swarms of Limacina, and of Sarsia and Aurelia[1] in the Bay of Kiel, and contrasts these swarms with the poverty of the surface of the sea far from land. We are scarcely justified in assigning the presence of food as the cause of the sudden appearance or disappearance of these swarms of pelagic animals, and we cannot entirely agree with Hensen when he asserts that the Pyrosomæ, Salpæ, and Ctenophoræ occur in limited schools, depending upon the influence of the richer or poorer Plankton. A single day in a given locality is certainly not sufficient time to allow for such a change in the food supply of the sea as to account for the sudden appearance at sea or along our coasts of such masses of Salpæ, of Ctenophoræ, and of Diphyes as often render all attempts at surface or other pelagic fishing hopeless.

It is true that in our experience we have frequently (in the open sea) passed over extensive tracts where the surface fishing was comparatively unproductive; but we have rarely been twenty-four hours without finding some district which more than made up for the poverty of its neighborhood.

Haeckel's Plankton Studies.

In Haeckel's historical sketch of the study of the pelagic fauna,[2] no well informed reader can fail to notice the absence of reference to most of the work done by Americans in this field. Surely, no investigator is justified in omitting from a general review of this kind the older literature on the subject. We naturally suppose that no one willingly ignores the work of his predecessors, and, indeed, any one may be excused for not having at hand the latest pamphlet on a given subject. But there is no such valid excuse for disregarding contributions which date back ten or more years, and have been regularly noted in the annual reports of progress in zoölogy, in order to give undue prominence to publications which deal only indirectly with the subject in hand.

If Haeckel had taken the pains to look up the literature of his subject, he would have found that there has been a vast amount of surface work accomplished by the American dredging expeditions, and that, while it is true that much of this material has not as yet been worked up, still it is not probable that any sea-coast has been so carefully explored as has the east coast of the United States along its immediate shores, and along the course of the Gulf Stream, by the "Fish-Hawk," the "Blake,"

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[1] Swarms of Aureliæ, forming huge patches which discolor the surface of the sea over considerable areas are not uncommon in Massachusetts Bay.

[2] Plankton-Studien, von Ernst Haeckel, Jena, 1890.

and more especially by the "Albatross," which has invariably, during more than six seasons, used the surface tow-net and an open deep-sea tow-net in connection with its other work, and which has been duly recorded in the Annual Reports of the United States Fish Commission.

As early as 1865, in the "Seaside Studies," a sketch of the pelagic surface fishing off the coast of Massachusetts was given. In addition to the chapter on the Pelagic Fauna of the East Coast of the United States given in the "Three Cruises of the Blake," papers on the surface fauna of the Gulf Stream, on the pelagic stages of fishes, and numerous notices scattered through various embryological and faunistic memoirs,[1] there is an account of the fauna of the surface water of the Gulf Stream off New England, drawn up by Professor A. E. Verrill[2] from the material collected by the United States Fish Commission during many seasons' work, up to 1883.

The "Albatross" used a number of muslin nets (silk bolting cloth), known as "trawl rings," attached to the ends of the trawl frame, so as to be somewhat above the bottom, and many pelagic species have been

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[1] Seaside Studies, by E. C. and A. Agassiz, Boston, 1865.

See also remarks on the occurrence of pelagic types, by A. Agassiz, scattered through the following papers: —

The Embryology of the Starfish, 1864, reprinted in Mem. Mus. Comp. Zoöl., Vol. V. No. 1, 1877.

Revision of the Echini, Ill. Cat. Mus. Comp. Zoöl., No. VII. Part IV., 1872–74.

North American Acalephæ, Ill. Cat. Mus. Comp. Zoöl., No. II., 1865.

Surface Fauna of the Gulf Stream, Mem. Mus. Comp. Zoöl, Vol. VIII. No. 2, 1883, and other papers on the Embryology of New England and Florida Invertebrates.

Embryology of the Ctenophoræ, Mem. Am. Acad., Vol. X. No. III., 1874.

Pelagic Stages of Young Fishes, by Agassiz and Whitman, Mem. Mus. Comp. Zoöl., Vol. XIV. No. 1, 1885.

On the Young Stages of Bony Fishes. I. Proc. Am. Acad., XIII., 1877–78; II. Ibid., XIV., 1878–79; III. Ibid., XVII., 1882.

Bull. Mus. Comp. Zoöl., Vol. VI. No. 8, Letter No. 4, 1880.

Bull. Mus. Comp. Zoöl., Vol. VI. No. 9, 1880, Sigsbee's Gravitating Trap.

Am. Jour. of Science, 1888, Vol. XXXV. p. 421, Review of Chun's Die Pelagische Thierwelt.

Three Cruises of the "Blake," by Alexander Agassiz, Bull. Mus. Comp. Zoöl., Vols. XIV., XV., 1888.

And, finally, Three Letters from Alexander Agassiz to Col. Marshall McDonald on the Cruise of the "Albatross" in 1891, Bull. Mus. Comp. Zoöl., Vol. XXI. No. 4, published before Haeckel's Plankton-Studien had reached this country.

[2] Results of the Explorations made by the U. S. Fish Commission Steamer "Albatross," Lieut. Z. L. Tanner commanding, off the Northern Coast of the United States in 1883, by A. E. Verrill, Washington, 1885. Annual Report of the Commissioner of Fish and Fisheries for 1883.

obtained which have not occurred in the surface nets. Of course, as Professor Verrill remarks, it is impossible to know whether such species actually live at or near the bottom, at the surface or in intermediate depths, for they are liable to enter these nets at any time during the descent or ascent of the trawl, as well as during the time that it drags on the bottom.

There is also a more detailed account of the Medusæ collected by the "Albatross," by J. Walter Fewkes, in the Annual Report of the Commissioner of Fish and Fisheries for 1884, Washington, 1886; but to give the lists of depths, varying from the surface to 2,369 fathoms, of specimens brought up with the trawl or in the "trawl rings," does not add to our knowledge of the bathymetrical range of the Medusæ collected. These localities and depths would have supplied Haeckel with many valuable bathymetrical stations. It is astonishing that he should not have availed himself of such appropriate data.[1] We can only suppose that Haeckel wilfully ignores whatever does not bring grist to his mill, or does not chime with his preconceived notions of the order of nature.

If Haeckel had taken the trouble to read the statements I made regarding the bathymetrical range of pelagic life,[2] he would have found that I stated in the "Three Cruises of the Blake" (Vol. I. p. 37): "These experiments serve to prove that the pelagic fauna does not extend to considerable depths, and that there is at sea an immense intermediate belt in which no living animals are found, — nothing but the dead bodies which are on their way to the bottom." I may also refer Haeckel to another and similar statement in the same volume (p. 202), in the chapter on the Pelagic Fauna and Flora: "The above experiments appear to prove conclusively that the surface fauna of the sea is really limited to a comparatively narrow belt in depth, and that there is no intermediate belt, so to speak, of animal life, between those living on the bottom, or close to it, and the surface pelagic fauna. It seems natural to suppose that this surface fauna only sinks out of reach of the disturbances of the top, and does not extend downward to any depth. The dependence of all the pelagic forms upon food which is most abundant at the surface, or near it, would naturally keep them where they found it in quantity." And again (p. 178): "How far down the pelagic fauna sinks during the day or night, to get out of reach of disturbances, is not

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[1] Haeckel likewise omits all reference to the experiments of the Prince of Monaco, as well as those of Professor Fol off the Riviera.

[2] Bull. Mus. Comp. Zoöl., Vol. VI. Nos. 8, 9, 1880. Letter No. 4, on the results of the third cruise of the "Blake," and description of Sigsbee's gravitating trap.

yet accurately known; we can only form a rough guess from the few experiments made on the 'Blake.' . . . The lowest point is probably not far from 150 fathoms, which is perhaps the limit also of the greater superficial disturbances of heat, light, and motion, within which we may imagine the pelagic fauna to oscillate."

I also stated, in 1888 (Am. Jour. of Science, Vol. XXXV. p. 422): "Neither can the method adopted on the 'Blake,' of collecting at intermediate depths by means of the Sigsbee collecting cylinder, be considered decisive. It has not been tried long enough, or frequently enough, at great depths (it was not carried beyond 150 fathoms) to decide the depth to which the surface pelagic fauna might sink, or to prove the existence of an intermediate deep-sea fauna in the depth between the surface fauna and the deep-sea fauna."

I would also recommend to Haeckel's notice the following statement, by Murray, which is in full accord with the experience of the cruises of the "Blake" and of the "Albatross": "Mr. Murray's[1] researches led him to conclude that the great majority of pelagic organisms live at various depths, down to and even deeper than 100 fathoms, during the day-time and rough weather,[2] and only come to the surface during the night and in calm weather."

Both Thomson and I were careful to state that the question of the bathymetrical range of the pelagic fauna could only be definitely settled by the use of tow-nets so constructed as to tow horizontally at intermediate depths, and capable of being closed at will.

As for the proposition I enunciated that the deeper parts of the ocean contained no organic life, and not, as Haeckel says, "dass die Pelagische Thiere nicht tiefer als 100 Faden hinabgehen"; that must stand or fall, or be limited by explorations of a very different character from those of the "Challenger." It is childish for Haeckel to state that the so called exact experiments of the "Blake" are absolutely contradicted by the positive results of the "Challenger." If Haeckel is satisfied to base his

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[1] Voyage of the "Challenger," Narrative of the Cruise, p. 218.

[2] Hensen considers the great percentage of water which enters into the composition of pelagic animals as a cushion against shocks, while the animals form, as it were, part and parcel of the surrounding medium. I may refer here to some measurements I made regarding the quantity of water entering into the composition of Echinoderms and Acalephs, which show how small a percentage of animal tissue they contain. For a large Cyanea there was no less than 99 per cent of water. The differences in the percentage of water contained in the tissues of pelagic types may account for their greater or less sensitiveness to the disturbing influences of waves and winds. See Proc. Bost. Soc. Nat. Hist., 1869, Vol. XIII. p. 107.

views on the population of the intermediate deeper parts of the ocean upon the positive results of the "Challenger" tow-nets, we must leave him to the full satisfaction of his belief. Haeckel's ideas of exact experiments must be very peculiar, if he imagines that an ordinary tow-net dropped to any depth, and then towed open all the way to the surface, will give us any exact data as to what is living at the deepest point reached. No amount of differential work will prevent that tow-net from gathering the pelagic fauna of the upper belt of 200 to 300 fathoms, which all the recent explorations at sea have shown to contain the greater mass of the pelagic fauna.

The dogmatic assertions of Haeckel regarding the value of the results obtained by the "Challenger" tow-nets are in marked contrast with the cautious statements of Sir Wyville Thomson, and they may be reproduced here for the benefit of Haeckel.

In the first place, the tow-net experiments of the "Challenger" were only conducted during the last part of the cruise: "In the investigations with the towing-net, made by Mr. Murray during the latter part of the cruise—at all depths, the nets being either sent down independently to the depths required, or attached to the dredge or trawl rope";[1] and while it is true that Thomson thought "that Radiolarians inhabit the water of the ocean throughout its entire depth, or, at all events, its upper and lower portions,"[2] yet we find in his summing up of the results obtained from the tow-nets the following statements:—

"We have every reason to believe, from a series of observations, as yet very incomplete, with the tow-net at different depths, that while foraminifera are apparently confined to a comparatively superficial belt, radiolarians exist at all depths in the water of the ocean. At the surface and a little beneath it the tow-net yields certain species; when sunk to greater depths additional species are constantly found; and in the deposit at the bottom, species occur which have been detected neither on the surface nor at 1,000 fathoms, the greatest depth at which the tow-net has yet been systematically used; and specimens taken near the bottom of species which occur on or near the surface give us the impression of being generally larger and better developed. The results from the tow-net are not so directly satisfactory as those from the trawl or dredge, which usually bring up animals which we know from their nature must have lived on the bottom, and it requires a little consideration to arrive at their precise value. . . . At present the tow-net, which

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[1] Challenger, Atlantic, Vol. II. p. 341.

[2] Ibid., p. 340.

consists simply of a conical bag of muslin or buntine attached to an iron ring, is constantly open, — descending, dragging along, and ascending. If worked on the surface there is of course neither difficulty nor question, but if brought up from 500 fathoms, at which depth it has been towing for some time, the net may be supposed to contain chiefly the species living at that depth; but mixed with these there must be a considerable number of more superficial forms, some taken when the net was going down with its open mouth downwards, and many more captured during its long ascent of half a mile through the upper layers. We cannot therefore as yet say with certainty whether the surface species live in the deeper belts or not, but we are justified in concluding that species which are absent on the surface, and present only when a certain depth has been gained, are special to that and probably to greater depths. If again species differing both from those procured on the surface and at intermediate depths are found in the bottom deposits, it is a legitimate inference that these live below the zone of our deepest tow-net observations."[1]

The expedition of the "National," much as it has been ridiculed by Haeckel[2] and his champion, Carus Sterne,[3] has done more to show that the pelagic fauna is a very scanty one to below 200 fathoms (400 meters) than all the work of all the other explorers together. The object was to work up the "Plankton." It is true it was not worked up according to Haeckelian methods,[4] but it has the immense advantage of being accurate, and not being based either upon guesses or upon misrep-

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[1] Challenger, Atlantic, Vol. I. p. 236.

[2] In his attack on Hensen's work, Haeckel constantly refers to the "Ziele u. Wege der heutigen Entwickelungsgeschichte," Jena, 1875. In the present diatribe, he has almost surpassed his former achievements. Such contemptible attempts to overwhelm one's opponents with calumnies as are printed on pages 80 and 81 of the pamphlet referred to above are in accordance with his customary mode of argument.

[3] Rundschau, March, 1891.

[4] I quote from Hensen's Die Plankton-Expedition und Haeckel's Darwinismus, (p. 9): "Der Angriff auf die Expedition . . . kann vielleicht viel schaden, den er wird getragen von einer Autorität und wird begründet mit einer so grossen Anhäufung von einseitig gedeuteten Thatsachen, dass jeder mit den Verhältnissen nicht genau Vertraute davon überzeugt wird, dass die Plankton-Expedition völlig verfehlt sein müsse. Dennoch ist solche Ueberzeugung nur auf Sand gebaut und steht in völligem Wiederspruch mit den Thatsachen; und zwar nicht nur mit denjenigen, welche unsere Expedition nachweist, sondern, wie ich zeigen werde, selbst mit den Berichten, welche andere Expeditionen gegeben haben, sofern man dieselben nur richtig versteht."

resentations and scientific dishonesty, nor is it bolstered up or strengthened by abuse of one's opponents.

The majority of the organisms of the so called intermediate oceanic zones, as enumerated by Haeckel, have thus far proved to be inhabitants of the upper belt of less than 300 fathoms from the surface, and his attempts to subdivide this comparatively narrow belt of vertical distribution by expanding it to depths of which nothing is known, is thoroughly Haeckelian.

I can imagine no more disingenuous statement than the following, where Haeckel is speaking of Murray's account of the probable contents of the "Challenger" tow-nets coming up from great depths: "Er konnte aber dabei nicht dem Einwand entgehen, dass der Inhalt dieser beständig offenen bleibenden Taunetze aus sehr verschiedenen Tiefen, *oder auch nur von der Oberfläche stammen könne.* Den beim Heraufziehen des offenen Taunetzes konnten *möglicherweise* Thiere aus den verschiedensten Tiefen-Zonen *zufällig* in dasselbe hineingelangen." The italics are mine, and the kindness of the inhabitants of the deep in marshalling themselves, for Haeckel's[1] special edification, according to the depth from which they came, must be self-evident.

The subdivisions of bathymetrical distribution of the Radiolarians in the intermediate zones adopted by Haeckel are based upon the kind of evidence detailed above. Their true value, as well as that of the new nomenclature he has been good enough to flood us with in order to denote his imaginary bathymetrical ranges and their organic contents, can be accurately measured by those who do not allow themselves to be deceived by the dust and mud thrown up by Haeckel in the discussion of this subject.

I should be the last to question the indefatigable industry of Haeckel, which has produced the Monographie der Radiolarien, the System der

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[1] It is one thing to clear up an old subject and introduce precision by a judicious manufacture of new terms, but it is quite another thing to burden a comparatively new and confused subject with such a superabundance of new names as are found in Haeckel's "Plankton-Studien." Moseley, in his Address on Pelagic Life, in 1882, was among the first to distinguish the different elements which go to form the pelagic fauna and flora, and his analysis has formed the basis of the endless subdivisions baptized by Haeckel. It is unfortunate that the value of Haeckel's analysis should be limited in so great a degree to his redundant terminology. Haeckel has enriched our nomenclature of deep-sea and pelagic faunistic combinations with a few dozen names which correspond usually not to anything known from observation or existing in nature, but to the pigeon holes skilfully put together by him.

Medusen, the deep-sea Medusæ, the Siphonophores, and the Radiolaria of the "Challenger" expedition. Yet I must remind the reader of Haeckel, that, in spite of the graphic account he gives of his own pelagic studies,[1] and in spite of his activity as a surface collector from localities near shore, he has had no experience whatever at sea of the sort of pelagic work which he so complacently condemns *ex cathedra*. The observations on the pelagic fauna on which Haeckel prides himself, made as a passenger in an East India steamer running from Suez to Bombay and to Ceylon, are of necessity, like its phosphorescent track, somewhat superficial.

The assumption made by Haeckel's satellite, Carus Sterne, that the cost of this expedition might have been saved had Haeckel been consulted as to its probable value, is as silly as it is unscientific. But it is fully in accordance with the dictum of the zoölogical pope at Jena that such an expedition was useless because he did not believe in its results. It is surprising that no one should as yet have objected to the cost of printing so many zoölogical fancy sketches as have come from Haeckel's facile pencil.

The account given by Haeckel of the distribution of the pelagic fauna and flora is premature, and as an accurate catalogue representing our knowledge is worthless. No attempt has been made to eliminate data which are in the least doubtful, but everything is enumerated as a correct observation of depth from the contents of the open townets of the "Challenger" to the material brought up on dredging and fishing lines and in the imperfectly self-closing nets of the "Vettor Pisani." The material obtained by Chun in the Mediterranean is not compared with that of the oceanic basins, and of the doubts which Chun himself and Hensen have thrown on the efficiency of the Petersen-Chun net he does not even speak. As a mere enumeration of the surface material, Haeckel's account will be useful if the future observer learns to separate fact from fiction.

The first observations of Chun,[2] as I have already stated, were made comparatively near shore and in the Mediterranean to a depth of 1,400 meters, and the conditions existing there or in the deep fiords of the coast of Scotland are of no value regarding the extension of the pelagic fauna in an open oceanic basin; and it certainly is noteworthy that Hensen should have considered it sufficient to explore a belt of only 400 meters in depth, to get an adequate idea of the Plankton of the Atlantic Ocean, during the "National" expedition.

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[1] Plankton-Studien, p. 16.

[2] Bibliotheca Zoologica, Heft I.

The regular appearance of certain forms at definite fixed periods has long been known to American investigators, as well as the periodic rising and sinking of fully grown forms of Salpæ and Ctenophoræ. But the facts seem to have had no value until rediscovered by Haeckel's friends.

It is not so astonishing as Haeckel seems to think that Hensen's results should be in direct opposition to those of the "Challenger"; the methods were entirely different, and the results of the "Vettor Pisani" were all vitiated by the serious defects of the net in use at great depths.

That I may not seem to be utterly prejudiced against Haeckel's methods, I will quote the views of one of the naturalists in the "National" expedition of the tactics in use by him: "Dass die Angriffe von Haeckel theils auf Mangel an Einsicht, theils auf Missverständnisse, theils endlich auf grobe Entstellungen und unverantwortliche Unrichtigkeiten in der Wiedergabe der Befunde anderer Forscher zurückzuführen sind."[1]

OBSERVATIONS ON THE PELAGIC FAUNA OF THE PANAMIC DISTRICT BY THE "ALBATROSS."

At every station we occupied, the surface tow-net was brought into requisition, and the contents of the net examined. The surface tow-nets, of about four feet in diameter, were made of muslin with a trap and a bag at the end of silk bolting cloth. A small net of finer bolting cloth was suspended in the centre of the opening of the net. This large tow-net was towed from the end of a boom off the ship's side when the speed of the vessel was sufficiently slow. A number of larger and more prominent surface animals were also constantly collected from the ship's deck with long hand nets. Excellent collections were invariably made with them when the electric light was lowered alongside. A very respectable collection of surface animals was thus brought together, which will form an interesting nucleus for comparison with the catches obtained by the Tanner tow-net at these same localities, either when dragged at definite depths, or when collecting on its way up from that point to the surface. As will be seen from the record of submarine tow-net stations (page 4), a number of collections were made which when carefully collated ought to give us important data respecting the bathymetrical range of the pelagic fauna.

In the Panamic region, currents from the west, from the north, and from the south meet, and then are diverted to a westerly direction, forming a sort of current doldrums, turning west, or east, or south,

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[1] Brandt, Schriften des Naturw. Vereins f. Schleswig-Holstein, VIII., Heft 2.

or north, according to the direction of the prevailing current. The amount of food which these currents carry is small compared with that drifting along the course of the Gulf Stream. I was also greatly surprised at the poverty of the surface fauna. Except on one occasion, when during a calm we passed through a large field of floating surface material, we usually encountered very little. It is composed mainly of Salpæ, Doliolum, Sagittæ, and a few Siphonophores, — a striking contrast to the wealth of the surface fauna to be met with on a calm day in the Gulf of Mexico near the Tortugas, or in the main current of the Gulf Stream as it sweeps by the Florida Reef or the Cuban coast near Havana.

Although we often dredged in strictly characteristic Globigerina ooze or over bottoms containing numerous tests of Globigerinæ and Orbulinæ, I was much struck with the absence of living Globigerinæ on the surface. Only on two occasions during a calm did we come across any number of surface Globigerinæ and Orbulinæ. No pelagic Algæ were found, yet they occur in great fields off the west coast of South America as far north as Ecuador.

The number of new species which were constantly turning up in the contents of our tow-net, when hauled from 200 fathoms to the surface, plainly shows that no reliance can as yet be placed upon deductions drawn from the comparison of the contents of the nets at different localities and at varying depths. We evidently know as yet too little of the characteristic pelagic species living within the 250 or 300 fathom bathymetrical belt to enable us to state that the contents of open townets lowered, say one to 500 fathoms and another to 1,000 fathoms, no matter how different they may be, are not due to the pelagic fauna living in the upper belt between the surface and 200 or 300 fathoms.

I am not questioning the existence of pelagic, or rather free-swimming species, at a moderate distance from the bottom, nor the presence near shore of such animals at considerably greater depths than those to which the oceanic pelagic fauna extends, or at short distances from shore, where an archipelago may form a barrier, as do the Canaries or the West India Islands, to the free action of oceanic currents, and where pelagic species may accumulate under radically different conditions from those of adjoining oceanic basins.

Too little is as yet known of the geographical distribution of the oceanic pelagic surface organisms of either the Atlantic or Pacific Ocean.[1] We know, it is true, something of their geographical distribu-

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[1] See an interesting note by Chun in the Zool. Anzeiger, Nos. 214. 215, January, 1886.

tion along our coasts. We can distinguish, to a certain extent, an Arctic, an Acadian, a Virginian, or a West Indian district, as it were, among the Acalephs and other pelagic forms close to our shores. But when we come to attack the problem of the distribution of the pelagic forms of the oceanic basins, we are at a loss, with our present knowledge, to recognize anything beyond geographical realms practically corresponding to the arctic, temperate, and tropical regions of the oceans. The results of the only expedition which has as yet made a preliminary survey of the North Atlantic are not published, and they will probably show us how complicated the problem is when examined with reference to both a horizontal and a bathymetrical range. This part of the problem has been ignored by Haeckel.

To satisfy ourselves of the difficulty of determining the bathymetrical range of pelagic animals by differentiation of the contents of tow-nets sent down open to tow at different depths, we spent some time at Station 3282 in sending open tow-nets to 100 and 200 fathoms, and also at two other stations, with the following results.

On March 7th we lowered a large surface tow-net to a depth of 200 fathoms, and towed at that depth for fifteen minutes, bringing the open net rapidly to the surface at the usual rate. This trial was made at Station 3382, the bottom depth being 1,793 fathoms, the distance from the 100 fathom line about sixty miles, and the distance from land seventy miles.

The bulk of the material collected consisted of masses of a small species of Doliolum and of Sagitta, among these many of the large species of these genera previously mentioned. Among the other pelagic material were to be found the separate bells of the large Siphonophore first observed off Mariato Point, fragments of an Agalma as well as of the huge Pterophysa so often brought up on the dredging-wire rope, many bells of Crystallodes, and species of Diphyes. The other Acalephs were represented by species of Cytaeis, of Liriope, of Æquorea, of Saphenia, of a Melicertum-like genus, and a Stomobrachium, a very delicate pyriform Mertensia remarkable for the great length of its funnel, a Cunina, and a Discophore allied to Nauphanta. The Heteropods were represented by a species of Firoloides. Finally, the surface swarmed with Orbulinæ having an orange-red nucleus; also specimens of Polyipnus and of another Scopelid, of Gonostoma, and of a small fish allied to Astronesthes, several species of delicately tinted rose-colored shrimps in different stages of growth, as well as many larval stages, specimens of Phronima and Hyperia, many young Squillæ, a large semi-transparent Calanus, many Copepods, and many species of Sergestes.

A second haul was then made with the open tow-net from the 200 fathom level to the surface without towing at that depth. The net was drawn up more slowly, but the contents of the net differed in no way from the preceding hauls, except that the quantity of pelagic life obtained was naturally much less than when we spent in addition fifteen minutes in towing at the 200 fathom level. In hauling the net from 100 fathoms to the surface in a still shorter time, the amount of material was still more reduced. The surface tow-net contained scarcely anything, the sea being quite rough, a fresh trade wind blowing.

These hauls, made with open tow-nets, showed little variety in the constitution of the pelagic fauna at 100 and 200 fathoms, the surface animals having been driven to deeper waters by the disturbed state of the upper layers. We obtained nothing in the hauls from 100 and 200 fathoms which had not on some other occasion been obtained in the surface tow-net, though not in as great quantities as when towing at greater depths.

On the evening of the same day, it being calm, the surface tow-net was crowded with Nautilograpsus, and contained also nearly every species we had caught in the morning while towing at depths of 100 and 200 fathoms, and the number of specimens was quite as large as in the greater depths. The Stomobrachium, Liriope, and Saphenia, and likewise the Diphyes and Crystallodes, were more numerous perhaps, while Doliolum and Sagitta constituted the bulk of the material of the tow-net.

On the 9th of April, the Tanner net was sent down to tow at 175 fathoms, and thence hauled open to the surface. The net contained numerous specimens of Doliolum, Salpæ, Sagittæ young and old, transparent Annelids, Tomopteris, masses of Copepods, Leucifer, Sergestes, Schizopods, Sapphirina, Hyperidæ, Phronima, Ostracods, a few small Stomobrachium and Liriope, and numerous bells of three species of Diphyes and of Crystallodes, a few specimens of Pneumodermon, of Atlanta, of Hyalea, and of Creseis, and the same species of Rhizopods found in the surface tow-net at the same locality. No fishes were obtained in this haul.

The haul of the surface tow-net at this locality, though towed on a smooth and calm sea in a bright sun and with no wind, was comparatively poor. The Rhizopods were more numerous than from the deeper haul, but the number of species and of individuals of the Crustacea, Worms, and Siphonophores was much smaller, and there were no Pteropods.

Copepods with large blue eggs were obtained in both these hauls, which were made about 300 miles southeast of Acapulco, and the depth must have been about 2,200 fathoms, as we were near soundings of over that depth.

The same evening, about 250 miles from Acapulco, with a smooth sea which had continued all day, we towed the surface tow-net, carrying the electric light alongside. The net contained small Sagittas, Diphyes, Doliolum, and Hyalea. A great number of Halobates were attracted by the electric light, and caught with hand nets; flying-fish of all sizes were darting about the electric light. The motion of the flying-fish could readily be followed in the water. They used their huge pectorals with extraordinary skill; opening and shutting their wings rapidly, they regulated their speed with ease, and by suddenly opening or shutting either wing, and planting it at a right angle to their course, they managed to check and change their motion and direction instantaneously. Either wing might in any stage of expansion be fully spread out or closed like a fan, and the wings were in constant play, opening and shutting their powerful fans to control their movements. We can understand how readily they manage to escape the attacks of fishes following them from below in the water, or of aquatic birds darting at them from above the surface. The surface net also contained Pteropods, Atlanta, Creseis, a large number of Schizopods, Sergestes, Leucifer, bells of Crystallodes, and numerous small Stomobrachium and Liriope, pelagic Annelids, Copepods, Sapphirina, Glaucus, Firoloides, and pelagic flounder embryos. The number of specimens of Sagitta was extraordinary; they practically filled the net.

In the evening the Tanner tow-net was also sent to 175 fathoms, where it was towed for ten minutes, and the messenger sent down to close it. The lower net came up well filled with the surface pelagic species, which on this day were unusually varied, it having been smooth and calm the previous night, and the morning before the towing was made. But the quantity of animal life was much less, although the deep haul was continued longer than the surface towing. So that on this occasion the bulk of the pelagic fauna was evidently nearer the surface.

The Acalephs of the Panamic District.

As far as I could judge from a preliminary examination of the fragments of Siphonophores and of the specimens in more or less perfect state of preservation brought in by the surface tow-nets and the Tanner net, as well as in the trawl and attached to the dredging rope, the following are the genera which were noticed by us: Anthemodes, Bassia, Agalma, Athorybia, Crystallodes, Nectophysa, Pterophysa, Rhizophysa, Velella, Porpita, Physalia, Praya, Diphyopsis, Diphyes, Abyla, and Cymba.

Crystallodes and the genera of Diphyes were by far the most common of the Siphonophores; we scarcely made a haul of the tow-net without finding some bells or fragments of these two groups.

The other Acalephs were not numerous in species, although sometimes we passed through great numbers of a large species of Liriope, and some of the Ctenophores, of which a species of Mertensia and a Mnemiopsis were the most common. Ocyroë was observed once, Idya was comparatively rare, and Cunina was found occasionally, while the trawl and tow-nets frequently brought up Periphylla, Drymonema, Nauphanta, Atolla, Stomobrachium, an Æquorean allied to Tima, genera allied to Saphenia, to Melicertum, to Lizzia, and to Cytæis, and a genus allied to Rathkea.

OBSERVATIONS ON THE PELAGIC FAUNA OF THE INTERMEDIATE DEPTHS IN THE PANAMIC DISTRICT, MADE BY THE "ALBATROSS" WITH THE TANNER TOW-NET.

As I stated at the time Chun published the results of his first experiments, I considered them inconclusive,[1] and was of course anxious to repeat them in a strictly oceanic district, in great depths, and at a considerable distance from shore.

On Plate I., I have given figures of a slightly modified Chun-Petersen tow-net, which was constructed by Ballauf, of Washington, for my use on this expedition.

Figure 1 shows the closed net ready to lower; Figure 2, the net opened, ready to tow at the required depth; and Figure 3, the closed net on its way up. *f* is the metal frame protecting the propeller *p*. The propeller shaft extends to the crossbar c'', fitting into a socket from which it is relieved after a few turns of the propeller, when the net is first moved horizontally, and liberates the rings of the chain *b* from the bar c'', and thus opens the jaws of the net, bringing the strain on the two parts of the chain *a*. As soon as the propeller shaft passes beyond the crossbar *c*, the upper parts of the chain *a* are relieved, and it then becomes the longest, and the strain comes upon the chain *b*, which pulls

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[1] Am. Jour. of Science, 1888, Vol. XXXV. p. 421.

together and closes the jaws of the net at the termination of the time of towing, and it remains closed until it reaches the surface.

The 25th of February we made our first attempt with the modification of the Chun-Petersen closing net for towing at intermediate depths. On towing the same horizontally near the surface, so that we might watch the operation of the propeller in releasing the chains to open and then to close the net, it became very soon evident that but little reliance could be placed on the working of the propeller from the great pressure brought upon the shaft even during the slowest towing; and from this the uncertainty of the action was so great that we could not feel satisfied that the net had closed and opened at the limits within which it was supposed to act. A very small net might work satisfactorily on this principle, and prove useful for attachment to a line for simultaneous serial observations after the fashion in use for serial thermometric work. This was a great disappointment, as from the first account given by Chun I inferred that there were no drawbacks to this machine. He mentions them in the account of his voyage to the Canary Islands. After this failure, we made no other attempt to use the machine, and subsequently our fishing at intermediate depths was carried on with the Tanner self-closing net, a description of which is given further on.

Thanks to the ingenuity of Captain Tanner, we overcame these obstacles. He devised a net which could be closed at any depth by a messenger, and which worked to perfection at 200, 300, 400, and 1,000 fathoms, and had the great advantage of bringing up anything it might find on its way up above the level at which it was towed.

Figure 1 of Plate II. shows the general arrangement of the Tanner deep-sea closing net attached below the heavy shot, *a*, at the extremity of the wire dredging rope, *r*. The net itself is suspended between two ropes, r', r', to which a sixty-pound shot, *b*, is suspended; the extremity of the net is kept in place by a slack line, r''. Around the lower part of the net a set of rings is fastened, through which passes a loop line, going out through pulleys, *p*. At each end of the loop line is fastened a fourteen-pound lead weight, *w*, which is hung close to the pulley by strings, l' l', suspended by loops from a crank, *t*; this crank is securely fastened to the wire rope by a clamp, *n*, the details of which are seen in Figures 4 and 5.

The outer net is made of twine netting, with a mesh for the support of the thinner and weaker muslin which lines the lower half of the net; this in its turn is lined for its lower half with fine close-mesh silk bolting cloth. The net is lowered with the open frame (as represented in Fig. 1) uppermost, at the rate of about 100 fathoms in four minutes; when the net reaches the requisite depth at which it is to be towed, sufficient slack of wire is let out, so that the angle of the wire rope due to the speed of the vessel will keep the net towing at a nearly uniform depth. It is usually towed for twenty minutes, when the speed of the vessel is slackened, as the rope is wound in, until the net is vertical when the ship stops; the messenger, *m* (Figs. 1, 2), is then sent down on the wire rope, and, striking the crank *t*, trips it, and it drops to the position *t′*, as seen in Figure 4. This liberates the loops of the string *l l*, by which the weights *w w* are hung; these drop rapidly to the position *w w*, as seen in Figure 6, pulling both together, and closing tightly the loop which passed round the lower part of the net. The net is then hauled up at the same speed at which it was lowered, and invariably comes to the surface with the bottom part tightly closed. The upper part of the net above the loop remains open, and collects anything found on its way from the depth at which the towing was made to the surface. When the net reaches the surface, the loop closing the net is at once supplemented by winding below it a stout twine; the bottom fastening of the net is then opened, and the inside net carefully washed in filtered sea water, and that in its turn carefully examined.

Figure 2, the messenger *m* (made in halves), showing the grooves, *s*, by which it is fastened to the wire rope *r*.

Figure 3, the extremity of the dredging-wire rope, with its weight, from which the net is suspended.

Figure 4, showing the clamp attached to the wire rope *r*, with its crank, *t*, from which are hung the loops of the line *l*, holding the weights *w w* suspended; *t′* shows the position of the crank after it has been tripped by the messenger *m*.

Figure 5, the same as Figure 4, seen from above.

It will be noticed that we used no contrivance by which the Tanner net was sent down closed, and subsequently opened when at the required depth. To obviate this difficulty, we loaded the wire rope with a heavy shot, *a* (Figs. 1, 3), to counterbalance its weight, and in addition attached to the bottom of the guides of the Tanner net a heavy weight, *b* (Figs. 1, 6), so that, when lowering the apparatus slowly, the net was sent down with the closed extremity leading. In this way the pressure of the water on the bag of the net kept the lower part of the sides closely compressed together. Water passed through only the upper open parts of the net, close to the mouth frame, where the meshes are those of an ordinary bait hand-net. As there is a double net of muslin and of fine silk bolting cloth extending half-way up the net, everything is kept out of the net on its way down. It is an interesting experiment to drag a tow-net through the water with the closed point leading, and to observe how completely the sides are collapsed, and prevent the admission of water into its lower extremity. The water in the pans in which the contents of the net were to be washed was always carefully strained through fine silk bolting cloth, as was done on the "Blake" with the Sigsbee trap. Two pans were thus prepared, one for the contents of the lower part of the net, — the closed part, — the other for the examination of the contents of the upper part of the net, which remained open all the way from the level at which the net was towed to the surface.

On the 9th of March, at Station 3388, at a depth of 1,168 fathoms, fifteen miles from the 100 fathom line and twenty-five miles from the nearest land, we made our first trial of the Tanner net. Before sending it down to the deeper belts, it was tried near the surface within sight, and, the performance of the messenger and the action of the closing weights having proved satisfactory, it was sent to tow at a depth of 400 fathoms, and towed for seventeen minutes, the ship being carefully slowed so as to keep the depth nearly uniform, and then the length of the wire rope gradually reduced from 570 fathoms, the length of line let out on the hypotenuse, to 400 fathoms vertically. The angle of the line was carefully checked the whole time by means of Captain Tanner's goniometer, so that the variation in the depth at which the net was towed could not amount to more than a few fathoms. The messenger was then sent down to liberate the weights hanging from the slings suspended upon the crank of the stopper, which were to close the bottom part of the net. The net was then hauled up at a speed of about four minutes to the 100 fathoms, so that for some sixteen minutes the upper open part of the net was scooping in the pelagic life in its track. When the Tanner net approached the surface, it was found that the bottom part of the net had been securely closed, as represented in Plate II. Fig. 6. The bottom part of the net was opened after having tied securely the upper end of the bottom of the bag, below the loop, to prevent any part of the contents of the open part of the net from falling into it. The lower part of the net was then carefully washed out in water which had been filtered, and that water was then examined. There was absolutely nothing found in the water. On the other hand, the upper part of the bag, which had remained open the whole way up from 400 fathoms to the surface, was found to contain very much the same species we had obtained when towing with the open surface net from a depth of 200 fathoms, two days before, at Station 3382, a distance of about sixty miles. We brought up, in addition to the species obtained at that station, Pyrosoma, Benthoteuthis, a number of Sternoptyx, some of them quite small, not measuring more than half an inch in length, Scopelus, Stomias, Gonostoma, Astronesthes, Melamphaës, Plagusiæ, a fine black Beryx-like fish of a new genus which we had brought up alive in the trawl at Station 3383, and which evidently is not a bottom fish, while I had assumed at that time that it might come from 1,832 fathoms. We also brought up in the open part of the net a number of young Eryoneicus, from half an inch to an inch in length. Our first specimens of the genus came up in the trawl at Station 3375, depth 1,201 fathoms, afterwards at Station 3377, depth 764 fathoms, and, before we lowered the Tanner net, the trawl at Station 3388 had also brought up a fine large specimen of this genus, which we then considered to have come from a depth of 1,168 fathoms. But it is more probable that even the old of this genus, with their huge swollen cephalothorax, are peculiarly adapted to float passively, and live in the intermediate belt between the surface and the deepest point to which the pelagic fauna may extend. At the time the haul with the Tanner net was made, it was blowing quite a fresh trade wind, and it was a favorable day for deeper hauls, as the disturbance of the surface had been great during the earlier part of the day and the preceding night.

On the 11th of March (at Hy. Station No. 2619, depth 1,100 fathoms) the Tanner net was sent to tow at a depth of 300 fathoms. We paid out 430 fathoms of wire rope and towed nineteen minutes. The extra length was slowly taken up, until the line became vertical. The messenger was then sent down to detach the closing weights, the time of the messenger to reach the tripping crank being two minutes and twenty seconds. The time can readily be ascertained by retaining a hold of the wire rope, as the shock of the striking messenger can be most distinctly perceived on deck. The net was then hauled up at the usual rate of about 100 fathoms in four minutes. The Tanner net reached the surface with the bottom of the bag well closed. The same precautions were taken to isolate the lower part of the bag, and with the water in which the net was washed, as on the first trial. As then, we found that the lower part of the bag, closed at 300 fathoms, again contained absolutely nothing.

The upper part of the net, which remained open all the way from 300 fathoms to the surface, contained the same amount and quality of material we had obtained on the first trial. There were, perhaps, not so many specimens of Doliolum, but the same types of Crustacea, Copepods, Macrurans, and Siphonophores, the same species of fishes, with a different larval Plagusia from that of the former haul, characterized by a dark violet black longitudinal band along the flanks, and a young Octopus.

Immediately after the above trial, at the same station (Hy. Station 2619, depth 1,100 fathoms), we sent down the Tanner net to tow at a depth of 1,000 fathoms, to endeavor to ascertain what might be obtained by towing as nearly as possible about 100 fathoms above the bottom. We let out 1,160 fathoms of wire rope, and towed for nearly sixteen minutes; the extra length of rope was then slowly wound in to bring it vertical, and the messenger was sent down to trip the crank; the time of the messenger in reaching the detacher was seven minutes and thirty-five seconds; the Tanner net was then hauled up at the usual rate of four minutes per 100 fathoms, and the customary precautions used in examining the contents of the upper (open) and lower (closed) parts of the net. A sounding was taken immediately after the net came to the surface, and we found that during the time we trawled and towed we had drifted into a depth of 1,482 fathoms, so that we failed in the immediate object of our trial. We found in the closed net a large violet Amphipod, and a brilliant carmine shrimp, of the usual color of the deep-sea Macrurans. These two specimens must have come from a belt of not more than 350 fathoms above the bottom, and were different from anything we had collected before. The open part of the bag contained an Atolla, a fine specimen of the pink Stomobrachium, both probably from a comparatively moderate depth, judging from their perfect state of preservation. The same Crustacea and fishes came up as on other trials in that part of the Tanner net, and also a fine orange Amphipod like one brought up in the trawl at Station 3383, and assumed then to come from a depth of 1,832 fathoms. The open net also contained a huge Noctiluca, measuring about half an inch in diameter, with a peduncle fully ten times the diameter of the disk.

On the 25th of March, at a point not quite half-way between Cape San Francisco and the Galapagos, Hy. Station 2627, the depth being 1,832 fathoms, the Tanner net was sent to tow at a depth intended to be about 100 fathoms above the bottom, and which varied from 1,773 fathoms to 1,739. Within these limits the net was towed for twenty minutes, the same precautions being taken to bring the wire rope gradually vertical before the messenger was sent down to close the net; the messenger was seven minutes in reaching the detacher. The net was then hauled up, and the contents of the lower part, which had closed, were carefully examined, using the same precautions to strain the water of the pans as on former hauls. With the exception of the fragments of a few decayed leaves, evidently caught while on their way to the bottom, the net contained nothing; it was barren of animal life.

The upper part of the Tanner net, which had remained open all the way to the surface, brought up the same species which on former occasions the net contained when towing at a depth of 200 fathoms from the surface. There were found a great number of small Doliolum and of a large Sagitta. The number of individuals as well as of species of Crustaceans in this haul was very marked. Several species of Leucifer, of Sergestes, of Schizopods, Copepods, and of highly colored Hyparinæ probably parasitic on a Salpa, which was abundant, as well as a number of Macrura fully as bright red as any of the deep-sea Schizopod types, in addition to the transparent pelagic types. We also obtained a Stomobrachium, a large Beroë measuring nearly six inches in diameter, a number of bells of Diphyes, and a huge Ostracod allied to Crossophorus, with a thin membranous test, — a giant of its kind, measuring somewhat more than an inch in length. The largest Ostracod previously known is not more than one third of an inch long. The pelagic Benthodytes, which first came up in the trawl at Station 3,364, also occurred in the open part of the net.

Among the so called deep-sea Medusæ several specimens of Atolla and of Periphylla were found in the open part of the net. The net also contained a Leptocephalus and two other species of fishes, the one allied to the Scopelids, the other to the Stomiadæ, many of which have been regarded as typical deep-sea forms.

The surface at this point was also examined with the tow-net, and the pelagic animals found to be the same as those brought up in the open part of the Tanner tow-net on its way from the bottom. The number both of species and specimens was, however, much less than in the Tanner net.

On the following day, March 26, the Tanner tow-net was sent to be towed at a depth of 204 fathoms. After twenty minutes the messenger was sent down and the net hauled up. The bottom part of the net came up tightly closed. Its contents were examined in the same manner as before, in well strained water, and the water was found to be absolutely barren, while the upper part of the net, which came up open and was not more than eight or nine minutes on the way, was only fairly filled with surface life. The upper net contained a few specimens of

Doliolum, Sagitta, Hyalea, Creseis, and a couple of species of Macrurans. The poverty of this deep haul may be accounted for by the corresponding poverty of the surface. The surface tow-nets hauled for nearly twenty minutes contained scarcely anything beyond a few Sagittæ, Appendicularíæ, Copepods, and pelagic fish eggs, and perhaps a larger number of bells of Diphyes and Crystallodes than in the Tanner net; yet the sea had been smooth during the night, and up to 9 A. M., the time of the haul, not a breath of wind had ruffled the surface. Our position, Hy. Station 2628, was a few minutes of latitude south of the equator, about 250 miles from the Galapagos, and about the same distance from Cape San Francisco; the depth probably between 1,500 and 1,800 fathoms. Soon after, the open tow-net was also hauled from a depth of 200 fathoms up to the surface. In addition to the species enumerated above, we obtained Sergestes, larvæ of Penæids, a bright yellow Æolis, a large Stomobrachium, and numerous bells of Crystallodes and Diphyes. The wire rope passed through myriads of Nautilograpsus swarming on the surface; they literally choked the surface tow-net.

On the 8th of April, about 7 A. M., Station 3414, depth 2,232 fathoms, 350 miles from land, the sea was quite rough, a heavy swell rolling, and the trade wind was blowing briskly; the Tanner net was sent to tow at 100 fathoms and closed by messenger; time of messenger in reaching the detacher, forty-five seconds; after towing the net about twenty minutes, it was hauled up to the surface. The lower closed part of the net, and the upper part, which had remained open the whole time, contained the same species. The lower part of the net contained a good deal more animal life, having been towed for twenty minutes at about 100 fathoms from the surface, while the contents of the open upper part passed through 100 fathoms in about four minutes. The haul of the upper net consisted of a large red Cypris, a small transparent cuttle-fish, a few Doliolum, a large pinkish Hyperia, a large Cystisoma parasitic on Doliolum, Sapphirinæ, transparent Penæids, bells of Crystallodes and of two species of Diphyes, fragments of Beroë, a number of Collozoum colonies, and Calanus and other Copepods. The lower net contained the same things, the Sapphirinæ and Hyperiæ being rather more numerous, and a few specimens of Atlanta which had not been obtained in the haul of the upper part of the net from 100 fathoms to the surface.

An hour later, the Tanner net was sent to tow at a depth of 200 fathoms. After towing for ten minutes the messenger was sent to close the net, the dredge rope having, as in all cases of towing at intermediate depths, been gradually brought to be vertical before the net was closed. We found in the lower closed part of the net, in addition to the same shrimps and Copepods obtained from 100 fathoms, Firoloides, Mertensia, and a small Sagitta. In the upper part of the net, which was towed open from 200 fathoms to the surface at the rate of four minutes to 100 fathoms, the animal life consisted of the same species as in the lower part of the net, and in addition the *tasters* of a large Pterophysa fully two and a half inches long, — the same species fragments of which so frequently came up on the dredge rope, — specimens of a large and of a small Sagitta, two species of Phronima, a Typhis, and two species of Salpæ; the Doliolum were more abundant than in the lower depths. Fragments of the bell of a large Diphyes of an unknown genus, from two to three inches in length, with a delicate yellow stem, and a few bells and fragments of another species of Diphyes and of Crystallodes, and a few specimens of Scopelus. Time of messenger in reaching the detacher at 200 fathoms, fifty seconds.

At this same station the Tanner net was next sent to tow at 300 fathoms, but, the detacher lines having got entangled with the dredge-rope swivel, it failed to close, and came up open all the way to the surface from 300 fathoms. The contents of the open net were identical with those of the previous haul from 200 fathoms to the surface; we added, however, a number of young specimens of Sternoptyx. The net was sent again to tow at 300 fathoms, and the messenger sent to close the net after towing fifteen minutes; time of messenger in reaching the detacher, two minutes and forty seconds. The lower part of the net came up well closed, and its contents were carefully examined, taking the usual precautions. The lower closed part of the bag contained nothing. The upper open part of the net contained Sternoptyx, Stomias, Scopelus, a small violet cuttle-fish, and a number of Schizopods, Euphausiæ, Thysanopodæ, Siriella, Nyctiphanes, Eucopia, and the like, apparently identical with those found in the hauls from a depth of 100 and 200 fathoms to the surface. Many of the same Crustacea (Schizopods, etc.) were also obtained in the surface tow-net at this locality, although the wind and swell continued during our experiments, and the surface was greatly disturbed.

On the morning of the 11th of April, the Tanner net was sent to tow for twenty minutes at a depth of 300 fathoms, at a locality about thirty miles southeast of Acapulco, at a depth probably of over 1,800 fathoms, the surface being moderately rough, a light wind having blown all night. The messenger was sent to close the net after the usual precautions, time occupied three minutes and fifteen seconds, and the net hauled rapidly to the surface. The lower part of the net had closed satisfactorily, and on examination was found to be barren of animal life, even at so small a distance from the land. The upper part of the net contained an unusually rich assortment of surface species, a large number of Scopelus, Euphausiæ, Leucifer, Sagitta, fragments and bells of Diphyes and of Crystallodes, species of Schizopods, Doliolum, Salpæ, and some undetermined Penæids, with many Rhizopods, mainly specimens of Collozoum and of Acanthometra.

On the 16th of April, at 10 A. M., about 120 miles in a northwesterly direction from Acapulco, probable depth over 2,000 fathoms, the surface tow-net was hauled, the surface being quite smooth, the wind having gradually lessened from the time we left Acapulco. It contained very little beyond the usual Sagittæ, a small species of Salpa, a few Doliolum and Appendiculariæ, Calanus and other Copepods, Sergestes, Leucifer, and Euphausiæ, the same Mertensia we had found farther south, as well as the bells of a couple of species of Diphyes and of Crystallodes, apparently the same as those we obtained earlier in our cruise.

We then sent the Tanner tow-net to tow for fifteen minutes at a depth of 175 fathoms; it was closed by the messenger as usual. The lower part of the bag contained the same species we had caught in the surface tow-net; the number of individuals, however, was somewhat more abundant, and we obtained in addition Hyalea and Creseis, as well as Squilla larvæ.

On the 22d of April, about 75 miles southwest of Guaymas, in the middle of the Gulf of California, Station 3436, at a depth of 905 fathoms, the Tanner net was sent to tow at a depth of 800 fathoms. We towed fifteen minutes, when the messenger was sent to close the net. We must have shoaled our water, as the bottom net came up containing some mud. We brought up in the net Periphylla, and a new genus of Bougainvillia, allied to Rathkea, having eight chymiferous tubes, but only four clusters of tentacles.

The same day, Hy. Station 2637, at a depth of 773 fathoms, the Tanner net was again sent down to tow for twenty minutes, at a depth of 700 fathoms. The wire rope having fouled the detaching lines, the net came up open all the way to the surface. It must have towed very close to the bottom, as we brought up a fine specimen of Nettastoma, and two of the red deep-sea Caridids; but otherwise it contained nothing which we had not on some previous occasion obtained inside the 200 fathom limit from the surface. The proximity of land was apparent from the presence of numbers of brachyuran larvæ, such as we had already found on the previous day in our surface haul. We obtained Periphylla, Stomobrachium, the new genus of Bougainvillia, bells of Diphyes and other Siphonophores, Doliolum, several species of Pteropods, Sagittæ, Ostracods, Copepods, Hyperiadæ, Schizopods, Penæids, and a few species of pelagic fishes.

On the 23d of April, a few hours before reaching Guaymas, we made one more attempt with the Tanner tow-net, Hy. Station 2638, at a depth of 622 fathoms, sending the net to be towed for about fifteen minutes, at a depth of from 500 to 570 fathoms. We found in this case in the bottom part of the net, which came up tightly closed, a Scopelus, a red Penæid, and a Hyalea, while the upper open part of the net contained the same surface species we had obtained in the surface tow-net on other occasions, such as Squilla larvæ, Ostracods, Doliolum, Euphausiæ, and Pteropods.

Our experience in the Gulf of California with the Tanner self-closing net would seem to indicate that in a comparatively closed sea, at a small distance from the land, there may be a mixture of the surface species with the free-swimming deep-sea bottom species, a condition of things which certainly does not exist at sea in deep water, in an oceanic basin at a great distance from shore, where the surface pelagic fauna only descends to a comparatively small depth, i. e. about 200 fathoms, the limits of the depth at which light and heat produce any considerable variation in the physical conditions of the water. The marked diminution in the number of species below 200 fathoms agrees fairly with the results of the "National" expedition.

The other experiments with the Tanner net, made in an oceanic basin on the way to Acapulco from the Galapagos, and to the Galapagos from Cape San Francisco, seem to prove conclusively that in the open sea, even when close to the land, the surface pelagic fauna does not descend far beyond a depth of 200 fathoms, and that there is no intermediate pelagic fauna living between that depth and the bottom, and that even the free-swimming bottom species do not rise to any great distance, as we found no trace of anything within 60 fathoms from the bottom where it had been fairly populated.

The first experiments of Chun regarding the distribution of the pelagic fauna were made in the Mediterranean, within a comparatively short distance from the shore, and in a closed basin having, as is well known, special physical conditions, its temperature to its greatest depths being considerably higher than the temperature of oceanic basins at the limit of 200 fathoms, or thereabout, which we assume now to be near the limit of the bathymetrical range of the true oceanic pelagic fauna. At 200 fathoms in the Panamic district, the temperature was from 49° to 53°, while, as is well known, the temperature of the Mediterranean soon falls, already at 100 fathoms, to about 56°, a temperature which is continued to the bottom in this closed basin. Of course, if temperature is one of the factors affecting bathymetrical distribution, there is no reason except the absence of light which would prevent the surface pelagic fauna from finding conditions of temperature at the greatest depth similar to those which the surface fauna finds within the limit of 200 fathoms in an open oceanic basin.

My reasons for modifying the results obtained by Chun on his trip to the Canaries, I have given elsewhere, on page 23.

The results even of those who claim to have proved the existence of an intermediate fauna agree in showing that the number of species and the number of individuals greatly diminish near the 200 fathom limit, and that though my first experiment on the "Blake" proved the rapid diminution of the pelagic fauna at or below 150 fathoms, yet the azoic limit is a most variable one, judging from the later results of Chun and of Hensen, and from my own on the "Albatross." As long and as often as the experiments for determining the lower limits are confined to the Mediterranean or any closed or comparatively closed sea basin, or are carried on within close proximity to land, disturbing influences are at work which carry this limit far lower than we find it to be in an open ocean basin, far from land, where below 200 or 250 fathoms; and at 300 fathoms little or nothing has been found by us.

The Galapagos Islands.

As is well known, the Galapagos, when discovered by the Spaniards in the sixteenth century, were uninhabited, and remain so to-day; with the exception of the colony still maintained on Chatham Island by Mr. Cobos, all other attempts at settlement have failed.

Distant only a little over 500 miles from the Ecuadorian coast, they have often been visited by whalers, who landed on the islands for water, and for a supply of the large land turtles which made a pleasant variety in the sea fare of the whaling fleet frequenting these waters during the first half of this century.

The temporary occupation of some of the islands as a penal settlement by the Ecuadorian government followed the attempt at settling

Charles Island in 1831. After the disappearance of the convicts, they were occasionally visited by the orchilla traders, who cut down the scanty forests for the sake of obtaining more easily the valuable moss growing on the trees.

Dr. Theodor Wolf,[1] Ecuadorian State Geologist, has given a most interesting account of his visit to the islands, supplementing in many ways the account we owe to Darwin in his "Voyages of the Adventure and Beagle," and his "Volcanic Islands."

The Flora of the Galapagos.

Dr. Wolf has given a most characteristic description of the three belts of vegetation, which can be recognized on all the islands. (Plates XV.–XX.) The lower or more barren belt, characterized by its stunted vegetation, consisting near the beaches of salt-loving plants, probably all immigrants from the mainland, followed by grayish white apparently dry bushes, with small leaves and inconspicuous blossoms, the most common of which are a Verbena bush and a species of Acacia, with a large tree, the Palo Santo, which grows to a height of thirty feet. Where the lava fields seem to prevent the growth of any other plants, we find a tree-like Opuntia and a huge Cereus (Plate XX.). The last disappear as we rise, and on reaching the so called high plateau, the Acacia and Palo Santo increase in size, and the Verbena vanishes. When we reach the second belt, the lava blocks have become decomposed into a soft reddish earth by the action of the moisture from the prevailing trade winds, which blow refreshingly across from the south, and, carrying with them masses of moisture, have completely changed the aspect of the vegetation on the plateau (Plate XVII.), and of the weather side of the islands. The woods are green, composed of small trees, principally recalling the Polylepis of the Andes; they are open, their paths separated by grassy plots, till we gradually pass into the last and highest region, bare of trees, and covered by a rather coarse grass, which extends to the highest summits of the islands (Chatham, Charles, Indefatigable, and James).

Chatham Island is noteworthy for the special development of the lower volcanic barren region, and of the higher and grassy woody district, and, in addition, is distinguished by the barren volcanic tract which forms the eastern extremity of the island, on which, as we sailed by, we could scarcely distinguish any trace of vegetation, — the whole a mass of blocks of volcanic rock scattered between the numerous small volcanoes

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[1] Ein Besuch der Galapagos Inseln, mit drei Kärtchen. Heidelberg, 1870.

so characteristic of that extremity of the island. Here and there grow, like huge candelabra, Cereus and Opuntias, forming clusters often over twenty feet in height, with thick branches; and close to the beach were clusters of small bushes and weeds, which probably represent, with the Opuntias growing between the lava blocks, the earliest flora which found a foothold in the Galapagos.

We may readily imagine, as pictured by Andersson, how, from the decomposition of a few Opuntias, a little humus formed the nucleus from which the seeds of other plants may have diverged, and gradually given rise, by a repetition of the process, to the soil supporting the present vegetation. Perhaps, if we contrast the so called characteristic species of the Galapagos, which find their analogues in the Central American district, we may be justified in looking upon the flora as a part of that district, an outlyer which has extended from the eastern centre to the westward, and yet regard the differences noticed in the flora as an expression of the special conditions due to the position, the climate, the age, and the soil of the islands, as contrasted with the corresponding conditions of the mainland.

As we ascend, we come upon thicker vegetation, not exactly of trees, but of large bushes, gradually passing into the region of small trees and of open fields, over which the mist hanging on the highest parts of the island spreads a slight moisture, and supplies the higher district with abundant vegetation and water over the fields which once were the home of the galapagos. And it may be that Chatham Island, as has been suggested by Andersson, being the one of the islands most exposed to the Humboldt Current and to the southeast trades, is the one which was first covered by South American plants.

On Charles Island, or Floreana, the vegetation is less luxuriant, the distance between the trees and bushes greater than on Chatham, and there seems to be a more definite limitation of the districts occupied by each group of plants (Plates XX., XXI.); and on the shore of Black Beach [1] we come at once upon a number of plants which are quite com-

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[1] "We anchored in Black Beach Road in eleven fathoms, sand. This anchorage is an open bay, but being on the west or lee side of Charles Island affords a good shelter from the trades, which blow most of the year. It is the seaport of what was at one time a flourishing settlement, now abandoned, and derives its name from a short stretch of black lava sand beach lying at the head of the bay, between low cliffs of dark lava rock. [See Plates XVIII., XIX.] At the time of our visit [1888] great numbers of cattle, horses, mules, donkeys, sheep, and hogs were running wild. The buildings were fallen to ruin, but there was a plentiful supply of fruit on the trees, from which we procured many bushels of oranges and limes, a

mon on the coast of Panama and Guayaquil. In the upper regions of Charles the vegetation is more luxuriant, the open fields forming quite extensive undulating plains.

The general appearance of the vegetation of Indefatigable is much the same in its general subdivisions as that of Chatham and Charles.

As Andersson says,[1] with the exception of Australia and some of the islands of that faunal district, no land perhaps possesses so many characteristic plants as the Galapagos, as more than half of the plants thus far known are peculiar to the Galapagos, and of these only a very small portion are common to all or a majority of the islands.

Part of the vegetation has come from the West Indies and Panama, or is allied to that of Southern California, of Mexico, of Southern Colombia, and of the high plains of the Western Andes, perhaps as far south even as Chili. No one has better than Hooker[2] given the probable course which was followed by the plants which have reached the Galapagos from these different regions, and which in the course of centuries have become more or less modified, so as to bear but a distant resemblance to the plants now growing in the very regions from which they came.

The course of the currents along the Mexican and the Central and South American coasts clearly indicate to us the sources from which the fauna and flora of the volcanic group of the Galapagos has derived its origin. The distance from the coast of Ecuador (Galera Point and Cape San Francisco) is in a direct line not much over 500 miles, and that from the Costa Rica coast but a little over 600 miles, and the bottom must be for its whole distance strewn thickly with vegetable matter, which, as I have already stated, came up in great masses in almost every haul of the trawl. This was especially noteworthy in the line from the mainland to Cocos Island, and certainly offers a very practical object lesson regarding the manner in which that island must have received its vegetable products. It is only about 275 miles from the mainland, and its flora, so similar to that of the adjacent coast, tells its own story. Malpelo, on the contrary, which is an inaccessible rock with vertical sides (Plate XIV., and destitute of any soil formed from the disintegration of the rocks, has remained comparatively barren, in spite of its closer proximity to the mainland.

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pleasant addition to our monotonous fare. The distance from the landing to the first improvements was about three miles, over what had been a good wagon road."— Tanner's Report.

[1] Linnæa, XXXI., 1861-62, p. 595.

[2] Hooker, J. D., Linn. Soc. Trans., 1851, Vol. XX. p. 163.

The velocity of the currents in the Panamic district is very great, sometimes as much as seventy-five miles a day, so that seeds, fruits, masses of vegetation harboring small reptiles, or even large ones, as well as other terrestrial animals, need not be afloat long before they might safely be landed on the shores of the Galapagos. Its flora, as is well known, is eminently American, while its fauna at every point discloses its affinity to the Mexican, Central or South American, and even West Indian types, from which it has probably originated; the last indicating, as well as so many of the marine types collected during this expedition, the close connection that once existed between the Panamic region and the Caribbean and Gulf of Mexico, — a connection once extending, probably, through deep and wide passages all the way from the northern extremity of Colombia, the Isthmus of Panama, Costa Rica, and as far north as the Isthmus of Tehuantepec.

Having followed in the footsteps of Dr. Wolf on Charles Island, I cannot do better than to refer to his accurate description of that island, to which I shall add my own observations, as well as those on Chatham and on Duncan, which the "Albatross" also visited. To attempt the ascent of any one of the islands directly from the beaches near the anchorages is a most difficult task. (See Plates XVIII., XIX., XX.) The lower slopes, although rising very gradually, yet are so covered with stunted vegetation, growing between the crowded angular blocks of lava (Plate XVI.), that progress is very slow. One has to pick one's way over the lower lava fields which extend unbroken to a height of nearly 800 or 900 feet from the level of the sea before they begin to show the effect of the disintegrating action of the moisture of the higher regions of the islands.[1] The general aspect of this higher plateau, both on Charles and Chatham (Plate XVII.), is much varied, a large number of small, isolated rounded peaks rising from the general level to a height of 200 to 400 feet, and culminating towards the central mass in the highest points of the islands. On the weather side the moist region reaches to a lower level than on the lee side, and on both Chatham and Charles this year quite heavy rains extended to the very level of the sea, a somewhat unusual state of things. I was informed by Mr. Cobos

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[1] Although Darwin, in his account of the visit of the Beagle to Charles Island, in the last part of September, 1835, after commenting on the similarity, in all the islands, of the first part of the road leading from the sea inland, says: "Higher up, the road gradually became greener, and immediately we had crossed the ridge of the island our bodies were cooled by the fine southerly trade wind, and our senses refreshed by the sight of a green and thriving vegetation."

that rains do not usually extend uniformly to so low a level even during the rainy season,[1] being limited to the higher levels above 500 or 600 feet, and to the higher plateaus, where even during the dry season, the fall and early winter, there are frequent falls of mist.

Arriving as we did at the Galapagos at the beginning of a remarkably early rainy season, I could not help contrasting the green appearance of the slopes of the islands, covered as they were by a comparatively thick growth of bushes, shrubs, and trees, with the description given of them by Darwin, who represents them in the height of the dry season as the supreme expression of desolation and barrenness.[2] Of course, here and there were extensive tracts on the sea-shore where there was nothing to be seen but blocks of volcanic ashes, with an occasional cactus standing in bold relief, or a series of mud volcanoes, or a huge black field of volcanic rocks, an ancient flow from some crater to the sea; but as a rule the larger islands presented wide areas of rich, fertile soil, suitable for cultivation. The experiments at Charles Island, where there is a deserted plantation, and at Chatham Island, where Mr. Cobos has under successful cultivation a large plantation, producing sugar, coffee, and all the tropical fruits, as well as extensive tracts on which his herds of cattle, sheep, and donkeys roam towards the higher central parts of the island, show the fertility of these islands. They are indeed as favorably situated for cultivation as the Sandwich Islands or Mauritius, and there is no reason why plantations, if properly managed, should not in the near future yield to their owners as large returns as they do on those islands.

From the very shore, after passing the coral sand beach (Plate XV.), the road leading from Wreck Bay,[3] Chatham Island, to the hacienda of

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[1] Yet the experience of Captain Tanner, in 1888, would seem to indicate that even at the level of the sea heavy rains may occur. He says: "The weather was partly overcast when we left our anchorage at Albemarle, but we thought little of it, supposing it to be one of the short passing squalls so frequent during the rainy season. When we reached the vicinity of Cape Berkeley, however, the rain poured down in torrents for several hours, and it became so thick that we were obliged to stop the engines until the weight of it passed, when we continued our course, anchoring in James Bay at 1.30 P. M. in six fathoms, white sand."

[2] Darwin says of his first landing on Chatham Island: "Nothing could be less inviting than the first appearance. A broken field of black basaltic lava is everywhere covered by a stunted brushwood, which shows little signs of life." And speaking of the plants, he says: "I succeeded in getting only ten kinds; and such wretched-looking little weeds would have better become an arctic than an equatorial flora."

[3] With the consent of the Commissioner of Fisheries, I have added to my own account of the Galapagos extracts from the excellent reports of Captain Tanner

Mr. Cobos was almost impassable from the mud, and on our way up in the last of March, we could not fail to see the traces of the damage done to the road by the washing of the heavy rains which had fallen during February and March, and which were falling during a part of the days we spent on the island. The higher part of the island (Plate XVII.), where the plantations of Mr. Cobos are placed, are well watered by irrigation, and the supply, brought from about five miles, is ample for a large extent of territory. But although there is an abundance of water in the central parts of the islands, we saw nowhere, as on Cocos Island, such an abundance of water running into the sea. The contrast between Cocos and the Galapagos is most striking. Although not very distant, yet the former is in the rainy belt, and its luxuriant vegetation, extending from the summit close to the water's edge (Plate XIII.), is in marked contrast to the distribution of vegetation on the Galapagos. Cocos Island is reeking with moisture, and its rocky faces, matted with ferns and covered with groves of palms towering above the other trees, seem to have nothing in common with the scanty vegetation characteristic of the lowest slopes of the Galapagos.

made to the U. S. Fish Commissioner relating to his visit to the islands in the "Albatross" during the early part of 1888, while on the way from New York to San Francisco: "This [Wreck Bay] is the seaport of the Hacienda del Progreso, a plantation located on the highlands in the interior of the island, about five miles distant, and connected with the coast by a good wagon road. The bay is surrounded by low land covered with bushes and small trees, and a smooth steep sand beach affords convenient landing. The land begins to rise a few hundred yards from the beach, and the ascent is constant until the hacienda is reached, at an elevation of about 900 feet above the level of the sea. The low lands of Chatham, in common with those of all the islands of the archipelago, are entirely without living water, and in the dry season present a most barren and desolate appearance. All this is changed, however, during the rainy season, which usually begins about the 1st of April, and continues until the last of June. It began in February this year, and in consequence everything was fresh and green, the general aspect being decidedly tropical. In company with Señor Cobos and son we rode over a portion of the estate, where we saw great fields of sugar-cane, sweet potatoes, and other tropical and semi-tropical products, growing side by side. A young coffee plantation gave promise of future profit, and oranges, lemons, and limes were growing in profusion. Large herds of cattle were seen feeding in excellent pastures, enclosed with iron fences, hedges, or the favorite broad deep ditch, the proprietor estimating the number of cattle on the island at 20,000. Horses, mules, asses, sheep, and hogs were seen in large numbers, more than sufficient for all purposes of the plantation. Water was procured from a large spring and carried to the settlement by ditches, which could be seen winding around the hills. Chatham Island, and in fact all the islands of the archipelago, are of recent volcanic origin, the only arable land being in the elevated basins of the craters. Here, on the principal cone near the centre of the island, we found the Hacienda del Progreso."

Topography of the Galapagos.

As seen from the sea from the southeast, distant about ten miles, the western half of Chatham Island forms its principal and highest part. It rises more rapidly from its western extremity at Wreck Point to a height of 2,490 feet, as marked on the Admiralty charts. This summit is separated by a high land from the next highest point, which reaches an elevation of nearly 2,000 feet. From here the western mass gradually falls with gentle slopes toward the east, and is separated by a low valley from the central mass, slightly undulating and with two nearly equal summits, which reach less than one third the height of the western half. This in its turn is separated from the eastern extremity of the island, which is somewhat higher than the central mass. The southern slopes of the western mass of the island are covered by numerous small craters, and here and there its even outline as seen against the sky is interrupted by the sharp line of a smaller crater. Along the southern shore on the eastern half of the island there are a large number of the so called tuff craters, readily distinguished from the other craters, even at the distance at which we saw them, by their reddish color. They form a prominent line of well defined low, sharp cones, with more or less perfect craters.

Hood Island we did not visit. Captain Tanner, who passed a day on the island in 1888, says: "It is low compared with others of the group, its surface being covered with masses of broken lava rock. A little soil has formed between the blocks, in which bushes of various kinds find root, and during the season of rains lend a rich green hue to the otherwise barren surface. It is wholly devoid of fresh water during the dry season, and has no commercial value. Gardner's Bay is a good anchorage in the fine weather that usually prevails."

Indefatigable Island is perhaps the one of the Galapagos which best shows the mode of their formation. It forms a single mass, rising gently on all sides toward the great central plateau; its sides are comparatively little broken by lateral craters; the central plateau is surrounded by a series of rounded elevations, the remnants of the rim of the old crater. According to Mr. Cobos, after passing the lower line of the lava boulders one reaches, at about the same elevation as on Chatham and Charles, the plateau region, where the lava has become decomposed into a most fertile soil, and for the size of the island its area fit for cultivation is quite extensive. The general character of the lower slopes, which reach to the water's edge, do not differ from those of the other islands we visited. Innumerable spits, composed of huge lava blocks running into the sea and separated by small coral rock beaches, similar to those I have described at Wreck Bay on Chatham Island, at Black Beach on Charles Island, and on Duncan Island. Conway Bay itself, where we anchored for the night, on Indefatigable Island, is a fine example of one of the coral rock beaches so characteristic of the Galapagos. Off to the north of Conway Bay are the Guy Fawkes Islands, one of the old craters of which is still barely visible. The craters of the other island appear to have been sloughed off on their southern face.

Captain Tanner, in the report of his visit to the Galapagos in 1888, says: "Indefatigable Island is circular in form and about twenty miles in diameter, with a central cone, in the basin of which lies a vast tract of arable, well watered land, capable of growing all the tropical and semi-tropical products in great perfection. Its natural resources are greater than those of any other island in the group, yet it is uninhabited and wholly undeveloped. The low lands are devoid of water, and, like the other islands, barren and desolate during the dry season, the rain only bringing life to the bushes and stunted trees, which find a precarious existence among the lava boulders and scoria."

Narborough Island, as stated by Captain Tanner, "presented in the distance (as seen from the weather side) an unbroken covering of rich green foliage to the very summit of its central peak, 3,720 feet above the sea, and, on nearer approach, a fringe of luxuriant mangroves, bordering the eastern shore and the margin of a small bay or lagoon, added fresh charm to the view. As we steamed through the narrows between Narborough and Albemarle Islands the contrast of a rich and abundant vegetation on the one hand, and utter barrenness and desolation on the other, was very striking."

Narborough, which on this trip we only saw from a distance, towering behind Albemarle, may show the character of the building up of the separate islands better even than Indefatigable, for its single cone, rising to a height of over 3,700 feet, still possesses a well preserved crater.

The composite nature of some of the islands is best seen on Albemarle. It rises to a greater height than any of the other islands (4,700 feet), and, as we saw it from the sea, the lower slopes of its five highest cones passed one into the other at various elevations. The three northern ones were separated by a comparatively low isthmus from the two southern peaks, which form the southern half of the island, the general trend of which is nearly at right angles to that of the northern craters.

We only saw Albemarle in the distance, and the following account of the island is taken from Captain Tanner's report : —

"Albemarle Island is by far the largest of the archipelago, but is uninhabited, and has no present commercial value except for its orchilla, which grows on bushes and trees, and has slight resemblance to Florida moss. It is used for making purple dye, and commands a high price in the European markets. The highest point on the island is within three or four miles of the southern extremity, and reaches an elevation of 4,700 feet. A rich green foliage covered the rugged surface of huge lava boulders to the very summit. Further to the northward, and all along the west coast as far as Tagus Cove, the land was comparatively low, and presented a striking resemblance to a burnt district dotted with numerous small volcanic cones. The general aspect was a reddish brown, but it was varied by occasional pyramids, symmetrical in form, and of lighter color, resembling artificial mounds of sand and mud which had had barely time to dry. The line of demarcation between the rich carpet of foliage and utter desolation of the barren district was so regular and well defined that it was difficult to realize that it was Nature's handiwork. The watering place marked on the chart was perfectly dry, and we learned from Mr. Cobos that it was only during the latter part of the rainy season that water could be found. There were patches of green near the northern end of Albemarle Island, but the general aspect was barren and desolate."

James Island as seen from Duncan rises rapidly on its western edge, culminates in a high crest, broken by numerous projecting rounded summits forming the central ridge of the island, and slopes rather gradually towards its eastern extremity, where there are a number of small cones and craters similar to those of the southeastern face of Chatham Island.

Darwin passed a week on James Island. He paid a visit to its upper regions, and reached an altitude of nearly 2,000 feet. He speaks of "the upper region being kept damp from the moisture of the condensed clouds, and supporting a green and flourishing vegetation," although he found the lower region covered by nearly leafless bushes.

James Bay, where the "Albatross" anchored in 1888, is, as Captain Tanner says in his Report to the Fish Commissioner, "on the west end of James Island, which protects it from the prevailing winds, the swell being partially broken by projecting points and small islands. It is a good anchorage with easterly winds, and may be recognized by the following landmarks. Albany Island is conspicuous, being lighter in color than its surroundings, and abreast of it are bold lava cliffs, which extend to a short stretch of white sand beach at the bottom of the bay. The southern extremity is marked by a point having a double peak, from which extends a barren lava-colored belt, resembling that described on Albemarle Island. Small salt lagoons lie just back of the sand beach. The watering place mentioned is on a point nearly abreast of Albany Island, and during the latter part of the rainy season furnishes a good supply, but at other times the flow is either very small, or fails altogether. The supply is so limited and uncertain that the orchilla pickers who visit the island periodically do not depend upon it. The general aspect north and east of the bay was fresh and green, and a fringe of mangroves surrounding the lagoons gave that portion of the bay a particularly attractive appearance, while to the southward was a barren waste."

The landing at Duncan is in a boat cove, protected by a small island. The bottom is covered by coral sand, formed of fragments of Pocillopora. A number of seals evidently had chosen this spot as their favorite haunt, and on their way to a small plateau a little higher up, which they evidently frequented, had in some places worn the shore rocks perfectly smooth. There were perhaps twenty or thirty seals here, who must have found an abundant supply of fish, judging from the number we saw around the ship while she lay at anchor off the island. They must have been quite common on the Galapagos, and have been noted as occurring on Hood, Charles, Chatham, James, and Jarvis. Both albatross and penguin appear to have been known on the islands, the latter a species characteristic of the group.[1]

The photograph of a part of the eastern slope of Duncan Island (Plate XXII.), opposite our anchorage, will give a better idea of the character of its shores and its vegetation than any more lengthy description I could give. Duncan Island rises quite abruptly on all sides from the sea, and with the exception of a small plateau on its southern extremity well towards the summit, and of a slight depression between the highest point and the northern end, presents a nearly regular conical outline as seen from the sea.

Opposite our anchorage on Duncan Island we found a number of

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[1] I am informed by Captain C. A. M. Taber of New Bedford, who twice visited the Galapagos, the first time as early as 1843, that he discovered an albatross rookery on the weather side of Hood's Island, and on his second visit he made a number of observations on the seal rookeries of various islands, which he mentioned in a late number of "Science," May 27, 1891.

the aquatic Amblyrhynchus crawling about upon the lava rocks, close to the water's edge. Neither at Chatham, Charles, nor Duncan did I see any specimens of the terrestrial species.

Captain Tanner in speaking of the anchorage off Duncan Island says: "We anchored in fifteen fathoms in an open bay on the northeast side of Duncan Island. We were off a conspicuous gorge in the mountain side, and about two hundred yards to the southward of a small islet which lay directly in front of it, and about fifty yards from the shore. Its surface was covered with bushes and other vegetation, which distinguishes it from rocks farther to the southward. There was an excellent landing place for boats inside of the islet. The general appearance of Duncan Island was green, bushes and cactus being distributed over its surface. There is no living water on the island, yet it is a favorite resort for the celebrated galapagos."

The northern and northeastern islands of the group are far more barren than the central and southern. This is natural, as neither Bindloe nor Abingdon is high enough to reach the altitude where in the larger islands we find a comparatively moist and cool climate, and where the high plateau is fairly fertile and capable of cultivation. On the Admiralty charts, according to the survey of Fitzroy, Bindloe is not more than 800 feet, and Abingdon has only a small area above 1,000 feet. So that, as far as we could judge while sailing by these islands, they hold an intermediate position as regards their appearance between such islands as Duncan and Wenman, and the larger, higher, and more fertile islands Chatham and Charles. Tower Island we did not sight. Seen from the ship, the geological structure of Abingdon and of Bindloe did not differ from that of the other islands of the group. Bindloe as seen from the west resembles Chatham somewhat, but is more broken by craters, and a large part of the southern face of the island is covered by a huge flow of black lava rocks, standing out in bold relief against the green slopes surrounding it on every side.

Bindloe, although so much broken up by its many craters, forms only a single mass, the craters being arranged in a somewhat irregular ring around the plateau which constitutes its centre.

The eastern face of Wenman is a perpendicular cliff. The top of the island is covered with a thin coating of green, consisting of tall grass, and of a scant vegetation, and is evidently more barren than Duncan Island. Its eastern face seems to have been sloughed off.

Culpepper Island we passed in the dark.

The Fauna of the Galapagos.

In addition to a large number of oceanic birds shot by Mr. Townsend during the cruise, he also made an important collection of birds from Chatham and Charles Islands, considering the short time we were there. On our way up to the hacienda of Mr. Cobos, we had our first experience of the great tameness of the birds. They did not seem to be in the least affected by our presence, and while we halted some of them rested on the mules' hind quarters, and even on the shoulders and hats of some members of the party. Our experience on Charles Island was similar. On all sides the finches and thrushes paid no attention to us, and a number could readily have been caught with a butterfly net, or even a hat. Yet there has been some population on Chatham Island for a number of years, and Charles Island has of late been rarely visited. I need only refer to Darwin's account of the tameness of birds, in his "Voyages of the Adventure and Beagle," Vol. III. p. 475.

As regards the fauna of the Galapagos, I may mention having seen a bat, which I was told by Mr. Cobos he had noticed on Chatham Island only for the last six or seven years. Dr. Wolf mentions them in 1875, and I hear from Dr. Baur that he has collected some specimens. It is interesting to remember that since Darwin's visit, in 1835, a number of domesticated animals have become wild, and have greatly multiplied since the abandonment of the settlements on Charles Island. We have wild cattle on Chatham, on Charles, on James, and on Indefatigable; also, wild donkeys, hogs, sheep, goats, cats, dogs, and the common fowl.

I collected insects on Chatham, Charles, and Duncan, and was amazed at the poverty of the catch. Of course a prolonged stay would undoubtedly bring to light many interesting things; but of the few species of Lepidoptera, an Argynnis, a Colias, a Eudamus, and a Lycæna seemed to be the most characteristic, and were found on all these islands. A few Noctuidæ, and only few species of Diptera, of Hymenoptera, or of Neuroptera, though one of the species of the Libellulidæ was very abundant on Chatham, two species of Acridium, a large one inland and a smaller species in the lower levels, and two or three species of Coleoptera, among which was a Carabus, were all I found. My short experience seemed not to differ materially from that of Dr. Wolf, whose entomological collections were most meagre, although he collected in the dry season. I was greatly struck with the vast number of caterpillars, but of a few species only, of Noctuidæ, Geometridæ, and Sphingidæ, which covered the grasses and bushes on Charles and Chatham Islands, and must have supplied the insectivorous birds with abundant food.

A few reptiles were collected at the Galapagos, Cocos Island, and Malpelo.

The only tortoise we obtained was found on Duncan Island by Mr. Townsend; we kept it on board the "Albatross" as far as Guaymas, and from there it was shipped to Washington, where it arrived safely.

The well worn tortoise tracks which Darwin saw on landing at Chatham Island, leading to the springs, which are situated on the larger islands towards the central parts and at a considerable elevation, are still quite marked on Charles Island. I saw no trace of them either on Chatham or on Duncan, on the parts of the islands which I examined. On Chatham, the tortoises, I was told by Mr. Cobos, have long since disappeared. According to Darwin, "it is said that formerly single vessels have taken away as many as seven hundred of these animals," so that the disappearance of the turtles is not astonishing; and they and the terrestrial Amblyrhynchus, which also serves as food, have become comparatively rare. We also collected at Duncan Island a few specimens of the aquatic Amblyrhynchus.

Sharks are very abundant throughout the waters of the Galapagos, and they, as well as the strong currents sweeping through the passages which separate the islands, may play an important part in checking the migration of animals from one island to another. We saw small sharks in great numbers at all our anchorages. Captain Tanner says that, in 1888, "the anchorage at Wreck Bay was infested with small sharks, which were taken by dozens until the fishermen tired of the sport."

A few specimens of rocks were also brought together from the different islands we visited, and such plants collected as it was possible to get during our short stay on shore.

The Coral Sand Beaches of the Galapagos.

I obtained from Mr. Cobos a piece of the so called sandstone said to occur on Indefatigable Island, and which of course I was most anxious to see, as the occurrence of true sandstone would have put quite a different face on the geological history of the Galapagos from the one usually received. This I found to be nothing but coral rock limestone, either a breccia or slightly oölitic, identical with the formation found back of the beach at Wreck Bay on Chatham Island. I found there an old coral rock beach, extending on the flat behind the present beach, composed entirely of fragments of corals, of mollusks, and other invertebrates, cemented together into a moderately compact oölitic limestone, which when discolored, as it often is, and turned gray, might readily be mistaken for sandstone. This coral rock is covered by just such a thin, ringing coating of limestone as characterizes the modern reef rock of other localities. On nearly all the islands there are a number of sandy beaches made up of decomposed fragments of corals and other invertebrates, and cemented together at or beyond high-water mark into the modern reef rock I have described. The coral is mainly made up of fragments of Pocillopora, which is found covering more or less extensive patches off these coral sand beaches, but which, as is well known, never forms true coral reefs in the Panamic district. The only true coral reef belonging to this district is that of Clipperton Island (if we can trust the Admiralty charts), situated about 700 miles to the southwest of Acapulco. But neither at Cocos Island, nor at the Galapagos, nor anywhere in the Panamic district, do we find true coral reefs, — nothing but isolated patches of reef-building coral. The absence of coral reefs in this district has of course already been noted by other naturalists, who have been struck by this feature in an equatorial region. Dana has ascribed it to the lower temperature of the water due to the action of the Humboldt Current coming from the south, pouring into the Bay of Panama, and then flowing westward with the colder northerly current running along the west coast of Mexico and Central America. From the investigations made this year by the "Albatross," I am more inclined to assume that the true cause of the absence of coral reefs on the west coast of Central America is due to the immense amount of silt which is brought down the hill and mountain sides every rainy season, and which simply covers the floor of the ocean to a very considerable distance from the land, the terrigenous deposits being found by us even on the line from the Galapagos to Acapulco, at the most distant point from the shore to the side or extremities of our line. The mud in Panama Bay to the hundred fathom line is something extraordinary, and its influence on the growth of coral reefs is undoubtedly greatly increased from the large amount of decomposed vegetable matter which is mixed with the terrigenous deposits.

The Origin of the Fauna and Flora of the Galapagos Islands.

In an article on "The Origin of the Galapagos Islands," in the American Naturalist, (March and April, 1891,) Dr. Baur has expressed views on the origin of the fauna and flora of the Galapagos entirely at variance with what is known of their geological structure. He speaks of the Galapagos as being connected with the mainland by the 4,000 meter line. The ease with which such connections are made on a chart requires no serious discussion. Then he adds, "This [the connection of the Galapagos with South America] is an important fact; all the older maps showed the Galapagos separated from Central America." (!)

The islands of Duncan and Gallego, which are said to have existed between Clipperton and the Galapagos, he assumes to have disappeared. Their existence does not rest on any better basis than that of so many islands and shoals constantly reported by inexperienced or hasty navigators. Take the Rivadeneyra Shoal, — on which the "Albatross" has paid out over 1,000 fathoms, — which has been twice reported of late years, and is either a rip or an effect of light.

The connection of Vancouver and the Alaska Islands with the mainland, or that of the Santa Barbara Islands, Guadalupe, and other Californian islands, has nothing to do with the question of the former connection of the Galapagos with the South American continent. Each case must be judged by itself. Baur also brings up the case of the Tres Marias, which consist of stratified rocks and are close to the Mexican coast, separated from it by a flat of not more than thirty fathoms, and speaks of them as on the same bank as Socorro and the Revilla Gigedo Islands. This seems to be taking a good deal of poetical license with our present knowledge, and especially to bring them up as an argument from analogy that the Galapagos have been a part of South America because they may have been and are within the 4,000 meter line. One would imagine from Dr. Baur's argument that the islands of Felice and Juan Fernandez are closely connected with and due south of the Galapagos. Surely so much is known of the habits of the seals and of the albatross that we need not look upon their existence on the islands as proving any land connection between the southern points where they are known to breed, and the Galapagos, where they also have colonized. Dr. Baur also mentions the case of the Sandwich Islands as having originated by subsidence. No more unfortunate suggestion could have been made regarding their origin. All we know of their geology seems to show that the different islands have been gradually built up around a central nucleus by successive eruptions, much in the same way that the Galapagos were. It seems hardly worth while, on the basis of the assumption of Dr. Baur, to renew speculations on the theory of the permanence of the Pacific Ocean basin. After Dr. Baur has completed his examination of the Galapagos, and has given us the additional soundings leading to different views from those based upon our present knowledge, it will be time to discuss the matter. When Dr. Baur says, "It would appear that the whole west coast of America has undergone subsidence," he is making a statement which is absolutely without foundation. On the contrary, all that we know of the geology of the west coast of Mexico, of Central America, and of South America, shows that their shores have been rising to a very great elevation as far south as the southern part of Chili. Dr. Baur need only refer to Darwin's "Geological Researches," and to the statements of the geologists who have examined the geology of Central America, to satisfy himself on that point.

What has taken place north of the Gulf of California need not detain us. Why should not Cocos Island and Malpelo come within the same influences of subsidence ? Some of the causes which Dr. Baur applies to the Galapagos to explain their present state have given the one its luxuriant vegetation, and have kept the other barren, and they are still plainly visible on the most cursory examination. The vegetation of the rainless belt along the coast of South America presents the same peculiarities and the same contrasts as that of the Galapagos and Cocos ; given an absence of rain, and what can be more desolate than the region around Payta, the greater part of the coast of Peru, and northern Chili ? Yet where do we find more brilliant verdure than along the river beds of the same region, or in districts which can be irrigated ? Absence of rain and moisture in the equatorial regions apparently produces as great a diminution in the size of the constituents of a flora as the excessive cold of an arctic climate or a high altitude.

It seems far more natural to us to appeal, as we have done, to the agency of the trade winds and currents to account for the origin of the fauna and flora of these interesting islands. We are thus not called upon to accept a theory of extensive subsidence in an area where all the geological indications are those of elevation, especially when the proof of this subsidence is based on no better evidence than the so called alpine character of parts of its flora, and upon the presumed former connection of the Galapagos Islands with the Central American continent. The alpine features of the flora we have attempted to explain by its similarity to that of the adjoining rainless belt of South America, and we deny the existence of a former connection of these volcanic islands with the mainland, separated as they are now by a plain of nearly 2,000 fathoms in depth.

While slowly steaming through the archipelago from island to island, we had an excellent opportunity of studying the natural features of these islands, and also as we passed their shores or were dredging within a moderate distance. As far as a cursory examination like ours could prove anything regarding the nature of the geological structure of the islands, our observations fully agree with those of Darwin and of Wolf, that this group presents one of the best examples of true volcanic islands.

The majority of the islands are evidently formed around a central crater or centre of elevation. They have increased in size and in height from successive lava flows. There is nothing to show that the separate islands are entirely the result of the disintegration of a larger volcanic chain, though of course a certain amount of denudation and submarine erosion has undoubtedly taken place, as is readily seen on the slopes of the islands and on examination of the soundings between them. Neither do we find any indications either of elevation or of subsidence of any part of the area of the Galapagos district which would affect their topography, and, as Wolf maintains, we can still less explain their formation by a separation in former periods from the South American continent. On the contrary, every part of their structure seems to prove that the islands have been slowly formed by submarine eruptions at first, and subsequently by similar accretions at the level of the sea, until finally some of the islands have reached an elevation of over 3,000 feet. During this process of growth some of the islands have become joined together, as for instance Albemarle, which is probably composed of three islands originally independent, and also the eastern and western parts of Chatham, which were surely once two separate islands, and are now connected only by a low isthmus.

The volcanic activity of some of the islands has continued to comparatively very recent times. I am informed by Mr. Cobos that smoke has been seen to issue from Narborough as late as 1836, and it is well known that Captain Collet was driven from Tagus Cove by the heat due to an eruption on the neighboring Narborough. It is quite probable that the age of the Galapagos does not reach beyond the earliest tertiary period, and many parts have undoubtedly not been formed before the present epoch, so that the time is geologically short during which so many animals and plants peculiar to the islands have developed from their South American, their Central American, their Mexican, or their West Indian ancestors.

Wolf has already called attention to the fact that the petrographic character of the Galapagos volcanoes is different from that of the volcanoes of the mainland, the latter consisting of trachytic and andesite material, while the former are made up of basaltic rocks. The specimens of volcanic rocks which I collected at Chatham Island, on Charles, and on Duncan Island, were all basaltic.

Wolf, whose acquaintance with the flora of the high Andes appears to be very extensive, was struck with the Andean character of the Compositæ, and with the analogy of a species of Polylepis and other trees with those forms that in the high Andes[1] make small forests, reaching to an altitude of 13,000 feet. He found also a remarkable similarity in the mosses and ferns with those of the Quito district, and some of the species he even considers as identical.[2] As he well says: "Es ist kein Zweifel, dass die Vegetation, trotz ihrer Eigenthümlichkeiten, im Ganzen einen südamerikanischen Typus besitzt, sowohl nach den Gattungen als nach dem äussern Habitus; wodurch sie sich aber auf den ersten Blick von der Flora des Festlandes auch dem Nicht-Botaniker unterscheidet, ist die Kleinheit der Blattorgane[3] die Abwesenheit schöner Blüthen, die Seltenheit der epiphytischen Gewächse, und das Fehlen der Lianen oder Schlingpflanzen." We miss all the wealth of the tropical forests, which is so striking in the equatorial zone of Central and South America.

The Deep-Sea Fauna of the Panamic District.

As a striking result of the character of the deep-sea fauna of the Panamic district, we found, in the first place, a great many of my old West Indian friends. In nearly all the groups of marine forms among

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[1] Is it not perhaps more natural to compare the vegetation of the lower belt of the Galapagos to that of the rainless belt extending along the coast of South America from Ecuador southward? The stunted character of the vegetation of the rainless belt is as marked a feature of that district as it is of the Alpine regions.

[2] Hooker, while discussing (Trans. Lin. Soc., 1851, Vol. XX. p. 163) the affinities of the flora of the Galapagos and its origin, lays great stress upon the action of currents coming north from the Guyaquil River, and those flowing westward from the Bay of Panama, as agents for the distribution of South and Central American plants. Speaking of the affinities of the plants of the Galapagos, he says: "The new species being for the most part allied to plants of the cooler parts of America, or the uplands of the tropical latitudes. The more peculiar are the same as abound chiefly in the hot and damper regions, as the West Indian Islands and the shores of the Gulf of Mexico."

[3] As Darwin says, the bush which from its minute brown leaves chiefly gives the leafless appearance to the brushwood is one of the Euphorbiaceæ, and an acacia and a cactus are quite common in some parts, while in the upper regions of the islands the ferns and coarse grasses are abundant.

the Fishes, Crustacea, Worms, Mollusks, Echinoderms, and Polyps, we brought up familiar West Indian types or east coast forms, together with quite a number of forms whose wide geographical distribution was already known, and is now extended to the Eastern Pacific. This was naturally to be expected from the fact that the district we explored is practically a new field, nothing having been done except what the "Albatross" herself has accomplished along the west coast of North and South America. The "Challenger," as will be remembered, came from Japan to the Sandwich Islands, and from there south across to Juan Fernandez, leaving, as it were, a huge field of which we attacked the middle wedge. As far as we can judge at present, it seems very evident that, even in deep water, there is on the west coast of Central America a considerable fauna which finds its parallel in the West Indies, and recalls later Cretaceous times, when the Caribbean Sea was practically a bay of the Pacific, — a deep-sea fauna showing relationship on the one side to Atlantic and West Indian types, and on the other pointing to the eastward extension of western Pacific types of wide geographical range, which mix with the strictly deep-sea Panamic ones. The western and eastern Pacific fauna, while as a whole presenting very marked features in common, yet also present striking differences. The vast extent of territory over which some of the marine types extend, through all the tropical part of the Pacific, may readily be explained from the course of the great western Equatorial Current and the eastern counter current, which cannot fail to act as general distributers in space for the extension of a vast number of marine Vertebrates and Invertebrates. A similar extensive geographical range from north to south has also been observed in the distribution of some of the Mollusks, Echini, and Starfishes, which extend all the way from the southern extremity of South America to the Panamic region. The course of the northerly current setting along the west coast of South America must of course act as a distributer of the marine fauna of that region. There are, indeed, a number of genera in the deep water, and to some extent also in the shallower depths, which show far greater affinity with the Pacific than with the Atlantic fauna. Of course, further explorations may show that some of these genera are simply genera of a wider geographical distribution; but I think a sufficiently large proportion of the deep-sea fauna will still attest the former connection of the Pacific and the Atlantic.

In the first part of our cruise I was somewhat disappointed in the richness of the deep-sea fauna in the Panamic district. It certainly does not compare with that of the West Indian side, or that off the eastern coast of the United States. I have little doubt that this comparative poverty is due to the absence of a great oceanic current like the Gulf Stream, bringing with it on its surface a large amount of food which serves to supply the deep-sea fauna along its course.

The same comparative poverty of animal life also characterized our second line of explorations. After we reached Galera Point, we began our line across the Humboldt Current, which was to give us a fair idea of the fauna of that part of the coast as far as the southern face of the Galapagos. With the exception of three good casts, the trawling on that part of the sea bottom proved comparatively poor, nor did the sea face of the southern slope of the Galapagos give us anything like the rich fauna I had expected. Theoretically, it seemed certain that a sea face like that of the Galapagos, bathed as it is by a great current coming from the south and impinging upon its slope, and carrying upon its surface a mass of animal food, could not fail to constitute a most favorable set of conditions for the subsistence and development of a rich deep-sea fauna.

On leaving the Galapagos we took up a former line of the "Albatross" run off Indefatigable Island, hoping to obtain from that quarter our best results, but our hauls were very disappointing. The ground proved not only most difficult to dredge upon, but also comparatively barren, and it was not till we got into the oceanic basin again, between the Galapagos and Acapulco, that our catches improved. But even then they were not to be compared with the hauls at similar depths in the Atlantic off the West Indies, or along the course of the Gulf Stream.

In the first cruise we also found great difficulty in trawling, owing to the considerable irregularities of the bottom. When trawling from north to south, we seemed to cut across submarine ridges, and it was only while trawling from east to west that we generally maintained a fairly uniform depth.

In the Panamic region proper, — the region occupied by our track to Cocos, to Malpelo, and back to Panama, and from there to Galera Point, the Galapagos, and on toward Acapulco, — the most interesting things we found were representatives of the Ceratias group of Fishes, which the naturalists of the "Albatross" tell me they have not met before on the west coast of North America. I may also mention many types of Macruridæ and of Ophidiidæ, fine specimens of Bathyonus, of Bathybrissa, and of Bathypterois, and a few specimens of Ipnops in excellent condition. The Crustacea have supplied us with a most remarkable type of the Willemœsia group (Eryoneicus), together with the many types characteristic of muddy bottoms, as Glyphocrangon, Notostomus, Heterocarpus, Pentacheles, and Nematocarcinus, many of which we afterwards dredged in the Gulf of California. I may mention one haul which contained a goodly number of a species of Nephrops. The paucity of Echini is most striking, although we brought up in one of the hauls numerous fragments of a gigantic species of Cystechinus, subsequently dredged in the channel between Galera Point and the Galapagos, as well as in the Gulf of California. The occurrence of Cystechinus so far north is interesting; the specimens collected by the "Challenger" came from the Southern Ocean, and a fossil species of the genus has been described by Gregory from Barbados. Other Echini characteristic of muddy bottoms, such as Aspidodiadema, Urechinus, Pourtalesia, and Schizaster, were brought up from deep water, while on rocky bottom we found Salenia and some species of Cidaridæ, all closely allied to their West Indian representatives. The number of Ophiurans was remarkably small as compared with the fauna of deep waters on the Atlantic side, where it often seems as if Ophiurans had been the first and only objects created. The absence of deep-sea corals is also quite striking. They play so important a part in the fauna of the deeper waters of the West Indies, that the contrast is most marked. Gorgoniæ and other Halcyonoids are likewise uncommon. We found but few Siliceous Sponges, and all of well known types. Starfishes are abundant, and are as well represented in the variety of genera and species as on the Atlantic side of the Isthmus. I may also mention the large number of deep-sea Holothurians (Elasipoda) which we obtained, as well as a most remarkable deep-sea Actinian, closely allied to Cerianthus, but evidently belonging to a new family of that group. We found occasionally, when trawling over the region of green mud, large tracts of mud tubes; they belong to the usual types of deep-sea West Indian Annelids.

In the deeper parts of the channel between Galera Point and the southern face of Chatham Island we found a great number of Elasipoda, among them several genera like Peniagone, Benthodytes, and Euphronides, represented by numerous species. The Starfishes of the second part of our cruise did not differ materially from those collected during our first trip, but we added some fine species of Freyella, Hymenaster, Astrogonium, Asterina, and Archasteridæ to our collections. Among the Sea-urchins on two occasions we brought up fine hauls of a species of Cystechinus with a hard test, many specimens of which were in admirable state of preservation. Among the Ophiurans nothing of importance was added, unless I may except a lot of Ophiocreas attached to a Primnoa, and a pretty species of Sigsbeia attached to a species of Allopora, from the south side of Chatham Island.

The Gorgonians were remarkably few in number. This is undoubtedly due to the unfavorable nature of the bottom we worked upon.

From the nature of the bottom we naturally expected rich hauls of Siliceous Sponges, but we did not find many, and I do not think there are many novelties among those we have collected. On two occasions, a number of specimens of Ascidians were brought up; among them was a fine white translucent Corinascidia.

Among the Bryozoans, the most noteworthy haul was a number of beautiful specimens of the delicate Naresia (Kinetoskias), in excellent condition. On the line from the Galapagos to Acapulco we brought up a good many Foraminifera from the mud bottoms. On several occasions the bottom must have been covered with huge masses of a new type of an arenaceous Foraminifer, forming immense curling sheets attached by one edge to stones or sunk into the mud. This Foraminifer seems to increase in size by forming irregular more or less concentric crescent-shaped rings. When it comes to the surface, it is of a dark olive-green color. This and a species of Rhabdamina allied to R. lineata were the most striking Foraminifera collected.

Among the Worms, the Maldaniæ, Halinæcia, Terebella, and limicolous types were unusually abundant at some localities, the empty mud tubes often filling the bottom of the trawl. Some very large specimens of Trophonia were collected, and remarkably brilliantly colored (orange and carmine) Nemerteans and Planarians.

The Mollusks were comparatively few in number, and the types eminently Caribbean. The absence of Comatulæ or other Crinoids was equally disappointing, even when trawling on the extension of the line started three years ago by the "Albatross," on the eastern face of the Galapagos slope, when on her way from Chatham Island to San Francisco, although we were fortunate enough to bring up off Mariato Point in 782 fathoms a single fine specimen of Calamocrinus, with a part of the stem and its base, showing the mode of attachment of this genus to be similar to that of the fossil Apiocrinidæ.

Two of the hauls made in the Gulf of California are specially worthy of mention, as being characteristic of the deep-water fauna of the Gulf of California, one made in 995 fathoms and the other in 1,588 fathoms. We obtained in these hauls a number of Ophiomusium and Ophiocreas, some fine specimens of Schizaster, a new genus allied to Paleopneustes, and also the same species of Cystechinus, with a hard test, and of Phormosoma, which we had obtained before on the line from the Galapagos to Acapulco. Besides these, there came up a number of specimens of an interesting species of Pourtalesia, most closely allied to Pourtalesia miranda, the first type of the group dredged in the Florida Channel by Count Pourtalès.

The deeper haul was especially rich in Holothurians, among them a fine large white Cucumaria, some specimens of Trochostoma, several species of Benthodytes, some of them remarkable for their white color, their huge size, and the comparatively small number of ventral tentacles. With these were numerous specimens of an interesting species of Euphronides. In this haul I was specially struck with the Elasipoda, and the great variety in the consistency of the skin in individuals of one and the same species; it varied in different individuals from extreme tenuity to a comparatively tough gelatine-like consistency. On carefully sifting the mud, we found a number of interesting Foraminifera, and of delicate and minute Gasteropods and Lamellibranchs, fragments of the shell of an Argonauta, and two species of a huge ribbed Dentalium. Among the Starfishes were specially noticeable a large Brisinga, a long-armed Cribrella, and several species of Astropecten. The usual types of Worms were found in the mud at these greater depths. In addition to a number of Macruroids, we obtained a pink Aphyonus, a large black Beryx-like fish, a fine Nettastoma, and a couple of species of Lycodes. The usual surface species of Stomias and of Scopelus also came up in the trawl. Among the Crustaceans were a fine lot of Arcturus, of Colossendeis, of Glyphocrangon, and of a Caridid with a deep blue patch on the base of the carapace, making the strongest possible contrast to the dark crimson coloring of the rest of the body. Blue is a very unusual color in the deep-sea types, although the large eggs of some of the deep-sea Macrurans are often of a light blue tint.

We brought up in the trawl at various times, and subsequently also in the Tanner net, from depths of less than 200 fathoms, the same gigantic Ostracod which I mentioned before, several specimens of Atolla, and fragments of a huge Periphylla, which must have been at least fifteen inches in diameter; also a most interesting new type of Bougainvillia, remarkable for having eight clusters of marginal tentacles, but only four chymiferous tubes. Of course neither these Acalephs, nor some of the Beryx-like fishes, of the Scopelids, Stomias, Melamphaës, and the like, which were brought up from less than 300 fathoms by the Tanner net, can any longer be considered as part of the deep-sea fauna.

After passing the Tres Marias, we made several hauls, and obtained some Umbellulæ, Pennatulæ, Trochoptilum, Anthoptilum, and a fine Antipathes, a few Comatulæ, a large Astropecten, some fine specimens of Urechinus and of Schizaster, a few Holothurians, Lophothuria, and Trochostoma, and two species of Elasipoda, besides a few fragments of Gasteropods, with an empty shell of Argonauta.

Among the Crustacea there came up the usual types found living upon muddy bottom, such as Glyphocrangon, Heterocarpus, Notostomus, Pentacheles, Nematocarcinus, and Nephrops, together with species of Lithodes and of Munida. The usual types of limicolous Annelids were also found here, Halinæcia, Terebella, Maldania, and the like; a few Ophiurans, Ophiopholis and Ophiocantha; a few fragments of Farrea, and a huge Hyalonema of the type of H. toxeres. Among the Fishes there were a few Macruridæ, Bathypterois, Lycodes, and Malthe.

Comparison of the Deep-Water Echini obtained in the Panamic and Caribbean Districts.

There will naturally be considerable delay in obtaining the results even of the preliminary examination of the collections sent to the different specialists. To illustrate, therefore, somewhat more in detail the contrasts between the deep-water fauna of the Panamic and of the Caribbean districts, I will make here a very general comparison of the Echini collected on the two sides of the Isthmus of Panama. The identifications here given are of course subject to the revision of the closer and final determination of the collections. This subject will later be fully illustrated by comparative tables of the distribution of the species on the two sides of the Isthmus.

I may state, in general, that we have discovered in the deep-sea fauna of the Panamic district only one genus of Sea-urchins, allied to Salenia, not previously represented on the Atlantic side. The poverty in Clypeastroids was as striking as on the Atlantic side, and in the very heart of the shallow water district so markedly characterized by Clypeastroids on both the Atlantic and Pacific sides we dredged only one specimen of Clypeaster, in 75 fathoms. As in the Caribbean, we find Phormosoma and Asthenosoma; also one species of Aspidodiadema and one of Salenia; Cidaris, Dorocidaris, and Goniocidaris, as well as Porocidaris; which offer an exact parallel in the Pacific to the same genera on the Atlantic side. Of course, how far they are allied a more accurate comparison alone can determine. We may, however, call attention to the absence of Arbaciadæ, which as littoral genera are eminently characteristic of the temperate and tropical American shores. Some of the genera of the family extend into deep water on the Atlantic side, but they have not been found by the "Albatross" in the Pacific Panamic district. Neither Podocidaris nor Cœlopleurus was dredged by us. The absence of the latter genus is specially noteworthy, as it is found at Mauritius and has been dredged by the "Challenger" in the East Indian Archipelago. The only Pacific genus found in deep water was Maretia. It should be remembered that the genera of Cidaridæ and of Echinothuriæ all have an extensive Pacific, as well as Atlantic distribution. There were no deep-water Nucleolidæ, although they are found in shallow water in the Central American district and in deep water in the West Indian fauna. The occurrence of Echinocrepis, Cystechinus and Urechinus, types characteristic of the Southern Ocean and Southern Pacific, is interesting, associated as they are with Pourtalesia proper, a genus of wide geographical distribution, which, as well as Urechinus, is found in the Caribbean district. The ubiquitous Schizaster and Brissopsis were associated on the Pacific side with Paleopneustes, Homolampas, and Hemiaster, as in the West Indian district; and the remarkable Aërope, which has an extensive geograpical distribution, — it is found in the Arafura Sea and off the eastern coast of North America, — was not uncommon in the Panamic area. Moira, on the contrary, which again is a characteristic American genus on both sides of the continent in the temperate zone, was not obtained by the "Albatross" on her present cruise.

I need at present only to refer to the chapter on the origin of the West Indian Fauna in the report of the "Blake" Echini,[1] where lists will be found of the Cretaceous and Tertiary Echini, and where they are compared with those living in the West Indian and neighboring areas at the present day. It is interesting to note here the occurrence of a species of Cystechinus from the Radiolarian Marls of Barbados, mentioned by Gregory.[2] I understand from him that a species allied to Paleopneustes has also been detected in the same beds. The existence of Cystechinus at Barbados is another link in the evidence of a former connection between the Caribbean and the Pacific, — of a time when, as I have suggested, the Caribbean was probably a bay of the Pacific, — until later cretaceous times; but they gradually during the tertiary period[3] became

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[1] Mem. Mus. Comp. Zoöl., Vol. X. No. 1, and Three Cruises of the "Blake," Vol. I. pp. 92, 109–124.

[2] See Quart. Journ. Geol. Soc. London, November, 1889.

[3] See the Memoir of Gabb on the Geology of Santo Domingo, in the Trans. of the Am. Phil. Soc., Vol. XV., 1873, pp. 49-259.

separated by elevations which finally left the Caribbean, up to a comparatively recent time, only connected with the Pacific, as it is to-day with the Atlantic, merely by narrow passages.

The Color of Deep-Sea Types.

During our cruise a good deal of attention was given to making colored sketches of as large a number of deep-sea types as possible. There is among them considerable variety as well as range of coloration. Although it is true, as has been noticed by Thomson and others, that the violets, reds, and purples are the prevailing colors, yet we find also a number of forms in which yellows prevail, as, for instance, in the Comatulæ and in Calamocrinus; the yellow in the latter genus passing to a greenish tinge, in the Comatulæ to a reddish tinge, or even to brilliant red as the principal tint. In the Crustacea the deep-sea types like Gnathophausia, Notostomus, and Glyphocrangon are of a brilliant scarlet; in some types, as in the Munidæ and the Willemœsiæ, the coloration tends to pinkish, or yellowish pink, while in Nephrops and Heterocarpus the scarlet passes more into greenish tints and patches. The color of the deep-sea Pycnogonidæ did not differ from that of the littoral species. The large eggs of some of the deep-sea genera are of a brilliant light blue, and in one genus of Macrura we found a deep dark metallic blue patch on the dorsal part of the carapace, in striking contrast to the brilliant crimson of the rest of the body. Blue is an uncommon color among pelagic animals, and is certainly not specially protective, as is stated by Hensen and others; for the Porpitidæ, Yanthina, Physalia, Glaucus, and a few other types, which form the exceptions, are among the most conspicuous of all surface animals. Many of these, especially among the Acalephs, are colorless, it is true, yet in spite of their transparency often become conspicuous objects from the development of more or less opaque genital organs or actinal appendages.

The Starfishes, as a rule, were of duller hues than the Crustacea, but all more or less tending to pinkish tints, with a greater or less mixture of yellow or orange among the Astrogonidæ on the one side, while on the other the Archasteridæ developed more into pinkish grays or ashy hues. The same was the case with the Brisingidæ. The Hymenasteridæ, on the contrary, varied from light bluish violet to deep reddish chestnut colors. Among the Ophiurans, with the exception of Ophiocreas, which are of a yellowish brick-red, the species we dredged (mainly from muddy bottoms) were of a dull grayish color, or with a more or less yellowish pink tint. A pretty Sigsbeia attached to an Allopora varied from nearly porcelain-white individuals to specimens more or less belted with bands of ashy violet.

The Pourtalesiæ with thin tests, like the other species of the family already known, were of a delicate pink color; those with stouter shells, of a dark violet or deep claret color. The same is true of Urechinus and of Cystechinus, in which the color varies from a light brownish pink to a pale claret tint.

The species of Asthenosoma were of a deep claret-color, varying from that to light brown, almost straw-color. Some of the Phormosomæ, on the contrary, are usually of a brownish brick-color, others of a deep violet. In Paleopneustes we find the same variation in tints as in the Echinothuriæ.

The coloration of the deep-sea fishes is comparatively monotonous. The tints are all of a light violet base, tending more or less to brownish or brownish yellow, or even to a greenish tint, especially among the Macruridæ. Some of the Liparidæ were of a dark violet, and one species was characterized by a brilliant blue band. The Ophidiidæ, Nemichthys, and the like, are usually of an ashy violet tint, while in Ipnops and Bathypterois the tints were of a decidedly yellowish brown. When we come to questionable deep-sea types, such as the Beryx-like fishes, we find some of them nearly black with a slight violet hue, resembling more in their coloring the prevailing body tints of Stomias and the like, and other fishes which occur within the 300 fathom line from the surface. Among the most strikingly colored fishes we obtained was a species of the Ceratias group, of a brilliant vermilion with yellowish blue patches on the sides, in striking contrast with its Atlantic congeners, which are usually of a blackish tint.

The semi-transparent deep-sea types, like Aphyonus, are usually pinkish, while the Scopelids and the like, which are pelagic fishes, the majority of which do not descend below 300 fathoms, have a dark, almost black coloration, in striking contrast with their silvery flanks, which often carry phosphorescent organs. In a species of Stomias there is on the sides a wide band, gradually tapering towards the tail, of a brilliant yellow.

Among the Holothurians we noticed the greatest variety in the coloring. In one species the color was of a delicate green tinge. Trochostoma does not differ greatly in coloration from its littoral allies. We obtained a white Cucumaria and some species of Benthodytes of the same color.

Peniagone and its nearest allies varied from a transparent milky white to yellow and light yellowish brown. Others again were of a pinkish color.

Deima, Orphnurgus, and their allies, were of a light brown or of a dirty yellow color. Benthodytes and Euphronides, with the exception of a few translucent specimens of a whitish tint, varied from a reddish violet to a deep claret, or to reddish with pronounced bluish tints, and one fine specimen of the group was of a bluish color with delicate violet shades passing into whitish milky blue.

Psychropotes and allied genera were of a reddish violet color on the dorsal side, with bluish violet of a lighter shade on the ventral surface.

The Maldaniæ, Serpulæ, and Terebellæ did not differ in their type of coloring from their littoral congeners.

The coloring of the so called deep-sea Acalephs, Periphylla, Atolla, and the like, has already been noted; it is usually of a deep violet or yellowish red. Although they have the characteristic coloring of many of the deep-sea types, yet they are known to live within comparatively shallow limits, inside the 200 fathom line, and even to come to the surface.

A species of Stomobrachium was remarkable for its light carmine color, a tint hitherto not observed among Acalephs.

The color of the Cephalopods, like that of the Acalephs, is limited mainly to violet, both in types which are undoubted deep-sea species and in those which are certainly pelagic.

Among the deep-sea Actiniæ, a species of a new Cerianthus was of a dark brick-red, while other Actinians allied to Bunodes were of a deep violet. Actinauge-like forms with tentacles of a pinkish violet tinge frequently have the column of a yellow shade. The Zoanthidæ were grayish green.

We cannot fail to be struck in this enumeration of colors with the preponderance of violet shades, as also with the great variety in tints, and their apparent absence of adaptation to the surrounding greenish gray waste of mud in which a fauna so diversified in coloring flourishes.

This variation in coloring extends to species of the same group, and is specially marked among the Holothurians. Among the Fishes and Crustaceans it is less so, the former having to a great extent apparently assumed the grayish or brownish shades of their surroundings; while in the Crustacea nothing could be more marked than the contrast between the brilliant coloring of the group and the dull surface upon which they dwell. In the Holothurians as well as in the Actinians we find both the contrast and the apparent adaptation to the surroundings.

This great diversity in coloration brings up interesting questions regarding the influence of the environment upon the fauna at great depths. But until we know more of the effects produced by the penetration of light through such masses of water, speculations as to their cause cannot rest upon a very substantial basis.

It is difficult to understand how so great and numberless variations may have been brought about, or to account for such a case of mimicry as was observed in a crab allied to the Maiadæ, in which the dorsal face of the carapace appears like a bit of muddy area covered by corals, with a huge white arm resembling a fragment of an Isis-like Gorgonian.

At present the simplest explanation is that suggested by Moseley, that the deep-sea types have little by little found their way into greater depths from the littoral limits, and have retained or lost many of the features characteristic of their littoral predecessors under conditions radically different from those existing in the abysses of the sea. As denizens of the littoral belt, they were subject to all the disturbing influences of the action of light, of heat, of a varying supply of food, and to a certain extent of the motion of the water. All these conditions are in striking contrast to those we may imagine to exist at great depths, where little change can be produced by whatever light may find its way to the bottom of an oceanic basin, where the temperature is uniform, where there is no motion, and where in fact all the factors we are accustomed to associate with marine life as we see it on our shores are practically wanting.

EXPLANATION OF THE PLATES.

PLATE I.

MODIFIED CHUN-PETERSEN TOW-NET.

Fig. 1. The net ready to lower.
Fig. 2. The net opened, ready to tow horizontally at the required depth.
Fig. 3. The net closed on its way up to the surface.

For lettering, see the description of the net, page 45.

PLATE II.

TANNER DEEP-SEA TOW-NET.

Fig. 1. Sketch of the Tanner tow-net open.
Fig. 2. Messenger for closing the net, sliding on wire rope.
Fig. 3. Sinker attached above the Tanner net.
Fig. 4. Bell crank tripped by messenger to liberate the slings.
Fig. 5. Attachment of bell crank to wire rope.
Fig. 6. Showing the lower part of the Tanner net when closed.

For lettering, see the description of the Tanner tow-net, pages 46, 47.

PLATE III.

HYDROGRAPHIC SKETCH OF THE PACIFIC, FROM THE GULF OF CALIFORNIA TO NORTHERN ECUADOR, WITH THE TRACK OF THE "ALBATROS."

PLATE IV.

SKETCH OF THE GALAPAGOS ISLANDS, WITH THE TRACK OF THE "ALBATROSS."

The sounding of 329 fathoms to the east of Indefatigable Island should read 392 fathoms.

PLATE V.

TEMPERATURE SECTION AND PROFILE, FROM MARIATO POINT TO COCOS ISLAND.

February 23d to February 28th.

PLATE VI.

TEMPERATURE SECTIONS AND PROFILES.

Fig. 1. From Cocos Island to Station 3375, a point 100 miles southwest of Malpelo Island. March 1st to March 4th.

Fig. 2. From Station 3375 to Malpelo Island, to Rey Island, one of the Pearl Islands in the Bay of Panama. March 4th to March 11th.

PLATE VII.

TEMPERATURE SECTIONS AND PROFILES.

Fig. 1. From Station 3392, thirty miles southeast from Point Mala, to Caracoles Point.

Fig. 2. From Station 3392, thirty miles southeast from Point Mala, to Point Mala.

Fig. 3. From Station 3383, fifty miles southeast from Caracoles Point, to Panama.

PLATE VIII.

TEMPERATURE SECTION AND PROFILE.

From north of Galera Point to off Galera Point, to Chatham Island, one of the Galapagos. March 23d to March 28th.

PLATE IX.

TEMPERATURE SECTION AND PROFILE.

From off Chatham Island to off James, to between Abingdon and Wenman Islands, to Acapulco. April 3d to April 12th.

PLATE X.

TEMPERATURE SECTIONS AND PROFILES.

Fig. 1. From north of Wreck Bay, Chatham Island, to Station 3408, six miles southwest of Bindloe Island.

Fig. 2. From Indefatigable Island to Bindloe Island.

Fig. 3. From Gordon Rocks, Indefatigable Island, to 392 fathoms, in an easterly direction.

Fig. 4. From north of Sulivan Bay, James Island, to Station 3407.

PLATE XI.

TEMPERATURE SECTIONS AND PROFILES.

Fig. 1. From Charles Island to Indefatigable Island.
Fig. 2. From Charles Island to Hood Island.
Fig. 3. From Hood Island to Chatham Island.
Fig. 4. From three miles south of Wreck Point, Chatham Island, to Station 3401.
Fig. 5. From ten miles northwest of Wreck Bay, Chatham Island, to twenty miles northeast of Hobbs Reef, Chatham Island.

PLATE XII.

TEMPERATURE SECTIONS AND PROFILES.

Fig. 1. From Hydrographic Station 2630, eleven miles east of Wenman Island, to Abingdon Island.
Fig. 2. From Hydrographic Station 2630 to Wenman Island.

PLATE XIII.

VEGETATION OF COCOS ISLAND, CHATHAM BAY.

PLATE XIV.

MALPELO ISLAND, SEEN FROM THE WESTWARD.

PLATE XV.

CORAL SAND FLAT, BACK OF THE LANDING BEACH AT WRECK BAY, CHATHAM ISLAND.

PLATE XVI.

VEGETATION CHARACTERISTIC OF THE BARREN BELT ON THE WAY TO THE COBOS HACIENDA, CHATHAM ISLAND.

About a mile from the landing at Wreck Bay.

PLATE XVII.

FERTILE HIGH PLATEAU OF CHATHAM ISLAND.

Seen looking east from the Cobos Hacienda.

PLATE XVIII.

Lava Blocks west of Black Beach, Charles Island (Floreana).

PLATE XIX.

Lava Rocks and Black Beach, Charles Island.

PLATE XX.

Vegetation near Black Beach, Charles Island.

PLATE XXI.

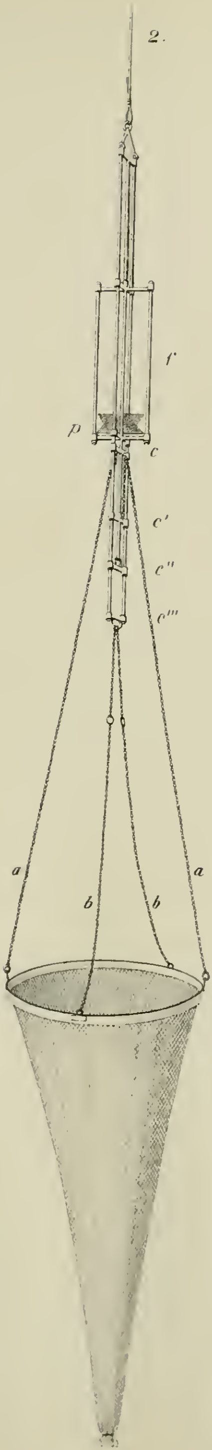
Vegetation on the Way to the abandoned Villamil Hacienda, Charles Island.

PLATE XXII.

Part of Eastern Face of Duncan Island, near the Landing Cove.

1.

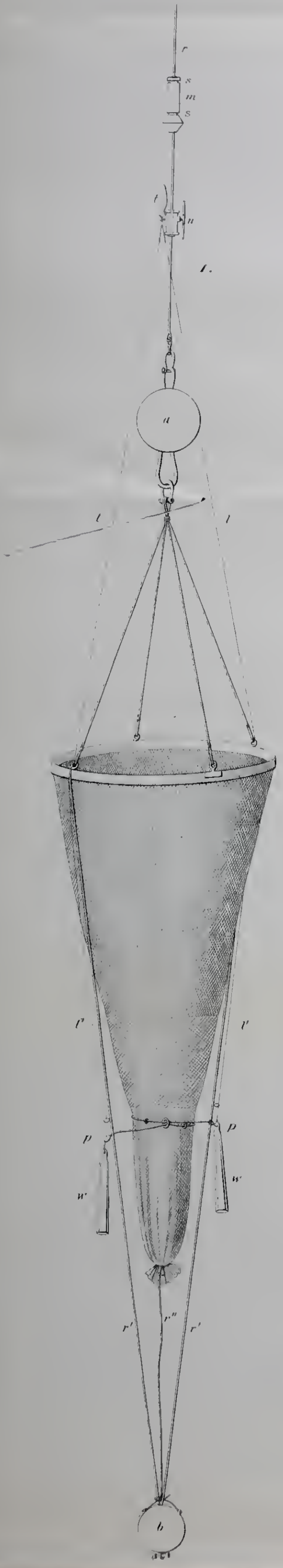
2.



3.

B. Meisel lith. Boston

1.



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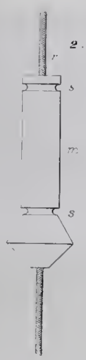

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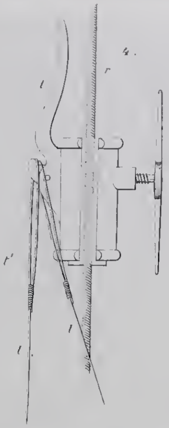

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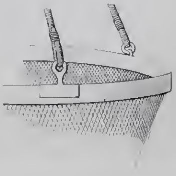

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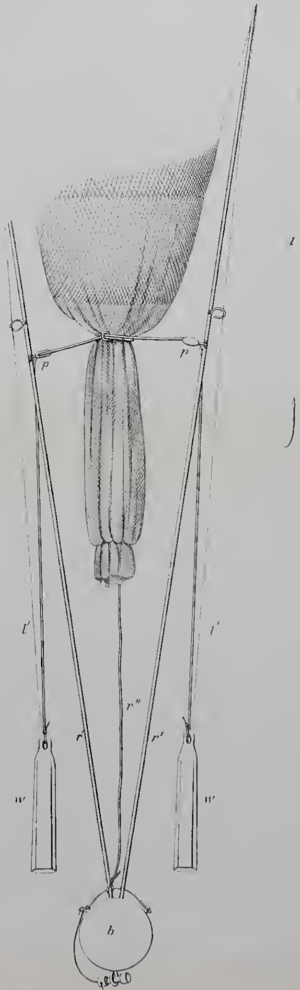
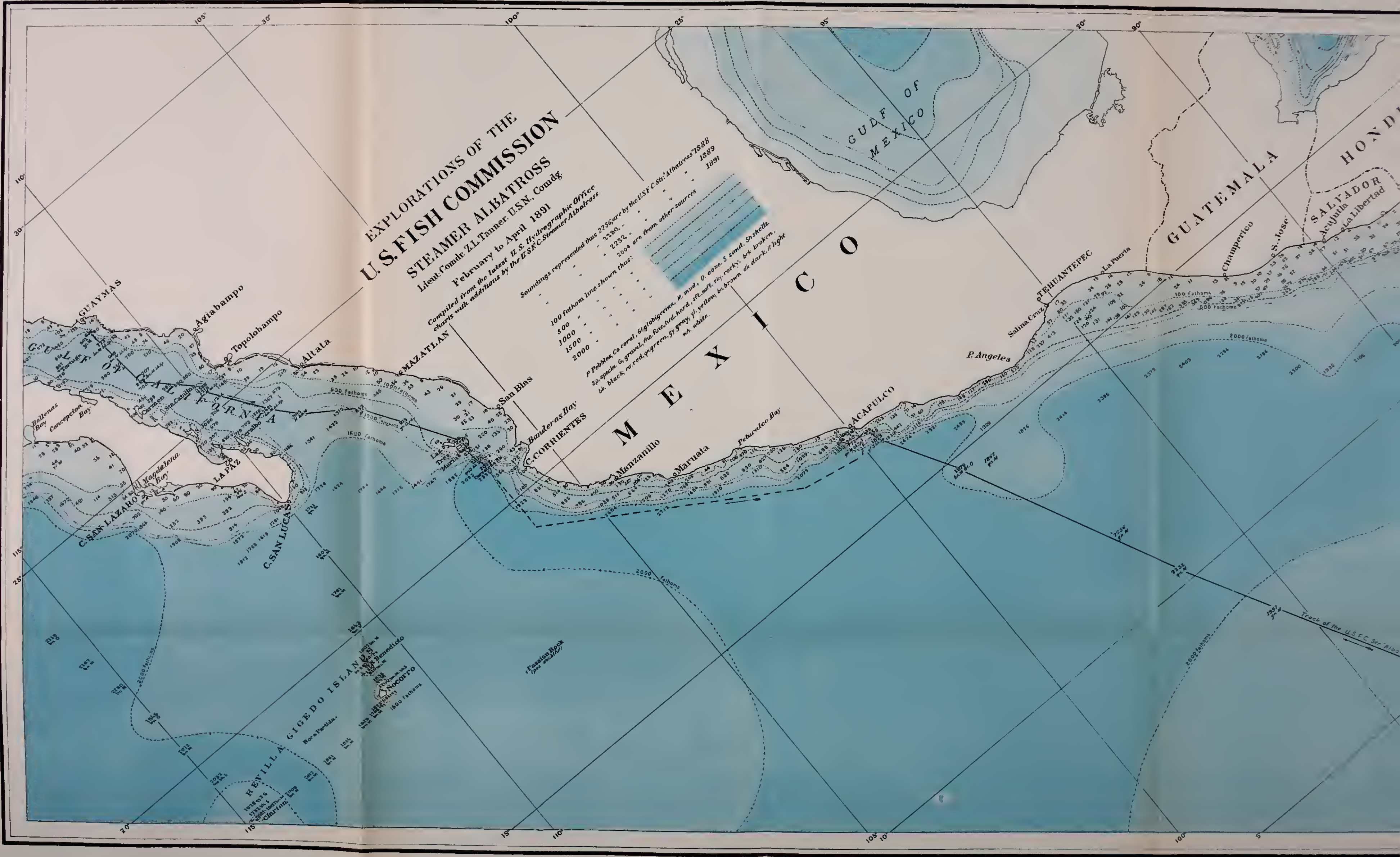
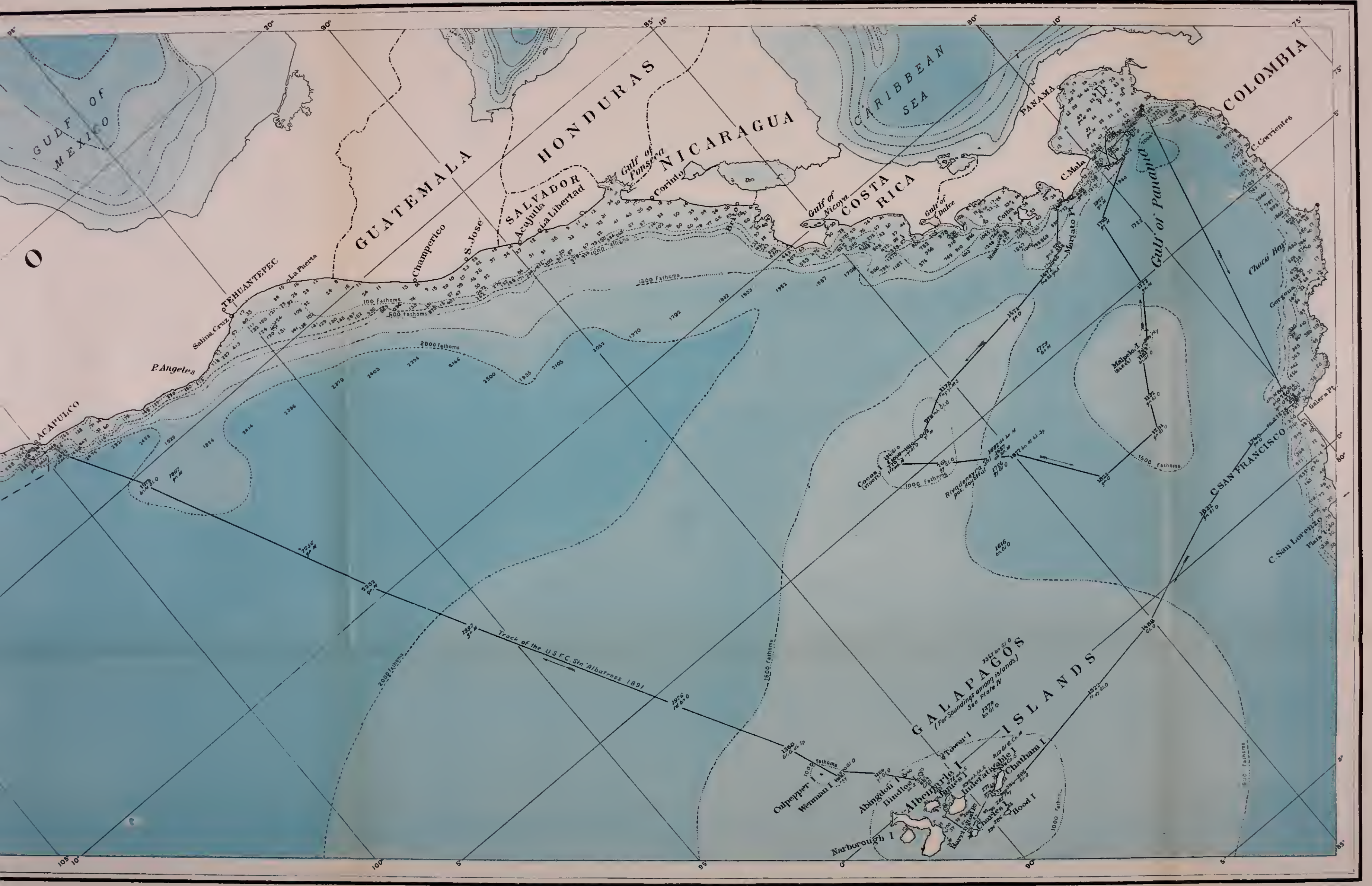


B. Meisel lith Boston


GUA
Gulf of Nicoya
CO
62
40
26
97
58
491
262
508
650
463
63
476
222
907
553
20
30
79
275
20
38
822
298
1708
1887
1952


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 2256, are by the U.S.F.C. Str. "Albatross" 1888
" " 2280, " " " " 1889
" " 2232, " " " " 1891
" " 2004 are from other sources
100 fathom line shown thus:
500 " " "
1000 " " "
1500 " " "
2000 " " "
P Pebbles, Co. coral, Gl. globigerina, M. mud, O. ooze, S sand, Sh. shells, Sp. specks, G. gravel, fne. fine, hrd. hard, sft. soft, rky. rocky, brk. broken, bk. black, rd. red, gn. green, gy. gray, yl. yellow, bn. brown, dk. dark, lt. light, wh. white.
GULF OF MEXICO
MEXICO
GUATEMALA
SALVADOR
HOND
GULF OF CALIFORNIA
GUAYMAS
Agiabampo
Topolobampo
Altata
MAZATLAN
San Blas
Banderas Bay
C. CORRIENTES
Manzanillo
Maruata
Petacalco Bay
ACAPULCO
P. Angeles
Salina Cruz
TEHUANTEPEC
La Puerta
Champerico
S. Jose
Acajutla
La Libertad
Tres Marias
Ballenas Bay
Concepcion Bay
Carmen
Sta. Catalina
S. Jose
Ceralbo
LA PAZ
Magdalena Bay
C. SAN LAZARO
C. SAN LUCAS
REVILLA GIGEDO ISLANDS
S. Benedicto
Socorro
Roca Partida
Clarion
Passion Rock (pos. doubtful)
Track of the U.S.F.C. Str. "Albatross"
100 fathoms
500 fathoms
1000 fathoms
1500 fathoms
2000 fathoms
105°
30°
100°
25°
95°
20°
90°
110°
115°
15°
10°
5°

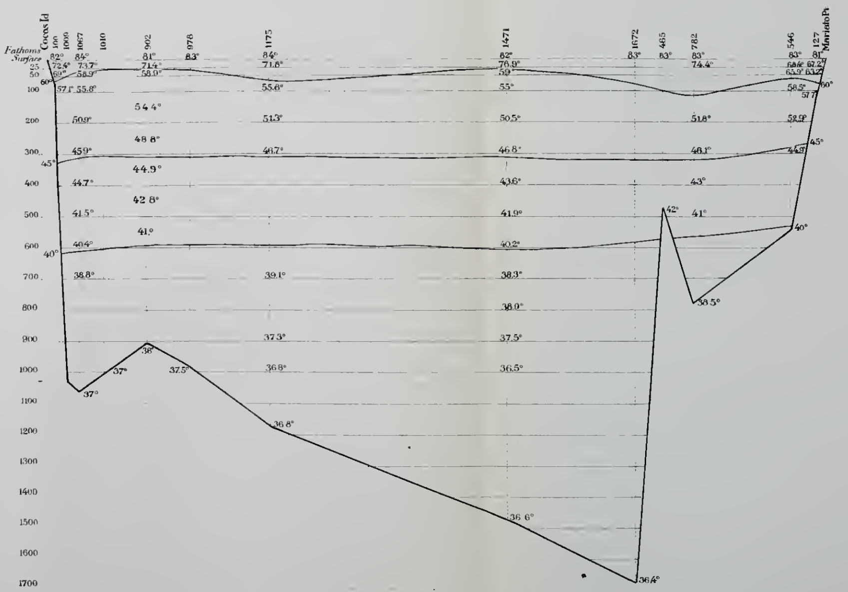

GULF OF MEXICO
O
CARIBBEAN SEA
GUATEMALA
HONDURAS
SALVADOR
NICARAGUA
COSTA RICA
PANAMA
COLOMBIA
TEHUANTEPEC
La Puerta
Salina Cruz
P. Angeles
ACAPULCO
Champerico
S. José
Acajutla
La Libertad
Gulf of Fonseca
Corinto
Brito
Gulf of Nicoya
Gulf of Dulce
Coiba
Mariato Pt.
C. Mala
Gulf of Panama
C. Corrientes
Chocó Bay
Gorgona I.
Galera Pt.
C. SAN FRANCISCO
C. San Lorenzo
Plata I.
Malpelo I.
Cocos I.
Rivadeneyra Sh'l pos. doubtful
100 fathoms
500 fathoms
1000 fathoms
1500 fathoms
2000 fathoms
Track of the U.S.F.C. Str. 'Albatross' 1891
GALAPAGOS ISLANDS
(For Soundings among islands) See Plate IV
Tower I.
Culpepper I.
Wenman I.
Abingdon I.
Bindloe I.
Albemarle I.
James I.
Indefatigable I.
Chatham I.
Narborough I.
Barrington I.
Charles I.
Hood I.
95°
90°
85°
80°
75°
20°
15°
10°
5°
0°
105°
100°


GALAPAGOS ISLANDS
SHOWING EXPLORATIONS
OF THE
U. S. FISH COMMISSION STEAMER "ALBATROSS"
Lieut-Comdr. Z. L. Tanner U.S.N. Comdg.
February to April 1891
Soundings represented thus: 671, are by the U.S.F.C.Str. 'Albatross' 1888
" " " 885, " " " " 1891
" " " 100, " from other sources.
P. Pebbles, Co. coral, Gl. globigerina, S. sand, Sh. shells, M. mud, O ooze, Sp. specks
fne. fine, hrd hard, rky rocky, bk black, wh white, gy. gray, yl yellow, brk. broken, dk. dark
Soundings shown thus 80 are negative
From B. A. Chart No. 1375
Track of the U.S.F.C. Str "Albatross" 1891
VAR. 8° 20' E
Culpepper I (850 ft)
Wenman I (830 ft)
Redonda Rock (185 ft)
Abingdon I
C. Chalmers
Cibbetson
Bindloe I
Tower I
Ripple
Albemarle Pt.
C. Berkeley
C. Marshall
Black Bight
Albemarle I.
C. Douglas
Narborough
C. Hammond
Elizabeth Bay
Webb Cove
Christopher Pt.
Iguana Cove
Essex Pt.
Albany I
James Bay
James
Sulivan Bay
C. Nepean
Cowley I
Jervis I
Daphne Is
Seymour Is
Guy Fawkes
Conway Bay
White Rk
Duncan I
Nameless I
C. Woodford
Crossman Is.
Brattle I
Gordon Rks
Indefatigable I
Barrington I
Chatham
Terrapin Rd
Finger Pt
Kicker Rk
Stephens Bay
Dalrymple Rk
Wreck Pt
Mt. Pitt
Hobbs Pt
East Rk
Freshwater Bay
Macgowen Reef
Post Office Bay
Charles
Blackbeach Rd.
Enderby I (330 ft)
Caldwell I
Gardner I (780 ft)
Watson I
Hood I
Gardner Bay
92°
30'
91°
90°
89°
2°
1°
0°

A

III.

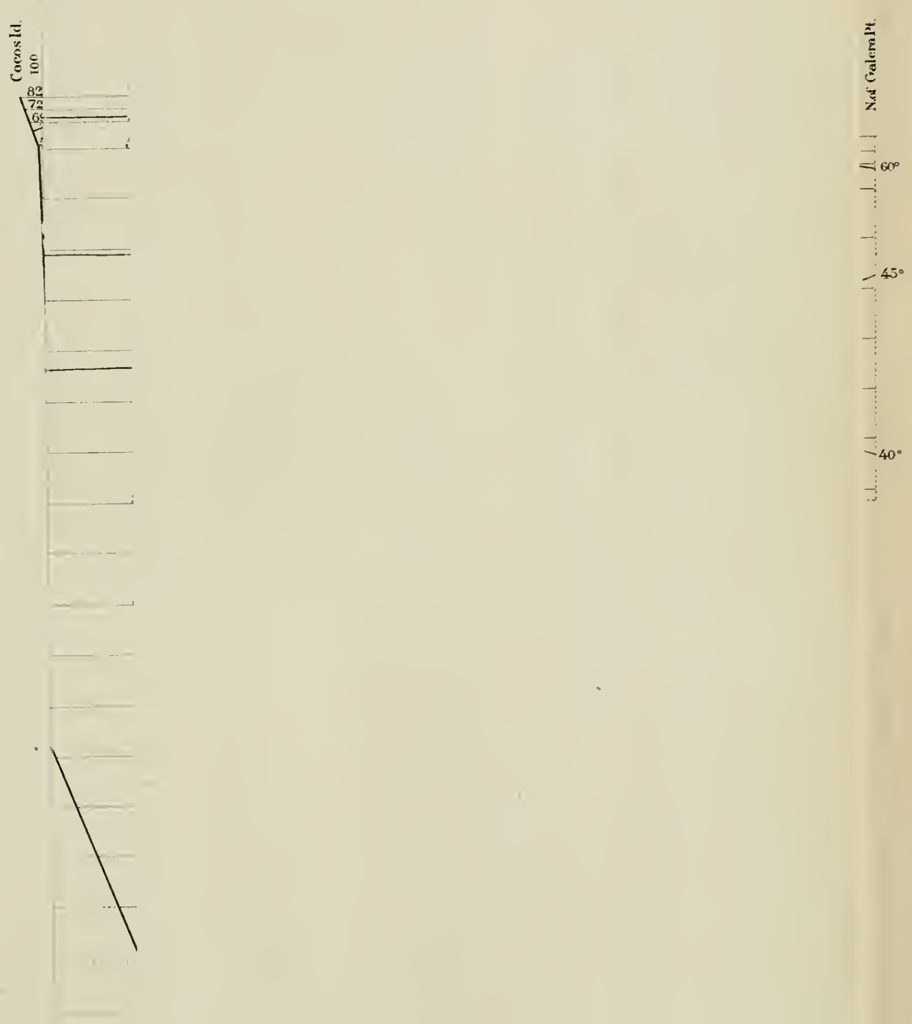
on



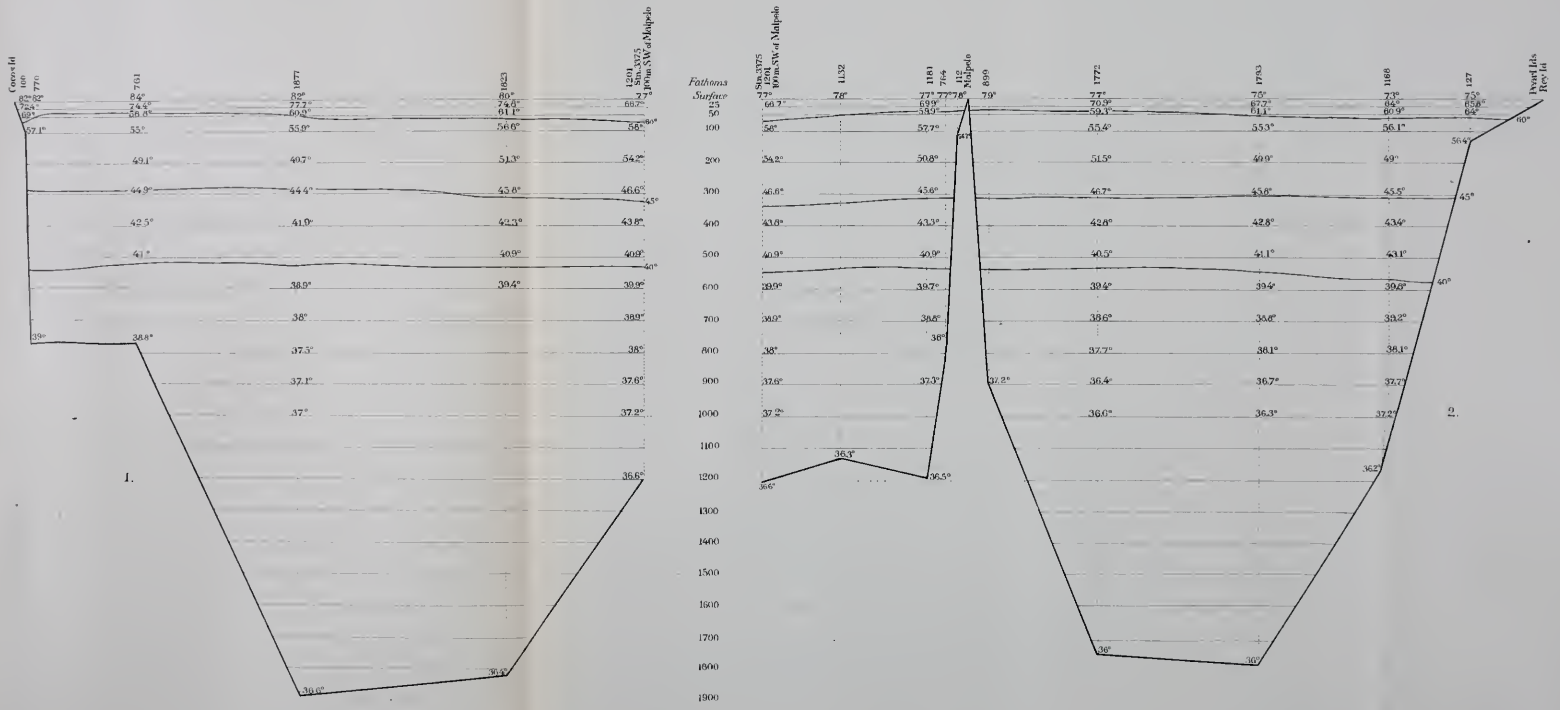
B. Meisel, lith. Boston

Ag

III.



on.



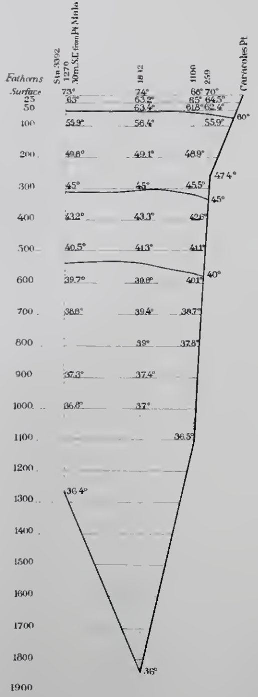
B. Meisel lith. Boston

AG

III.

ton.

1



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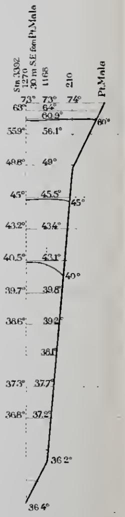
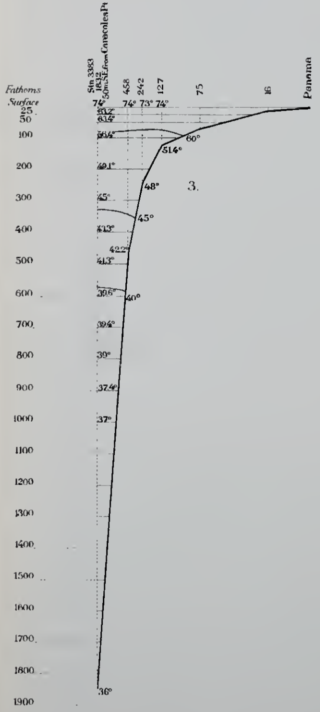
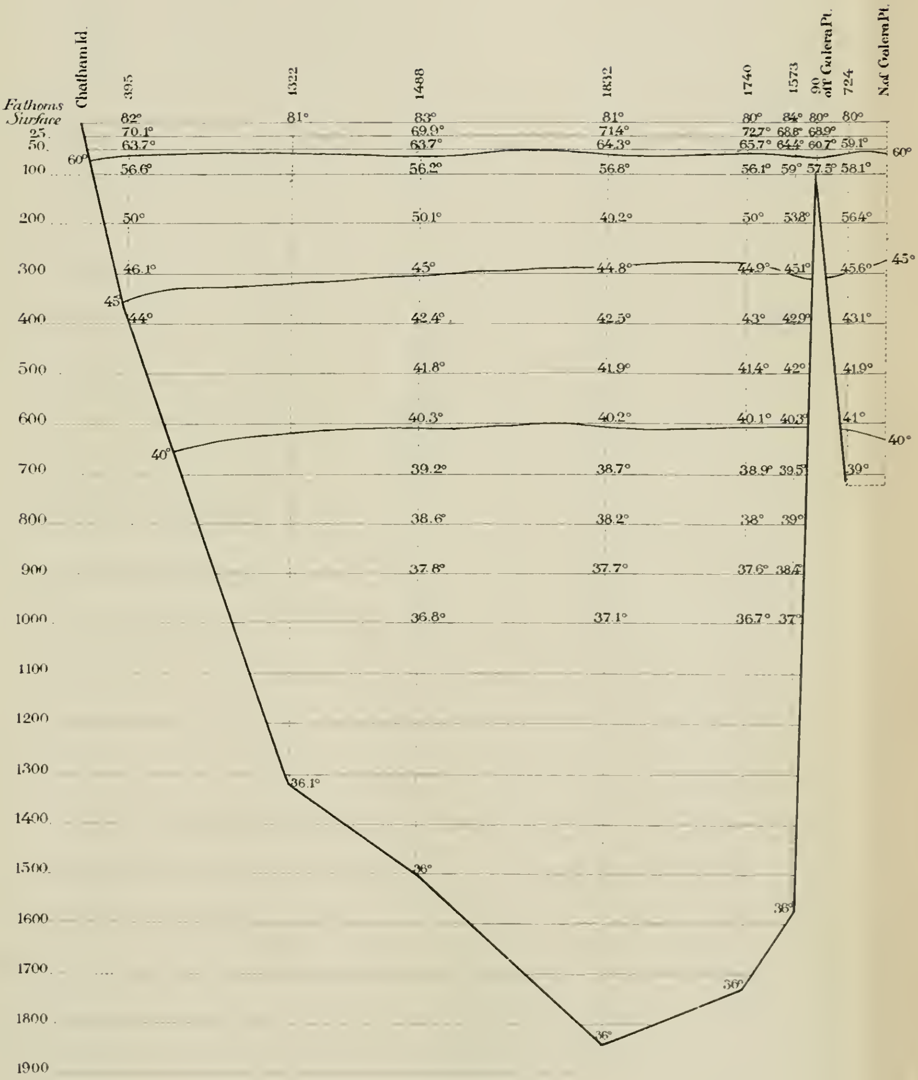




3.

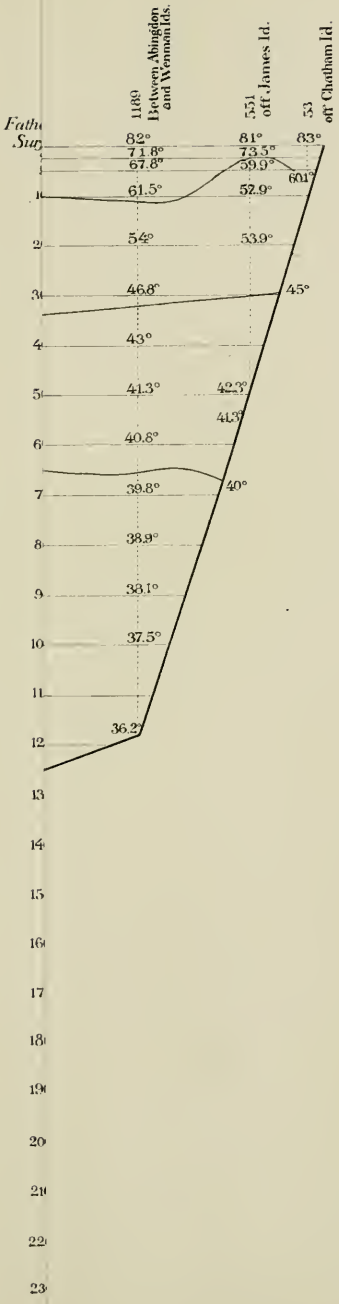
B Meisel lith Boston



B Meisel lith Boston

A

PL. IX



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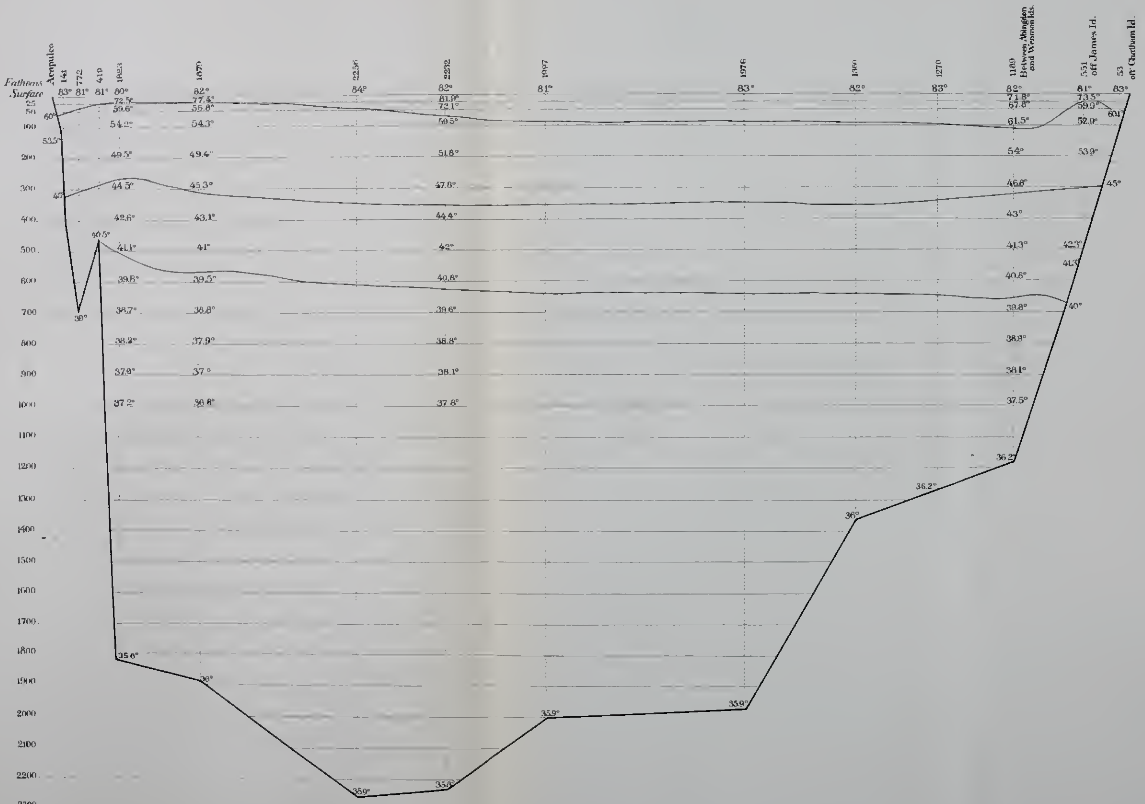
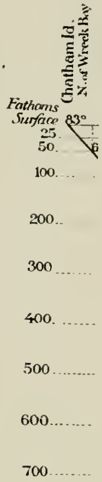
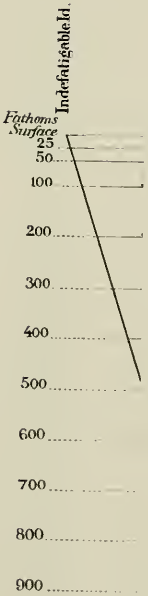
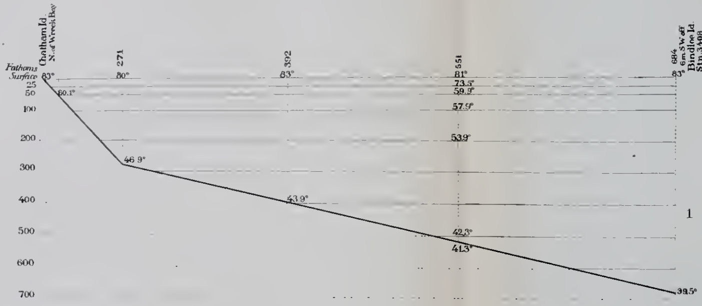


B. Meisel lith Boston


Chatham Id.
N. of Wreck Bay
Fathoms
Surface
83°
25
50
6
100
200
300
400
500
600
700


Indefatigable Id.
Fathoms
Surface
25
50
100
200
300
400
500
600
700
800
900



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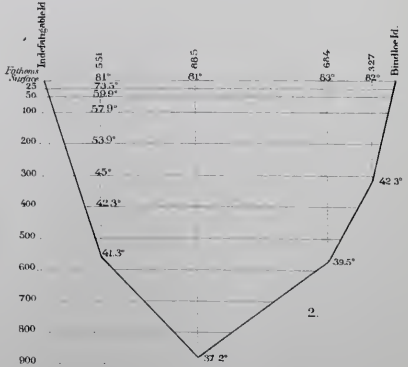

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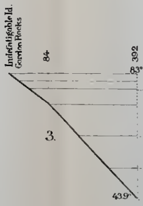

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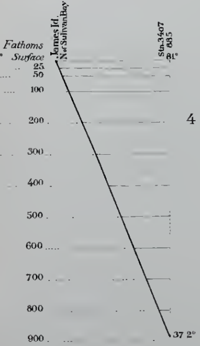

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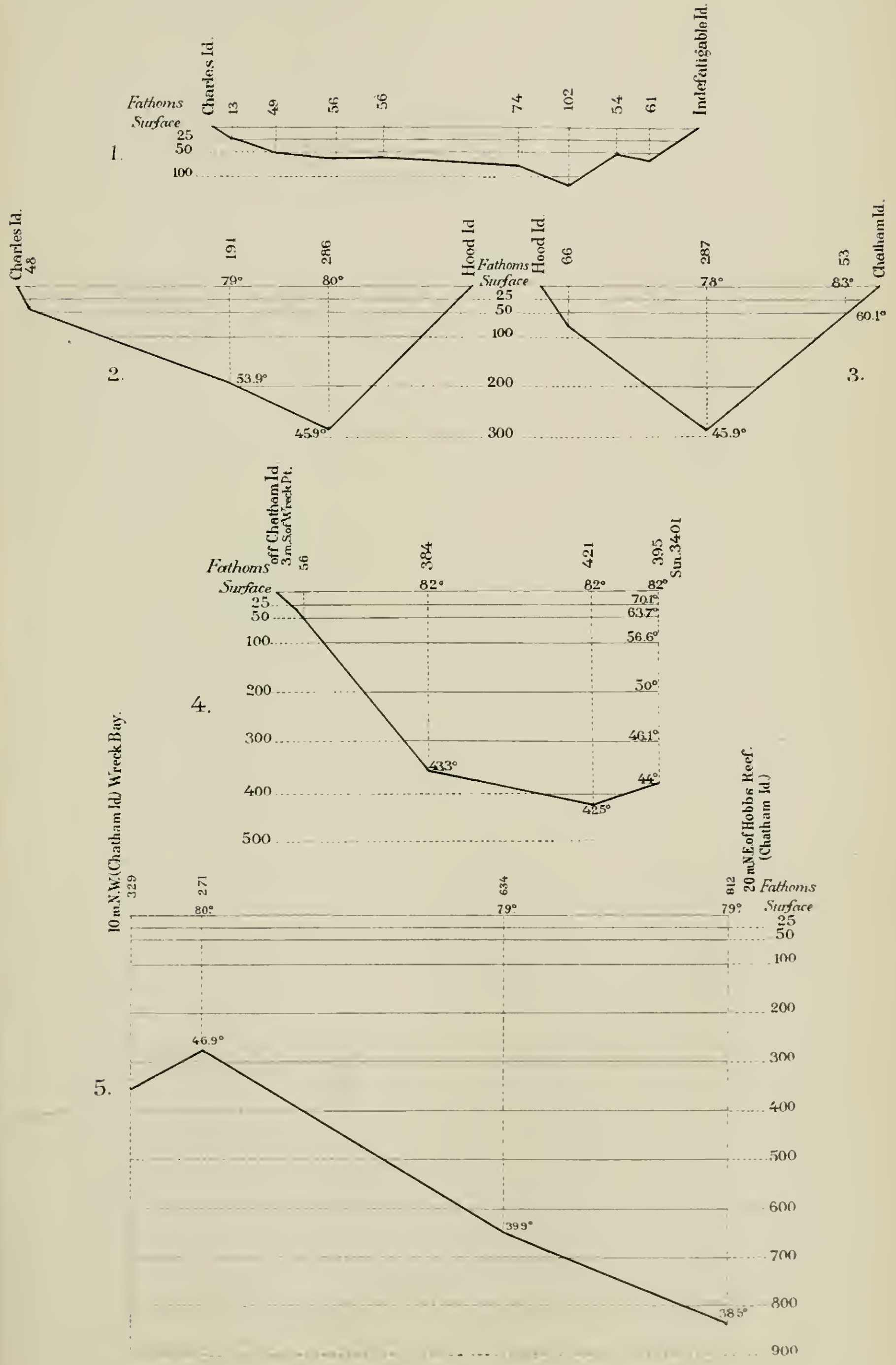
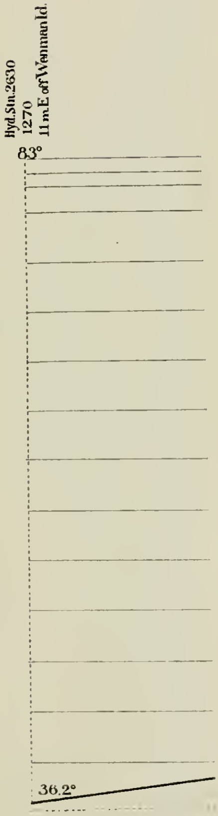
B. Meisel, lith Boston


1.
Fathoms
Surface
25
50
100
Charles Id.
13
49
56
56
74
102
54
61
Indefatigable Id.
2.
Charles Id.
48
191
286
79°
80°
53.9°
45.9°
Hood Id
Fathoms
Surface
25
50
100
200
300
3.
Hood Id.
66
287
53
Chatham Id.
78°
83°
60.1°
45.9°
4.
Fathoms
Surface
25
50
100
200
300
400
500
off Chatham Id
3 m. S. of Wreck Pt.
56
384
421
395
Sta. 3401
82°
82°
82°
70.1°
63.7°
56.6°
50°
46.1°
44°
43.3°
42.5°
5.
10 m. N.W. (Chatham Id) Wreck Bay.
329
271
634
812
20 m. N.E. of Hobbs Reef. (Chatham Id.)
80°
79°
79°
46.9°
39.9°
38.5°
Fathoms
Surface
25
50
100
200
300
400
500
600
700
800
900

1.



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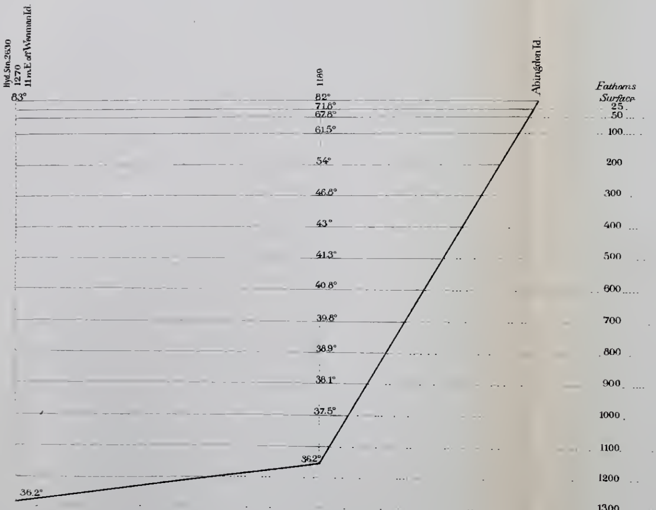

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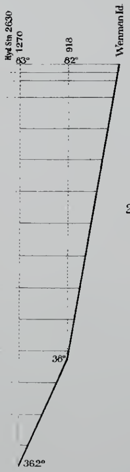

B. Meisel, lith. Boston

N. B. MILLER, PHOTO

ARTOTYPE, E. BIERSTADT N. Y.

CHATHAM BAY COCOS ISLAND.

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MALPELO ISLAND.

SEEN FROM THE WESTWARD.

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CORAL SAND FLAT, BACK OF LANDING BEACH, WRECK BAY.

CHATHAM ISLAND.

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ON WAY TO HACIENDA.

CHATHAM ISLAND.

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PLATEAU SEEN LOOKING EAST FROM HACIENDA.

CHATHAM ISLAND.

N. B. MILLER, PHOTO. ARTOTYPE, E. BIERSTADT N. Y.

LAVA BLOCKS WEST OF BLACKBEACH.

PLATE XIX.

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ROCKS AND BLACKBEACH.

CHARES ISLAND.

PLATE XX.

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VEGETATION NEAR BLACKBEACH.

CHARLES ISLAND.

N. H. MILLER, PHOTO.

ARTOTYPE, E. BIERSTADT, N. Y.

CHARLES ISLAND.

VEGETATION ON WAY TO HACIENDA

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ARTOTYPE, E. BIERSTADT, N. Y.

DUNCAN ISLAND.

EAST FACE NEAR LANDING COVE

No. 2. — *The Mesoderm in Teleosts: especially its Share in the Formation of the Pectoral Fin.* By E. R. Boyer.[1]

Table of Contents.

I. INTRODUCTION.

Balfour was the first to study the ontogeny of the paired fins in Elasmobranchs with sufficient fulness to determine the source of the musculature. His discoveries practically ended the discussion which was aroused by the widely different views concerning the phylogenetic origin of the vertebrate limb advocated by Thacher, Mivart, and Balfour on the one hand, and by Gegenbaur and Huxley on the other.

It is a well established rule, that, in the development of the paired limbs of Vertebrates, the earliest trace is a lateral ectodermal fold or diverticulum, into which subsequently the indifferent mesoderm grows

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

to form the rudimentary limb; and it is well known that, in some forms at least, in the further development of this rudimentary limb, or limb-bud, there are contributed by the myotomes secondary mesodermal elements which are destined to form its skeleton and musculature.

It has been my purpose in this paper to determine, if possible, the source of the mesoderm which enters into the formation of the paired fins of Teleosts, and to ascertain to what extent Fundulus conforms to this general rule. This problem involves, to a greater extent than I had anticipated, the early differentiation of the mesoderm itself, and indeed the origin of the mesoderm; but the latter subject, although very interesting and important, I have been obliged to omit entirely from my present study.

The protovertebræ, the lateral layers, and the structures known as "head mesoderm" and "intermediate cell-mass" are intimately related in their origin, and the source of the mesoderm in the pectoral fin has been referred by various authors to one or more of these structures. I therefore begin my observations with the formation of these parts, and trace their development and relations through the early stages, with a view to ascertaining their connection with the origin of the pectoral fin.

The very high degree of specialization which characterizes the ontogeny of Teleosts renders the investigation of certain questions quite difficult, and problems concerning points of homology and phylogenetic significance are beset with limitations and uncertainty. The extreme variation in the development of different forms of this vertebrate phylum also renders hazardous any attempt to draw general conclusions from the investigation of a single or only a few forms. Hence I cannot hope to place beyond the reach of criticism the conclusions which I have ventured to draw from observations made almost exclusively upon a single form.

This paper is the result of studies carried on during the year 1889–90 in the Zoölogical Laboratory of Harvard University, under the direction of Dr. E. L. Mark, at whose suggestion this problem was taken up. I owe grateful acknowledgment of my obligations to Dr. Mark for the uniformly kind and valuable assistance rendered to me in this work. I am also under great obligations to Prof. Alexander Agassiz, through whose courtesy I enjoyed the advantages of pursuing my studies at the U. S. Fish Commission Laboratory at Wood's Holl during the summer of 1889, where I was enabled to secure the material upon which the following observations were made. I am also indebted to Colonel Marshall McDonald, U. S. Commissioner of Fish and Fisheries, for various favors received through his department, and especially for many courtesies while

I was at the Fish Commission Laboratory, and for his kind co-operation in securing embryological material both at Gloucester and at Wood's Holl, Massachusetts.

II. Preliminary Account.

(*a*) *The Material.* — The material upon which the following observations are based is from Fundulus heteroclitus, an oviparous Cyprinodont, known in common parlance among fishermen as the "Short Minnow." The material was secured during the month of July, 1889, at Wood's Holl. The adult fishes of both sexes were taken with a seine along the shores of Buzzard's Bay, and confined in the aquaria of the hatchery at the Fish Commission station. At the proper time the ripe ova and sperm were taken by the process known as "stripping," and the ova were "artificially" fertilized and kept in running sea-water in a laboratory aquarium. From this supply of ova small quantities were taken at intervals up to the time of hatching, which varies from sixteen to eighteen days after fertilization, the temperature of the water being at an average of about 20° C.

The ova are submersal, remaining at the bottom of the aquarium, unless the current is strong enough to agitate the water sufficiently to raise them. They are covered with fine filaments, which are produced, according to Eigenmann ('90, pp. 129–132), by a membrane lying outside the zona radiata. The filaments of different eggs become entangled, and hold the eggs in clusters. The ova are about 2 mm. in diameter, with considerable variation in ova taken from different females. They are somewhat translucent, contain numerous oil globules, which are at first near the blastodisc, but are gradually carried over the yolk during the course of the development of the blastodisc. In Fundulus the yolk is not all absorbed until several days after hatching.

(*b*) *The Technique employed.* — The ova were killed at intervals increasing from one hour in the younger to eight hours in the older stages. The killing reagents used were Perenyi's fluid, Kleinenberg's picro-sulphuric mixture, and a solution of 0.25% osmic acid, followed by Whitman's modification of Merkel's fluid. The osmic material was washed in water, both before and after the use of Merkel's fluid, and all the material subsequent to the use of the killing reagent was carried through grades of alcohol to 90%. The material preserved with Perenyi's fluid has proved to be the most satisfactory, especially with the younger stages, but Kleinenberg's picro-sulphuric mixture is perhaps rather better for the more advanced stages. Both these reagents may be successfully used without the removal of the egg-shell; but in the use of osmic acid it is necessary to remove the shell, in order to enable the reagent to penetrate with sufficient rapidity.

In staining, I have attained my best results from the use of Kleinenberg's hæmatoxylin *in toto* for 20 to 24 hours, and decoloring with 70% acidulated alcohol for about 2 to 4 hours. This statement applies to material preserved with Perenyi's fluid and Kleinenberg's mixture. With osmic material the best results in staining have been attained by the use of Czokor's cochineal for 10 to 12 hours. The embryos were removed from the yolk under the dissecting microscope, dehydrated, penetrated with clove or cedar oil, followed with paraffin at a temperature of about 55° C., imbedded in paraffin in the usual way, and sectioned with a Thoma or a Cambridge rocking microtome.

(*c*) *Variation in the Development of Fundulus.* — In Fundulus I have noted a very considerable individual variation in the progress of embryonic development. Inasmuch as the ova of several individuals were placed together in the same aquarium for fertilization, this variation could not be owing to differences of surroundings, but may be due to a difference in the stages of maturity of the ova from the different females. I do not believe that a delay in the fertilization of some of the eggs could be sufficient to account for the existing variation in development. The period of vitality of the free teleostean spermatozoön is not very accurately known, but it probably does not exceed *a few hours.* It seems to me quite certain that no possible delay in the fertilization of any of the ova could account for the great difference in the hatching period, which has been found to vary as much as forty-eight hours; and since this variation also exists at the point of hatching, it cannot be assumed that all the retarded embryos below the hatching period are imperfect and do not reach maturity.

It is very probable that ova which are removed from the ovary by the process of "stripping" may not have reached the highest degree of maturation, and it may be possible that such ova are yet capable of fertilization, but that when thus artificially fertilized the development is not as rapid as in case of fully matured ova.

Owing to this variation, the embryos preserved at the same time do not all show the same stage of development; hence, to ascertain the relative advancement of the individual embryos of the same age requires considerable study of certain structures, — e. g. the condition of the optic and auditory vesicles, the nephrostome, gill-clefts, etc., — which may be selected as a safe index to exact stages of development. It has frequently occurred that, while seeking an embryo slightly more advanced than that just studied, one was found among *later* killings which represented a stage twelve to eighteen hours *younger*. This fact has vastly increased the task of finding a more or less complete series of successive stages.

III. — Summary of the Literature on the Development of Paired Fins in Fishes.

In this summary an attempt is made to trace the history of the observations which have led to our present knowledge of the development of the pectoral fins in fishes. Papers containing only purely theoretical and phylogenetic considerations upon the intensely interesting question of the origin of the vertebrate limbs are omitted, and also the observations which are based exclusively upon the morphological conditions of the adult forms. Hence, only such as are in the main embryological are referred to. Several papers are included which do not refer to fishes, but deal with the early development of the limbs in groups closely related to fishes. The earlier accounts of the fins by Rafinesque, Forchhammer, Rathke, von Baer, Lereboullet, and others, are not of much importance in considering the relation of the limb-buds to the germinal layers, and are consequently omitted.

(*a*) *Teleosts.* — Oellacher ('79, pp. 141–143), in a preliminary notice, which has not, to my knowledge, been followed by a more comprehensive communication upon the same subject, gives an account of the development of the paired fins in the Brook Trout. He maintains that the protovertebræ in the region of the pectoral fins grow out laterally into a mass of cells, which in cross section of the embryo gives the appearance of a triangular plate, lying directly upon the upper peritoneal layer, or somatopleure, and bounded by ectoderm above, the inner face of the triangle being continuous with the protovertebræ. This lateral mass of mesoderm becomes thinner in passing forward, backward, and outward, ending in a distinct margin, while it is thickest at its base, where it is continuous with the protovertebræ. Later, a change takes place in the contour of these plates, so that, instead of being thickest at their inner limit, where they are in connection with the protovertebræ, they are now thickest in a region farther from the axis of the embryo, and in cross sections of the latter present the outline of a triangle, with a slightly acute angle above, a sharply acute angle outwards, the point of the inner angle being in continuity with the protovertebræ.

Oellacher says nothing concerning the histological character of these structures, and gives no drawings. He makes no mention of the modification of the ectoderm in the region of the pectoral fin, and believes the ectodermal fold to be absent in these fins ; but he observed it in case of the pelvic and dorsal fins, and upon this difference he raises the question as to the different morphological signification of the pectoral and pelvic fins from the standpoint of their genesis. Oellacher was the first observer to trace the origin of the paired fins from the mesoderm, but it is evident that he failed to see the primary source of the mesoderm of the limb-bud, and did not understand the secondary relation between the pectoral plate and the protovertebræ.

'Swirski ('80, p. 15) has studied the limb-buds of the young fry of the Pike, and gives an account of their later structure and the development of the rudimentary skeletal parts. His description of the appearance of the mesoderm in cross sections of the pectoral fin of a young Pike, a day old, substantially agrees with that given by Oellacher ('79) for the Brook Trout. He also describes briefly the cells of the ectodermal fold, stating that the ectoderm in the region of the fold consists of beautiful large, cubical cells, with fine-grained nuclei and dark-grained protoplasm. 'Swirski notes that the ectodermal fold develops independently of the mesoderm, and is not continuous along the side to the region of the ventrals ; that it is present in the case of the pectoral fins is a fact which Oellacher had overlooked. 'Swirski does not, however, note any observations upon the earlier development of the limb-bud, or upon the source of its mesodermal elements, and regards the ectodermal fold as the beginning of the pectoral fin.

Emery ('83, p. 338) first directed attention to the homogeneous stratum developed in the fin-fold of embryos of Bony Fishes. He studied the larvæ of Fierasfer, Belone acus, and Lophius, and regards the substance between the ectodermal layers of the fin-fold as mesenchymatic ; this substance may originate as a secretion partly by ectoderm and partly by mesoderm ; and he believes that it may be comparable to the gelatinous substance of the umbrella of Medusæ. His observations were however made upon the folds of the unpaired fins.

Kingsley and Conn ('83, p. 210) did not see the earlier stages in the development of the pectoral fins in the Cunner, Ctenolabrus cœruleus. The earliest condition noted by them was that of the ectodermal fin-fold just prior to the time of hatching. They say, " The fins, which are first seen in an egg about as far advanced as Figure 51, arise in the Cunner as a simple outgrowth, and not as a continuous lateral fold, as is found in many forms."

Prince ('86, p. 697) regards the pectorals of Osseous Fishes as at the beginning *ectodermal* in origin. He states that "they are differentiations of a continuous lateral expansion of *epiblast*, passing along each side of the trunk, and are formed by the folding of this epiblastic layer upon itself at the point where the fins appear. Each fin consists, therefore, of two epiblastic lamellæ (separated by a fissure), lying flat upon the vitellus, and continuous with the extra-embryonic blastodermic membrane." The participation of the mesoderm is presumably a secondary process. Concerning the origin of the mesodermal cells which are introduced into the fin-fold, Prince says, "They seem to be derived from the 'intermediate cell-mass' in close proximity to the Wolffian ducts."

Ziegler ('87, p. 619), in his excellent paper on the origin of the blood and the vascular system in the embryonal Teleost, has touched upon the source of the mesodermal elements of the pectoral fin. He has observed in the embryos of the Salmon and Pike, in stages immediately following the closure of the blastopore, a layer of cells lying upon the somatopleure just back of the gill region. This layer of cells he regards as the beginning of the pectoral fin. Anteriorly, it is intimately connected with the mesoderm of the head; it extends laterally in front of the first protovertebra, and obliquely backwards upon the somatopleure, gradually losing its identity in the latter. Ziegler also states that the development of the pectoral fin is accompanied by the formation of a lateral longitudinal fold of the ectoderm, but does not give details.

Ryder regards the modification of the ectoderm as the earliest differentiation in the development of the pectoral fins in Teleosts, and therefore the differentiation of mesoderm as a *secondary* process. His observations have been very extensive, and include representatives of various groups of Osseous Fishes. He states ('86^a, p. 24) that in the stickleback, Apeltes quadracus, "immediately behind the auditory vesicles, and shortly after their invagination, the rudiments of the breast fins appear as a pair of low longitudinal folds." In the common Shad, Clupea sapidissima ('86^a, p. 43), the modification of the ectoderm is the earliest process noted in the development of the pectorals. It is implied ('82, p. 293) that in the Silver Gar, Belone longirostris, substantially the same condition exists. Many of Ryder's observations are apparently based upon surface views only. He ('84, p. 65) states that in the evolution of the pectoral fin of the Cod, Gadus morrhua, the first appearance is "a slight longitudinal elevation of the skin on either side of the body of the embryo, a little way behind the auditory vesicles. . . . At the very first, it appears to be merely a dermal fold, and, in some forms, a layer of cells extends out underneath it from the sides of the body, but does not ascend into it." He adds: "In some species I am *quite well assured* that there is at an early period a mesodermal tract or plate of cells developed just behind the auditory vesicle, just outside the muscle-plates of this region, on either side, which may be regarded as the source of the mesodermal cells which are carried up into the pectoral fin-fold. This is developed at the time of the closure of the blastoderm, and these lateral mesodermal tracts may be called the pectoral plates." In later stages of development, Ryder observes that mesodermal cells make their appearance at the base of the ectodermal fin-fold, and enter the basal part of this fold. Referring to the Carp, Gambusia patruelis, he ('85, p. 153) states that the muscles of the pectoral fins "are probably derived, as in Elasmobranchs, from buds given off by the muscular segments above the rudiment of the girdle"; but the evidence from which this inference is drawn he does not state. Ryder ('86, pp. 1010, 1018) has studied the development of the fin-rays in the lateral ectodermal fin-fold, and has written upon theoretical considerations concerning the evolution of the fins in fishes.

M'Intosh and E. E. Prince ('90, pp. 800–803) have assumed that the paired fins in Bony Fishes are of ectodermal origin, and begin as horizontal ridges, in accordance with Balfour's theory of a primitive lateral fin. They regard the lateral margin of the blastoderm, at a stage in which the blastopore is not yet closed and the embryonic thickening has merely begun, as the first trace in the development of the pectoral fins. This lateral margin of the blastodermic swelling is described as an "alar expansion" along each side of the embryo, and "consists of epiblast and hypoblast resting upon the stratum of periblast below" (p. 800). From these lateral wing-like expansions of ectoderm and entoderm, between which apparently no mesoderm extends, the fins are developed. The views of these authors may be more fully comprehended from the following quotation (p. 801): "A pair of lateral, horizontal alæ (*al.*), indeed, stretch along the whole trunk, — from the pectoral to the post-mesenteric region. It is in reality the elongated and narrowed blastodermic sentum (Plate XXVIII. Fig. 5), and extends in front and behind the two points mentioned, though it is there thinner and hardly distinguishable. In Plate III. Fig. 19, such a pair of lateral horizontal fin expansions are present, extending from the trunk region proper, and their limits are very definite when viewed from above. Just as in the case of the median vertical fins, certain areas in these horizontal alæ become defined as special fin regions by a visible thickening, apparently from the folding under of the epiblast. Thus two flattened oval pads, consisting of a double epiblastic fold like the double median fin-fold, are disengaged from the rest of the alar expanse. Before and behind this pair of pads the lateral membrane thins away and atrophies, while the special portions continue to increase in density as a pair of pectoral limbs." Into these "fin-pads," or limb-buds, the mesoderm later enters, separating the two ectodermal layers of the fold. The source of the mesoderm of the pectoral fin is referred to "a mass of cells in which the Wolffian ducts lie and out of which they are developed" (p. 802). This conclusion leads the authors to the following speculations concerning the relation and evolution of the Wolffian ducts and the mesoderm of the pectoral fins: "If these ducts, as appears to be the case, arise as lateral ridges or diverticula of the somatopleure, then the mesoblast cells of the fins must be pronounced somatopleuric. But no ridge of somatopleuric cells comparable to the Wolffian ridges of higher forms has been recognized in fishes, and we must regard this mesoblast as indifferent, and forming an 'intermediate cell-mass' adjacent to the excretory system." The observations by M'Intosh and Prince refer to various Bony Fishes, including Gadus morrhua, Molva vulgaris, Trigla gurnardus, Cottus scorpius, etc. The statement is made (note, p. 801) that in all forms studied at the St. Andrews Marine Station the pectoral fins arise out of the lateral extensions of ectoderm and entoderm.

(*b*) *Elasmobranchs, etc.* — Balfour ('78, pp. 101, 102), as is well known, was one of the first to advocate the theory that the limbs of Vertebrates are remnants of a continuous lateral fin. This view of the phylogeny of the Vertebrate limb led him to a careful study of the development of the paired fins in the ontogeny of several types of Elasmobranch Fishes, including Torpedo, Pristiurus, and Scyllium. A brief summary of Balfour's extensive and detailed account may include the following conditions in the early development of the paired fins: (1) a continuous lateral thickening, or ridge of ectoderm, extending from the head to the level of the anus; (2) between the regions of the pectoral and pelvic fins this ridge of modified ectoderm may be so slight as to be observable only upon a careful examination of sections; (3) special developments of this lateral ridge — one opposite the anterior end of the segmental duct, the other just in front of the anus — constitute respectively the rudiments of the pectoral and pelvic fins; (4) the rudiments of the anterior pair of fins develop much more rapidly than those of the posterior pair; (5) the connecting ridge of ectoderm between the rudiments of the paired fins disappears; (6) these ectodermal rudiments develop into elongated projecting folds; (7) the mesoderm at the base of these folds becomes closely packed, and forms a slight projection; (8) the cells of *both* layers of the ectoderm, judging from Balfour's drawings ('78, Plate XI. Fig. 9, and Plate XII. Fig. 1), take on a columnar form in the regions of the fin-folds.

It is evident that Balfour regarded the primary modification of the ectoderm into a thickening or ridge as the earliest step in the development of the paired fin in Elasmobranchs, and the modification of the mesoderm as a *secondary* condition, and *coincident* with the formation of a distinct fold by the ectoderm. Balfour ('81, Vol. II. p. 500) also held the same view concerning the similar modification of the ectoderm in other groups of fishes.

During the course of the further development, the mesoderm passes into the fold of ectoderm, and assumes the appearance of a closely packed mass of indifferent cells, which, together with its ectodermal covering, now presenting a somewhat rounded contour, constitutes what is known as the primitive "limb-bud." Subsequently the muscle-plates grow in a ventral direction to the level of the limb-bud, and several of them turn slightly outward at their distal ends, and give off small masses of cells, the myotome-buds, which pass into the blastema of the limb-bud, where they soon lose their former distinctness, but presumably constitute the source of the musculature of the limb. The muscle-plates, after having given off the myotome-buds, lose all trace of this modification, and continue their growth in the ventral direction.

Balfour did not determine the real character of the myotome-buds, or the number for each myotome; nor did he trace them to their subsequent fate. This, however, was accomplished by Dohrn a few years later.

Kölliker ('79, p. 805) held that the muscle-plates as such in no case grew into the limb-buds, and that the view of an independent formation of the limb-muscles is provisionally quite as correct as the other view, although Remak ('50–'55) had shown that in the Rabbit the muscle-plates extended at least a short distance into the limb-bud.

Dohrn ('84, p. 161) did not investigate the primary source of the mesoderm which passes into the ectodermal fin-fold, but, accepting Balfour's account of the origin of the limb-bud, began his studies with the secondary contributions of the mesodermal elements from the muscle-plates. Dohrn pointed out that in the region of the pectoral fin, in the embryo of Pristiurus, each myotome gives off at its ventral margin two small buds, one from its anterior and the other from its posterior edge. These buds, after losing their connection with the myotome, lengthen in a dorso-ventral direction, and then divide parallel to the surface of the body, thus forming four secondary cell-masses for each myotome, — two dorsal, or outer, and two ventral, or inner. These masses of indifferent myotomic elements pass into the limb-bud, and ultimately assume positions which make them here also respectively dorsal and ventral, and constitute the source of the entire musculature of the limb. Dohrn was, however, unable to determine the exact number of myotomes which thus contribute elements to the pectoral limb-bud, nor could he ascertain which myotome is the most anterior, or which the most posterior, to give off buds to the pectoral fin.

Ziegler ('88, pp. 388–390) has briefly described the source of the mesoderm of the pectoral fins in Elasmobranchs. In stages *H* and *J* (of Balfour, '78) there is produced upon the somatopleure, chiefly by cell proliferation, a layer of formative tissue, which extends caudad through the pectoral region. This process is accompanied by an upheaval of the ectoderm, and constitutes the beginning of the formation of the fore limb. Ziegler believes that this formative tissue (Bildungsgewebe) of the pectoral is continuous with the sclerotome, passing over between the segmental tubules. He has also pointed out that the dorsal ends of the myotomes at first give off to the dorsal fin formative tissue as single-cell strands, and later the myotome buds observed by Dohrn and Paul Mayer ('86). It is to be inferred, in the absence of any statement upon this point, that similar cell strands have not been observed on the ventral sides of the myotomes passing to the pectoral fins.

Beard ('89, p. 114) has observed the contribution of muscle-buds from the myotomes in Lepidosteus osseus. He says: "The somites become much elongated, and their ends are constricted off as buds to form the musculature of the paired and unpaired limbs. Each end of each somite constricts off a single bud, which only divides into two at a stage later than that of the twenty-first day. The posterior pair of fins begin to develop only towards the end of the third week, and the muscle-buds of the unpaired fins remain in an embryonic condition beyond this period."

Van Bemmelen ('89, p. 240) has studied the limb-buds of the Lizard, and has pointed out the presence of myotome buds. In a stage in which five gill-pouches are developed, the myotomes back of the auditory vesicle, from the fifth to the thirteenth inclusive, contract at their ventral ends into cell-strands (Zellenstrange), which extend ventrally and terminate blindly in an indifferent cell-mass, the limb-bud. Van Bemmelen is convinced that these cell-strands, or myotome-buds, give rise to the musculature of the fore limbs, but he is unable to determine the further process by which this is effected. Similar contributions of mesoderm are made by the myotomes in the region of the hind limbs. Each myotome is said to develop only one bud, whose cells at its ventral end stain more deeply than the surrounding cells of the embryonal tissue, and later are entirely lost in the tissue of the limb-bud.

IV. The Axial and Parietal Mesoderm.

(*a*) *Formation of the Primitive Layers, and the Differentiation of Protovertebræ and Lateral Plates.* — With the temperature of the water at an average of 20° C., the blastopore in the embryo of Fundulus heteroclitus closes during the period between forty-six and forty-eight hours after fertilization of the ovum. If in an embryo in which the blastopore is not yet closed, a transverse section be taken through the region indicated by the line at *5* in Figure 1 (Plate I.), the condition of the primitive embryonic layers will be shown. From such a section (Fig. 5) it can be observed that the spinal cord (*cd. sp.*) is not yet fully formed, and that the superficial layer of the ectoderm (*ec'drm.*) is not involved to form later the medullary canal (*can. med.*, Plate V. Fig. 30); hence in this particular the development of the spinal cord in Fundulus differs from that in Amphibians, Elasmobranchs, and, according to recorded observations, in some Bony Fishes.

The endoderm (*en'drm.*, Fig. 5) is already clearly differentiated, and lies directly upon the yolk, extending as a single-cell layer from the keel laterally to the ectoderm; hence it comes in contact with the ectoderm both in the axial region of the embryo, ventrad of the keel, and also at its extreme parietal margin.

The mesoderm appears as a band of cells between the ectoderm and endoderm, extending longitudinally along either side of the embryonic keel. In a transverse section (*ms'drm.*, Fig. 5) the mesoderm has the appearance of a layer of cells which is somewhat thickened in the middle, while it gradually becomes thinner toward the axial and lateral margins. In a stage of fifty-two hours (Fig. 2) the embryo has become relatively much elongated, the optic vesicles (*vs. opt.*) are already quite prominent, Kupffer's vesicle (*vs. K.*) can be distinctly observed in a clove-oil preparation, and the chorda is formed as far forward as the pectoral region, where it is now closing in, but is not yet distinct from the endoderm (*cd.*, Fig. 6). The endodermal cells in the parietal regions are rapidly moving in the direction of the embryonic axis, but no trace of the lateral infolding to form the tube of the intestine is as yet discernible.

The condition of the mesoderm may be observed in a transverse section (*ms'drm.*, Fig. 6) of an embryo perhaps a little more advanced than the one represented by Figure 2, taken from the region indicated by the line at *6* in Figure 2. In this region the mesoderm appears as a solid mass of cells which, in transverse section, has a triangular contour, ending in blunt angles at the dorsal and ventral limits of its axial boundary, and tapering laterally into a single-cell layer, which now extends beyond the lateral margin of the endoderm, the latter having shifted towards the axis of the embryo to form the chorda, as already noted. It follows, therefore, that the distal margins of the lateral mesodermal plates lie directly upon the yolk. The differentiation of the mesoderm into protovertebræ and lateral plates has evidently not yet begun at this stage, and no trace of a split in the mesoderm to form the somatopleure and splanchnopleure can be seen.[1]

The most anterior protovertebra is formed immediately back of the auditory vesicle; in fact, it at first extends rather forward and below the posterior limit of the auditory vesicle (Fig. 8, *pr'vr. 1*). It is interesting to note that later a considerable space intervenes between the latter and the most anterior protovertebra. (Compare Fig. 21, Plate III.) This intervening space is equal to the length of at least one protovertebra, and still later (Plate I. Fig. 8^a) to about two protovertebræ. There is some uncertainty as to the process by which the increase in this space is produced. There are at least four possible methods of increasing it: first, there might be an actual shifting of the anterior protovertebra caudad; secondly, a shifting of the auditory vesicle cephalad is conceivable; but I believe that neither of these is realized; thirdly, there might be a *relative* shifting of these structures in the respective directions named, caused by a voluminous cell proliferation of the head-mesoderm (*ms'drm. cap.*, Fig. 21, Plate III.) between the auditory vesicle and the first protovertebra, causing an elongation of the embryonic axis in this region; fourthly, the first — and perhaps also the second — protovertebra may degenerate, remaining only as

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[1] I have used the words *somatopleure* and *splanchnopleure* in the sense of somatic and splanchnic mesoderm respectively.

head-mesoderm, and thus, through the obliteration of the first two protovertebræ, the original third would now be recognized as the most anterior. The mass of the obliterated protovertebræ, which, however, has not been decreased in volume, but whose contour as protovertebræ has disappeared, is now recognized as head-mesoderm, and has thus augmented the space intervening between the auditory vesicle and the now most anterior (original third) protovertebra. It is highly probable that the last two processes enumerated, namely, the proliferation of head-mesoderm and the degeneration of protovertebræ, combine to produce the apparent removal of the first protovertebra from the auditory vesicle, or the increase in the space intervening between these structures. It is certain, at any rate, that there is at this time an active cell proliferation in the head-mesoderm of this region, and that the first and second protovertebræ become less distinct and more or less imperfect subsequent to their early formation.

(*b*) *Topography of the Embryo.* — For convenience in description and reference to the different regions of the embryo, I have adopted the following general divisions in the topography of later stages: —

(1) *The head region* includes all of the embryo from its anterior end to the posterior limit of the auditory vesicle.

(2) *The pectoral region* includes all from the posterior limit of the auditory vesicle to the nephrostome.

(3) *The abdominal region* embraces all of the embryo included between the nephrostome and the point of the future anus.

(4) *The caudal region* includes all back of the anus.

This classification is slightly different from that adopted by Ziegler ('87, p. 643). The boundary between the head region and pectoral region cannot be definitely fixed, inasmuch as the position of the first protovertebra is changeable. Although not embraced in the region of the *head* by this classification, the axial mesoderm between the auditory vesicle and the first protovertebra is designated as "head-mesoderm." As will be seen later, this region is probably involved in the origin of the pectoral fin.

(*c*) *Differentiation and early Development of the Mesoderm in the Pectoral Region.* — The changes which take place in the pectoral region during the earlier embryonic stages are of special importance in tracing the exact topography of the mesoderm, and the necessity of a reliable starting point in the topography will be apparent in subsequent considerations. The differentiation of the mesoderm into protovertebræ can be readily traced from the third or fourth protovertebra into the caudal region. In an embryo of about fifty-six hours (Fig. 8), five protovertebræ are distinctly formed, and the mesoderm back of the fifth protovertebra as far as the caudal region still consists of a compact plate of cells (*ms'drm. ax.*), whose boundary is easily distinguished from the ectoderm above and the endoderm below. The nuclei in the region of the axial mesoderm are undergoing rapid division as shown by the abundance of their various karyokinetic conditions. The protovertebræ which are already formed in an embryo at the beginning of the third day, are somewhat irregular in outline and vary considerably in size. The first (Fig. 8, *pr'vr. 1*) is considerably larger in its antero-posterior dimensions than any one of the other four. This condition I have observed in several instances, but apparently it does not always obtain; for in two embryos of the same age, but perhaps slightly more advanced than that of Figure 8, I find the first protovertebra not only shorter in its antero-posterior direction, but also decidedly more irregular in outline than the others in the same embryo. Possibly the superior size of the first protovertebra in an earlier stage may be the rule, but this condition must be very transitory; so that, owing to individual variation, embryos of the same age, but slightly more advanced, may show the inferior size and imperfect contour in the first protovertebra as a secondary condition. The axial mesoderm in front of the first protovertebra (Fig. 8) extends forward under the auditory vesicle, and its cells are disposed in two more or less distinct layers, the boundary between which extends outward, i. e. laterally from the axis of the embryo, where it is continuous with a similar boundary (Fig. 7, *cœl.*) between the layers of the lateral plate in the trunk region.

The changes in the development of the mesoderm in the pectoral region can be most profitably studied from transverse serial sections. The differentiation of the protovertebræ and lateral layers, and the formation of the cœlomic split, are intimately involved, and must therefore be traced conjointly in the pectoral region.

In the anterior region of the auditory vesicle, the axial mesoderm is reduced to its minimum volume. A transverse section through this region from an embryo of about seventy-one hours shows (Plate II. Fig. 9) that the mesoderm consists of two portions, the axial and the lateral; the latter is composed of two single-cell layers, somatopleure and splanchnopleure (*so'plu.*, *spl'plu.*), which in this region form the boundaries of the pericardial cavity (*cav. pi'cr.*). These layers are continuous with each other in their proximal (axial) region, but separate at their distal (lateral) margins, the splanchnopleure extending farther laterally than the somatopleure, and the margins of both lying close against the ectoderm.

The axial mesoderm, or protovertebral part (*ms'drm.*), consists in this region of only a few cells. These lie between the proximal portion of the lateral layers and the brain (*en'c.*), and are bounded dorsally by the incipient auditory vesicle (*vs. au.'*) and ventrally by the endoderm (*en'drm.*). The axial mesoderm may be traced as head-mesoderm from this point caudad into a region where it is more or less distinctly segmented into protovertebræ (Figs. 12–14).

In the middle region of the auditory vesicle (Fig. 10), the axial mesoderm becomes more voluminous and presses the pericardial cavity farther away from the axis of the embryo. The lateral layers are not separated from the axial mesoderm (compare Fig. 9), and their distal margins are united. The most anterior protovertebra in this stage (Fig. 11) is not wholly cut off from the lateral mesodermal layers. The lumen of the body cavity (*cœl.*) can be traced cephalad into the pericardial cavity, and extends into the interior of the protovertebra as well as laterally between the somatopleuric and splanchnopleuric layers. The dorsal boundary of this lumen is a single-cell layer, while the layer on its ventral side is of variable thickness; in its proximal or protovertebral region it is about three cells in thickness, while in the middle it is two cells and at its distal margin only one cell thick, thus giving in cross section a cuneiform outline; it represents a portion of the protovertebra and the undifferentiated splanchnopleure. The section drawn in Figure 12 is the third section (about $22\frac{1}{2}$ μ) back of Figure 11, and represents the posterior part of the corresponding (first) protovertebra on the opposite side of the embryo.[1] In this region of the protovertebra, the dorsal contour is more rounded, and the body cavity does not extend into it; the nuclei outline a boundary between the protovertebra and the lateral plates more distinctly than in the anterior region of the protovertebra (compare Fig. 11).

The second protovertebra is cut off from the surrounding mesoderm more completely than the first. A cross section from its middle region (Fig. 13) shows a more or less distinct boundary separating it from the lateral layers. It has a sharply rounded contour at its dorsal limit, and the nuclei show a tendency to assume a peripheral position. The body

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[1] The embryo being cut exactly in the transverse plane, and the conditions in the mesoderm on both sides of the axis being identical, I have taken my drawings alternately from the right and left sides (Plate II), in order to economize space in the arrangement of the figures on the Plate.

cavity is less marked than in the first protovertebra, but the cells are quite uniformly arranged into the two mesodermal layers. It may be noted, in passing, that while the pericardial and body cavities are continuous at an early stage, they are not developed simultaneously; that the pericardial cavity is well advanced before any trace of the corresponding split, or body cavity, occurs in the pectoral region.

All the protovertebræ caudad from the second are distinctly cut off from the lateral layers. In the region of the fifth (Fig. 14) and for some distance caudad from it, the lateral layers (*so'plu.*, *spl'plu.*) end more abruptly at their distal margins, while in the proximal region there is a tendency on the part of the cells — due apparently to rapid proliferation —to become aggregated, and thus to render somewhat obscure the boundary between the two lateral layers; meanwhile the proximal margin of the lateral mesoderm (Fig. 14) shifts its position ventrad along the side of the protovertebræ.

Still farther back in the region of the sixth or seventh protovertebra, the proximal region of the lateral mesoderm is distinctly cut off from the more lateral portion (Fig. 15, *cl-mo. i'm.'*); as will be seen later, it has a very interesting and significant fate. At this stage the nuclei of the cells of the complete protovertebra are clearly arranged in a peripheral position (Fig. 14, *pr'vr.*). Rarely nuclei are observed in the interior. If, however, the plane of the section is not parallel with the transverse dorso-ventral plane of the protovertebra, or chances to pass through its anterior or posterior wall, the section shows nuclei which are apparently in the middle of the protovertebra. These are in many instances the nuclei of cells forming its anterior or posterior wall; but in other cases they do not represent cells in the peripheral walls, for the condition in which all the cells have this position is very transitory. Immediately following this stage (Plate III. Figs. 17, 18), nuclei are observed which are unquestionably in the middle of the protovertebra. The nuclei which are thus found in the interior of the protovertebra no doubt have their origin in the peripheral cells, and usually are undergoing division rapidly at this stage. Not only do the peripheral cells thus contribute to the interior of the protovertebra, but also to the increase in the superficial extent of the peripheral wall, and in many cases it is not difficult to determine from the direction of the nuclear division whether the contribution is to the wall or to the interior. In Figure 18 (Plate III.), on the left side of the embryo (right in the figure) in the dorsal region of the protovertebra, is an example of nuclear division (*nl.'*), in which one of the daughter cells is destined to pass into the interior; in the protovertebra shown in Figure 27 (Plate IV.), the two pairs of nuclei in the upper region bounding the spinal cord, which have just undergone division (*nl.''*), are destined to increase the periphery of the protovertebra; and in Figure 17 (Plate III.) is an example of the proliferation of cells in the interior of the protovertebra.

These three examples are the same in character, and tend to the same general purpose, viz. the enlargement of the protovertebra itself; but there is also a cell proliferation going on in its ventral region which has a purpose foreign to the augmentation of the protovertebra, for here the histological elements experience a very different fate. In the ventral region near the chorda a rapid cell proliferation (Plate III. Fig. 18, *nl.''*) is going on. Some of the cells which originate here pass ventrad, and take a position immediately under the chorda (*nl.**), and I believe it very probable that they are concerned in the formation of the aorta.

In this stage the lateral mesodermic layers are more distinctly separated from each other, leaving between them a relatively larger body cavity (compare Fig. 17, Plate III., and Fig. 13, Plate II.), and in the anterior region of the trunk they are undergoing rapid development. The process of shifting toward the median plane along the ventral side of the protovertebræ, the beginning of which has already been noted (p. 107), has perceptibly advanced. This process does not begin in the pectoral region and proceed backward, as might be inferred; but is at first more pronounced back of the pectoral region, and only later takes place as far forward as this. This fact will be evident upon a glance at the series of drawings from a younger stage (Plate II. Figs. 11–15).

In an embryo of seventy-one hours the head-mesoderm (Plate IV. Fig. 23) in the region of the auditory vesicle consists of only a few cells, whose nuclei do not assume any definite arrangement. This condition is probably due, in part, to pressure upon the original mass of mesodermic cells by the ectoderm and endoderm. The latter, constituting the beginning of the gill-clefts (*fs. brn.*, Fig. 23), presses upward, while the former, constituting the beginning of the auditory vesicle (*vs. au.*, Fig. 23), presses downward, thus confining the mesodermic cells within very narrow limits. The nuclei of the head-mesoderm are, however, readily distinguished from the surrounding ones of ectodermic and endodermic origin. In the region of the gill-clefts the head-mesoderm is completely cut off from the part which represents the somatopleure and splanchnopleure (Fig. 23), and the latter (*so'plu.*, *spl'plu.*) are relatively thin layers, bounding the pericardial cavity. In this stage of development the distal end of the gill-cleft (*fs. brn.*) has apparently nearly broken through to the exterior, the invagination of the ectoderm (*ec'drm.'*) having almost reached the endoderm; but the fourth gill-cleft (*brs. brn.*) has not yet advanced so far, as is shown by a section (Fig. 24) from the same embryo, but 30 μ farther back; hence the head-mesoderm is now more voluminous in this region than in the region of the third gill-cleft, and more than it will be here in later stages. It is evident that, as the fourth cleft develops, it will invade the region now occupied by this mass of head-mesoderm, hence the latter must migrate. But since the gill-clefts develop from before backward, and since the third cleft has already so far developed as to occupy together with the auditory vesicle practically all the space (Plate IV. Fig. 23), there is no possibility of that part of the head-mesoderm which is now back of the third cleft migrating or being pressed forward in order to yield its space to the intruding fourth gill-cleft. Being thus guarded in front and on its ventral boundary by the endoderm, on its axial boundary by the spinal cord, and on its lateral by the pericardial cavity, the only possible course left for this mesoderm is to pass in a posterior direction toward the pectoral region. Furthermore, the endodermal evaginations forming the gill-clefts do not lie in an exactly transverse dorso-ventral plane, but extend obliquely from below upward and backward as well as outward and backward; hence, as this evagination proceeds, there is a natural tendency to press the head-mesoderm in advance of it in the same direction. It may be safe, therefore, to base upon these facts the inference that the position of the gill-clefts, and the order and direction of their development, tend to cause the head-mesoderm of the branchial region to pass in a posterior and lateral direction.

The relation of the head-mesoderm to the axial mesoderm in the pectoral region may be better understood by sectioning different parts of a single embryo in planes perpendicular to each other. An embryo in which the distal tip of the fourth gill-cleft (Plate III. Fig. 16, *brs. brn.*) extends about midway through the region of the head-mesoderm (*ms'drm. cap.*) toward the ectodermic invagination (*ec'drm.'*), is sectioned transversely through the branchial region from the anterior end of the embryo to the plane of the fourth cleft, represented by the drawing, Figure 16. The remaining part of the embryo is then re-oriented upon the microtome, and sectioned in a longitudinal (sagittal) direction, beginning on the left side of the embryo and proceeding toward the axis. Figure 16 represents the anterior face of the last section of the transverse series from an embryo treated in this way, and Figures 19–21 show the series of sagittal sections in the same embryo. The vertical parallel lines *19*, *20*, *21*, through Figure 16, indicate the direction and the relative positions of the planes of the sagittal sections shown in Figures 19–21. The relation between the head-mesoderm and the splanchnopleure in the pectoral region is represented in Figure 19. This section is taken from a region too far from the axis of the embryo to show any trace of the protovertebræ, nor is the fourth gill-pocket yet developed far enough in a lateral direction to reach this vertical plane; but the auditory vesicle (*vs. au.*, Fig. 19), which extends farther laterally (compare Fig. 19 with Figs. 16 and 24), is shown in the section. Hence the head-mesoderm (Fig. 19, *ms'drm.*), as represented in this section, may be said to extend back of the auditory vesicle and laterally of the fourth gill-pocket, and to converge at its posterior margin into the single-cell layer (*so'plu.*) of the somatopleure. The ventral surface of the head-mesoderm may be regarded morphologically equivalent to the somatopleure.

In Figure 20, drawn from a section about $22\frac{1}{2}\ \mu$ nearer the axis of the embryo than Figure 19, the fourth gill-pocket is intersected, and also the distal face of the first protovertebra. Here the head-mesoderm is represented by a voluminous mass of cells which abut upon the anterior boundary of the first protovertebra (*pr'vr. 1*). In the next section (Fig. 21), whose plane lies still nearer the axis of the embryo, the head-mesoderm (*ms'drm.*) passes back and fuses with the first protovertebra, no boundary between the two being distinguishable. From this double series of sections the close relation existing between head-mesoderm, protovertebræ, and somatopleure must be evident.

I shall now consider the changes taking place in the two parietal layers during slightly older stages; these present three principal features: (1) their shifting in a median direction along the ventral surface of the protovertebræ; (2) the contribution of elements from their proximal region; and (3) the modification of the somatopleure in the formation of the beginning of the pectoral fin. But these changes, as in case of those involving the head-mesoderm, are taking place at the same time, and hence must be traced conjointly. The first two processes may be considered under the head of "intermediate cell-mass."

V. Intermediate Cell-mass.

(*a.*) *Brief Review of the Literature.* — The term "intermediate cell-mass" (Mittelplatte) was originally applied by Waldeyer ('69) to the mass of mesodermal cells between the protovertebræ and lateral plates in the Chick. The intermediate cell-mass in Birds is so well known that it is unnecessary to review its morphology in detail; suffice to say that it appears immediately subsequent to the formation of the protovertebræ, e. g., in case of the Duck, as a band of mesodermal cells extending lengthwise of the embryo, between the protovertebræ and the lateral layers, somatopleure and splanchnopleure; that at first it remains in histological connection with the protovertebræ on the one side, and with the lateral layers on the other; that in later stages, as shown by Sedgwick ('80), the intermediate cell-mass is at intervals entirely cut off from relation with the lateral layers, while at alternating intervals it remains continuous with them and is penetrated by the body cavity; and that *subsequently* the structure is *wholly* disconnected from the lateral mesodermic layers, and constitutes what has been designated the "Wolffian blastema." These three steps in the process of development of the intermediate cell-mass in the Duck are represented in the Chick, according to Sedgwick's ('80) account, *only* in the anterior region of the embryo, to about the twentieth somite; while posterior to this region the intermediate cell-mass is from the beginning independent of the lateral mesoderm, thus presenting, apparently, an abbreviation of the process which takes place in the anterior part of the trunk.

The expression "intermediate cell-mass" is also applied to the homologous structure in Elasmobranchs. According to Balfour ('78, pp. 108, 109, 127, 128), in Pristiurus and Torpedo at the time when the third visceral cleft appears, the intermediate cell-mass arises as the result of a fusion of the somatopleure and splanchnopleure at about the level of the dorsal aorta, and immediately above the dorsal limit of the true body cavity. The mass of cells involved in this fusion Balfour regards as homologous to Waldeyer's "intermediate cell-mass" in the Chick. He does not state how far forward in the trunk this fusion of the mesodermal layers extends, but points out that from it the urinogenital system is developed, and shows that the first trace in the development of this system is the beginning of the segmental duct, which appears as a solid knob in the region of the fifth protovertebra, and grows backward along the inner surface of the ectoderm as a solid rod of cells.

An homologous structure is also present in Lacertilia. The accounts of the intermediate cell-mass in the Lizard by different observers agree in general, but differ somewhat in their details, and especially concerning its fate. As shown by Braun ('77) and Weldon ('83), it is present in the Lizard from the beginning of the segmentation of the mesoderm, and is connected both with the protovertebræ and the lateral mesodermic layers. According to Weldon's account, in an embryo of Lacerta muralis at a stage in which eleven protovertebræ are formed, there are developed in the intermediate cell-mass, which previously appeared as a continuous solid mass of cells, a series of circular cavities, each opposite a protovertebra. The cavities thus formed in the intermediate cell-mass are the "segmental vesicles" described by Rathke ('33) and later observers. Weldon has shown that the segmental vesicles are not evaginations of the peritoneal epithelium, and do not form the Wolffian duct, as supposed by Braun, but that the latter structure is developed a little later and in a more peripheral or lateral region of the intermediate cell-mass, — indeed, from the lateral walls of the segmental vesicles. Other observers, however, differ in their views concerning the details in the formation of the Wolffian duct, and I do not propose to enter upon the discussion of this interesting subject. It is sufficient for my purpose to recognize the presence of the intermediate cell-mass in Lacertilia, and to note the fact that in its origin and fate it resembles very strongly the intermediate cell-mass in Birds and Elasmobranchs.

In Teleosts there is also present a structure very similar to the intermediate cell-mass of Birds, Reptiles, and Elasmobranchs, whose homology with the intermediate cell-mass has, however, been questioned by Ziegler ('87, p. 645). Oellacher ('73, pp. 76, 77, 102) was the first to describe this structure in Bony Fishes, and to adopt for it the name "intermediate cell-mass." According to his observations, in the Brook Trout, at the stage in which the vertebræ are forming, there remains between the lateral plates and protovertebræ a band of undifferentiated mesoderm, which later moves medianward, and meets its fellow from the opposite side, uniting with it under the chorda. Ziegler ('82 and '87) and Wenckebach ('84 and '86) have since observed this structure in the Salmon, Trout, and Pike. The intermediate cell-mass in Salmo salar is formed, according to Ziegler's ('82) account, at the time when the protovertebræ are cut off, which takes place on the thirteenth day, and after this process it remains as an unsegmented band of cells, extending throughout the whole length of the trunk of the embryo, and embracing the entire thickness of the mesoderm. It soon becomes crowded ventrally and medianward, so that the lateral layers draw near to the protovertebræ. The lateral band, constituting the intermediate cell-mass of either side of the body, moves toward the median plane, and the two bands finally meet above the intestine, where they form a single compact mass or rod of cells, which in an embryo of nineteen days extends from the pronephros to the posterior end of the trunk. Ziegler ('82, pp. 46, 47) in his description implies, without directly stating it as a fact, that in the anterior trunk region this cord gradually diminishes, and then disappears.

Wenckebach ('84, p. 235) observed the intermediate cell-mass in Perca fluviatilis. He did not observe its origin, but described it as a solid mass of tissue, situated in the region where afterwards the vena vertebralis is found. This structure is regarded by Wenckebach as the source of the blood corpuscles. The cells composing the axial portion of this cylindrical mass gradually become detached from one another, and are carried away by the plasma which appears at this time ; they acquire a yellow tint, and become the blood corpuscles. These conclusions were reached independently of Ziegler's ('82) previous observations on the same structure in the Salmon. In a more recent paper Wenckebach ('86, p. 246) maintains that in Belone acus the intermediate cell-mass arises as a single cord of cells below the chorda, and not as two lateral ones which later unite, as in case of the Salmon, according to Ziegler ('82), and in the Brook Trout, according to Oellacher ('73). As to the method of its origin in Belone acus, the author believes that in an embryo of seventeen days individual cells are set free from the mesoblastic somites, and pass between the chorda and intestinal canal, and in this place undergo proliferation until a massive solid cord of cells is produced, which constitutes the intermediate cell-mass.

In a more recent paper Ziegler ('87) has discussed quite fully the fate of the intermediate cell-mass and its relation to his formative tissue, "Bildungsgewebe." The latter corresponds in general to Hertwig's "Mesenchyme." Ziegler assigns to it a comprehensive meaning. According to his use of the term, Bildungsgewebe embraces a wide range of tissues of various origin, which in distinction from epithelial tissue consist of cells more or less independent of histological connection with one another, or connected only by means of delicate processes ; in other words, the term includes all mesodermic primitive connective tissue, including the blood corpuscles. The use of the term enables the author to make a simple general classification of the mesoderm in Vertebrates, viz. (1) the muscle-plates, (2) lateral layers, and (3) formative tissue.

The formative tissue, which arises in later stages, is, according to Ziegler's view, chiefly formed from the lower, hinder margins of the protovertebræ. He is inclined to believe that the intermediate cell-mass also may yet be shown to be in histological connection with the protovertebræ, and hence prefers not to separate intermediate cell-mass and formative tissue. At the same time this observer regards the intermediate cell-mass as the beginning of a blood-vessel, which is formed as a solid mass, of which the peripheral cells constitute the venous wall, while its central cells float away as blood corpuscles. In later stages of the Salmon, Ziegler has traced the cells of the intermediate cell-mass in their migration to the ventral side of the intestine and over the yolk, where they practically separate the yolk below them from the lateral layers above.

Wiedersheim ('90, p. 131, Taf. VI.) has shown that in later stages of Proteus anguineus, the segmental duct ("Vornierengang") lies in a "blood space" just below the aorta and above the intestine. These blood spaces come from the two sides and are united in the median line, hence their contour in a cross section shows a double or paired outline. They are densely packed with blood corpuscles, and, no doubt, represent the posterior cardinal veins. Some distance (fifteen sections) back of the nephrostome (Taf. VI. Fig. 10) the segmental ducts are distinctly formed, as seen in transverse sections, one on each side of this bilobed mass of cells.

(*b*) *The Origin of the "Intermediate Cell-mass" in Fundulus.* — In Fundulus the intermediate cell-mass originates in two ways; it appears both as a primary and as a secondary formation. It first appears in about the middle of the trunk region, where it occurs as a cord of cells between the protovertebræ and lateral layers, at the time the latter are cut off. In this region it probably retains no histological connection with either protovertebræ or lateral layers. In a more anterior region it is also independent of the protovertebræ from the time of its earliest formation, but here it remains for a time in histological union with the proximal margin of the lateral layers, from which it is subsequently cut off as a secondary process.

This separation of the intermediate cell-mass from the proximal margin of the lateral layers proceeds forward from the anterior limit of its primary formation to the region of the nephrostome. It may be stated that in Fundulus the intermediate cell-mass on either side of the embryo moves ventrally toward the median plane, and that the two structures meet under the chorda; but this statement must be modified to represent the exact conditions in the two regions.

In the region of its primary formation, the intermediate cell-mass does, indeed, pass ventrally as a mass of cells, and take its position under the chorda; but in the region of its secondary formation, although it begins this ventral migration, it never reaches the median line as a compact mass. When it reaches the level of the future segmental duct it remains here for a time as an undifferentiated mass of cells, from the ventral part of which individual cells sever their connection and pass to a position under the chorda. In the region of the nephrostome, where no intermediate cell-mass is formed, individual cells are given off from the proximal margin of the lateral layers, and pass ventrally under the chorda in a manner similar to those contributed by the intermediate cell-mass.

In an embryo of about three days the intermediate cell-mass is distinctly formed from the vicinity of the sixth protovertebra backward, but in this region (Plate II. Fig. 15, *cl-mo.i'm.'*) and through a short distance in front of it (Fig. 14^a, *cl-mo.i'm.'*), although the protovertebræ are distinctly cut off from the remaining portions of the mesoderm, yet the line of separation between intermediate cell-mass and lateral layers is only faintly outlined. A little later, in an embryo of three and a half days, this structure is distinctly differentiated over a region extending from the sixth (Figs. 28, 29) as far forward as the third protovertebra (Fig. 26).

At this stage the ventral migration of mesodermal elements begins in this region. At first only a limited number of cells migrate to the median line under the chorda (Plate IV. Fig. 27^a, *nl.**, *nl.*†), but later they are more numerous (Plate V. Fig. 33, *cl-mo.i'm.'*); yet the total number of cells which reach the median line is never as great as in the posterior part of the trunk.

In the region of the second protovertebra (Plate IV. Fig. 25) the endoderm abuts bluntly against the proximal region of the lateral layers, which has shifted about half-way down along the side of the protovertebra. Here there is no positive evidence of any outgrowth from the lateral layers toward the median line, but frequently nuclei are found which are of doubtful origin (*nl.*††, Fig. 25), arising either from protovertebra or from lateral layers. In the region about opposite the middle of the third protovertebra (Fig. 27) the endoderm has not yet begun the infolding of its distal margin to form the intestine, and hence it extends farther out under the lateral layers than in the region of the second protovertebra (compare *en'drm.*, Figs. 25 and 27), and the lateral mesodermic layers (*so'plu.* and *spl'plu.*, Fig. 27) extend farther under the protovertebra than they do in a more anterior region. In a later stage, the nephrostome is formed in the proximal region of the lateral layers, opposite this protovertebra (Fig. 27). In the same protovertebra, but in its posterior region (Fig. 27^a) nuclei (*nl.*†) which evidently originate from the proximal region of the lateral layers, pass ventrally under the chorda. Here too, as in case of Figure 25, are nuclei (*nl.*††) the origin of which is doubtful. This condition obtains through the third protovertebra also. In the region from the third to the sixth protovertebra (Fig. 29) the condition of the mesoderm is quite different. Here the proximal part of the lateral layers is cut off, and constitutes the intermediate cell-mass (*cl-mo.i'm.'*, Figs. 28 and 29). From the ventral and inner region of this structure cells are given off, which pass toward the median line.

The intermediate cell-mass moves still farther medianward under the protovertebra, and the cells from the two sides accumulate in the median line under the chorda. Back of about the sixth or seventh protovertebra, the elements which have thus been aggregated under the chorda form a mass of considerable volume (*cl-mo.i'm.'*, Plate V. Figs. 36 and 37). In later stages this mass extends forward, but in a much reduced volume, into the region of the nephrostome, or third protovertebra (Fig. 33).

The mesodermal elements which may be said to migrate toward the subnotochordal region are the following: —

(1) The original intermediate cell-mass in the region of its primary formation.

(2) Individual cells from the intermediary cell-mass in the region of its secondary formation.

(3) Individual cells from the lateral layers in the region of the nephrostome, and forward to the head-mesoderm.

(4) Individual cells from the ventral region of the protovertebræ, at an early stage.

(5) The formative tissue (Ziegler's Bildungsgewebe) from the lower margins of the protovertebræ at a much later stage.

(*c*) *Concerning the Fate of the "Intermediate Cell-mass."* — I have not made a detailed study of the fate of this structure in Fundulus, and my only reason for including a brief account of my observations on it is based upon the fact that some recent observers have held that it is intimately related to the beginning (Anlage) of the pectoral fins; in fact, that it constitutes one of the sources of the mesodermal elements which are contributed to the latter structure. It seems to me that in Fundulus such a relation between intermediate cell-mass and pectoral fin is impossible; the basis for this belief I shall point out later.

It is very evident, however, that the lateral region of the intermediate cell-mass gives rise to the segmental duct. The anterior region of the segmental duct is formed at nearly the same time as its nephrostome.

In Figures 26 and 27 (Plate IV.) is represented the region of the nephrostome just prior to the beginning of its formation, and Figures 28 and 29 represent the anterior region of the segmental duct in the same embryo. At this stage no trace of either structure can be seen, but a little later both appear. In an embryo about six hours older than the stage to which reference has just been made, these structures are in process of formation. In the corresponding protovertebræ (Plate V. Figs. 31, 32, 33) the nephrostome (*pr'nph.*) is in process of formation as an evagination of the proximal region of the lateral mesodermic layers opposite the third protovertebra. The lumen of the nephrostome, continuous with the body cavity (*cœl.*), is plainly seen and persists very conspicuously in stages more advanced (Plate VI. Fig. 42, and Plate VII. Fig. 46). In the fourth protovertebra of the embryo in which the nephrostome is forming, a mass of cells is seen in a position corresponding to the nephrostome, but it is without any distinct connection with the proximal margins of the lateral layers. This mass of cells is also more or less detached from the principal part of the intermediate cell-mass, which now occupies a position under the chorda. In the next (fifth) protovertebra (Fig. 34) this structure is plainly recognized as the segmental duct (*dt. seg.*) ; it is independent of any connection with the lateral layers, and more nearly detached from the intermediate cell-mass than in the fourth protovertebra ; its cells are arranged in a peripheral order, and a faint lumen can be observed. The condition of the segmental duct for some distance back of the fifth protovertebra is the same as here, unless perhaps the development may be slightly more advanced than in the extreme anterior end. It appears, therefore, that the anterior portion of the segmental duct is developed from the distal (lateral) margin of the intermediate cell-mass ; that, as the nuclei arrange themselves to form the walls of the tube (Fig. 28), a lumen is formed and the whole is gradually cut off from the inner (axial) portion of the intermediate cell-mass, which passes to the axis of the embryo, becomes more voluminous, and, as we shall see, has a different fate. In more advanced stages the duct becomes more perfectly cylindrical, and its central area more nearly circular in cross sections. (Compare *dt. seg.* in Figs. 35, 43, 44, 49, 50.)

The segmental duct retains its original position, but the proximal margin of the lateral layers passes toward the median line, and, as the entoderm closes in to form the tubular intestine, these layers press upon it from the two sides, and later clasp it, as may be seen by reference to Figures 34, 35, and 43. Hence it follows from these changes that the segmental duct, subsequent to its early development, occupies a position along the dorsal surface of the somatopleure (*so'plu.*, Figs. 35 and 43), with which it lies in close juxtaposition.

It should be noted in this connection that in the posterior trunk region the segmental duct is developed somewhat later than in the more anterior region, and its development is also slightly modified, owing to the great volume of the axial portion of the intermediate cell-mass (Fig. 37) and the retarded progress in the development of the lateral layers and intestine; but its source is exactly the same as in other regions, viz. from the lateral portion of the intermediate cell-mass.

The fate of the axial portion of the intermediate cell-mass is not so easily traced as that of the lateral portion. I have not been able to demonstrate any differentiation of it prior to the beginning of the third day, and therefore only after the formation of the nephrostome and segmental duct in the anterior trunk region. That it is the source of the blood corpuscles seems to me almost beyond doubt, and that it also contributes the elements which form the walls of the aorta, at least in the middle and posterior trunk regions, seems to me equally certain; but what *rôle* it takes in the anterior trunk region, where it consists of relatively few cells which are brought in juxtaposition with elements from other sources, is not easily determined; it is, however, highly probable that these elements have the same fate as those originating from the same structure in a more posterior region of the embryo, — that it gives rise to the blood corpuscles.

It is worthy of note, that before the cells coming from the intermediate cell-mass have reached their position under the chorda, a few nuclei, whose origin I have referred to the ventral margins of the protovertebræ, are seen in this position. These are the nuclei (*nl.**, Figs. 24–27^a) of cells which lie directly below the chorda and form a slender structure resembling the subnotochordal rod in those Chordata which are lower than the Teleosts; but the origin of the subnotochordal rod is in all cases, so far as I know, referred to the endoderm. Hence, if my supposition concerning the origin of these cells is correct, the two structures cannot be homologous, one being mesodermal and the other endodermal in origin. There is, however, this similarity, that this structure in Fundulus, as in case of the subnotochordal rod, does not exist until some time after the formation of the chorda, and that it entirely disappears at a later stage. In an embryo of three days (Plate II. Figs. 11–14) no trace of these nuclei can be seen between the chorda and the layer of entoderm below it; about two days later, when the intestine in the anterior region of the trunk has just closed, it has again entirely disappeared. The identity of these nuclei is lost at the time of the formation of the dorsal aorta, but the subnotochordal rod, according to Balfour's ('81, pp. 620–622) account, persists until later, and then atrophies.

Whatever may be the source and fate of these cells in Fundulus, it is certain that there are other cells contributed from the ventral margins of the protovertebræ which do not take this definite arrangement, and whose fate is not involved in much doubt. These nuclei (*nl.*, Fig. 30, and *nl.**, Figs. 24, 25) I believe to be concerned in the formation of the walls of the aorta. In later stages, subsequent to the formation of the aorta (Figs. 42–44), there is also a very large contribution of elements from the ventral region of the protovertebræ to the median line. The greater part of the axial intermediate cell-mass is probably converted into blood corpuscles, which are seen enclosed within the delicate wall of the aorta (Figs. 35 and 43) from its earliest formation.

By a comparison of Figures 34 and 35 (Plate V.) from the fifth somite, the change which takes place in the axial cell-mass may be appreciated. These drawings represent sections from the corresponding regions of embryos of four and five days respectively. In Figure 34, no differentiation of the intermediate cell-mass (*cl-mo. i'm.'*) is to be seen, but it consists of closely packed indifferent cells. In Figure 35, the aorta is formed, its walls being outlined by delicately drawn-out cells, in section spindle-shaped, enclosing blood corpuscles (*cp. san.*), which must have originated from the cell-mass. Outside the walls of the aorta, and between it and the intestinal canal, are seven nuclei, which are the remaining representatives of the original cell-mass. The change has resulted in the densely packed cell-mass being replaced by the aorta, its contained blood corpuscles, and the small number of nuclei on its ventral side where the trunk vein will be formed later. The aorta can be traced from the anterior trunk region to about the seventh somite.

The number of nuclei, or blood corpuscles, lying within the aorta, increases in passing back from the region of the nephrostome, until a point is reached where it is relatively large, and the mass of cells within it seems to be continuous with the original cell-mass, and aortic walls cannot be readily distinguished.

The following table shows the variation in the number of nuclei lying inside and those lying outside the aorta, through a series of consecutive sections, beginning with the fifth somite of an embryo of about five days.

No. of Section.	No. of Nuclei within the Walls of the Aorta.	No. of Nuclei outside the Walls of the Aorta.
1	7	0
2	6	0
3	7	0
4	7	2
5	4 (?)	4 (?)
6	4	7
7	3	7
8	7	5
9	7	8
10	6	8
11	6	7
12	8	10
13	10	7
4	11	8

(*d*) *Comparative Review.* — From a brief summary and comparison of the observations on the origin and morphology of the intermediate cell-mass in Teleosts, it appears that Wenckebach's ('86, p. 246) account for Belone differs materially from Oellacher's ('73) for the Brook Trout, as well as from Ziegler's ('82) observations upon the Salmon and my own on Fundulus; that is, he did not observe its true lateral origin, or any modification of it in different regions of the trunk. If Wenckebach's account of the origin of this structure is correct and complete, Belone is an exception among Bony Fishes, and differs materially, in this point, from other groups of Vertebrates. As has been stated (p. 113), Wenckebach refers the origin of the intermediate cell-mass to individual cells, which migrate from the protovertebræ to a position under the chorda, and here proliferate and form the compact cord of cells which may be designated the axial portion of the intermediate cell-mass. My observations on Fundulus agree in general with Oellacher's for the Brook Trout, so far as he describes the structure. I have seen no evidence in Fundulus in support of the theory toward which Ziegler inclines, namely, that the intermediate cell-mass retains histological connection with the protovertebræ.

Ziegler's observations on his "formative tissue" in the Salmon, and his study of the relation between it and the intermediate cell-mass, are based on relatively older stages than those in which I have observed the origin of the intermediate cell-mass in Fundulus. The identity of the intermediate cell-mass and the formative tissue arising from the protovertebræ, or even an intimate relation between the two in Fundulus, must be questioned when we consider the fact that the intermediate cell-mass originates prior to the formative tissue, and in a very different manner; that it has already given rise to the segmental duct, and that the dorsal blood-vessel and contained blood corpuscles have taken their origin from it before the period is reached at which the formative tissue arises from the protovertebra. According to Ziegler's account, the protovertebræ, at the stage in which the formative tissue arises, already show differentiation of muscle fibre. In Fundulus these two processes also occur during the same period (*fbr. mu.*, Plate VI. Figs. 43, 44), but subsequent to the formation of the intermediate cell-mass. It is true, however, that a certain portion of this cell-mass still remains in an indifferent state at this stage, and its loosely disposed cells are brought into juxtaposition with those of the formative tissue, and are identical with them in appearance.

If Ziegler's comprehensive definition for Bildungsgewebe be employed, all migatory cells which originate from the mesoderm, of whatever source, must be included in it; hence those originating from the intermediate cell-mass, and indeed the entire cell-mass itself (excepting perhaps its lateral portion, which gives rise to the segmental duct, whose cells in the anterior trunk region have from the beginning more or less of an epithelial character) are also embraced under this term; i. e. the intermediate cell-mass is Bildungsgewebe. Ziegler says ('87, pp. 646, 651) that *the intermediate cell-mass can at no time be distinctly separated from Bildungsgewebe.* This statement is superfluous, unless it is intended to mean that the formative tissue (migratory cells) which arises from the intermediate cell-mass is identical with that arising from other sources (the lower margin of the myotomes); but with this construction, the statement is true only so far as the appearance of the cells and their migratory condition are concerned, the *source* and *fate* are different.

I believe that the origin of the "blood-spaces" in Proteus (Wiedersheim, '90) has not been traced through earlier stages; but it seems to me very probable that they represent the intermediate cell-mass of Teleosts, and that the bi-lobed condition of the cell-mass in the Salmon is here a more permanent one, and that the segmental ducts, instead of being formed in the lateral region of the intermediate cell-mass, as in the case of Fundulus, are here developed in a less peripheral region. It appears that the segmental ducts, which at an earlier stage lie in a central region of the "blood-spaces," later come to occupy a position entirely outside of them, but near their lateral boundary, as in the case of the segmental ducts in Teleosts. In Proteus the bi-lobed cell-mass, or the "blood-spaces," are said to move from their original lateral position and unite in the median line between the chorda and intestinal canal, which is also true of the intermediate cell-mass.

When the source and fate of the intermediate cell-mass in Teleosts are compared with those of the corresponding structure in other Vertebrates, — the "intermediate cell-mass" in Elasmobranchs, Lacerta, and Birds, — it seems to me that the negation of the homology of these structures (Ziegler) is not justifiable; but that, on the other hand, a comparative view affords evidence in favor of such homology. The variation in the morphology of the intermediate cell-mass in Teleosts, Elasmobranchs, Lacertilia, and Birds seems comparatively insignificant when we consider its variation in representatives of the same group, e. g. the Chick and Duck, and especially when its variation in the different regions in the same embryo is considered. When we take into account the characteristic peculiarity of the Teleostean embryo, — namely, the compact condition of the primitive layers, the embryo being pressed down into the relatively large amount of yolk beneath, — a cause is found which is apparently adequate to explain this modification in the morphology of structures which are homologous. The points of similarity in the origin and fate of these structures in the different groups of Vertebrates are strong and significant.

VI. Origin of the Pectoral Fin.

(*a*) *Proliferation of Somatopleure.* — The earliest trace of any modification of the mesoderm in the region of the pectoral fin takes place opposite the nephrostome (Plate V. Fig. 33, *so'plu.*), and consists of a thickening of the somatopleuric layer. This is observed in an embryo of eighty-four hours. In front of this region, opposite the third protovertebra, the somatopleure consists of a single layer of cells (*so'plu.*, Fig. 30), and as such is continuous with the head-mesoderm. At an earlier stage, in the region of the first and second protovertebræ there is a thickening of the somatopleure (Plate IV. Fig. 25, *so'plu.*), which extends forward to the head-mesoderm; but this is only a temporary condition, which exists at the time when the lateral margin of the entoderm (*en'drm.*, Fig. 25) begins to fold toward the axis to form the intestine (*in.*, Fig. 30). During this period there is apparently a crowding of cells toward the proximal region of the somatopleure, which later, when the entoderm is well advanced in the process of its infolding, assumes again the form of a single layer of cells (*so'plu.*, Fig. 30).

The cell proliferation in the somatopleure seems therefore to produce a temporary thickening in front of the third protovertebra, but the only region in which this original thickening remains permanent is that of the nephrostome. I am therefore led to believe that the condition in the second and third protovertebræ is not concerned with the beginning of the pectoral fin, and that, if there is at this stage any trace of its formation, it must be referred to the region opposite the nephrostome.

Shortly after the nephrostome is formed, a thickening of the somatopleure by cell proliferation takes place, which is permanent, and leads to the development of the pectoral plate. This modification of the somatopleure extends from the head-mesoderm backward through the region opposite the third protovertebra. It may be said that it develops from the head-mesoderm in a posterior direction; yet from the first the most conspicuous portion of this thickening is not in the anterior part of the pectoral region, but rather in the middle of it, first in the region of the third, and later opposite the second protovertebra.

It is clear that at the time of the beginning of this thickening of the somatopleure, and during a brief period following, there is no connection between it and the adjacent protovertebræ (see Plate V. Figs. 30–34). In a later stage, however, such a connection is established.

I shall now describe a stage in which the pectoral plate is well advanced, and is in histological connection with the adjacent protovertebræ.

(*b*) *Contribution of Myotomic Elements to Pectoral Plates.* — In front of the first protovertebra the indifferent head-mesoderm extends laterally, and diminishes to a single layer of cells (Plate VI. Fig. 39) corresponding to the somatopleure in the protovertebral region. This lateral somatopleuric plate thickens in the region opposite the first protovertebra; the thickening may be regarded as the anterior region of the pectoral plate, and results principally from a cell proliferation in the somatopleure. In the region of the first protovertebra there is no separation between the protovertebræ and the lateral or pectoral plates, i. e. the protovertebra passes gradually over into the lateral layer, which is in no sense cut off from it. This lateral mesodermic plate (*la. pct.*, Fig. 40) is therefore continuous anteriorly with the head-mesoderm, and axially with the first protovertebra; in its relation to the cœlomic cavity it represents morphologically the somatopleure. The somatopleuric thickening is still more pronounced in the region of the second protovertebra (Fig. 41, *la. pct.*), where it is about three or four cells in thickness. The pectoral plate is here so closely connected with the protovertebral mesoderm as to render it impossible to distinguish any sharply defined boundary between them.

In the region of the third protovertebra it (*la. pct.*, Fig. 42) is only about two cells in thickness, and is less intimately connected with the protovertebra, while in the region of the fourth protovertebra the pectoral plate or somatopleuric thickening (Fig. 43, *so'plu.*) is independent of the protovertebra, and is composed of but a single layer of cells. The nuclei are however closely crowded in the somatopleure, and give evidence of active karyokinetic change. Caudad of the fifth protovertebra, the somatopleure consists of a thin single layer of cells, independent of the protovertebræ.

It has been pointed out in the foregoing account, and demonstrated in the figures of Plate VI., that a connection between the pectoral plate and adjacent protovertebræ has been established. The method by which this connection has been effected and its morphological significance remain to be considered. It is evident that the pectoral plate is passive in this process, whereas elements from the protovertebræ lose their former epithelial arrangement in its peripheral layer and pass over into the pectoral plate. It can hardly be said that the elements in this contribution take the form of well defined cell-masses or buds, nor are they strictly isolated individual cells, and yet to a certain extent both conditions exist. The first step in establishing this connection consists in an increase in the number of cells at the outer ventral margin of the protovertebra, at this stage more correctly designated myotome. The peripheral or somatic layer of cells in the myotome, the cutis-plate, is only one cell deep (Plate VII. Fig. 47, *la. mu.*), excepting in the region where later the connection is formed with the pectoral plate. Here by cell proliferation the peripheral layer (cutis-plate) is augmented to a mass of cells (*pr'f. my'tm.*, Fig. 47) which projects laterally in the direction of the pectoral plate, finally, in fact, extending over the proximal margin of the latter. This projection is especially pronounced in the middle of the first, second, and third myotomes. In the next step, the cells of those myotomic proliferations, which already lie in contact with the pectoral plate, fuse with the latter; that is, the ventral margin becomes continuous with the pectoral plate, as already described, so that the mass of cells constituting the former projection of the myotome is gradually reduced until there is a complete blending of myotome (Plate VIII. Fig. 51) and pectoral plate. Subsequent to this connection of myotome and pectoral plate, cell proliferation is continued in the region of the former myotomic projection, and the elements thus produced seem gradually to crowd outward into the pectoral plate.

The myotomic projections here described are observed in the three anterior myotomes; but in the posterior region of the pectoral plate, i. e. the region of the fourth myotome, no such distinct cell-mass is produced prior to the connection of myotome and pectoral plate. The process in this region seems to consist from the first in the passing over of *individual* cells into the pectoral plate (*pr'f. my'tm.*, Figs. 48, 49, and 50).

It is highly probable that the projection of the ventral portion of the myotome is due in part to the tendency of the myotomes at this stage to fold upon themselves. This tendency can be readily seen in sections back of the pectoral region (Fig. 44), and is the result of the relatively large amount of yolk in the Teleostean ovum, causing not only the lateral layers, but also the lower portion of the myotomes, to present the appearance of being pressed upward and outward. While it is true that myotomes back of the pectoral region, as well as those adjacent to the pectoral plate, show this tendency of their ventral portions to project outward, two points of difference must be noted. (1) In the pectoral region the myotome extends outward relatively much farther than in the post-pectoral region (compare Figs. 44 and 47); and (2) the peripheral layer of this projecting portion of the myotomes in the post-pectoral region consists of a layer only one cell in thickness, similar to that of the upper and outer boundary of the myotome, whereas the laterally projecting portion of the myotome in the pectoral region, prior to its connection with the pectoral plate, consists of a mass of indifferent cells, equivalent to a layer three or four cells in thickness (compare Figs. 44 and 47). This condition of the myotome and the accumulation of this mass of indifferent cells cannot, therefore, be regarded as insignificant, or common to all regions of the trunk, but must be looked upon as a growth leading to the contribution of elements to the pectoral plate. I am at present undecided whether any distinction should be made between the earlier contribution of elements, which is in the form of a mass of cells, and the later, which consists of single cells. It seems to me, however, to be beyond doubt that in both cases the source of the elements is the peripheral layer of the myotome, the cutis-plate, and I am inclined to believe, both from this and from the fact that in the posterior pectoral region the contribution seems to be from the beginning by single cells only, that the latter form may be regarded as a modification of the earlier and more conspicuous method.

In addition to this contribution from the muscle plates, it is highly probable that single cells, originating in the ventral and more axial region of the myotome, pass over into the pectoral plate. There are cells in this region such as Ziegler ('87) describes and designates "Bildungsgewebe," which exhibit active nuclear change, but I have not seen sufficient evidence in Fundulus to affirm their migration into the pectoral plates. If a migration of such elements does take place, it must be subsequent to the connection between the myotomes and pectoral plate, i. e. subsequent to the contribution by the cutis-plate, since prior to this there is no connection between the elements in question and the pectoral plate.

The inferences which I am led to draw from my observations on Fundulus concerning the origin of the pectoral fin are: (1) that the first step is a differentiation in the somatopleure caused by cell proliferation in the region of the nephrostome; (2) that this process leads to the formation of the pectoral plate; (3) that a connection is formed between each of the four most anterior myotomes and the pectoral plate, and that elements from the peripheral layer of these myotomes are contributed to the pectoral plate; (4) that, although the lateral portion of the head-mesoderm is continuous with the lateral plates, as its axial region is with the most anterior protovertebra, the head-mesoderm does not really appear to be concerned in the earliest formation of the pectoral fin.

VII. Concerning the Relation of the Pectoral Plate and the Ectodermal Fold.

The earliest trace of a modification in the ectoderm which can be regarded as leading toward the formation of an ectodermal fold in the region of the pectoral fin, is observed in an embryo of about four days, and this modification (Plate VII. Fig. 46) merely consists of a more compact arrangement of the nuclei in the lower cell layer of the ectoderm (*la. sns. ec.*, Fig. 47) than is found in the preceding stages. This modification, however, does not in any sense involve the superficial ectodermal layer (*cta.*, Fig. 47); it is not of the nature of an evagination or folding of the layers of the ectoderm, and it does not at this stage modify even the external contour of the sections. But at this stage the mesodermal pectoral plate is already far advanced.

An ectodermal fold cannot be seen before the fifth day; the ectoderm then rises into a distinct fold (Plate VIII. Fig. 54, *pli. ec'drm.*) and extends in a longitudinal direction, but not quite parallel, to the axis of the embryo. Concerning the nature of this fold in Fundulus, I may say that my observations confirm, in the main, 'Swirski's ('80) description for the Pike. The ectodermal fold develops independently of the mesoderm; the nuclei of the lower layer of the ectoderm are relatively large, and, like their cells, are more or less wedge-shaped in outline. It is worthy of note in this connection that the cuticular layer of the ectoderm is also peculiarly modified in the region of the ectodermal fold. The nuclei lose their characteristic flattened appearance (Fig. 54, *nl.*[1]), and become irregular in form and much enlarged. So great is their increase in size, that, although the cuticular layer is already materially thickened, still in the region of each nucleus the surface is carried outward by the enlarged nucleus beneath, and the external contour is thus thrown into numerous irregular elevations (Fig. 54). In Fundulus, as in the Pike, the ectodermal fold does not extend back along the side to the ventrals, but only through the region of the pectoral plates. It cannot be held that the ectodermal fold takes its beginning as the result of an outward growth of the mesodermal cells, for the latter do not commence their outward migration until after the formation of a distinct lumen or fold (*pli. ec'drm.*, Fig. 55). The statement that the formation of the ectodermal fold takes place prior to the outward migration of the mesodermal elements cannot be construed to mean that the modification of the ectoderm precedes that of the mesoderm in the development of the pectoral fin; since it has been shown in Fundulus (Plate VI. Figs. 40–43) that the pectoral plate is developed before any modification in the ectoderm.

Hence it follows that in Fundulus the ectodermal fold does not begin to be formed until several days after the formation of the pectoral plate in the mesoderm, as already described; and the statement of authors that the earliest trace in the development of the pectoral fin in Osseous Fishes is the formation of the ectodermal fold, does not apply to Fundulus at least.

Nor can it be said that there is at any time in Fundulus any trace of a continuous longitudinal modification of the ectoderm along the side of the embryo, such as has been observed by Balfour in Elasmobranchs, and maintained by Ryder for the Cod, Stickleback, Shad, etc. I am convinced from my own observations upon Shark embryos, that in the latter, as in Fundulus, the earliest step in the development of the pectoral fin is not a modification of the ectoderm, as supposed by Balfour and accepted by Dohrn, but that the beginning must be referred to the proliferation of the mesoderm in the somatopleure, as I have already pointed out for Fundulus (p. 126). My observations on the Shad (*Clupea sapidissima*) and the Cod (*Gadus morrhua*) also confirm this point for other Osseous Fishes besides Fundulus, and I believe that this condition is typical, if not constant, in the entire group of Fishes.

As I have already stated (p. 96), Oellacher traced the origin of the pectoral fin from the mesoderm. He did not, however, believe simply in the priority of the mesodermal modification, for he supposed an ectodermal fold to be absent in the case of the pectoral fin in the Trout. He evidently saw the pectoral plate at a stage prior to the ectodermal modification,— a stage presumably corresponding to Figure 41 (Plate VI.) of Fundulus, — but he did not discover that *subsequently* an ectodermal fold is developed; hence his observation did not reveal the error of Balfour and others, who assumed that the ectodermal fold is the first step in the development of the pectoral fin.

I am unable to make any comparison between the condition of the unpaired fins in Fierasfer and my own observations in Fundulus, as I have discovered no structure in the pectoral fin of Fundulus comparable to the homogeneous stratum which has been observed by Emery, and is regarded by him as partly mesodermal and partly ectodermal in origin.

The extreme view held by Prince ('86, p. 697), that the pectoral fins of Osseous Fishes are of ectodermal origin, and are differentiations of a continuous lateral expansion of the epiblast, seems to me to be based more upon theoretical considerations than upon observed facts. The only way in which I can account for the author's description is to assume that his "two epiblastic lamellæ (separated by a fissure) lying flat upon the vitellus," which he regards as the beginning of the pectoral fin, are really the primitive embryonic layers, either including the three at an early stage (compare Fig. 5 in Fundulus) before their complete differentiation, or including only ectoderm and mesoderm at a later stage (compare Fig. 26 in Fundulus). Indeed, more recently a similar belief is defended by M'Intosh and Prince ('90, pp. 800–803) in their joint paper on the development of Teleosts. In this paper the ground taken is still more peculiar, and the interpretation is much involved in speculation.

I have already quoted at some length the views of these authors (pp. 98, 99), and need here only recall the fact that they regard the lateral margin of the blastoderm at an early stage, virtually before the complete differentiation of the primitive layers, as the beginning of the pectoral fins. Their assumption that the pectoral fin begins its differentiation in a stage as early, for example, as that shown in Figure 5 (Plate I.) for Fundulus, meets with serious obstacles. It presumes a recognition of the pectoral fin prior to the complete differentiation of the primitive germinal layers themselves, and hence refers the beginning of the pectoral fin to a structure (an "alar expansion" which "consists of epiblast and hypoblast") which evolves the entoderm or hypoblast. But in what sense the entoderm is identified with the beginning of the pectoral fin they have not explained.

It is evident that a view of the blastoderm seen from above (Plate I. Fig. 1) presents such lateral expansions of the primitive layers as M'Intosh and Prince have designated alæ. These expansions not only extend along the sides of the embryonic axis, but are also continuous in front of the embryonic swelling; to draw any analogy, however, between this blastodermic rim and the pectoral fin, or to regard this condition of the primitive layers as representing in any sense the pectoral or paired fins, seems to me fanciful and unwarranted. At a later stage (Plate I. Fig. 3), in which the somatopleure has undergone a thickening in the pectoral region, or still later, when the pectoral plate is formed, it is true, as described by these authors, that a parietal (lateral) thickening in the pectoral region may be observed when the embryo is examined from above in surface view or by transmitted light; but this appearance is at first due entirely to a modification of the somatopleure, and at no time are the other layers — splanchnopleure and entoderm — concerned. This fact can be readily demonstrated by serial sections from the proper stages of the embryo; hence I believe that the interpretations of these authors upon the origin of the pectoral fins are misleading, and that their views are untenable.

Ziegler maintains that the thickening of the somatopleure is accompanied by the upheaval of the ectoderm, and evidently does not regard the ectodermal fold as the first step in the development of the pectoral fin in the embryo of Elasmobranchs. In his studies of the Salmon and Pike he reaches substantially the same conclusion, but gives no further details concerning the formation of the lateral longitudinal fold of ectoderm. The facts upon which his statements are based may be identical with the conditions in Fundulus, but, not being specially interested in the ectoderm, he may have omitted a more exact account of its modification; at any rate, it cannot be affirmed that in Fundulus the proliferation or thickening of the somatopleure is at first accompanied by an upheaval or any other modification of the ectoderm, this latter change being a secondary step, which is preceded by the proliferation of the somatopleure and the formation of the pectoral plate, as already described. This difference should be noted, that in the Salmon, according to Ziegler's ('87, p. 619) account, the lateral ectodermal fold extends from the pectoral region to that of the anus, whereas in the case of Fundulus no such fold of the ectoderm is found.

I have examined both the Cod and the Shad, in which Ryder affirms that the ectodermal fold is the earliest trace of the pectoral fin, and find that these forms agree with Fundulus to the extent at least that the proliferation of the somatopleure in the pectoral region precedes any specialization or modification in the ectoderm. I cannot account for this difference in our results, unless my supposition, that Ryder's studies were made chiefly without the aid of sections, is correct.

Chicago, January, 1892.

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EXPLANATION OF FIGURES.

All the figures were drawn with the aid of an Abbé camera lucida from preparations of Fundulus heteroclitus, Linn. All transverse sections were taken in serial order from the anterior toward the posterior end of the animal, and the drawings represent the anterior faces of the sections. The drawings of frontal sections represent the dorsal faces.

ABBREVIATIONS.

ao.	aorta.
au.	auditory vesicle.
bl'po.	blastopore.
brs. brn.	gill-pouch.
can. med.	medullary canal.
cav. pi'cr.	pericardial cavity.
cd.	chorda.
cd. sp.	spinal cord.
cl. cn't. tis.	connective-tissue cell.
cl.-mo. i'm.'	intermediate cell-mass.
cl. mu.	muscle cell.
cl. pig.	pigment cell.
cn't. tis.	connective tissue.
cœl.	body cavity.
cp. san.	blood corpuscles.
cta.	cuticular layer of ectoderm.
dt. sg.	segmental duct.
ec'drm.	ectoderm.
ec'drm.'	ectodermic thickening.
en'c.	brain.
en'drm.	endoderm.
fbr. mu.	muscle fibre.
fos. olf.	nasal pit.
fs. brn.	gill-cleft.
in.	intestine.
la. l.	lateral plate.
la. mu.	muscle plate.
la. pct.	pectoral plate.
la. sns. ec.	lateral sensory layer of ectoderm.
ms'drm.	mesoderm.
ms'drm. ax.	axial mesoderm.
ms'drm. cap.	head-mesoderm.
my'tm.	myotome.
nl.	nucleus.
nl.'	nucleus in process of division.
nl.''	nucleus soon after division.
*nl.**	nucleus from protovertebra (?).
nl.†	nucleus from lateral plate.
nl.††	nucleus of doubtful origin.
nl.^{1}	spindle-shaped nucleus of the cuticular layer.
nl. pi. 'bl.	periblast nucleus.
oc.	eye.
o. ln. l.	lateral line organ.
pin. pct.	pectoral fin.
pli. ec'drm.	ectodermic fold.
pli. l.	lateral fold.
pli. pct.	pectoral fold.
pr'f. my'tm.	proliferation from myotome.
pr'nph.	pronephros (head-kidney).
pr'vr.	protovertebra.
scl'tm.	sclerotome.
so'plu.	somatopleure (somatic portion of mesoderm).
spl'plu.	splanchnopleure (splanchnic portion of mesoderm.
tb. sg.	segmental tube (duct).
va. san.	blood-vessel.
vn. marg.	marginal vein.
vs. au.	auditory vesicle.
vs. au.'	ectoderm from which *vs. au.* is formed.
vs. K.	Kupffer's vesicle.
vs. opt.	optic vesicle.

PLATE I.

Fig. 1. Clove-oil preparation of a blastoderm, shortly before the closure of the blastopore, 46 hours after fertilization of the ovum. Perenyi's fluid. Czokor's alum cochineal. × 48.

Fig. 2. Clove-oil preparation of an embryo of 52 hours, soon after the closure of the blastopore. The optic vesicles are prominent, but the auditory vesicles have not yet been formed. Perenyi's fluid. Czokor's alum cochineal. × 48.

Fig. 3. Clove-oil preparation of an embryo of 90 hours. Perenyi's fluid. Czokor's cochineal. × 42.

Fig. 4. Clove-oil preparation of an embryo of about 23 days. Kleinenberg's picro-sulphuric mixture. Czokor's cochineal. × 42.

Fig. 5. Transverse section through the pectoral region, at a point indicated by the figure *5* in Fig. 1. From an embryo of 46 hours, showing the condition of the primitive layers soon after the closure of the blastopore. Perenyi's fluid. Kleinenberg's hæmatoxylin. Section is $7\frac{1}{2}\mu$ in thickness. × 310.

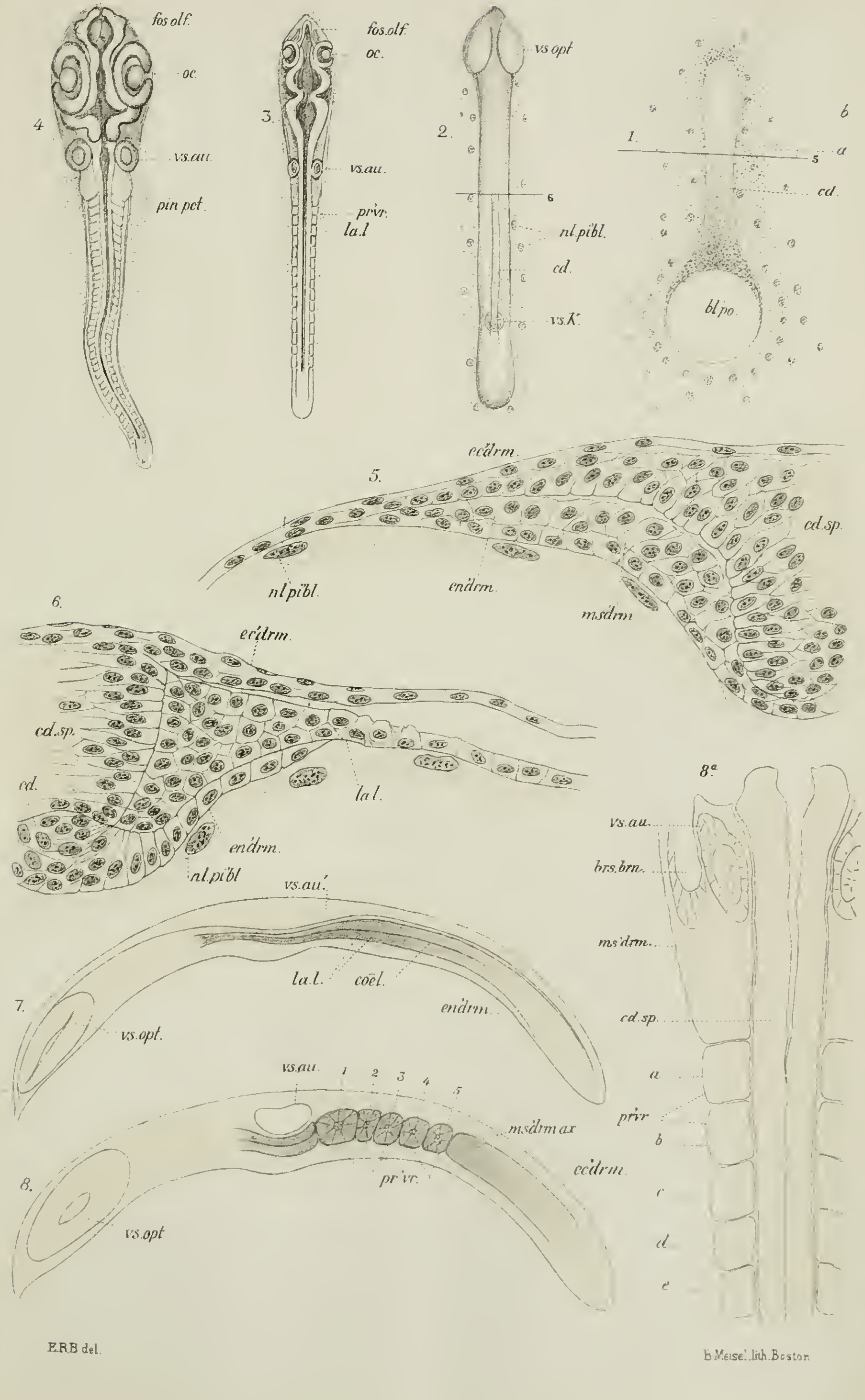
Fig. 6. Transverse section from the pectoral region, indicated by the figure *6* in Fig. 2. From an embryo of 52 hours. Perenyi's fluid. Kleinenberg's hæmatoxylin. Section $7\frac{1}{2}\mu$ in thickness. × 310.

Fig. 7. Sagittal section through the parietal plates, taken from the left side of an embryo of 56 hours and a little more advanced than Fig. 2. Section 10μ in thickness. Perenyi's fluid. Kleinenberg's hæmatoxylin. × 65.

Fig. 8. Sagittal section through the protovertebral region of the same embryo as Fig. 7. × 65.

Fig. 8^a. Frontal section through the protovertebral region of an embryo a little more advanced than that of Fig. 3. Perenyi's fluid. Kleinenberg's hæmatoxylin. × 165.

BOYER—MESODERM IN TELEOSTS. PL. I.



E.R.B. del.

B. Meisel, lith. Boston.

PLATE II.

All drawings of this plate were made from transverse sections of one embryo of 72 hours. Embryo killed with Perenyi's fluid, stained with Kleinenberg's hæmatoxylin, and mounted in balsam. Sections $7\frac{1}{2}\,\mu$ in thickness. All drawings are magnified 310 diameters. The sections are: —

Fig. 9. Through the anterior region of the auditory vesicle.
Fig. 10. Through the middle region of the auditory vesicle.
Fig. 11. Through the anterior region of the first protovertebra.
Fig. 12. Through the posterior region of the first protovertebra.
Fig. 13. Through the middle of the second protovertebra.
Fig. 14. Through the middle of the fifth protovertebra.
Fig. 14^a. Through the middle of the sixth protovertebra.
Fig. 15. Through the posterior region of the seventh protovertebra.

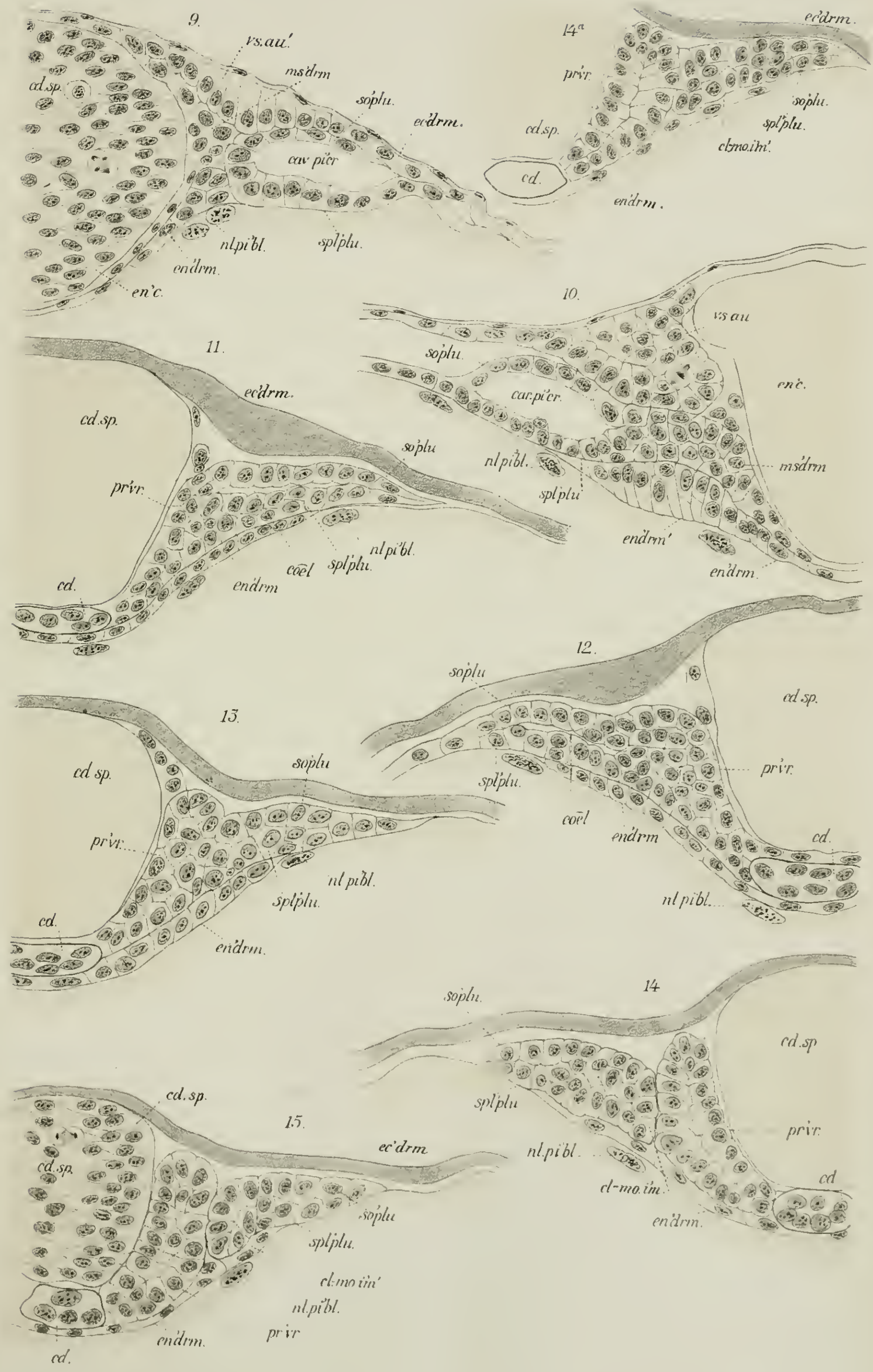


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PLATE III.

The embryos from which the drawings of this plate are made were killed with Perenyi's fluid and stained with Kleinenberg's hæmatoxylin. Figs. 17 and 18 are from an embryo of 79 hours. The sections are about 8 μ in thickness. Figs. 16 and 19–22^a were made from an embryo of about 76 hours. Sections are 7½ μ in thickness.

Figs. 16–18. Transverse Sections.

Fig. 16. Through the region of the auditory vesicle and fourth gill-pocket, showing right side. × 310. (See explanation of Fig. 19.)

Fig. 17. Through the middle region of the first protovertebra, showing the left side. × 310.

Fig. 18. Through the middle region of the second protovertebra, showing the right and left sides. × 310.

Figs. 19–22^a. Sagittal Sections.

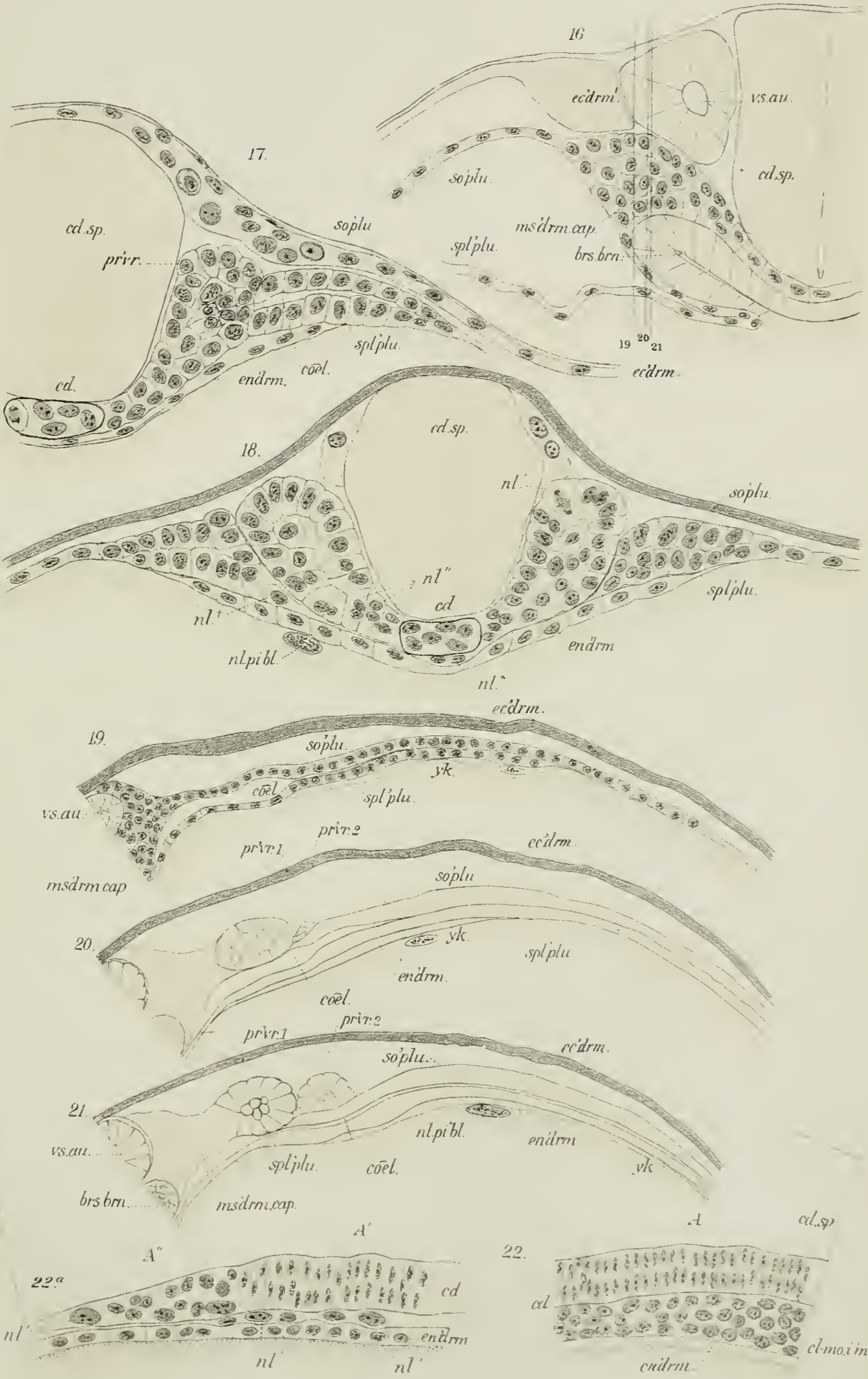
Fig. 19. From the right side of the same embryo as Fig. 16. The anterior edge of the section in Fig. 19 joined the posterior (under) surface of the section shown in Fig. 16, and the planes of the two sections intersect each other at right angles. The vertical lines in Fig. 16 indicate the positions and direction of the planes of the sections shown in Figs. 19–21, and are numbered correspondingly. × 175.

Fig. 20. From the region indicated by the vertical line numbered *20* in Fig. 16. × 175.

Fig. 21. From the region indicated by the vertical line numbered *21* in Fig. 16. × 175.

Fig. 22. Through the median plane of the chorda, in the posterior trunk region. × 310. The region embraced under *A* shows a portion of the chorda in which the cells are flattened, and the nuclei are consequently arranged in planes at right angles to the axis of the embryo. *A′* (Fig. 22^a) shows the anterior portion of this region, and *A″* embraces the anterior end of the chorda, in which the nuclei are few, and have not yet arranged themselves in the vertical plane.

Fig. 22^a. Through the median plane of the chorda, showing the anterior end. This drawing is made from a part of the same section as Fig. 22. × 310. See also explanation of Fig. 22.



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E Meisel lith. Boston

PLATE IV.

The material from which the drawings of this plate are made was killed with Perenyi's fluid, stained with Kleinenberg's hæmatoxylin; sections are $7\frac{1}{2}\,\mu$ in thickness and magnified 310 diameters. Figs. 23 and 24 are from an embryo of about 3 days, and all the others from an embryo of $3\frac{1}{2}$ days.

Figs. 23–29. Transverse Sections.

Fig. 23. Through the region of the auditory vesicle and third gill-cleft, showing the small volume of mesoderm and relatively large space occupied by the endodermal evagination forming the gill-cleft (*fs. brn.*). The sections give an anterior view on the left side.

Fig. 24. Through the region of the fourth gill-cleft, showing an earlier stage of endodermal evagination than Fig. 23, and a relatively large amount of mesoderm still in its original position.

Fig. 25. Through the region of the second protovertebra, showing the ventral shifting of the lateral layers, and nuclei (*nl.**) of protovertebral origin and some (*nl.*†) of doubtful origin.

Fig. 26. Through the posterior region of the third protovertebra, being the region in which the nephrostome is formed later, showing also the shifting of the lateral plates along the protovertebræ and the migration of cells from the lateral plates toward the median line.

Fig. 27. Through the middle region of the third protovertebra, showing three nuclei (*nl.**) under the chorda, which probably have a protovertebral origin.

Fig. 27^a. Through the posterior region of the third protovertebra, showing the migration of nuclei from the lateral plates toward the median line.

Fig. 28. Through the middle region of the fifth protovertebra, showing the "intermediate cell-mass" cut off from the lateral layers, and nuclei passing from its proximal margin toward the median line.

Fig. 29. Through the posterior region of the fifth protovertebra, showing nuclei from the "intermediate cell-mass" in position under the chorda.

This section represents a condition in which only a few cells have taken their place between the chorda and entoderm; but in the fourth section back of this, the mass of cells in this position is three to four cells in thickness.

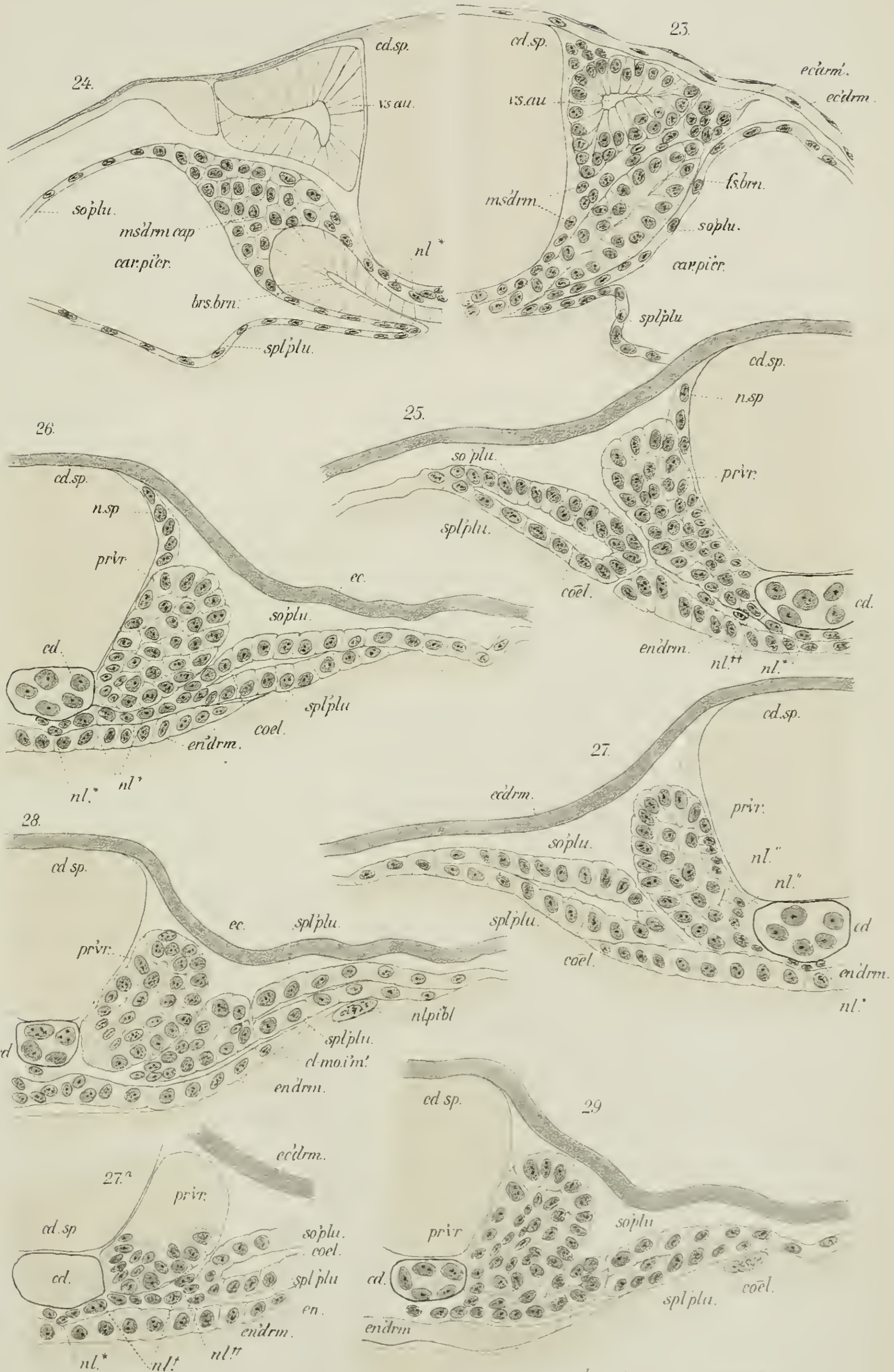

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PLATE V.

Material treated the same as in the case of Plate IV. Figs. 30–34 from an embryo of 84 hours. Figs. 35–37 from an embryo of 108 hours.

Figs. 30–37. Transverse Sections. (Magnified 310 diam.)

Fig. 30. Through the second protovertebra, being in front of the evagination forming the nephrostome, and showing that the somatopleure is composed of a single layer of cells.

Fig. 31. Through the third protovertebra, showing the anterior region of the nephrostome.

Fig. 32. The next section back of the one from which Fig. 31 was taken.

Fig. 33. Through the posterior region of the third protovertebra.

Fig. 34. Through the posterior region of the fifth protovertebra. The lateral portion of the intermediate cell-mass has formed the segmental duct (*dt. sg.*), and has separated from the axial portion of the intermediate cell-mass (*cl.-mo. i'm.'*). The aorta is not yet formed, and the intestine (*in.*) is not closed.

Fig. 35. Section of an embryo 24 hours older than that of Fig. 34, representing the same region. In this embryo the aorta (*ao.*) is formed as far forward as the third protovertebra. There remain in this region a relatively small number of undifferentiated nuclei of the intermediate cell-mass. The segmental duct (*dt. sg.*) is completely formed.

Fig. 36. From the eighth protovertebra of the same embryo as Fig. 35. The aorta is not yet formed. The axial portion of the intermediate cell-mass is relatively large. The segmental duct (*dt. sg.*) is formed, and the intestine (*in.*) has closed in and assumes a tubular form.

Fig. 37. From the posterior trunk region of the same embryo, showing a voluminous intermediate cell-mass (*cl.-mo. i'm.'*). The segmental duct (*dt. sg.*) is not distinctly separated from the axial cell-mass, and shows as yet no trace of a lumen. The intestine has not yet assumed its tubular form.

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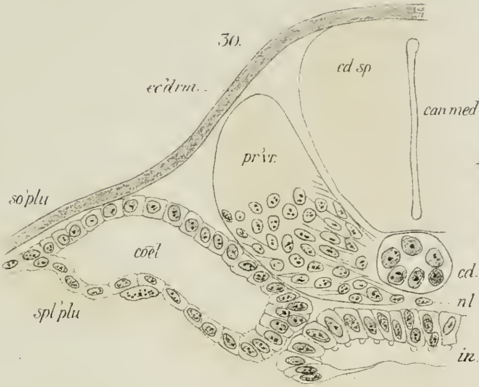

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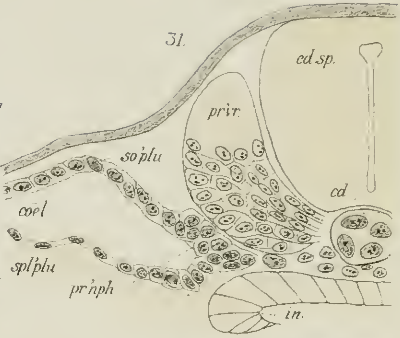

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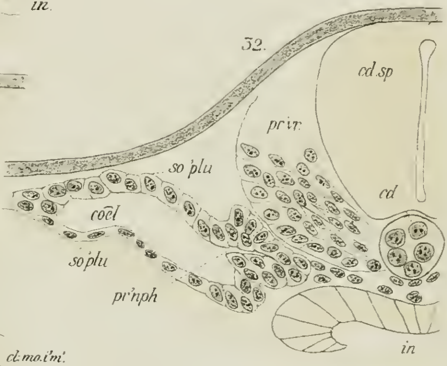

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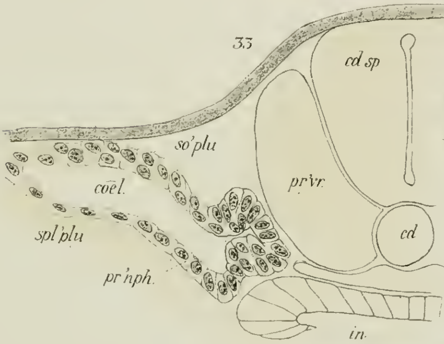

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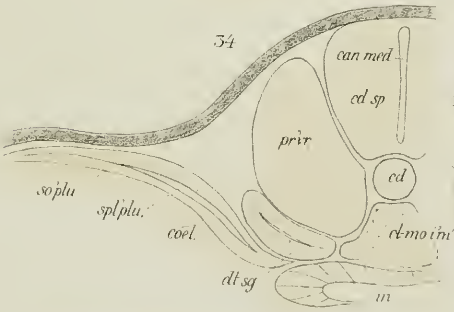

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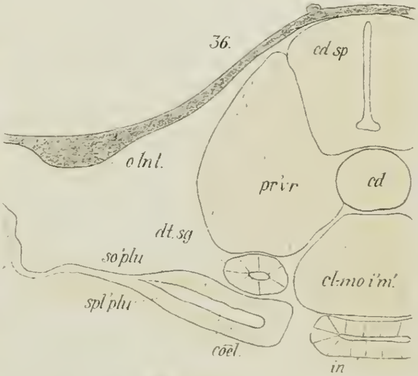

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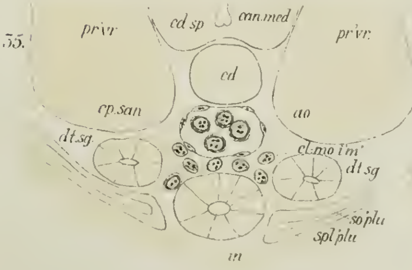

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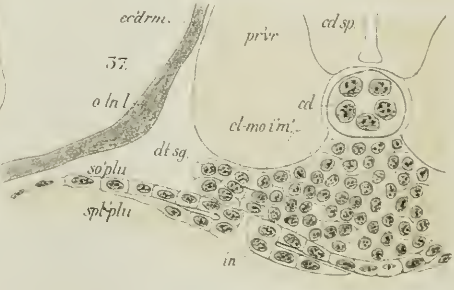

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PLATE VI.

All drawings on this plate are from embryos at 96 hours. Figs. 39–44 inclusive are from the same embryo; it was killed with Perenyi's fluid and stained with Kleinenberg's hæmatoxylin. Sections $7\frac{1}{2}\,\mu$ thick.

Fig. 38. Dorsal view of a portion of a clove-oil preparation to show the relative position of the pectoral plate and the anterior protovertebræ. The principal part of the somatopleuric thickening which constitutes the pectoral plate is opposite the first four protovertebræ (*1–4*). × 65.

Figs. 39–44. Transverse Sections. (Magnified 310 diameters.)

Fig. 39. In the region immediately in front of the first protovertebra. The axial mesoderm extends laterally continuous with the somatopleure (*so'plu.*).

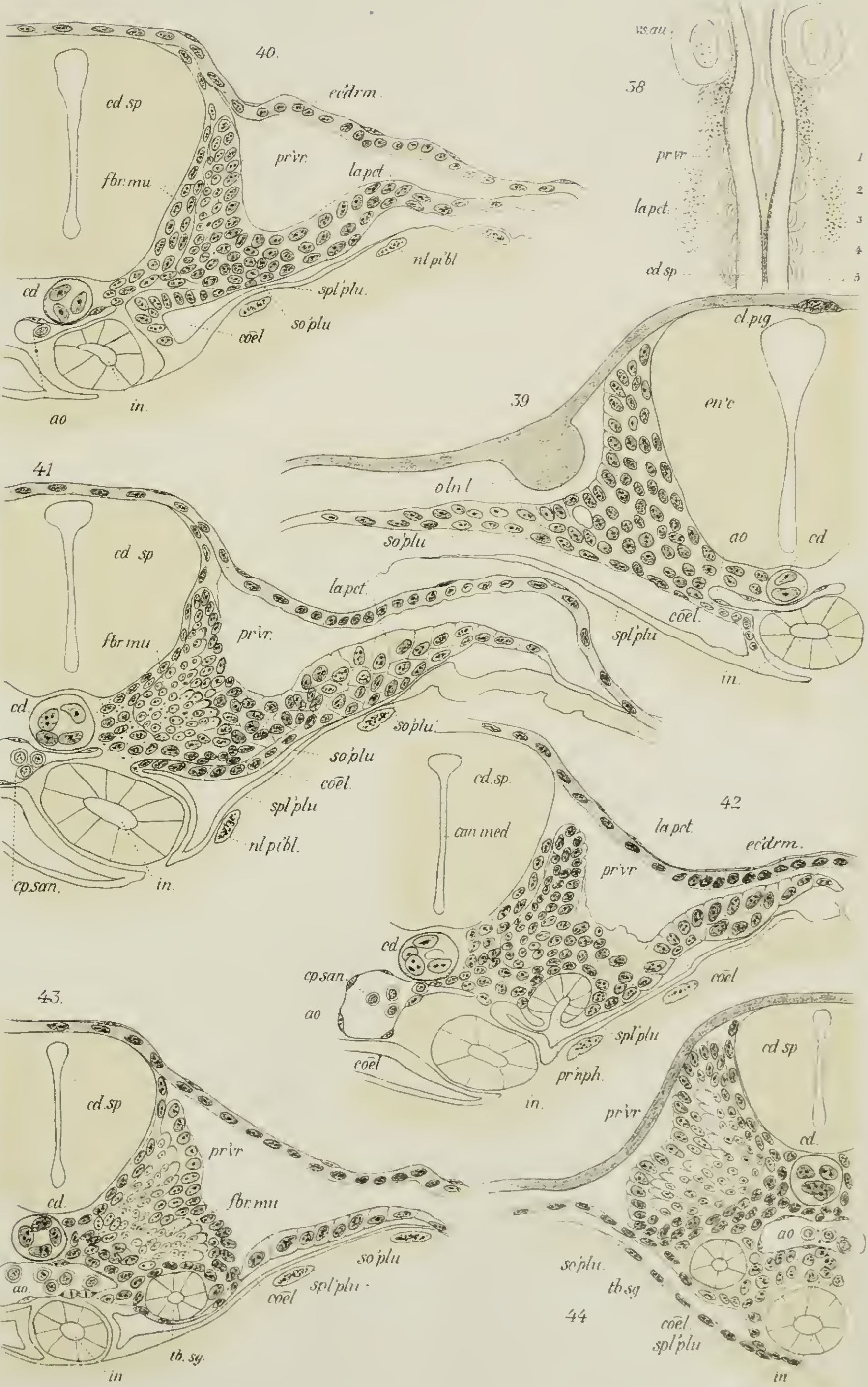
Fig. 40. From the first protovertebra. Here the protovertebra (*pr'vr.*) passes gradually over into the pectoral plate (*la. pct.*). The peripheral cells define the contour of the protovertebra only in its upper region. In the region of the pectoral plate no boundary of the protovertebra is distinguished. The space between ectoderm and mesoderm is due to their artificial separation during preparation.

Fig. 41. From the second protovertebra, showing the same histological connection between the protovertebra (*pr'vr.*) and pectoral plates (*la. pct.*) as is shown in Fig. 40. This section is taken from the posterior region of the (second) protovertebra, and is the tenth section ($75\,\mu$) back of the one represented in Fig. 40. The intervening sections represent the same relation between protovertebra and pectoral plate.

Fig. 42. From the third protovertebra, showing less advancement in the development of the pectoral plate than in the preceding sections, and not so firm a connection between it (*la. pct.*) and the protovertebra (*pr. vr.*). The section passes through the middle of the nephrostome (*pr'nph.*).

Fig. 43. From the fourth protovertebra, showing the pectoral plate as a single layer of cells and continuous with the somatopleure (*so'plu.*). No definite connection between somatopleure and protovertebra is shown. The section passes through the segmental tube (*tb. sg.*).

Fig. 44. From the sixth protovertebra. The somatopleure (*so'plu.*) shows no trace of any thickening to form the pectoral plate, and it has apparently no connection with the protovertebra.



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B. Meisel, lith. Boston

PLATE VII.

Drawings on this plate are transverse sections from an embryo of 96 hours, but somewhat more advanced than the one represented in Plate VI. Perenyi's fluid. Kleinenberg's hæmatoxylin. Sections $7\frac{1}{2}\mu$ thick.

Fig. 45. Through the region of the marginal vein (*vn. marg.*) in front of the pectoral plate on the right side. The marginal vein in front of the first protovertebra runs obliquely (see this region in Fig. 56); hence in sections successively nearer the tail it is seen farther from the axis of the embryo. × 310.

Fig. 46. Through the pectoral plate in the region of the nephrostome (*pr'nph.*). At this stage the lateral-line organ (*o. ln. l.*) extends backward through a portion of the pectoral region (compare Figs. 46 and 42); this is not the case in a stage slightly less advanced. The proximal region of the pectoral plate stands in close histological connection with the elements in the ventral region of the protovertebræ. × 310.

Fig. 47. Through the pectoral plate in the region immediately in front of the nephrostome. A few closely arranged nuclei below the protovertebra are from the anterior wall of the nephrostome (*pr'nph.*). The next section back shows the nephrostome, which is similar to that of Fig. 46. × 310.

Fig. 48. Through the pectoral plate back of the nephrostome, showing the elements (*pr'f. my'tm.*) passing over from the myotome into the pectoral plate. The proliferation of cells takes place both from the ventral margin of the myotome and from the peripheral layer, or muscle-plate (*la. mu.*). × 750.

Fig. 49. Through the pectoral region at the fourth section back of the one represented in Fig. 47. Nuclei (*pr'f. my'tm.*) are shown, which undoubtedly originate in the myotome, undergo rapid division, and later constitute a part of the pectoral plate (*la. pct.*). × 530.

Fig. 50. Through the pectoral region, at the next section back of that represented in Fig. 49. × 530. (Compare the relation between the pectoral plate (*la. pct.*) and the migratory cells (*pr'f. my'tm.*) of Figs. 49 and 50.)

BOYER—MESODERM IN TELEOSTS. PL. VII.

E.R.B. del. B. Meisel lith. Boston

PLATE VIII.

Fig. 51. Transverse section through the posterior region of the pectoral plate of an embryo of 4½ days, being 1½ days older than the one represented in Plate VII. This section is from the region corresponding to Fig. 50, Plate VII., and shows a more complete histological connection between pectoral plate and myotome. × 288.

Fig. 52. Transverse section, sixth section back of the one represented in Fig. 51. This section is from the posterior region of the pectoral plate. × 288.

Fig. 53. Longitudinal section from the pectoral plate of an embryo of 5 days. The section passes between the vertebral region and the longitudinal ectodermic fold. The outer layer of the ectoderm is unmodified and the lower only slightly modified. The pectoral plate (*la. pct.*) extends forward to the lateral blood-vessel (*va. san.*), and backward it tapers into the single-cell layer of the somatopleure. × 288.

Fig. 54. Transverse section through the pectoral plate of an embryo of 5 days, — but slightly more advanced than the one represented in Fig. 53, — showing the beginning of the ectodermal fold (*pli. ec'drm.*) and the modification of both layers of the ectoderm. Two nuclei (*nl.*[1]) in the cuticular layer are shown which still retain in section their characteristic spindular form. × 500.

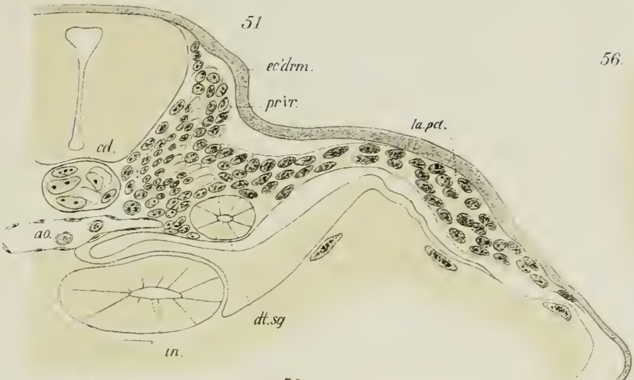
Fig. 55. Transverse section from the pectoral plate of an embryo of about 5½ days. The ectodermic fold (*pli. ec'drm.*) is more marked than in Fig. 54, and the mesodermal elements are beginning to enter it. Two nuclei (*a*, *b*) are at the base of the space included between the two layers of the folded ectoderm. × 750.

Fig. 56. An oblique frontal section from the left pectoral region of an embryo of about 4½ days. The plane of the section is higher in the axial region than in the lateral region. It shows the marginal vein (*vn. marg.*) with contained blood corpuscles, and the relation of the vein to the first four protovertebræ and to the pectoral plate. The auditory vesicle (*au.*) and the posterior gill-pocket are shown directly in front of the marginal vein. The pectoral plate, excepting its proximal region, is too high to show in the plane of this section. × 65.

Fig. 57. A transverse section through the right pectoral plate of an embryo of 6 days. The pectoral plate is beginning to shorten in the antero-posterior direction, and its contour is beginning to extend outward to form the limb-bud. In relation to the pectoral plate, the marginal vein (*va. san.*) lies father back and in a more ventral plane than in former stages. (Compare *va. san.*, Fig. 53.) × 65.

Fig. 58. A section through the limb-bud of the pectoral fin on the right side of an embryo of 7 days. The contour of the limb-bud has been carried some distance beyond the general surface of the embryo. The mesoderm has entered and closely packed all parts of the limb-bud excepting the distal tip of the ectodermal fold. The marginal vein has moved posteriorly and ventrally, and now lies directly below the limb-bud. (Compare *va. san.* of Figs. 53, 57, and 58.) × 65.

51



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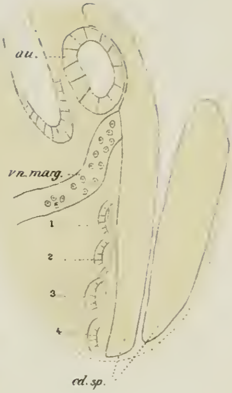

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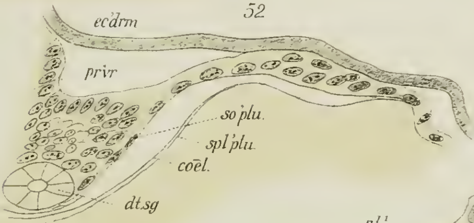

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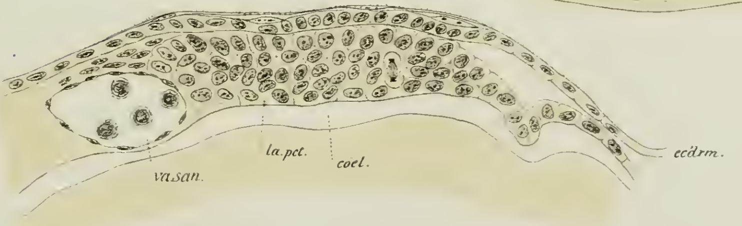

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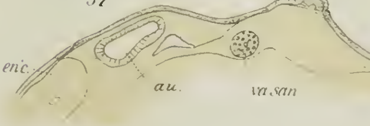

F.R.B. del.

B. Meisel lith. Boston

No. 3. — *On Nectonema agile, Verrill.* By Henry B. Ward.[1]

Contents

I. Introduction.

For more than twenty years an interesting pelagic worm has been frequently captured at the Newport Marine Laboratory. It was probably first seen by Dr. Alexander Agassiz, who encountered it as early as 1870. His first recorded observations, made in 1871, as well as his subsequent studies, have remained, however, in the form of unpublished notes and drawings, which were placed at my disposal in June, 1891, when I began the present study. Two of these drawings, which illustrate most clearly the external appearance, and show also some of the internal organs, are reproduced on Plate I. Figs. 3, 6.

In 1873 Professor A. E. Verrill published, under the title "*gen. indet.*," a short description of two specimens captured in towing near Wood's

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[1] Contributions from the Zoölogical Laboratory of the Museum of Comparative Zoology, under the direction of E. L. Mark, No. XXXII.

Holl, Massachusetts, and in 1879 he established a new genus *Nectonema* with the type species *N. agile*,[1] regarding it as a Nematode of uncertain systematic position.

Dr. J. W. Fewkes ('83, p. 201) was the first to figure this form; he also gave a short account of its external anatomy. But unfortunately both text and figures are somewhat inexact.

Last summer there appeared a paper by Dr. O. Bürger ('91) on the anatomy and histology of Nectonema, which placed beyond question its affinity to the Nematodes, and for the first time furnished evidence as to the details of internal structure. His work was based on material collected at Newport in 1885, but, as he himself says, it consisted of only a few specimens, and these were not in good histological condition. The gaps in his description, as well as the errors, which were largely due to insufficient and poorly preserved material, influenced me to carry out my work, which was already well advanced before the receipt of his paper. For the sake of comparison it will be more advantageous to consider under the appropriate topic the various points of structure which he describes, rather than to give a connected *résumé* of his paper at this place.

The material at command for the following study consisted of fourteen specimens, collected and preserved with great care at Newport last summer, besides those received from other persons. From Dr. E. A. Andrews I received five, which he had collected at Wood's Holl in 1890, and from Dr. W. M. Woodworth one, which was obtained at the same place in 1888. Professor Verrill, at the solicitation of Dr. Agassiz, very kindly sent me his entire collection, consisting of thirty-five specimens taken in Vineyard Sound between 1875 and 1883. For all these kindnesses, and especially to Professor Verrill for his courtesy in supplying me with personal information on numerous questions addressed to him, I desire to return my sincere thanks. To Dr. Agassiz I am deeply indebted for the hospitality of the Newport Marine Laboratory last summer, and for permission to use his notes and drawings, as well as for many other favors. To Professor E. L. Mark I owe much for valuable suggestions, and for his continued personal interest in the progress of the work.

METHODS.

Nectonema is certainly an animal which it is difficult to preserve well. This is largely due to its resistent cuticula, which hinders the

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[1] *N. agilis*, Verrill, '79, p. 187.

passage of most fluids. It shows, further, a strong tendency to curl in the killing fluid, thus rendering it less serviceable for section cutting. There is no reagent which does not in some cases produce a collapse of the body wall and consequent distortion or maceration of the internal organs. No reagent gave uniformly good results; the best were (1) a saturated aqueous solution of corrosive sublimate, and (2) Perenyi's fluid, heated to a temperature of about 60° C. Picro-nitric acid gave nearly as good results. The curling of the specimens may be largely prevented by straightening the worm gently with the fingers, and dropping it suddenly into the warm killing reagent. Flemming's chromosmic-acetic mixture made the material very brittle, even after subsequent treatment with Merkel's fluid, and is not to be recommended. Material preserved simply in alcohol, however carefully, is useful for little more than topographical work.

Bürger mentions the difficulty experienced in staining the material satisfactorily, and I agree with him fully. I experimented more than a month before obtaining a really satisfactory method of preparation; it may therefore be advisable to review the methods employed. The only carmine solution of those (8) tried which will stain it at all is Mayer's hydrochloric acid carmine, and this only after prolonged immersion. All hæmatoxylin solutions stain it fairly well, but require more time than usual. Böhmer's and Ehrlich's give brilliant results, but on the whole the latter is more reliable and can be highly recommended. The results obtained by Pfitzner's safranin are also good, and various aniline dyes are nearly as satisfactory.

In embedding in paraffin it is necessary to keep the temperature low. Series cut in paraffin of 50°–52° C. were in all respects most successful. The infiltration must be complete, but a long immersion in paraffin renders the objects very brittle.

Maceration was tried on preserved material with little success.

Great assistance was derived from the study of portions of the body cleared in clove oil before staining. Only in this way was it possible to obtain a clear idea of the structure of the two ends.

II. Systematic.

Since none of the previous observers have given an accurate description of the female, if indeed it has been seen at all, and since a more extended study has modified some of the points given in the original description of the genus and species, I have determined to restate here the characters in synoptic form. The original description (Verrill, '79) has been followed as closely as was compatible with the changes necessitated by the discovery of the female, and by a more perfect acquaintance with the anatomy of the male.

Nectonema, Verrill, *char. emend.* — Body long, slender, nearly round. Cuticula finely ringed, on the median lines often deeply infolded and bearing on each line two rows of hair-like bristles. Bristles hollow, superficial and unconnected with each other. Head without appendages, obtusely rounded or bluntly conical with a shallow dorsiventral furrow on its anterior aspect. Mouth-opening in the centre of this furrow, minute. In the male the tail is curved ventrad, and terminates in a small conical intromittent organ. Female smaller, the posterior end slightly enlarged, abruptly truncate, with terminal vaginal (?) opening. Alimentary tract rudimentary and anus wanting in both sexes.

Nectonema agile, type species. — A long, slender, and exceedingly active round worm, resembling in form and motions a Gordius, found swimming at the surface of the sea with a rapid undulatory motion. Integument firm, opaque, smooth, except for many minute circular ridges interrupted at the median lines, which are themselves often thrown into larger, deeper folds, locally very prominent. Body in life round, of nearly uniform size throughout, tapering slightly close to the head, and somewhat more towards the posterior end in the male. Each median line is distinguished by two narrow longitudinal bands of minute dots between which stand two longitudinal rows of hair-like bristles. The worm undergoes torsion in the anterior third of the body, so that the median lines appear lateral in the posterior two thirds of the body. The double row of bristles extends from a point 1 or 1.5 mm. behind the apex of the head to about the same distance from the posterior extremity of the body. The bristles are 0.3 mm. in length, opposite to each other, hollow, unconnected by any web, entirely superficial, and hence easily detached and often injured or lost over considerable stretches of the body. The head is marked anteriorly by the presence of a shallow median dorsiventral furrow, on each lateral edge of which are one, sometimes two, low rounded papillæ. The anterior portion of the body is semi-transparent, externally not separated by any constriction from the rest of the body; but internally an anterior chamber is divided from the general body cavity by a partition which is concave anteriorly. The anterior chamber is traversed by the œsophagus, and contains ventrally the brain, while the dorsal space is filled by four large conical cells which send processes down into the nervous matter of the brain. The œsophagus is lined by a minute chitinous tube, which is intracellular in position, and after forming a loop opens out into an intercellular intestine that is highly degenerate posteriorly and in the adult lacks a terminal opening. The posterior end of the male is a ventrally curved conical intromittent organ with a terminal opening. The female is provided with a terminal bulb having a central cloacal (?) opening. The small spherical eggs are filled with large refractive yolk granules and protected by a shell, the thickenings of which become long and pointed spines on coming in contact with the water. The eggs measure 36–40 μ in diameter without the spines, which are 8 to 10 μ long. Color of the animal in life grayish to yellowish white with transparent anterior end. The median lines each show two narrow longitudinal bands of dark slate color.

Length of the male, 50 to 200 mm.; of the female, 30 to 60 mm. Diameter, 0.3 to 1 mm.

Habitat: Narragansett Bay, R. I., A. Agassiz (1870–90), J. W. Fewkes (1883); Vineyard Sound, Mass., S. I. Smith (1871), A. E. Verrill (1879); Wood's Holl, Mass., W. M. Woodworth (1888), E. A. Andrews (1890).

III. Biology.

Up to the present time Nectonema has been reported from two places only, Newport, R. I., and Wood's Holl, Mass., and the south shore of New England may fairly be considered as its home. Here it is not so rare as has been supposed, for by systematic search fifteen specimens were secured in one summer. The dates of capture of some sixty-five specimens show that it may be found from the last of June to the first of October,[1] with two maxima, one in July and a second in September, more than two thirds however having been caught at the earlier date. It is noteworthy that, of the fifteen individuals captured at Newport last summer, all were taken while the tide was going out, and on evenings when there was no moon, the ordinary time of towing being between 8 and 10 P. M. The latter circumstance seems to indicate that the worms are susceptible to light; the possible significance of the former will be discussed later. It is also an interesting fact, that they were caught in towing near the shore, two in fact having been dipped up one evening in July when filling a pail with water at the landing of the

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[1] I do not believe that towing has been done in this region with any regularity at other times of the year, so that these dates cannot be accepted as fixing the time of its occurrence

laboratory, which is located on a small cove near the mouth of Narragansett Bay.

When first caught they were very active, swimming vigorously from side to side of the vessel into which the tow was emptied, and trying alternately the surface and the bottom of the water. Their motions are of two kinds; first, a rhythmical movement, evidently caused by progressing waves of muscular contraction alternating on the two sides of the animal; and, secondly, a more violent motion, which consists in first coiling the body into two large successive loops, and then straightening it suddenly and coiling it at once in the opposite direction. In this way the worm assumes much the general appearance of a figure ∞. By the first kind of motion it makes rapid and definite progress; but the purpose of the latter did not seem to be *locomotion*; it was rather relief from some irritation, which on one occasion was apparently a mass of foreign matter which had accumulated on the bristles. These, together constituting what has been called the lateral fins, can ordinarily be easily seen even during the motion of the animal, and evidently are not actively concerned in its movements.

Nectonema always swims with the translucent end, which, as will be seen later, is the head, in advance. How long the activity exhibited at first persists, I do not know. The animals captured in the evening were usually found on the following morning resting on the bottom of the dish, and exhibited only occasional fits of activity. This may have been due to the effects of light or of captivity. I am inclined to consider it to be the result of the latter, since usually before noon of the first day after capture the worms voided into the water masses of eggs or spermatozoa which were often unripe, and then became more and more sluggish. But the material was too valuable to warrant the risk of its becoming injured for histological purposes by longer delay, and observations were therefore terminated at this point by killing the animals.

IV. General Morphology.

1. External.

Nectonema is in life of an opaque grayish white with semi-transparent ends. The body is perfectly round and the median lines show no trace of the flattening described by Verrill and Fewkes, and so often seen in the preserved specimen. This condition is unquestionably the result of collapse. The general surface of the body is smooth, except for the many fine circular striations which are so characteristic of Nematodes in general. Here however the striations are interrupted by the median "lines,"[1] whose smooth surface is marked off more or less regularly by deep furrows which extend transversely, yet only across the line itself. These lines may be seen to start near the anterior end of the body on its dorsal and ventral surfaces. Owing to a gradual torsion of the anterior third of the body, they are brought at the end of this portion into a lateral position, which they preserve throughout the rest of their course, i. e. up to a short distance from the posterior end. This apparent change in position is diagrammatically represented in Figure 1^a. They are really the median lines, though their position throughout the greater part of the body caused them to be described at first as the lateral lines. Each of them is limited on either side by a narrow dark-colored border which under a high power resolves itself into a crowded mass of deep-seated dots (Fig. 7). Between these two marginal bands, on the lighter portion of each median line, are located in a double row the characteristic bristles. Their arrangement and structure will be considered later.

It is the deep furrows in the median lines together with the dark borders they transsect which produce the "squares marked in outline by black pigment" described by Fewkes ('83, p. 201). The transverse furrows appear and disappear with the movements of the animal, while the squares vary both in form and size (Fig. 7) and are due merely to the folding of the lines necessitated by the contraction of the adjacent muscular areas, as Bürger ('91, p. 636) has shown. They have, then, nothing to do with internal segmentation, but are purely mechanical in their origin.

The length of the males that I have examined varies from 32 to 130 mm.[2] Of the seventeen which were measured exactly, only three were less than 55 mm. long, and the same number were over 100 mm., the most of the rest being close to the average, 68 mm. The diameter of the male varies at the head from 0.32 to 0.65 mm., at the middle from 0.4 to 0.75 mm., and just in front of the terminal papilla from 0.2 to 0.4 mm. The three females caught measured 34, 38, and 40 mm. in length, and at the regions of the body mentioned above on the average 0.35, 0.45, and 0.25 mm. in diameter. Thus, excepting the imperfect specimen men-

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[1] The name "line" seems to be peculiarly inappropriate as a designation for these broad bands, but I have used it in the technical sense in which it has been employed for Nematodes in general.

[2] There was but one male less than 45 mm. in length, and this one must also have been nearly as long, since the head and a portion of the body were gone.

tioned above, they are shorter than any of the males, though in diameter intermediate between the extremes of the latter. The only female among the specimens sent by Professor Verrill measured 60 mm., which still is shorter than the average male, and far below some of the large males in that collection, one of which reached even 200 mm. in length.

Not only is the female smaller than the male, but also far less plentiful. Among the sixty-five specimens which I have examined, there were but four females, a proportion so small as to suggest that it is due in part to other causes than the greater number of males produced. Possibly the female, being the less active of the two, is not so often at the surface, and consequently is less frequently caught.

From the general external appearance one easily recognizes three main parts of the body, a short semi-transparent anterior portion, a very long opaque middle region, and a terminal part, which resembles in transparency and length the anterior portion. The anterior region goes over into the body proper without any external demarcation. There is no constriction at this point in the living animal, and although one is usually found here in alcoholic specimens, it is surely the result of contraction or collapse. If, however, the living animal be studied under a compressor (Fig. 2), or still more clearly if the anterior part of the body of an alcoholic specimen be examined in clove oil, this clear portion is seen to be cut off from the general body cavity by a transverse partition (Plate I. Fig. 8), thus forming an anterior chamber, which will be considered in detail later.

Following this the body proper is uniformly opaque in appearance, and constitutes the greater part of the entire length, passing over insensibly near the posterior end of the body into the posterior translucent region, which is however by no means so clear as the anterior part. The body terminates in the female abruptly, but in the male it is prolonged into a ventrally curved conical organ with a terminal opening. The general appearance of the worm is shown in Figure 1, which represents in its natural size one of the largest specimens captured. The difference between the posterior end of the male and that of the female is easily seen by comparing views of the two as seen under a dissecting miscroscope (Plate I. Figs. 4, 5). The female is represented in the act of discharging eggs. The end of the body of the male differs greatly in appearance in different individuals. It may be nearly straight with only the intromittent organ turned slightly ventrad (Fig. 89), or for a greater or less distance anterior to this point it may be flexed ventrally or even coiled (Fig. 1). The end of the female is on the other hand nearly straight, slightly enlarged, and blunt. The centre of the blunt surface shows the terminal orifice, from which the eggs are being voided.

The general external surface, more particularly on the lines and about the rows of bristles, is often covered with minute algæ and dirt. A similar mass frequently envelops the posterior end, making the determination of its character a difficult matter, especially in the case of the female, if an egg mass be protruding from the opening. It may have been such an appearance which caused Verrill ('79, p. 187) to describe the female as possessing a small terminal papilla.

2. INTERNAL.

The general plan of the internal anatomy may be easily understood from any cross section (Fig. 11). Passing from the surface inward, the thick cuticula is followed by a thin hypodermis, beneath which is the highly refractive muscular layer. The protoplasmic ends of the muscle cells, together with other elements, form the layer immediately surrounding the body cavity. Dorsally and ventrally the muscular layer is broadly interrupted by the prominent median lines. The body cavity contains in a varying position the alimentary canal, which is strikingly small and sometimes wanting. A sac-like organ varying in size hangs from the dorsal line into the body cavity, which may also be filled with generative products. The ventral line encloses the ventral nerve cord. A comparison of the various figures will show the variation in the proportions of the ventral line at different points in the body and in the two sexes.

V. Anatomy and Histology.

1. BODY WALL.

In treating of the finer anatomy I shall consider first the structure of the part under consideration in the male only, and at the end of each section give a comparative account of its character in the female.

a. Cuticula.

The cuticula, which covers the entire body and is continuous with the lining of the œsophagus and of the terminal sexual opening, is of nearly equal thickness throughout, averaging 3 μ on the side of the body, being however perceptibly thicker (about 4 μ) over the median lines. On top of the anterior chamber it is only 2 μ thick, which partially explains the transparency of that region. At the front of the head, on the other hand, it measures from 5 to 10 μ in thickness. It is highly refractive, and similar to chitin, although not identical in composition with that substance, since it may be easily dissolved in boiling KOH. Occasionally one notes a fibrous or lamellar structure, the layers being parallel to the surface. In most places an outer extremely thin layer may be easily distinguished from the subjacent portion by its higher refractive power. The inner surface of the cuticula is not always even and clearly marked off from the hypodermis, but frequently shows a jagged outline with underlying granules, which decrease rapidly in size toward the muscular layer.

On the front and upper surface of the head one finds occasional fine pore canals, and in total preparations short hairs were seen, but no connection between the two could be established. In the hollow produced by the ventral flexion of the posterior end, the cuticula displays a curious peculiarity. The highly refractive outer layer remains intact, but the inner layer is, as it were, bored with conical holes, into which the hypodermal tissue projects. These probably represent sensory organs, but in spite of the proximity of the anal ganglion a nervous supply could not be demonstrated.

There are present as structures of undoubted cuticular origin the hairs or bristles of the lines and peculiar scales found along the posterior portion of the body of the male.

The *bristles* (Fig. 72) form a double row along the dorsal and ventral lines, beginning only 0.2 mm. behind the transverse partition which cuts off the anterior chamber, and extending to within 0.5 mm. of the posterior end of the body. The two rows are only 15 to 25 μ apart, and the bristles stand opposite each other (Plate II. Fig. 12) at regular intervals of 10 μ. Normally they are entirely unconnected by any web of tissue or mucus. They are, moreover, but lightly attached to the cuticula, and hence easily broken off, so that even in the living animal it is rare to find any considerable tract perfect. One can usually see the scars that have been left, and apprehend from these the normal relation of the bristles. Each bristle is, when perfect, about 0.3 mm. long and hollow, having in cross section (Fig. 13) an external diameter of 5 μ and an internal one of 2 μ. The base is slightly enlarged, and rests on the cuticula (Fig. 13), from which in sections it is separated by a definite line of demarcation. From the base the bristle tapers very gradually to a fine point. Its cavity is simply rounded off at the base, being separated from the cuticula by a thin layer; toward the point its cavity gradually disappears. These structures are, then, entirely superficial, and evidently cannot be actively moved by the animal. They are in all respects carefully to be distinguished from the setæ of Annelids, with which they have nothing in common. Bürger ('91, p. 634) called attention to the fact that the hairs are hollow, and are purely cuticular structures.

Scales. — One finds on the sides of the male near the posterior end numerous scale-like cuticular outgrowths. My attention was first attracted to them in transverse sections, where they present the appearance of a tooth (Plate II. Fig. 14). Seen from the surface (Fig. 18) they have much the shape of a clam shell. They are found scattered over both lateral aspects of the animal, in spots so thickly that from one to seven are cut in each transverse section (Fig. 14). They vary much in size, the smallest occurring near the beginning and end of the area, whereas they are interspersed with larger ones at the centre. The area which they occupy begins about 1.2 mm. from the posterior end of the body, and extends over 5 to 10 mm. In general such a scale may be said to resemble a narrow clam shell attached along the hinge side (Fig. 18). The line of attachment is always parallel to the long axis of the body, but the concavity of the scale is directed indiscriminately dorsad or ventrad (Fig. 14). The length of the scale is about 40 μ, its height averages 15 μ, and the thickness varies from 7 to 8 μ.

In most transverse sections the external layer of the cuticula is continuous over the entire surface of the scale (Fig. 15), and only in certain cases can one see that it is interrupted by a minute opening (Fig. 16), which is connected with a fine canal. On account of its minute size this canal can be traced through its entire length only in exceptional cases, and usually appears as a groove at the outer or inner margin of the scale (Fig. 17). I was unable to find either gland cell connected with the canal or sensory filament passing through it.

The core of the scale is formed of a substance which stains like the internal layer of the cuticula, but which is in nearly all sections well marked off from that layer. If the scales be treated with caustic potash, the core is broken up into lamellæ by lines which radiate from the apex of the scale. In transverse sections, however, the core is marked by fibres parallel to the central canal, and thus nearly perpendicular to the fibres of the internal layer of the cuticula elsewhere. This difference in the direction of the component fibres serves to separate the core of the scale from the internal layer of the cuticula in and near the plane of the central canal (Fig. 17), whereas elsewhere one finds no definite line of demarcation between the two (Fig. 15).

It is difficult to believe that this canal represents merely the central protoplasmic core upon which the scale was formed, since, if this were the case, it would be closed terminally by at least a thin layer of cuticular substance. But this is not the case. The opening is always larger and plainer than the canal itself, which is too narrow to be measured.

These structures are entirely lacking in the female. Their occurrence in the male alone, and over only a limited area near the posterior end, suggests connection in some way with the sexual act. If it be the case here, as in Gordius, that the male grasps the female during copulation by winding itself about the posterior portion of her body, the use of these scales in holding on to the cuticula, which differs from that of Gordius in being smooth, is at once suggested. The canal may then be either the duct of a gland or a tactile organ.

The cuticula of the female is nowhere more than 1 μ thick, and precludes thus any profitable study of its structure. The bristles are present, and do not differ materially from those of the male. They are, however, somewhat more slender and shorter. The scales of the male are entirely lacking, and no analogous structures were found.

b. Hypodermis.

The hypodermis, or subcuticula, as it is often called in Nematodes, forms immediately under the cuticula a layer of comparatively uniform thickness and structure, being, however, peculiarly modified in the anterior chamber, in the median lines, and in the terminal organ of the male. Its modifications will be considered under the organs in question. Sometimes no trace of this layer can be found, but in the majority of sections it can be demonstrated in some places.

The hypodermis (Fig. 20) normally appears as a narrow granular layer 7 μ in thickness, without cell walls, but containing numerous prominent nuclei arranged somewhat regularly, and characterized particularly by the indefinite distribution of their chromatic matter and the faint, uncertain way in which they are stained. It is separated from the underlying muscular layer by a delicate basement membrane, which ordinarily cannot be demonstrated, but which is easily seen where the muscle cells are shrunk apart or torn away.

Median Lines. — The hypodermis appears to be highly differentiated in two regions, the dorsal and ventral lines, where it becomes so much thicker as to cut down into the muscular layer and separate it into two lateral areas. These lines were regarded by Verrill and Fewkes as lateral; but, as Bürger has clearly shown, they undoubtedly correspond to the median lines of other Nematodes. The curious torsion, by which in the normal position of the body they come to lie laterally for the larger portion of its length, has already been described.

The two lines, dorsal and ventral, are very similar in form and structure (Plate VIII. Figs. 101, 102), except that the ventral line contains the prominent ventral nerve cord, which will be described in connection with the other portions of the nervous system.

The *dorsal line* can first be seen distinctly immediately behind the partition which cuts off the anterior chamber. In front of this I find no dorsal differentiation of the hypodermis, and consequently no dorsal line. At its anterior end the dorsal line has a thickness of 20 μ ; passing posteriad, this gradually increases to 40 μ, and this thickness remains nearly constant until within a short distance from the end of the body, where it becomes gradually reduced and finally disappears. The line is separated from the body cavity by a prominent basement membrane, the direct continuation of that which separates hypoderm and muscular layer. The elements which make up the dorsal line (Fig. 102) appear both in longitudinal and in transverse sections as a row of elongated cells, the walls of which are usually first visible a short distance below the cuticula, although in one specimen preserved in Flemming's mixture they could be traced even up to the lower surface of the cuticula itself. The nuclei are oval, poor in chromatic substance, hence pale and not at all prominent. They lie with the long axis perpendicular to the surface of the body, nearly or quite filling the entire diameter of the cell. In most cases they are found at about the same level in the different cells, which thus form a regular epithelial layer. The deep ends of the cells are prolonged into processes which extend down to the basement membrane through a mass of fibres which cross in every direction. Among this net-work of fibres in the lower portion of the line one finds occasional cells with branching processes (*, Fig. 102), which may be nervous. There is however no definite nerve cord extending through the line, and no evidence was found of the connection of these cells with other parts of the nervous system.

The *ventral line* is similar in structure to the dorsal line, in that it consists likewise of a layer of high cells of an epithelial character immediately underlying the cuticula (Fig. 101). Their deep ends are also prolonged into processes, which are here bent around the ventral nerve cord, which lies in the centre of the line. Between the cord and the basement membrane below is seen again a confused mass of fibres, into which, as in the case of the dorsal line, the deep ends of the cells pass. The boundaries of the epithelial cells extend in this case also only to within a short distance of the cuticula ; they cannot ordinarily be traced up to it, except, as in the case of the dorsal line, in material preserved in Flemming's mixture. The entire ventral line is separated from the body cavity dorsally, and from the muscularis on both sides, by a basement membrane.

In the adult female the lines do not exceed 8 μ in width, and are consequently difficult to study, but I think the same elements can be seen, though not so clearly as in the case of the male.

Bürger ('91, p. 636) believed the collection of long cells at the apex of the head to be a part of the dorsal line. I can find no special connection between the two regions, and no striking similarity in structure. The shallow groove which he believed characteristic of the external surface of the dorsal line is not present in the living animal. It is undoubtedly the effect of collapse, since it is found only in preserved specimens. I did not find the large cells which he says occur at regular intervals in the dorsal line. Perhaps they are found only in individuals of a certain age, or they may be connected with the formation of the hairs. Proof of the existence of a columnar epithelium, which he conjectured to be present, has been given above.

c. *Muscular Layer.*

In cross sections of the body the muscular layer presents two sharply marked portions, a peripheral, radially striated zone (Plate I. Fig. 11) and a deep protoplasmic region. Along the line of union of the two lies a double or triple row of thickly crowded nuclei, and in some regions, or under certain conditions, other nuclei are found scattered through the protoplasmic portion. The relative thickness of the two zones varies greatly. In the most of the specimens which I cut they were of nearly equal breadth, but in some the protoplasmic zone was more than twice as wide as the striated portion, and in other cases not half so wide. These conditions are represented somewhat diagrammatically in a number of transverse sections (Plate II. Figs. 23 to 26), which are taken from different individuals.

The general meaning of the two zones is at once apparent. The striated portion is made up of the contractile fibres of the muscle cells ; the protoplasmic area represents the non-differentiated portions of the same cells together with certain other elements. I met with indifferent success in attempting to make macerations of this region and I am not able to affirm definitely what proportion of the protoplasmic zone is made up of the ends of muscle cells and to what extent it is formed of other elements. Certain it is that this zone contributes to the formation of at least a certain number of other elements: this may be by a differentiation from the protoplasmic body of the muscle cell, or it may be that the elements have no genetic connection with the muscle cells. In order to discuss this question it will be necessary first to consider carefully the structure of the individual muscle cell.

For this study the region near the dorsal or ventral line is very favorable, since here the cells are shorter and broader than elsewhere, and thus it is easier to trace the cell walls. Cross sections of this region (Plate II. Fig. 21) show with perfect clearness that each muscle cell is composed of two portions, corresponding in appearance and position to the two zones of the muscular layer. The highly refractive peripheral portion is seen in longitudinal section (Fig. 22) to consist chiefly of fibrillæ; these are, however, developed only at the periphery of this portion of the cell, the core of which is composed of a finely granular protoplasm. The latter is directly continuous with the granular protoplasm of which the deep-seated part of the cell is exclusively composed and in which the nucleus is located. This is the condition of the typical muscle cell of the "Cœlomyaria." In the centre of the muscular layer, i. e. in the lateral walls of the body, the cells differ only in being much deeper and more flattened. From maceration preparations (Fig. 22) it may be seen that the inner or deep margin of the band of fibrillæ is bounded by a very thin layer of protoplasm which at intervals is continued downward into the elongated cell body. This is also seen in transverse sections (Figs. 28–30). It would seem (Fig. 22) as if each muscle cell had more than one protoplasmic prolongation, but since I was unable to ascertain the length of the individual cells this cannot be positively asserted.

The nuclei usually lie just below the contractile portion of the cell. They are oval, and each has a thick nuclear membrane, which stains deeply, but encloses very little stainable substance, the numerous nucleoli being minute and faint. There are also at times unquestionably as many as two nuclei in each protoplasmic projection, and in certain specimens it was common to find nuclei far down toward the deep end of the cell.

I must call attention in this connection to some very peculiar nuclei which were found among the nuclei of the muscle cells, but which differ from them strikingly (Fig. 27). They were usually located rather more distally than the others, and each showed a tail of varying length, which projected far up among the contractile fibrillæ. Tailed nuclei have been found by various observers, and sometimes the form has been attributed to mechanical injury in cutting. But this cannot be the case here, since they were plainest in sections 20 μ thick at a level distinctly between the two surfaces of the section. From the general appearance of the sections I doubt the probability of the form being due to pressure in killing or preparing, and am inclined to regard their form as normal. Such nuclei have been explained as nervous; the only argument which can be said to favor that view in this case is their position, and the absence of other known nervous terminations in the muscular layer.

The striated zone is narrow in the anterior chamber and at the posterior end of the body, but is elsewhere of nearly uniform width in any one specimen. It remains entirely colorless in carmine stains, but takes up hæmatoxylin with avidity and does not give it up in acid fluids.

The protoplasmic portion of the muscular cell is highly granular and ordinarily does not stain at all. In the protoplasmic zone, however, there are cells which stain in eosin much deeper than the remaining elements (Fig. 29, x). The contents of these cells are so finely granular as to appear almost homogeneous. Lying in the body cavity near these cells are corpuscles, which in general appearance and affinity for stain are identical with them. It will appear probable, I think, from the figures given (Figs. 28–30), that these corpuscles are derived by abstriction from the deeply staining cells of the protoplasmic zone. They are found of all sizes, but never in very great numbers. There is some evidence to show that the deeply staining cells are the proximal ends of certain muscle cells, the contents of which are perhaps chemically altered; the corpuscles, however, never contain nuclei, so far as I have seen. In view of the evident correlation between the thickness of the muscular wall of the body and the sexual maturity of the animal, it is possible that the function of these corpuscles is nutritive. This will be discussed in connection with the description of the sexual organs.

Evidence which goes to prove the formation of true cells from this layer is obtained from the study of the female in which the eggs were in the most immature condition of any which I had. Here (Plate IV. Fig. 59) sections show the body wall to be composed of the layers already described, except that the protoplasmic portion of the muscle cells is much shorter, and there seem to be proportionally fewer nuclei and fewer cells than in the sections previously described. In addition to these there is, however, the remnant of a deeper layer. Certain cells (*, Fig. 59) project into the body cavity; they are homogeneous and lightly stained, in opposition to the muscle cells which remain unstained, and they contain nuclei at the proximal end of the cell. In the body cavity of this specimen were found, in addition to the eggs, cells of a very similar appearance to these, and at points along the wall of the body cavity flattened cells had arranged themselves in the form of an epithelium. All these points naturally suggest that this layer is concerned in the production or nourishment of the sexual cells, and that the remnant of the layer is in process of forming itself into a secondary epithelium. The evidence is however too incomplete to justify more than a suggestion; but it points strongly to the existence of more than one kind of histological element in the protoplasmic zone of the muscular layer.

The foregoing description of the muscularis differs essentially from that given by Bürger ('91, p. 635). Especial attention must be called to the fact that the relative thickness of protoplasmic and contractile portions as he gives it, namely, 2 : 1, is true in only one of the sections he figures (Taf. XXXVIII. Fig. 5), whereas others of his sections (Figs. 3, 4) represent exactly the opposite extreme.

2. Alimentary Canal.

a. Œsophagus.

Attention has already been called to the fact that one finds a shallow dorsiventral groove (Fig. 2) at the front of the head, and that the minute mouth opening is located at the centre of this groove (Plate V. Fig. 63). The cuticula, which is extremely thick at this point, is here infolded; the deep layer extends but a short distance, while the external layer is continued backward to form the œsophageal tube. Here as elsewhere this layer is highly refractive, and has walls 2 μ thick, enclosing a lumen only 3 μ in diameter. The deep layer, which surrounds the beginning of the œsophageal tube, measures 9 μ in thickness. After this layer stops, the chitinous œsophageal tube, which is the continuation of the external layer, becomes somewhat thicker, and it is seen that the entire tube is contained within a cell of small diameter (Plate III. Fig. 32). From longitudinal sections it is seen that the cell is coextensive with the tube; at least there are no transverse cell boundaries, though throughout its length one finds many nuclei which lie closely packed together. In transverse sections the nuclear matter appears fragmented, and usually has a more or less concentric form surrounding the tube (Fig. 50). That face of the nucleus which is turned toward the tube is less regular than the other, and usually shows a broken and less sharply marked contour than elsewhere. The amount of chromatic substance, large in proportion to the somewhat meagre supply of protoplasm in the cell, is also noticeable.

The œsophageal cell with its contained tube traverses the anterior chamber; from the mouth opening it first passes through the hypoderm, then it lies in a groove on the dorsal surface of the brain (Plate VI. Fig. 73), and later is spanned by the dorsal commissure (Fig. 80), directly behind which (Fig. 81) it extends a short distance free until it reaches and pierces the transverse partition (Plate I. Fig. 8). It is enveloped throughout its course by the same peritoneal membrane which lines the anterior chamber. The occasional flattened nuclei of this membrane may be seen at intervals on the outside of the œsophageal cell, even where the latter is surmounted by the dorsal commissure of the brain.

Before tracing the further modifications of the œsophageal cell, it is interesting to note one or two points of variation in the portion already described. Although the tube is commonly of uniform caliber and open from end to end, this is not always the case. Figure 50 (Plate III.) shows a cross section of the œsophageal cell 0.1 mm. from the apex of the head. Here the tube is of the usual appearance, but a few sections farther back not only lumen, but tube as well, has disappeared (Fig. 51). Some distance farther posteriad the tube appears again, but as a solid cord, which, however, acquires a lumen at a point 0.4 mm. from the apex of the head, and from this place on preserves its ordinary character. Furthermore, variations in the diameter of the lumen are common. The important physiological bearing of these features will be discussed subsequently.

The œsophageal tube and cell enter the partition and pass through with only a slight expansion in the size of the cell (Plate V. Fig. 63). Bürger has figured and called attention ('91, p. 643) to the presence of a strong dorsal bend of the tube within the partition. This is assuredly abnormal, since it is found but rarely. It is entirely wanting in the other individual figured by him (Taf. XXXVIII. Fig. 1). When present it is probably *on*, not *in*, the partition, and is evidently due to the ventral flexion of the œsophageal cell and tube resulting from the forcing forward of the partition in preservation. This wall is in life concave anteriorly, and it will be clear at once, from a glance at Figure 3, that, if at any time in the course of manipulation a change to a denser fluid be made too suddenly, the result will be to force the partition forward, and consequently to bend the œsophagus in the space between the brain and the partition, where it is free from supporting tissue. Exactly this is shown to have happened, only in a less degree, in my Figure 8.

Following now the course of the œsophageal cell after it emerges from the partition into the general body cavity, one finds a second cell alongside of it (Plate III. Fig. 33, *cl. in.* I.), which resembles it in the entire absence of transverse cell boundaries and in the presence of many nuclei, but is unlike it in the highly granular condition of the protoplasm and in the shape and appearance of the nuclei. Since the intestine hangs free in the body cavity, the position of the cells can be determined only in a general way. The new cell, which may be named the first intestinal cell, lies approximately lateral to the œsophageal cell (Fig. 33). It begins at about 0.8 mm. from the apex of the head; about 0.4 mm. farther back, a second intestinal cell (*cl. in.* II., Fig. 34) is added. This lies nearly ventral. A third cell (*cl. in.* III., Fig. 35) begins 1.3 mm. from the apex of the head, and a fourth (*cl. in.* IV., Fig. 36) 0.1 mm. farther posteriad. This completes the number. The œsophageal cell, which may be recognized by the presence in it of the cross section of the chitinous tube, now lies lateral to the four intestinal cells (Fig. 36), but soon wedges itself in between two of them until it reaches the centre of the group (Fig. 43), and then suddenly ends, leaving a cavity (Fig. 44) surrounded by the four intestinal cells which have accompanied it a longer or shorter distance from their origin.

It is now necessary to ask how the chitinous tube is concerned in these changes. Up to the point where the fourth intestinal cell is added, it remains a straight simple tube. Shortly beyond that point it makes a complete turn upon itself (Plate I. Fig. 8), and from a lateral position with reference to the four intestinal cells it reaches a median one (Plate III. Figs. 37–43). Hence the loop lies in that portion of the œsophageal cell which is wedged in between two of the intestinal cells (Fig. 38), and almost completely fills the space. The tube proceeds a short distance farther, 60 μ only, tapers to an exceedingly fine point, and opens out into the space which has arisen between the four intestinal cells (Figs. 8 and 44). This space is the intestine proper, and justifies the application of the name "intestinal cells" to those elements which, though originating farther forward, were destined to bound it. These relations, which are evident in every complete series through this region, are represented in a succession of figures taken from one series of transverse sections at short intervals (Figs. 31–44). The general form of the tube may also be seen in the optical section represented in Figure 8.

The œsophagus varies from 0.75 to 1.5 mm. in length, being from $\frac{1}{40}$ to $\frac{1}{30}$ of the total length of the worm. The loop which occurs near its posterior termination measures from 50 to 100 μ in length, and from 20 to 30 μ in width. It lies nearly in the sagittal plane, and ventral to the general course of the œsophageal tube. The absolute uniformity of its occurrence and the normal appearance of the adjoining intestinal cells preclude the idea that this is an accidental fold. It must be regarded as a normal yet very curious feature of the œsophagus.

b. Intestine.

The intestinal cells, which, as has been shown, are first encountered on the œsophageal cell just behind the partition, are four in number at the point where the intestinal cavity is formed and the œsophagus opens into it. These four however clearly constitute two pairs which are unlike (Fig. 37). The contents of one pair is a coarsely granular plasma, whereas that of the other pair is finer. The first remains unstained in hæmatoxylin, but takes up enough hydrochloric acid carmine to give the plasma a reddish tinge. The reverse is true of the other pair of cells. Occasionally the granules in the first pair of cells become very coarse, and then appear like excretory secretions. As already mentioned, there are no transverse partitions dividing the cell (Fig. 52), although a very large number of nuclei are present, usually several in each section (Fig. 39). Only two of the four cells are represented in Figure 52, which is a surface view. The differences in the character of the nuclei are well shown in the figure.

The walls of the intestinal cells are very strong, perhaps even cuticular, since they remain intact long after the cell contents have been completely macerated out. There is however, no special chitinous lining for the intestine, such as Bürger has figured ('91, Taf. XXXVIII. Figs. 25, 29). This appearance is probably due to the partly macerated and detached membranes of the adjacent cells.

The portion of the intestine bounded by four cells is relatively short. One of the finely granular cells[1] dwindles down to a point (Fig. 45) and a new one takes its place. This pushes itself obliquely under the adjacent coarsely granular cell on one side, so that the latter is excluded

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[1] Owing to a break in the series figured, I am unable to state positively which one of the original four is the first to disappear.

from participating in the boundary of the lumen, which is now limited by only three cells, one dorsal and two ventral. The cell, thus forced back from the lumen, dwindles away, and is not replaced by another.

A lumen bounded by three cells persists for some distance backward, but finally another cell disappears and the lumen lies between two cells (Fig. 49). I did not succeed in finding the exact spot where the disappearance of the third cell takes place, and am hence unable to give the details of the process. From this place posteriad all further change is of degree and not of kind, since the intestine simply grows smaller, the lumen all but disappears (Figs. 46–48), and finally the whole structure vanishes (Fig. 9) shortly before the end of the body is reached. In no case, either in entire preparations or in sections, was I able to trace it nearer than within a few millimeters of the posterior end of the body; and since it was entirely free at its termination, no clue was given as to its relation to the terminal orifice of the body. Since this orifice is clearly connected with the sexual organs, as will be demonstrated later, it remains doubtful whether it is a cloacal opening, or whether the end of the intestine is to be found elsewhere. Certain it is that in the intestine we have a highly degenerate organ, so that from a study of the adult alone no light can be gained as to its termination. It is interesting to note that the œsophagus is intracellular, the intestine however clearly intercellular.

No mesenteries were found binding the intestine to the body wall, and consequently its position varies in different individuals. It was more often ventral than dorsal, and lateral than median. In the female (Plate IV. Fig. 58), however, it extends directly through the middle of the mass of nearly ripe eggs.

The description of the structure of the alimentary canal already given for the male, holds good for the female as well, except that the lengths of the various parts are somewhat less than those of the male. The anterior chamber is much smaller, and the parts contained in it more compressed.

Bürger ('91, p. 643) described in general the four intestinal cells under the somewhat inappropriate name of œsophageal cells. He failed to recognize the cellular nature of the real œsophageal cell, since he speaks only of the tube and of a fibrous envelope. He seems to have entirely overlooked the loop in the tube, which probably existed in sections between those represented in his Figures 22 and 23, and naturally was able to give but little on histological structure. I do not believe it is advantageous to speak, as he does, of the intestinal cells as cell-rows. There certainly are no transverse cell walls and no very regular distribution of nuclei; and while they may be potentially equivalent to rows of cells, they certainly are not the same as the structures in the Trichotrachelidæ known as cell-rows. To use the expression, then, is to emphasize a morphological relationship which, if it exist, is much more distant than the use of this word would lead one to suppose. Bürger also described the regions of the intestine bounded successively by four, three, and two cells; but in spite of his strongly expressed doubts on the subject, he was led to regard the terminal orifice of the papilla as the anus, following the description of Verrill and Fewkes. It must have been poorly preserved material which gave the appearances shown in his Figures 25 and 29, for I am convinced that the supposed cuticular lining of the intestine does not exist. I have found nothing which supports his claim, set forth at length, that the intestinal lumen when apparently bounded by three cells is really formed at the expense of only one, and belongs to that cell alone.

3. Anterior Chamber.

The anterior chamber is a prominent and characteristic feature of the anatomy of Nectonema. Even in the living animal one can usually distinguish its main features (Fig. 3) under a compressor. The semitransparent area extends as far as the transverse partition which, at about 0.3 to 0.4 mm. from the apex of the head, cuts off this portion from the general body cavity. In the living animal this partition is concave anteriorly, and apparently slightly thicker at the centre; on sections it is seen to be covered on its anterior face by a thin peritoneal membrane, whose flattened nuclei (Plate VII. Fig. 95) may be easily discerned at intervals. I am not sure that this same peritoneal membrane lines the entire anterior chamber. It can easily be demonstrated over the lateral surfaces and around the œsophageal cell, where similar nuclei may be demonstrated even under the dorsal commissure of the brain and farther forward. On the dorsal surface of the brain I have searched in vain for the nuclei or the membrane; yet it is equally impossible to find where it stops, if it does not line the entire chamber.

In alcoholic specimens much of the regular character of the partition is lost, and it is usually found to be more or less distorted, as the effect of the various processes through which the material has passed. The fibres of which it is composed run in all directions, chiefly radiating from the centre toward the body wall. They show frequent pale nuclei (Fig. 95). The partition is pierced by the œsophagus alone, and it encloses the œsophageal cell, so that no space is left on any side. The dorsal line does not extend as far forward as the partition, but the ventral line, which takes its origin from the brain, passes under the partition, the fibres of which spread out above it.

The anterior wall of the chamber is grooved externally, and this median groove, already mentioned, is supplied with one, or often two, low papillar elevations on each side. The cuticula on the anterior face of the head has about twice the thickness of that over the body in general. The underlying hypodermis from the mouth opening upward over the anterior dorsal aspect of the head is composed of high narrow cells, which are continued basally into one or more processes that are probably connected with nerve fibres. These relations are represented in Figure 92 (Plate VII.), which shows a somewhat oblique section near the apex of the head. It is the dorsal and lateral cells that are in question, and they show in some places very clearly the basal processes. Two such cells more highly enlarged are shown in Figure 93. The fibrous masses on either side into which the processes pass are the anterior prolongations of the fibrous mass of the brain. Bürger ('91, p. 637) has described these cells as rounded at the deep end, and he did not find their connection with the nervous system.

Along this part of the head and farther ventrad on the anterior face minute pore canals in the cuticula are by no means uncommon, and once or twice in total preparations fine hairs were seen in this region. Without having demonstrated any connection between the canals and hairs, I believe they are really united, and that the mass of cells which is here connected with the brain is sensory in function. Just dorsad to the mouth opening there was found in three specimens a small perfectly regular cuticular pocket about 30 μ in diameter. Its nature and value could not be determined, but, if at all significant, it is probably the remnant of a larval organ.

The striking transparency of this region in the living animal is due to the thinness of its walls. Everywhere but at the extreme anterior end the cuticula is thin, and, although the muscular layer begins in this region, it is insignificant. Only on the ventral surface does one find a mass of tissue, the brain with its capsule. The dark streak which in the living animal crosses the anterior chamber just in and above this mass is the œsophagus already described. The chamber is filled with a fluid in which float small scattered corpuscles of great transparency. Two such are shown in Figure 95, immediately below the ganglionic cell, *cl. gn.* V.

The most prominent objects in the anterior chamber, however, are the four big cells which, in two pairs, an anterior and a posterior, fill almost the entire space above the brain, and send their processes ventrad into its substance. They are the cells which Fewkes ('85, Expl. of Plates, p. 208) designates as "ova (?)," and which Bürger ('91, p. 646) supposed to be salivary glands. Neither hypothesis has much in its favor, and I shall present evidence which I believe shows them to be clearly nervous, i. e. ganglion cells. Accordingly, the description of their structure and relations will be deferred until the consideration of the ganglion cells in the brain.

4. Body Cavity.

The main body cavity extends from the posterior face of the partition which cuts off the anterior chamber to the extreme posterior end of the body. It varies much in size in different individuals (Plate II. Figs. 23–26, Plate IV. Fig. 58, and Plate VIII. Fig. 96) and can hardly be said to have a definite form. It is smallest in immature individuals, and most capacious after sexual maturity. It differs somewhat from the body cavity of the anterior chamber. The latter, as has been shown already, is lined, in great part at least, by a peritoneal membrane, but the general body cavity shows no trace of such a lining. The protoplasmic ends of the muscle cells terminate at variable depths, thus giving it an irregular boundary, which shows no sign of an endothelium. In the body cavity one finds neither dissepiments nor mesenteries; the intestine floats free, or at regular intervals in its course is grown fast to cells in some part of the body wall.

In the male one always finds a sac more or less developed hanging from the dorsal line, and varying in form and structure. This will be more fully described under the sexual organs, to which it unquestionably belongs.

There is often a small amount of coagulated substance in the body cavity which contains scattered corpuscles similar to those of the anterior chamber. They are very pale, entirely unstained, and of a spongy texture. One finds various sizes, and their origin from the protoplasmic ends of the muscle cells has already been maintained. They are by no means abundant, and the amount of coagulum found in the body cavity is also small. In addition to these one always finds in the body cavity of the male free spermatozoa in greater or less numbers. In all of the females obtained the body cavity was nearly or quite filled with eggs.

5. NERVOUS SYSTEM.

a. Brain.

The anterior ganglionic mass, or brain, forms the larger portion of the floor of the anterior chamber (Plate V. Fig. 63). In general it is somewhat wider than long, being from 0.16 to 0.28 mm. in width, and from 0.12 to 0.2 mm. in length, and has an average thickness of only 0.14 mm. (Figs. 3, 8, 63, 72–88). Its anterior limit is the one most difficult to make out, since the brain substance goes over gradually into the tissue in front of it, from which it is not separated by any prominent capsule. The middle of the dorsal surface is marked by a longitudinal groove, in which the œsophagus lies. Behind the narrow meagre cerebral commissure the œsophagus is separated from the brain by a considerable space, and here the dorsal groove in the latter is wider and less defined than farther forward. (Cf. Plate VI. Figs. 72–88.) Laterally the limits of the ganglionic mass are more distinct, although no envelope of connective tissue separates it plainly from the adjacent cells. In fact, there does not seem to be a definite capsule anywhere, even on the dorsal surface. In places the limits of the mass are so sharp as to suggest a covering membrane, but I was unable to find any corresponding nuclei. The connective-tissue fibres which bound the ventral nerve cord dorsally are first apparent behind the last pair of large ganglion cells of the brain.

α. Ganglion Cells. — On the whole the brain is poorly supplied with ganglion cells; of those found, one can nevertheless distinguish two kinds, which represent extremes in size. The first and smaller kind is only moderately abundant, but they far exceed in number the second. No appreciable amount of cell protoplasm can be seen about them, but they appear everywhere simply as small oval nuclei (Plate V. Fig. 68) only 4–5 μ in diameter. These nuclei stain deeply, and show a thick nuclear membrane with numerous chromatic granules, of which one, or occasionally two, are very prominent. In general they correspond closely to the nervous nuclei (Nervenkerne) described by various observers for different groups of animals. A further point of resemblance is found in their position, for they lie embedded in a mass of fibres, and, although it is difficult to decide whether certain of the fibres are connected with them, appearances decidedly favor this view. Cells of this kind are most abundant on the anterior face of the ganglionic mass, and around the stalks of the dorsal cells. In the fibrous mass of the brain they occur ordinarily only at the ventral surface, and in one or two definite lines whose significance will be considered later. (Cf. Plate VI. Figs. 72–88.)

The large ganglion cells so far surpass in size those of the first kind that they might well be called giant cells were it not that the name implies a homology which I do not wish to affirm. There are in all five pairs of these large cells, which are nearly constant both in position and in size. Figure 94 (Plate VIII.) represents them diagrammatically and from a comparison of this with Figure 63 (Plate V.) the different cells may be recognized at once. It will be convenient in the description to designate them by numerals, beginning with the most anterior pair.

Since the chief characteristic of the cells of the second class taken as a whole is the nucleus, I shall begin with a description of this structure, which is relatively very large and somewhat irregular in form (Plate V. Fig. 69). It never stains deeply, and shows one or more clear vacuolated areas. The nuclear membrane is delicate, and the chromatic substance finely distributed in lines or rows of dots. The nucleoli vary; sometimes (Pl. VII. Fig. 95, *cl. gn.* III.) none are present, and again there are (Fig. 95, *cl. gn.* V.) one or two very prominent ones, or in other cases (Pl. V. Fig. 69) a number of smaller ones. Frequently, one finds within the nucleus structures (Fig. 69) of an irregular appearance surrounded by a clear space of varying width, and bounded externally from the surrounding nuclear matter by a very definite line. It appears as if the irregular bodies had originally filled the clear space or vacuole, and had shrunken away from the enveloping nuclear matter in the process of preservation. Exactly similar structures occur in the nuclei of the dorsal cells to be described, as well as in the nuclei of the large cells in the anal ganglion: whatever the nature of these enclosures may be, they seem to be characteristic at least of the larger ganglion cells. I do not know that similar bodies have been found in ganglionic cells of other animals.

The amount of protoplasm which surrounds the nucleus in the five pairs of large ganglion cells varies, somewhat in relation to the position occupied by the cells. The cells of the most posterior pair (Fig. 95, *cl. gn.* V.), which protrude above the mass of the brain, have a considerable amount of cell protoplasm; those of the third pair (Fig. 95, *cl. gn.* III.), which are only partly surrounded by fibres, show a lesser quantity, while the others, which are deeply embedded in the fibrous substance, have merely a thin mantle of protoplasm surrounding the nucleus.

Although numerous fine processes pass off from the cell body in various directions, each cell has one prominent process, which may usually be followed without difficulty. They are, hence, really unipolar cells. Of these cells the first and fifth pairs (Fig. 94) are much larger than the others, the third is intermediate in size, and the second and fourth are considerably smaller, though nearly equal in size to each other. All things considered, each of these cells has such a characteristic appearance that after study it is possible to recognize at once a cell from any pair.

One also finds a few cells about half as large as those of the second class; they vary in position and seemingly in number in different specimens. A pair of these are shown in Figure 84 (Plate VI.) between the nuclei of the fifth pair of large cells. These cells are too indefinite in number and position to be regarded as constituting a third class. They resemble the cells of the second class in general appearance, differing from the latter only in size. At most one finds two pairs of such cells ventral to the fourth pair (Fig. 84), and another pair anterior to the third pair of large ganglion cells (Fig. 76). They constitute perhaps an appendix to the cells of the second class.

It is necessary now to ascertain the exact position and relation of these cells to other parts of the nervous system. Figures 72 to 88 (Plate VI.) represent a series of successive transverse sections including the entire brain. By comparing them with Figures 63 and 94, one may determine the exact position of the large cells, and follow their processes. In the cross sections only the nuclei are represented, since the cell body is too small and too poorly marked off from the surrounding tissue to be seen under this power.

The first pair (Plate V. Fig. 63, *cl. gn.* I.) lie farthest anterior, as well as most ventral of all. They usually approach the median plane of the body very closely, being separated from each other by only a narrow space. Occasionally one of them lies a little higher than the other in the fibrous mass of the brain. These cells are pear-shaped (Plate VII. Fig. 94), with the long diameter parallel with the chief axis of the animal. Each possesses a single large process, which passes directly backward. As the two processes from these cells pass posteriad they approach each other and rise slightly, by which they come to lie in the central V-shaped portion of the ventral nerve cord (Plate VI. Fig. 88).

The second of the five pairs of large cells is somewhat smaller than the first, and its position varies within narrow limits (Plate VII. Fig. 94).

In Figure 75 (Plate VI.) the left cell of this pair is represented; the corresponding right cell has fallen out or is aborted in this series. The general position of these cells may be said to be midway between the first and third pairs, as well in height as in antero-posterior relation. They may in some cases lie nearer the median plane than the following pair, as well as farther from it in other cases. The extremes of variation in both directions are shown in Figure 94 (compare the right with the left). It was very difficult to follow the processes of this (second) pair, and I can only say I think they pass into the dorsal commissure, and through that to the opposite side of the body; but their further course could not be made out. It is close to this pair of cells that the stalks of the anterior dorsal cells enter the brain. (Compare Figure 94, *pd. cl. d.*, the anterior of the two stalks.)

The third pair of large cells may properly be called the commissural cells, on account of their intimate connection with the dorsal commissure. They are pear-shaped cells, and lie on the extreme upper surface of the brain, and near the median plane, as may be seen in cross sections (Fig. 77). Their position with reference to the commissure is somewhat variable. Sometimes they are located well to one side in the brain mass (left side, Fig. 78), but again they are found well up on the commissure, even so far that the apex of the cell reaches the median plane, and the entire cell is dorsal to the œsophagus (Plate VIII. Fig. 99, *cl. coms.*). As has already been intimated, the processes of these cells cross through the commissure to the opposite side of the body. After leaving the commissure, they bend at once sharply to the rear, and may be followed some distance. They were ultimately lost to view near or alongside of the fifth pair; not because they are in any way connected with those cells, but rather because the size of the latter tends to obscure the neighboring processes. I believe that the processes pass one into each lateral bundle of the ventral nerve cord, but this point could not be established with absolute certainty.

The fourth pair of cells (Figs. 63 and 94, *cl. gn.* IV.) makes its appearance several sections back of the third. They are intermediate in size between those already described, and possess nearly spherical nuclei (Plate VI. Fig. 82, *nl. gn.* IV.). They occupy the dorsal portion of the ganglionic mass near its posterior end (Fig. 63), and are situated only a short distance from the median plane. Their processes pass sharply ventrad and toward the median plane, where they ultimately come to lie near the processes of the first pair of cells in the central unpaired portion of the ventral nerve cord. In spite of the difference in size between the first and fourth pairs of cells, their processes cannot be distinguished from each other in size (*pr'c. gn.*, Fig. 88).

The fifth pair of cells lies farthest lateral and dorsal of all (Plate V. Fig. 63), forming as it were the posterior outer corners of the ganglionic mass. They are the largest of the five pairs of cells, on account of the larger amount of protoplasm which surrounds their nuclei, and they lie wholly without the fibrous mass of the ganglion (Fig. 63); in fact, they often project above the general level of the brain (Plate VI. Fig. 85). The processes of these cells are the most prominent of all, having a diameter twice as great as those from any other pair of cells. They pass directly backward into the corresponding lateral bundle of the ventral nerve cord, and for a long distance occupy the centre of this portion; but farther back they cannot be distinguished among the numerous processes which occupy this portion of the cord.

β. Dorsal Cells. — The probable nervous nature of the dorsal cells has already been referred to, and to make this clear it is necessary to consider in detail their structure and relations to the brain. In life they appear spherical when viewed from above (Fig. 2), but when seen from the side (Fig. 3) they are evidently conical. The two constituting the anterior pair lie in juxtaposition at the median plane, the posterior ones farther apart and in contact with the posterior and lateral portions of the first. No particular structure can be made out in the living cell further than the presence near the stalk of a dark body, presumably the nucleus. The stalks pass ventrad and slightly posteriad into the substance of the brain, where they are seen to bend decidedly backwards (Fig. 3), and are then lost to view. Nothing further was determined from the living animal, since the possibility that they might be nerve cells did not force itself upon me until much later.

In preserved specimens the shape of the cells is much altered. They are usually shrivelled and distorted; or, again, they often contain a huge vacuole on one side (Plate VIII. Fig. 98). Unstained specimens cleared in clove oil serve only to confirm what is seen in the living animal, and show quite distinctly that the stalks of the cells are not connected either with the œsophagus or the external cuticula at any point. There is also clearly apparent in the cell a fine network, which takes its origin from the stalk (compare Fig. 99), and fills the whole cell with a mass of minute meshes. If now we examine sections through this region, the peculiar character of the cells becomes more apparent (Fig. 99). Each is surrounded by an extremely fine membrane, which is continued on to the stalk as a delicate superficial layer hardly recognizable. The dorsal end of the stalk projects a perceptible distance (Figs. 99 and 67) within the membrane into the cell, and seems to be resolved into a number of fine branches, which make their way in all directions through the cell, and give off still finer processes, which anastomose to form a network of finest fibrils. These are highly refractive, and, like the stalk, take up staining fluids slightly, so that the coarser branches assume a decided tint in well stained specimens.

Near the stalk in the lower portion of the cell lies a stainable body, the nucleus (Plate VI. Fig. 78, *nl. d.*) ; this is of such a peculiar character as to make its right to the name nucleus appear at first sight questionable. It is irregular in form, and often has a very indistinct contour (Plate V. Figs. 64, 65), since a nuclear membrane can be seen only in places. The larger branches of the network already described connect directly with the projecting angles of the nucleus, so that the latter often seems to be prolonged some distance out into the cell. In the ground substance of the nucleus, when lightly stained, one sees a network similar to that already described as existing in the cell plasma, and with which it seems to be connected. There are, besides the network, at least two distinct sorts of enclosures in the nucleus : first, comparatively regular bodies (Fig. 64, *nll.*), nearly spherical in shape and about 5 μ in diameter, which are uniformly and deeply stained, and which in every respect resemble nucleoli ; secondly, irregular bodies (Fig. 64, *x*), which are always surrounded by a lighter area of varying width, and which thus have the appearance of being shrunken. These do not stain either like the first-mentioned bodies or like the rest of the nucleus itself, but in depth of color are half-way between the two. What these enclosures may be I do not know, but I believe the larger mass itself to be the nucleus, despite its peculiarities, and I regard the dark round bodies enclosed within it as nucleoli. It may be urged in this connection, that the very irregular form of the nucleus makes it impossible to cut the surface perpendicularly for more than a short distance, and that an oblique cut would make the membrane very indistinct. This probably accounts for its apparent absence in places.

It is possible, I think, to furnish at least a partial explanation of these peculiarities. Evidently the cells contain a highly fluid plasma. This is shown by the small quantity of solid matter found in those that have been "fixed," and by their variation in size. This condition might indeed be expected on purely physical grounds, since the cells float entirely free in the fluid which fills the anterior chamber. If however cell and nucleus contain more fluid than ordinarily, the curious appearance, especially of the latter, can be easily understood : the nucleus has been shrunk by dehydration in the course of preservation. This shrinkage was prevented in a measure at certain points where the strong threads of the network were connected with it. It is important in this connection to call attention to the fact, that in those cases where the cells were unusually small the nucleus was most nearly regular in shape (Fig. 66). No particular attention was paid to this point when studying the living animal, but in the sketches made at the time I find that the nucleus, which in general size and position agrees with this structure, was drawn with a regular oval outline (Fig. 2). This may well be its shape in life.

The stalks of these four cells present a uniform appearance. They, or at least their initial portions, stain more deeply than any other tissue both in hæmatoxylin and in carmine solutions, and hence are easily traced so far as the stained portion extends. Under a high power the stalk exhibits in places a faint longitudinal striation, and sometimes shows lines of minute vacuoles between the striations. The method of termination in the cell has already been described. From the cells the stalks pass directly into the brain, those of the first pair entering just lateral to the second large ganglion cell on either side, and those of the second pair just antero-lateral to the fifth pair of large ganglion cells in the brain (Plate V. Fig. 63, *pd. cl. d.*). The processes, which in transverse sections appear to be directed toward the median plane, show in longitudinal section (Plate VII. Fig. 95, *pd. cl. d.*) a backward tendency also. They may in this way be followed for a very few sections ; in the last, in which they are prominent, one sees a splitting or branching of the process in various directions, but beyond this the parts can be traced at most a couple of sections. The more compact character of the mass and the large number of other fibres make it difficult to say whether any part of the process extends farther, or whether the whole is split up at this point into fine fibrillæ. The place where the splitting begins is surrounded by a considerable number of small ganglionic cells (Plate VI. Figs. 78, 82).

Bürger ('91, p. 639) describes two pairs of large ganglion cells and two subordinate pairs in the brain. His description is not in all points clear, and to judge from appearances the figures do not correspond to his interpretation. Of the structures which he calls "giant cells," the anterior pair is my third or commissural pair ; his posterior pair corresponds to my fifth pair. Of his subordinate cells, the pair which lies close to the commissure corresponds perhaps to my second pair, and those described as lying between the two pairs of giant cells are my fourth pair. His figures do not fully agree with this, however. His Figure 2, *Gz*, shows the "anterior giant cells," which are clearly my commissural cells; Figure 11, *Gz*, which he regards as one of the same pair, has more of the appearance and position of a cell of the fifth pair. The dorsal cells are described as salivary glands (*Spdz*, Figs. 1, 2, 11), and it is curious that he has nowhere represented the prominent processes (stalks) of these cells, unless, indeed, they are the structures labelled *Gz F* (Fig. 12). Although the position is somewhat peculiar, they certainly look more like the stalks of the dorsal cells than like processes of the cells marked *Gz* in the same figure, which is his interpretation, since the latter usually extend directly backward.

Bürger expresses a doubt that the posterior giant cells (i. e. my fifth pair) lie opposite each other. If not, it was because of some deformity or twisting of the head, as they evidently are opposite each other in my preparations (Figs. 63, 85). Instead of being nearer together than the other cells, as he maintains (p. 640), they are certainly farther apart than the components of any other pair (see my Figs. 63, 85).

γ. *Fibrous Mass.* — The central fibrous portion of the brain shows few definite points of structure. The fibres run in every direction; one finds few commissural bands, and in general no fixed arrangement. At two points, however, one notices (Fig. 99) vertical bands of fibres which divide the brain into three parts, a central and two lateral portions, which in position correspond to the three divisions of the ventral nerve cord, which will be described later. The dorsal commissure (Plate VI. Fig. 80, *coms. œ.*) is very meagre, being cut in only two or three sections. The number of fibres in it is consequently small, but there are at least four large nerve processes; two belong to the third or commissural pair of cells, the other two perhaps to the second pair. A few finer fibrils accompany these.

In the female the brain measures only 0.08 mm. in length, and 0.1 mm. in width. In consequence of its more compressed form, the cells stand closer together, and are more difficult to study. One finds exactly the same number of large ganglion cells, and they occupy corresponding locations. It may, then, be fairly assumed that the processes are distributed in the same manner, although I was unable to follow them as clearly as in the male.

In total preparations (Fig. 63) one often sees groups of fibres passing anteriad from the brain into the front wall of the anterior chamber. As has been shown from sections, however, this is all solid tissue in front of the brain, and these groups of fibres are apparent merely by virtue of a different refractive power. They are somewhat irregularly arranged, and yet correspond very nearly on the two sides of the body. I regard them as groups of nerve fibres. They may be seen to turn dorsad (Plate VII. Fig. 92, *n. a.*) in the tissue of the wall, and probably innervate the numerous sensory cells found in this wall.

b. Ventral Nerve Cord.

The ventral nerve cord extends directly posteriad from the brain through the entire body. It is located in the ventral line just above the epithelial layer, and appears in cross sections near the middle of its length as a roughly cordiform mass (Plate VIII. Fig. 101), which is separated by internal divisions into three areas. These areas represent the three nerves of which the cord is composed. The median area (Plate VIII. Fig. 101, *n. m.*) is triangular, with its apex directed ventrad, and is, so to speak, wedged in between the two oval lateral areas. Near the brain the form of the ventral nerve cord is somewhat different, and gives a hint as to its relation to the brain, which can be easily traced in any series of sections which includes the brain and the following portion of the body. The first trace of a partition in the fibrous mass is found well forward in the brain, and is shown in the arrangement of the small nervous nuclei, and of the dorsoventral groups of nerve fibres already mentioned; these indicate a division of the brain into a central mass quadrangular in cross section, and two lateral masses more or less rounded off on the outer side (Plate VI. Fig. 86). At the position of the fourth pair of large cells a row of small cells, already mentioned, makes this division more apparent, and even before reaching the ventral nerve cord one sees the separation of the three portions by fibrous bands which cross the brain vertically. At the beginning of the nerve cord the three portions are of about equal size; gradually the lateral areas push themselves in under the central portion until the latter has been compressed into a triangular shape, with the lateral areas almost touching in the median plane beneath it. This relation, with slight modifications, is preserved throughout the entire length of the animal, and I do not find, as Bürger (p. 641) has maintained, that the median portion is more prominent in the anal ganglion (Plate VIII. Fig. 96, *n. m.*). The central and lateral portions seem to be, so far as I can find, alike in structure. The number of faintly stained homogeneous processes in the three portions is nearly equal; in the posterior part of the body they are perhaps more numerous in the lateral portions of the cord. Each part also contains nerve fibrillæ, and the relation of the ganglion cells to each appears to be the same.

There are, moreover, ganglion cells in the ventral nerve cord; they may be conveniently treated of in two groups, which correspond in general to those of the brain. The first are simple nervous nuclei, distinguished from the nuclei of the surrounding connective tissue especially by the intensity with which they take up stains. They are small oval nuclei, measuring 4–5 μ by 6–8 μ in diameter, and possessing a prominent nuclear membrane, but not provided with any appreciable amount of surrounding protoplasm. They are found along the dividing lines between the areas of the cord (Plate VIII. Fig. 101) and also on the external boundary of the latter, usually closely crowded together; in cross sections they appear as a single or double row; in longitudinal sections they are collected into a certain area (Fig. 97). They are about equally distributed throughout the length of the cord, and produce the dark dotted rows seen on the ventral line in the living animal (Fig. 7).

The large cells of the ventral cord form the second class, and in many cases are equal in size to those of the brain. Though not plentiful, they are scattered along the whole length of the cord. I was unable to find, however, any regularity of distribution, since the interspaces vary considerably in extent. Furthermore, they are not plainly paired except in rare cases. Usually the successive cells are separated from one another by a distance equal to the thickness of ten, or even twenty, cross sections (100 to 200 μ). Bürger (p. 641) has described these cells under the name of median cells. I do not think that they begin, as he maintains, in the brain; but I agree with him in regarding them as unpaired. These big cells are ordinarily found wedged in between the two lateral areas and immediately below the ventral portion of the cord (Plate VIII. Fig. 101). So far as I have seen, these cells possess each but a single process, which passes dorsad between the median and one of the lateral areas, but its ultimate fate I was unable to determine. Rarely one finds a large cell below the lateral area on one side or the other. In this case the nucleus is much flattened dorsoventrally. Bürger regards these cells as bipolar. I have seen appearances such as he represents in his Figure 13, but do not regard this as decisive, since the two processes are not shown, so that, while I have no positive contradictory evidence, I am also unable to confirm his statement.

The form of the ventral nerve cord may be much altered by collapse of the body, which flattens the cord between the two lateral muscular areas. By this process the elements of the ventral line, as well as those of the cord itself, are so changed as to give rise to abnormal appearances even in otherwise well preserved specimens. Such a crushed condition of the cord is figured by Bürger (Fig. 19).

Strictly speaking there are no nerves arising from the cord. The fibres which branch from it are nowhere collected into a group worthy the name of nerve. In every second or third section one finds a few delicate fibrils arising from the nerve cord; some emerge from the dorsal surface and some from the median ventral cleft, and in both cases they pass off towards the lateral hypodermis (Fig. 101). They may be traced as far as the beginning of the hypodermis proper, but their ultimate fate is unknown. If these are not nerve fibres, I am at a loss to explain them, or to find other branches which may be nervous. Only once did I find any evidence of a large process leaving the cord; in one cross section a process like those found cut transversely in the cord was cut longitudinally; it passed out from above the lateral area and followed the course of the fibres already described, as far as the hypodermis.

c. *Anal Ganglion.*

Bürger has shown (p. 638) that the anal ganglion far exceeds the brain in size, and is in no sense a small local thickening of the ventral nerve cord, but that it is a gradual differentiation of its posterior portion. In a total view (Plate VI. Fig. 89) one is unable to see any definite line of demarcation between the ventral nerve cord and the ganglionic enlargement which terminates it. There is seen to be rather a gradual increase in the size of the cord extending over a distance of about 1.2 mm., and culminating at the posterior end, where the ganglion is abruptly rounded off. In some specimens the differentiated portion of the cord is deeply cut by cross furrows which give it a metameric appearance. Although these may be present at times when no external folding of the cuticula can be found (Bürger, '91, p. 638), they certainly do not indicate any metameric condition of this organ, since they vary in size and since there is no corresponding structure in them. The furrows are entirely wanting in most well preserved specimens (Fig. 9), and when present are simply due to a folding of the cord, such as occurs in other portions of its length as well, but is more prominent here on account of the thickness of the organ.

A cross section through the anal ganglion (Plate VIII. Fig. 96) shows at once that the increase in size is due chiefly to the addition of a peripheral layer of cells above the cord proper. On account of this increase in size it is no longer possible for the ventral line with the entire nervous mass to be retained in its usual position. It is therefore forced upward into the body cavity, and fills a considerable portion of it (Fig. 9). In fact, near the end its diameter is half as large as that of the body at that point.

Seen in cross section (Fig. 96) the nerve cord itself presents little here that is different from its general character throughout the body. It is the peripheral layer which demands particular attention. This is crescent-shaped, and composed of a dense matrix in which are embedded many nuclei. Along its periphery the matrix is finely striated perpendicularly to the surface, and is separated from the underlying nerve cord by a narrow space filled with loose fibrous tissue (Fig. 97). The horns of the crescent are turned ventrad around the nerve cord, and are connected with the tissue lying below it. In these horns one sees a fine longitudinal striation; occasionally more plainly marked fibres, coming from the cells above, may be traced into them. The matrix, which usually takes a faint stain, contains numerous oval nuclei (Plate V. Fig. 71) with a sharply defined nuclear membrane. The nucleus in general does not take up the stain, so that the one or two large nucleoli stand out in strong contrast to the rest. One can neither find any cell boundaries in the matrix, nor determine how much, if any, of the surrounding protoplasm belongs to each nucleus. In fact, the fibres which one finds often appear to extend from the nucleus itself around into the horn of the crescent.

In addition to this thick peripheral layer, which I regard as nervous, there are in the anal ganglion a few large cells. Some are wedged in below the middle portion of the cord like those which have already been described. Others may be found in the space between the peripheral layer and the cord (Fig. 96), with the process directed ventrad. These cells do not as a rule appear to be paired.

At the extreme posterior end of the cord one finds somewhat different conditions. Here there is a mass of large ganglionic cells of varied size, closely crowded together, and with their processes (Plate VII. Fig. 90) mostly directed forward into the ventral nerve cord. The space between the cord and the peripheral layer does not exist, and, curiously, the ganglion cells of the latter have nearly always two nucleoli instead of one as is usual elsewhere. The relation of the cells and processes is very complicated here, and the gradations of size are so fine that with the material at my command I was unable to determine the exact number of cells, or the plan on which they are arranged. The nuclei of these cells recall those of the brain. One finds (Plate V. Fig. 70) the same distribution of chromatic substance, but with more numerous nucleoli, and the same sort of enclosed bodies. One edge of the nucleus shown in the figure is very indistinct, because it was cut obliquely. It recalls the appearance presented by the nucleus of the dorsal cells. The same is true of the nuclei of the large ganglion cells in the ventral nerve cord seen in longitudinal section.

The female does not show any such extreme modification of the posterior end of the ventral nerve cord as was found in the anal ganglion of the male. The only specimen favorable for the study of these relations shows (Plate IV. Fig. 57) a slight swelling in the ventral nerve cord just at its end, which lies below the terminal bulb. There appear to be a very few large ganglion cells at this point, and yet it is an unimportant modification as compared with that of the male. The peripheral layer of ganglion cells, so characteristic of the anal ganglion in the male, seems to be entirely lacking in the female.

6. Sexual Organs.

a. Male.

In all males one finds a sac suspended from the dorsal line and filling a larger or smaller portion of the body cavity. It shows the character of its walls best when almost empty. Then one sees a fine outer boundary (Plate IV. Fig. 54), with occasional elongated deeply stained nuclei. From this fibres radiate through the cavity of the sac to form a delicate large-meshed network, or the sac may in places be entirely empty. These details are all hidden when the organ is filled; even the walls cannot be demonstrated, although their presence may be inferred from the regular outline of the mass. In this case the sac is enlarged so as to fill a considerable portion of the body cavity. This is true of the anterior or middle region of the body; farther posteriad the sack seems to become crescentic in cross section, the two horns of the crescent being fastened to the lateral body walls. When the sac here is filled, it occupies the entire space dorsal to the anal ganglion (Plate VII. Fig. 90).

In most cases the sac is filled with minute oval bodies of uniform size, only 1 μ in diameter. No other structures are constantly present, so that their abundance, minuteness, and uniformity in size and appearance render it practically certain that they are spermatozoa, and that the sac is the male generative organ.

In some specimens cross sections through the middle or anterior region of the body show that the sac is moderately filled with cells whose nuclei stand close together and are in a kinetic condition. Here the ventral boundary of the dorsal line seems to be wanting in places, as if the cells in the sac were directly connected with those of the dorsal line, while the wall of the sac is laterally directly continuous with the basement membrane, which covers the line ventrally. One can sometimes find among the cells in this region stages which seem to show a transition between the kinetic nuclei and the groups of spermatozoa found among them ; but this condition was encountered in only a single specimen, and the material was not in sufficiently perfect histological condition to allow a study of spermatogenesis. This anterior portion of the sac I regard therefore as testis, and the posterior crescent-shaped portion as at once receptaculum and vas deferens. In the stage in which the kinetic nuclei were found in the anterior portion of the sac, the walls of the posterior portion were collapsed, and hardly a single spermatic element was to be found in it. This is the youngest stage which I have studied.

In another, older stage the sac was filled from end to end with the deeply stained highly refractive spermatozoa, and so enlarged that it occupied nearly the entire body cavity. Finally, in the oldest stage found the sac (Fig. 11) appears in the anterior part of the body as a mere remnant with collapsed walls containing an occasional spermatozoön. At the tail, however, a small quantity of spermatozoa was collected near the terminal orifice. The diminished thickness of the protoplasmic zone in the body wall shows this individual to have been comparatively old. In one specimen in which the sac was thus collapsed, however, the body wall was moderately thick. In these cases copulation seems to have taken place, and the few spermatozoa are merely remnants of the original contents of the sac.

The organ described by Bürger on pages 646, 647, is evidently the same as this, and his belief that it was a testis rather than an ovary is confirmed by the preceding account. The description he gives of the organ either shows that the specimen studied by him was intermediate between the first and second stages here described, or else was based upon different individuals and represents different stages.

In one of my individuals which, to judge from the thickness of the body wall, must have been young, there were clusters of polyhedral cells here and there in the anterior portion of the body cavity, and these clusters were crowded full of spermatozoa in small bunches, as if they had originated there. The dorsal sac was moderately large, and contained numerous spermatozoa, which were, however, scattered, and not in groups. I do not know how to explain this case, unless indeed it be due to a rupture of the dorsal sac in places, and the consequent evacuation into the body cavity of a part of its contents. Although I did not find any point at which this could be shown to be unmistakably true, yet there were many places where the wall could not be distinguished; furthermore the body was in this case much distorted in killing. Even when the outlines of the sac are plainest, one always finds spermatozoa in the body cavity in greater or less numbers; so, for example, in the cavity of the terminal organ (Plate IV. Fig. 53). This, so far as I know, is the only fact which favors the view that their place of origin is in the body cavity; aside from this, the evidence points to the dorsal sac as testis. A further study of additional material is necessary to determine finally this point, as well as many others.

The external sexual organ of the male consists of the terminal papilla to which reference has often been made. It has much the shape of a slightly curved truncated cone (Fig. 53) with an opening at the smaller base, and with the larger bāse joined to the body obliquely, so that it naturally turns ventrad. The length and curvature of the organ vary a little, as can be seen from the different figures (Figs. 4, 9, 53, 89, 90). The essential features of its structure can be made out from a total preparation in clove oil (Fig. 53). The muscular layer of the body wall, which for some distance has been growing thinner, stops suddenly along a well defined line. Beyond this only the hypodermis lies between the cuticula and the body cavity. The cuticula, which is here a little thicker than usual (see also Plate VII. Fig. 90) is infolded at the end of the organ and runs forward as the lining of the cavity for a variable distance. I was at first inclined to believe that this infolded portion could be to a limited extent extruded and then drawn in; but further study seems to show that it cannot. The thick cuticula is too stiff to be rolled in or out without being folded somewhere, yet on sections it is always smooth; moreover, there is no muscular provision for moving the organ in this way. At its anterior end the cuticular infolding is continous with a sac (*va. df.*) having delicate walls, and this is in turn connected with the dorsal sac previously described (Fig. 53 and Plate VI. Fig. 89, *va. df.*). Although I plainly saw and drew in several cases the walls of this connecting portion from clove oil preparations, yet they are so delicate that in sections they were not once preserved except as loose shreds of tissue. I was consequently unable to ascertain whether there was anywhere the trace of a connection with the intestine. On general grounds one would be inclined to believe that the single terminal opening was that of a cloaca; but no evidence of any connection between the end of the intestine and this thin-walled portion communicating with the dorsal sac was obtained. It must then remain for future investigations to decide whether this is morphologically a cloaca or merely a vas deferens.

The hypodermis in the terminal papilla is composed of a single layer of approximately cubical cells (Plate VII. Fig. 90). This is the only portion of the body wall in which the boundaries of the hypodermal cells can be seen.

The spermatozoa are usually found in such enormous numbers that it is difficult to make out their true shape. They appear much like micrococci, and when seen alone (Plate IV. Fig. 55) are slightly oval, highly refractive bodies 1 μ in diameter. The merest indication of a protoplasmic envelope surrounding them is found in the shape of a very narrow light peripheral zone. They stain very deeply, and their minute size renders it impossible to recognize any structure in them. It is probable that, as in other Nematodes, the spermatozoa undergo some metamorphosis after being introduced into the body of the female. From one individual spermatic masses were voided into the sea-water in which it was kept. There was no sign of motion in the mass when flattened under a cover glass, and when dried on a cover glass and stained nothing besides the oval spermatozoa could be seen, except a certain amount of coagulated fluid.

There may be found in the dorsal sac as well as in the body cavity of certain male specimens peculiar pale bodies, not easily stainable and varying greatly in form. They are probably the same as those which Bürger (p. 647) speaks of as "ovale Gebilde von mattem Glanze, an denen nicht zu errathen war, ob sie gleichfalls Kerne oder Einlagerungen bedeuten." Macerations show that they are probably parasitic Gregarinida, the various appearances obtained from sections being due to their having been cut in different planes (Plate VII. Fig. 91).

b. Female.

I do not believe that any of the previous observers have had a female. Verrill ('79) described the posterior end in the "female" as "subtruncate with a small terminal papilla." This applies exactly to some males, and, as Figure 56 (Plate IV.) shows, is very unlike the female.[1] Furthermore, in the entire collection which Professor Verrill kindly placed at my disposal there was only one female, that one being found coiled up in a mass of twenty specimens.

Bürger (p. 647) describes one form which differs materially in structure from all others studied by him; he was inclined to regard it as a female. He found a sac with flattened walls hanging from the dorsal line. The description and figures given by him resemble strongly an immature testis, — certainly it cannot be an *empty* ovary. But the termination which he describes for it is so extraordinary that one must doubt the normal nature of the specimen or the accuracy of the observations. Certainly neither in male nor female does one find anything like the tube and cells which he describes as lying on the ventral cord, except the œsophagus. It is impossible, however, that he has mistaken the anterior for the posterior end of the worm, because he mentions the head of this specimen. There are certain points in his description of this individual, especially the lack of an anal ganglion, which recall the female, yet in view of the many problematic points which cannot be referred to either sex, I am of the opinion that this must have been a very abnormal specimen. I shall give a description of the sexual organs of the female without any further reference to his work, describing only those conditions which I believe to be normal.

The three females obtained present three stages in the growth of the egg, but unfortunately all are too far advanced to give any clue as to the place or method of origin of the egg cells. In the first stage the body cavity is already half filled with well developed eggs, and no trace of ovaries or of the walls confining the ova is present, but the ova seem to lie free in the body cavity. Each egg (Plate IV. Fig. 60) has a firm outer membrane, highly granular protoplasmic contents, and a large irregular nucleus, which has a very thin nuclear membrane and is strikingly poor in chromatic substance. Between and around the eggs one finds a granular substance, and more rarely small nuclei.

In the next older stage the body cavity is more nearly filled, and the eggs are very similar except that the nucleus is smaller and more deeply stained. One finds also around each egg an external covering of minute quadratic blocks, which seem to be easily separable from the egg and from one another.

The oldest stage observed differs from that just described in some

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[1] I should not neglect to mention that a female with protruding egg mass (see Fig. 10) would correspond generally to this description; but such a state would hardly be available for identification.

small particulars. The nucleus (Fig. 61) is now so small as to be found with difficulty among the large opaque yolk granules, the external membrane is firmer, and the blocks with which it is covered are more prominent. In this stage the eggs fill the entire body cavity (Fig. 58), being roughly arranged in nearly concentric layers. It was from this individual that eggs were discharged into the water and later preserved. At first sight (Fig. 62) such discharged eggs appear very different from those previously described, being armed with a thick covering of long conical spines. An examination of the posterior end of this animal, which was killed while the eggs were being discharged, showed that the eggs which were still in the body and those in the mass outside possessed not a trace of these spines, but simply the blocks on the external membrane, as already described. Further investigation showed that *not all* the eggs which had been laid were already provided with long spines. In some cases the spines were very short and thick; indeed, all stages were found from this condition up to the one first described. The probable explanation of this phenomenon is, that the block-like thickenings on the membrane of the immature egg are swollen by the sea-water, first into shorter, then into longer spines, which at the beginning are probably soft and become rigid later. Certainly in alcoholic specimens they are rigid.

In almost every transverse section one finds a delicate membrane stretching from the ventral line to the egg mass (Fig. 58). This may represent a mesentery, as it is too uniform to be merely accidental. In only one case (Fig. 57) was there anything present in the body of the female which had the appearance of spermatic elements, but the poor histological condition of this specimen prevented an accurate determination of the matter.

The body of the female ends (Fig. 10, and Plate IV. Figs. 56, 57), as already mentioned, in a slight bulbous enlargement with a central terminal opening. The cuticula turns inward for a short distance, as in the male, but in the specimens at my command there were no internal organs connecting with this opening. The mass of eggs filled the body cavity up to the tissue of the terminal bulb. The same question recurs here which suggested itself in the case of the male, as to the morphological value of this opening, — whether it is or is not a cloacal orifice; but I have no evidence to present on either side of the question. The bulb is made up of elongated cells containing pale nuclei, and passing off at right angles to the infolded cuticula. These cells have much the appearance of unstriped muscle cells, and seem to be able to affect the caliber of the opening (Figs. 10, 56), and thus to facilitate the passage of the egg mass. The hypodermis can hardly be followed around the bend under the infolded cuticula. If it exists there, it is certainly a very much attenuated layer. I do not think that the elongated cells of the bulb can be regarded as modified hypodermal cells.

VI. Discussion.

1. Dorsal Cells.

The nature of the dorsal cells is not definitely determined, yet I have little doubt as to their nervous character. The interpretation of them as gland cells (Bürger, '91) seems to me untenable for many reasons. The cells do not have at all the appearance of gland cells, there is no trace of any secretion in the cell or its process, nor anything in this process which suggests even remotely a duct, and finally one finds no connection of the stalk with the intestine or with the exterior. Against the possibility that they may be *degenerate* gland cells, functional in larval life, it may be urged that there is absolutely no evidence of degeneration in the appearance of the cells.

If the positive evidence on the other side be examined, it will be found to be almost equally strong, and in favor of their nervous character. In the first place, their nuclei are like those of the large ganglion cells in affinity for stains, in the possession of one or two large homogeneous nucleoli, and in the curious unstained enclosures already described. On the other hand, it cannot be denied that the nuclear membrane is more irregular, and seems to be connected with the fibres of the cell substance, a condition which was not seen in the large ganglion cells.

The stalks of these cells certainly resemble nervous processes optically, as well as in their relation to the cell body, and in their termination, which has been considered in detail. Unless one regards the stalk as differentiated into a stainable and a non-stainable portion on account of some unknown difference in the chemical nature of the parts, it must be granted, I think, from the evidence previously produced, that the process branches at or near its termination in the brain. This branching seems to me to be an insuperable objection to the interpretation of these cells as glandular, and indeed to render it almost certain that they are nervous. Their enormous size and extremely fluid contents may be due to the freedom for growth which they enjoy in an unrestricted space, and, in part at least, to osmotic conditions.

Since in the ripe individual the mass of sexual products whch fills the body cavity would exert a dangerous or even fatal pressure on cells so delicate as these, it is evident that the partition is absolutely necessary for their development, and may be so for the protection of the brain. While the presence of the partition is essential to the existence of these cells as they are, it is impossible from the evidence at hand to form any idea of the cause which led to its development. However, the partition being formed, I believe it is possible to understand how the large cells may have attained their size and position.

It has already been mentioned that the dorsal cells vary considerably in size; an early sketch of a living animal, made before the structure was well understood, shows in a dorsal view, not two, but three successive pairs of large cells. There were, however, in this case, actually only two pairs of dorsal cells, and the supposed third pair was the most posterior pair of large ganglion cells in the brain. It has already been said of these that they are located, not *in* the mass of the brain, but in great part *above* it. Now, given two pairs of lateral cells located on the upper surface of the brain anterior to the fifth pair of ganglion cells near the place where the processes of the dorsal cells enter the brain mass, it is easy to conceive how they may have become larger and larger, and finally may have risen entirely above the brain into the free space dorsal to the œsophagus, where no obstacle is offered to their further increase in size. At the same time, the stalk would be produced as a mere mechanical result of the lengthening of the cell process to accompany this migration. Once free in this cavity there is every reason to believe that the cell might continue to develop in size until, with its companions, it should occupy the entire space, which is approximately the present condition of affairs. The fifth pair of large ganglion cells in the brain, half projecting, as they do, above its surface, would then represent the first stage in the migration which the dorsal cells have already accomplished. Attention must be called to the fact that the three pairs of cells which have been compared in this hypothetical statement of the case are not similar in one important particular; for whereas the processes of the fifth pair of ganglion cells are unbranched and may be traced far posteriad through the ventral nerve cord, the processes of the dorsal cells are branched and can be traced only a comparatively short distance. I do not see, however, that this difference greatly affects my explanation, — which is purely mechanical, — since the cell and not the process is directly concerned. The nuclei of both kinds of cells are nearly equal in size and alike in structure. The great difference between the two is due to the preponderance of the cell body in the dorsal cells, which I have assumed to increase by virtue of its changed surroundings. A similar difference in the size of the cell body is found between the fifth pair of ganglion cells, half projecting above the surface of the brain, and the first pair, which is deeply embedded in its substance.

One further point of interest suggests itself. It has already been mentioned that the commissural cells vary in position, being in many cases higher on the commissure than in others. If there be a tendency toward a more dorsal position in this case as well, — which on the basis of free space for development is more probable than the opposite movement, — then there are two distinct ways in which originally ventral elements may reach a dorsal position; first by the independent dorsal migration of superficially located ganglion cells, and secondly by a movement of commissural cells dorsad along the commissure. The first method is illustrated in the case of the dorsal cells, the second in the case of the commissural cells (the third pair). In both instances the cause of the migration may well be gain in nourishment and vigor as such cells advance more and more into the free space above the brain mass. If such a change in position involve a gain in vigor on the part of the cells concerned, then the origin of a dorsal ganglion from a simple commissure by the dorsal migration of elements either independently or along the commissure may be easily conceived, since around the ganglion cells which have acquired this position other nervous elements will collect with the increase in the amount of nervous matter accompanying the development of the nervous system. In this way, then, lateral and dorsal ganglia may arise.

If the brain of Nectonema shows distantly how the higher development may be reached, it shows still more clearly its immediate relation to the ventral nerve cord. The anterior ganglionic mass may be viewed as a differentiation of the anterior portion of the cord. The agreement between the portions of the brain and the three bundles of the cord has already been emphasized. It remains to call attention to the correspondence in the location of ganglion cells. As it was true of the cord that ganglion cells were found on the borders of the three fibrous tracts, so it is correct to say of the brain that the ganglion cells are developed on the edges of the corresponding tracts. This will be easily seen if, in a comparison of Figures 72–88 (Plate VI), one proceeds from behind forward; and it is still more evident when the vertical bands of fibres are taken into account; the fibres are, however, not represented in these figures.

2. Large Ganglion Cells.

The large ganglionic cells of the brain and ventral nerve cord were called by Bürger "giant cells." So far as mere size is concerned, the name is well chosen, but it has been pre-empted for the neurochord cells of higher groups. To avoid the confusion which has entered into other divisions of morphology owing to the use of a single name for a multiplicity of organs, this designation should not be employed here unless there is some reason for regarding them as homologous with the cells of Annelids and Crustacea which first received the name. In comparing these large cells with the neurochord cells of Annelids, the first point of difference to be noted is the number of the former. There are, as we have seen, at least five pairs of such cells in the brain and others along the ventral nerve cord. In the Nemertines, as in the Annelids, there is only a single pair of neurochord cells in the brain; and those in the ventral nerve cord are distributed in pairs and at regular intervals, which does not seem to be the case in Nectonema.

The second prominent point of dissimilarity has to do with the processes. The fibres of these large cells vary somewhat in size, and do not possess any very definite shape, being now nearly round, now angular, with a variety of form which may, however, be in part due to the effect of reagents. In optical appearance and in reaction toward staining fluids they recall strongly the neurochords or giant fibres of higher groups. They also extend for long distances, perhaps the entire length of the worm, in an unbranched condition. But they differ from the giant fibres in one striking respect, — they have no sheath; in fact, it is very difficult to say that they are even enclosed by a delicate membrane, so fine is the boundary between them and the surrounding tissue. On the other hand, the sheath of the giant fibres is the most striking peculiarity which they possess, and often exceeds in prominence the fibre itself.

These seem to me sufficient reasons for regarding the cells in question as not homologous with the giant cells of other groups. I have therefore avoided using the expression "giant cells" to designate them, in order not to suggest a false homology. It cannot be denied that these may represent the primitive form of the giant cells, in which the fibres have not yet acquired the highly differentiated sheath; but until this becomes more probable by reason of evidence as yet lacking, it is better to use the non-committal term, and to designate them as large ganglion cells.

3. Rows of Hairs.

The lateral rows of hairs are evidently developed in connection with the free life of Nectonema. Moreover, they are not structures without a parallel among the Nematodes. Many forms have been described with hairs distributed irregularly or regularly — sometimes in rows (Trichoderma) — over the surface of the body. Unfortunately, in such cases little or no idea has been given of the size and structure of the "hairs" by the authors who have mentioned them. In one form at least, the peculiar free-living marine genus Chætosoma (Giard et Barrois, '75), there is found a double row of hairs along a portion of the ventral line. The setæ are hollow and entirely superficial, thus agreeing in several points with those of Nectonema; they are not, however, so extended in their distribution as in the latter form.

4. Muscular Layer.

The complete degeneration of the posterior portion of the alimentary canal in the adult, as well as its minute size in comparison with the body of the worm, makes it at once evident that this organ cannot be functional in the adult. The question then suggests itself as to the source of nourishment during this period of life. As has been already noted, the protoplasmic zone of the muscular layer is thicker in the immature individual, and diminishes in thickness with the attainment of sexual maturity. This decrease in volume may take place in two ways, — by the formation of corpuscles directly from the cells of the layer, and by the giving up of food matter to neighboring cells or to the cœlomic fluid and thus to all tissues of the body.

As has been shown, the corpuscles of the body cavity probably originate from the cells of this layer by a process of abstriction. This process is never very extensive, so far as I have been able to judge, and hence will hardly serve to explain entirely the decrease in the volume of the layer. One is, therefore, compelled to accept the second method suggested, that of the indirect transmission of food matter either through neighboring cells to remote tissues, or by means of the fluid in the body cavity. The unusually large size of the protoplasmic portion of the muscle cells, and its granular condition, are well explained on the supposition that these cells have secondarily acquired the function of storing up nourishment for the support of the body during the period of adult life.

5. Parasitic Nature.

Nectonema possesses neither eye spots nor sense organs, such as are present in practically all cases of free-living, and especially of pelagic forms. The general structure of the alimentary tract, its diminutive size as compared with that of the animal, its occasional closure anteriorly, the complete degeneration of its posterior portion, and the absence of any functional anus, speak even more strongly against the possibility of regarding Nectonema as primarily a free form, and practically force one to the conclusion that it is a parasite, which passes its larval life in some unknown animal, wandering out of its host at sexual maturity and passing the final stage of its life history in a free condition, in which alone it is at present known. On the analogy of Gordius, the host may be surmised to be some fish or crustacean, and, since Nectonema is not so rare as has been supposed, it ought not to be difficult in its proper home to discover its host.

There are certain facts which should be mentioned in this connection. As has already been said, Nectonema was caught only on an ebbing tide and in the bay near shore, not in open water. And although a large amount of truly pelagic material was obtained in the same manner, yet numerous Annelids which are by no means truly pelagic were found in the same towing. The latter form part of the bay or shore fauna which in towing near the land is habitually found in the net. In the same way, Nectonema, which is probably set free from some one or more of the small fish or Crustacea which inhabit the shores of the bays or shallow water in general, will live normally in the little coves and quiet places along shore, but may be carried out by the tidal currents even to some distance. It is probably found at or near the surface at night only, and at the bottom during the day. The greater prominence of the contractile portion of the muscular layer in the male would seem to indicate that it is the more active of the two, and to this may be due in part the much larger number of males captured.

VII. Comparison with other Forms.

Numerous possible relationships have been suggested for Nectonema, many of which rest upon resemblances of a superficial character, such as the comparison with Sagitta on the ground that both possess lateral fins. Bürger ('91, p. 650) has sufficiently shown the fallacy of any comparison with Eubostrichus, which resembles Nectonema at most in possessing external hairs! It is an interesting and at once a significant fact that Chætosoma possesses a double row of hollow hairs or bristles on a portion of the ventral line. These hairs strongly resemble those of Nectonema, but it is apparent at once from a comparison of internal organs that the resemblance is purely superficial, since Chætosoma is as like the Nematodes *s. str.* as Nectonema is different from them; this is simply an interesting case of the development of like structures in widely different forms, which may be traced perhaps to similarity in their conditions of life.

In much the same way the resemblance to the Trichotrachelidæ emphasized by Bürger ('91, p. 649) is at most an instance of the convergence of parasitic types. The resemblance is indeed close in the muscular and digestive systems. The latter is, however, the system most immediately and directly affected by parasitism, and such resemblances may easily have arisen independently in any number of animals. The peculiar structure of the œsophagus is shared by the Mermithidæ as well; and so far as the muscles are concerned this type is common to an entire group of Nematodes, the Cœlomyaria. On the other hand, the reproductive and nervous systems of Nectonema and the Mermithidæ represent opposite extremes in the class Nematoda.

There is one comparison, however, which deserves more detailed consideration. Verrill ('73, p. 632) said of Nectonema, "In general appearance when living and moving, it resembles Gordius"; and again ('79, p. 187) he calls attention to the external similarity of the living animals. Bürger ('91, p. 649) enumerates the points of agreement between the two as the absence of lateral lines and the position of the nervous system in the ventral line, and emphasizes the difference in the digestive system and in the structure of the muscles. This is not a sufficiently broad and accurate comparison, and it will be valuable to enumerate here more exactly the points of agreement and difference for the various systems of organs in order.

The cuticula differs both in thickness and in the possession of rows of bristles and scales in the one form, and of scattered papillæ and sensory bristles in the other. The subcuticula has in both the characteristic Nematode nature. The muscular elements show at first sight a considerable difference in structure, yet I am convinced that this is more apparent than real. The muscle cells of Nectonema are those of the typical Cœlomyarian, in which the muscle fibrillæ are arranged in a peripheral ∩-shaped layer about the distal edge of the muscle cell. Into the hollow of this contractile portion extends a projection from the plasmatic portion of the cell which is found at the inner border of the contractile portion. If now we conceive this plasmatic portion to be reduced to a minimum, the form of muscle cell characteristic of Gordius will be reached; for in this genus the projecting protoplasmic portion is entirely lacking, the layer of contractile fibrillæ surrounds the entire cell, and the nucleus is found in the thin strip of plasma which occupies the centre. Not only do we find in a typical Cœlomyarian cells in which the plasmatic cell body hardly projects beyond the contractile layer, but I have also been able to find in cross sections of Gordius *sp. ?* certain regions where the fibrillar layer in the proximal portion of the cell differs in thickness and in refractive power from that in the distal portion. I do not believe, therefore, that the difference in the muscular systems is so great as has been maintained.

To consider the second objection urged by Bürger against the relationship of Gordius and Nectonema, namely, the structure of the intestine, it will be necessary to make a short digression to consider the structure of the alimentary canal, and especially of the œsophagus, in Nematodes. Most text-books recognize only one type of œsophagus in this group, a muscular organ with a more or less triangular lumen lined with chitin, from which muscle fibres radiate perpendicularly to the long axis of the tube. This organ evidently acts like a suction pump in taking up nourishment.

If, however, one examines the literature on the group, it is evident that there are a number of families to which this description will not apply, and that there is really a second well marked type of œsophagus. This consists of a minute chitinous tube extending through a cell, or row of cells, with which no muscle fibres are connected. Evidently there is here no means of varying the size of the lumen. I believe the œsophagus in every family of Nematodes may be reduced to the one type or the other. The larger number of forms show the first, but in the Trichotrachelidæ and Mermithidæ the œsophagus is constructed on the second type, as is also the case in Nectonema. In Gordius this organ is found to be highly degenerate, and in certain species, or in specimens of a certain age, has entirely disappeared. Its condition appears to be different according to the descriptions given ; but in a specimen collected in Cambridge there is absolutely no trace of an œsophagus in a perfect series of transverse sections. From the account of Vejdovský ('86, p. 404) it is at once evident that the œsophagus does not belong to the first type, and according to his description[1] and figures ('86, p. 404, Taf. XV. Fig. 35) it bears a

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[1] Vejdovský says (p. 404) : " Als Mundhöhle bezeichne ich das enge Kanälchen," etc. It is this portion of the alimentary canal which I regard as the morphological equivalent of the œsophagus of the second type.

strong resemblance to the second type. At any rate, I am unable to see the striking difference in this region on which Bürger lays great stress. As for the intestine proper, it is not of great importance whether the lumen be bounded by four or eight cells. There are evidently differences in the alimentary canal of the two forms; one of the most striking is the degeneration of the anterior portion in Gordius, and of the posterior part in Nectonema. This is, however, of minor importance on the question of general relationship.

At first sight nothing could appear more unlike than the reproductive systems in the two forms, and so far as external sexual organs are concerned there does exist a great difference. The papilla and terminal opening of the male Nectonema do not resemble in the least the forked tail and subterminal opening of Gordius. The female organs bear an external resemblance, but internally there is nothing in Nectonema parallel to the complicated structure of the system in Gordius. Too little is known of ovaries or testes in Nectonema to permit of a comparison, but the apparent absence of mesenteries and the probability that the organs are not paired in this case are certainly important differences. On the other hand, certain striking points of similarity must be noticed. The position of the sexual organs dorsal to the intestine is a peculiarity in Nectonoma which is shared only by Gordius among all the Nematodes at least. The same may be said of the fact that both male and female sexual organs possess terminal or subterminal openings. If my conjecture be correct that in Nectonema this is a cloacal opening, then this feature is also common to both. Moreover, of all Nematodes these two families are the only ones in which spicula are entirely wanting.

The body cavity in the two forms differs in that a lining epithelium is present in Gordius, but probably absent in Nectonema, except in the anterior chamber. The body cavity of both increases in size, however, by the cell masses which bound it taking part in the formation of sexual products or the nourishment of the body; but it is doubtful if this process goes so far in Nectonema as in Gordius, where it leaves only a thin row of cells, the peritoneal epithelium. This matter is, however, hardly cleared up for Gordius, even after the numerous investigations that have been made, and it cannot be regarded as more than formulated for Nectonema by the present study.

The lateral lines, as well as the contained excretory canals which are so characteristic of all other Nematodes, are wanting in both Nectonema and Gordius. In Gordius, moreover, no probable excretory system has been shown to exist, and I have looked in vain for evidence of one in Nectonema. The only indication of a dorsal line in Gordius is the median dorsal interruption of the longitudinal muscles in the posterior portion of the body; in Nectonema, on the contrary, this organ is well developed. In both forms the ventral line is prominent, and in both it contains the ventral nerve cord.

Of the nervous system it may be said that the brain is more highly developed in Nectonema, the dorsal cells as well as the correlated anterior chamber being structures entirely without parallel in Gordius. But the ventral nerve cord in the two genera shows a similarity not only in position, but to a certain degree in structure, being made up in general of three portions, a median and two lateral. (Cf. Vejdovský, '86, Taf. XVI. Figs. 51, 63, *et al.*) Like many other Nematodes, both forms possess an anal ganglion.

Numerous lesser points of likeness may be mere coincidences. Such are the great numerical superiority of males over females, — which, among all Nematodes, is found only in these two groups, — the parasitic nature, and the mode of motion. The spermatozoa which I have described recall the unripe sperm of Gordius; yet such evidence is interesting rather than weighty.

In summing up this detailed consideration it may, I believe, fairly be said, that the points of difference between Gordius and Nectonema are more numerous than those of likeness, but that the latter are more general and important. This agreement in general characters is so striking that I cannot believe it is due to anything else than affinity. It will be noticed that the characters which separate the Gordiidæ from the other Nematodes are shared with Nectonema; thus the absence of lateral lines, the existence of *one* principal nerve cord (ventral), the dorsal position of the sexual organs, and the terminal openings of the same. Again, the points of difference between the two groups are largely those which separate the various families of Nematodes *s. str.* from one another; namely, the structure of the muscles and alimentary canal (?), and the character of the ducts and external sexual organs.

We do not know how much the change from salt to fresh water has modified Gordius, which is evidently the more degenerate form, as may be inferred, for example, from the greater reduction of the alimentary canal and of the nervous system. Certainly the rows of bristles in Nectonema are to be attributed to its free life and more active habits. With the latter also one would naturally look for a more highly developed nervous system. Further evidence, that to be gained from the embryonic development as well as from the life history and structure of the larva, will make this matter clearer.

Nearly all writers agree in placing the Gordiidæ in an isolated position under the Nematodes. If, according to the proposal of some, this family be raised to the dignity of a separate order, then there is no doubt in my mind of the right of Nectonema to a position in that order as the representative of a new family, the Nectonemidæ. But whatever may be the final decision in regard to the rank of the Gordiidæ, this new family must take its position near that group. That the relationship is close enough to warrant the inclusion of the genus Nectonema in the family of the Gordiidæ is hardly possible, but a final opinion on this point can be given only in the light of more complete knowledge, especially on the points just enumerated. It is my intention to investigate the subject further, and to follow if possible the life history of this most interesting form.

CAMBRIDGE, March 25, 1892.

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EXPLANATION OF FIGURES.

All figures were drawn with the aid of Zeiss lenses and an Abbé camera unless otherwise stated, and represent preparations of *Nectonema agile*, Verr. The method of staining, the lenses, and the magnification employed, are noted briefly for each figure.

ABBREVIATIONS.

cd. n. v.	ventral nerve cord.
cl. coms.	commissural cells of brain.
cl. d.	dorsal cell.
cl. gn. I., II., etc.	first, second, third, etc. large ganglion cell of brain.
cl. in. I.–IV.	intestinal cells I. to IV.
cl. mu.	muscle cell of body wall.
cl. œ.	œsophageal cell.
cl. sns.	sensory cell.
coms. œ.	dorsal (supra-œsophageal) commissure of brain.
cp′.	corpuscle of body cavity fluid.
cta.	cuticula.
e'th. pi't.	peritoneal epithelium.
fbr′. mu.	contractile fibrillæ of muscle cell.
fbr. n.	nervous fibrillæ.
gn. an.	anal ganglion.
h'drm.	hypodermis.
in.	intestine.
ln. d.	dorsal line.
ln. v.	ventral line.
mb. ba.	basement membrane.
n. a.	nerve fibres anterior to brain.
nl. d.	nucleus of dorsal cell.
nl. gn.	nucleus of large ganglion cell.
nl. gn. I.–V.	nuclei of ganglion cells I. to V. of brain.
n. l.	lateral nerve of ventral nerve cord.
nll.	nucleolus.
n. m.	median nerve of ventral nerve cord.
n. n.	nervous nuclei.
œ.	œsophagus.
pd. cl. d.	stalk of dorsal cell.
pr'c. gn.	process of ganglion cell.
sac. d.	dorsal sac.
sp'z.	spermatozoa.
st. pi'ph.	peripheral layer of anal ganglion.
te.	testis.
va. df.	vas deferens.

PLATE I.

Fig. 1. Male Nectonema, natural size. The bristles are so minute that they could not be represented in proper proportions. Free hand drawing.

Fig. 1^a. Anterior end of the same to show torsion of the body. Somewhat diagrammatic.

Fig. 2. Dorsal view of anterior end of living animal. × 32.

Fig. 3. Lateral view of anterior portion of living animal. Drawn by A. Agassiz, August 5, 1871.

Fig. 4. Posterior portion of male. Drawn from specimen cleared in clove oil. Simple microscope. × 7.

Fig. 5. Posterior portion of female discharging eggs. Drawn from specimen cleared in clove oil. Simple microscope. × 7.

Fig. 6. Lateral aspect of central part of body. Drawn by A. Agassiz, August 2, 1877.

Fig. 7. Ventral aspect of body. Drawn from living animal, and afterwards reduced one half. 1. A. $\times \frac{62}{2}$.

Fig. 8. Right half of anterior portion of the body drawn from a transparent object in clove oil, and represented as though the near (left) half of the body had been removed. 1. A. × 48.

Fig. 9. End of body of male viewed as a transparent object in clove oil. 2. a*. × 17.

Fig. 10. End of body of female viewed as a transparent object in clove oil. 2. A. × 50.

Fig. 11. Cross section from centre of body of male. Kleinenberg's hæmatoxylin. 2. A. × 98.

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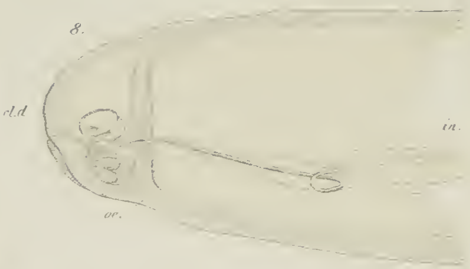

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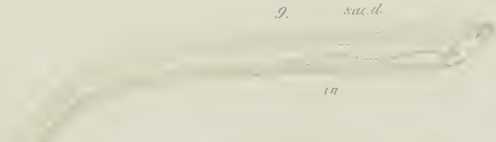

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PLATE II.

Fig. 12. Tangential section, including cuticula of dorsal line with bristles. 1. C. × 180.

Fig. 13. Cross section of cuticula with bristles attached, only the basal portions of which are represented. At the lower side lies a cross section of a bristle. 4. C. × 400.

Fig. 14. Cross section of cuticula with scales attached. Apochr. 4 mm. Compens. Oc. 4. × 360.

Fig. 15. Cross section of scale with cuticula and hypoderm. Apochr. 4 mm. Compens. Oc. 12. × 1,050.

Figs. 16, 17. Cross sections of scale on cuticula to show central canal. Apochr. 4 mm. Compens. Oc. 4. × 360.

Figs. 18, 19. Surface view of scales on cuticula. Apochr. 4 mm. Compens. Oc. 4. × 360.

Fig. 20. Cross section of cuticula and hypoderm. Ehrlich's hæmatoxylin. Apochr. 4 mm. Compens. Oc. 8. × 720.

Fig. 21. Cross section of body wall just lateral to dorsal line to show structure of the muscles. Apochr. 4 mm. Compens. Oc. 8. × 720.

Fig. 22. Fragment of muscle after maceration in 60 % KOH, and subsequent treatment with potassic acetate. 3. C. × 320.

Figs. 23–26. Cross sections of body wall from different individuals to show the different widths of the contractile and protoplasmic zones in the muscular layer. The contractile zone is represented by a dark band, and the protoplasmic by a lighter tint. 1 A. × 52.

Fig. 27. Tailed nuclei from muscular layer. Mayer's HCl carmine. Apochr. 4 mm. Compens. Oc. 8. × 720.

Figs. 28–30. Portions from protoplasmic zone of muscular layer, showing the formation of corpuscles from the free ends of the muscle (?) cells. Gentian violet and eosin. Apochr. 4 mm. Compens. Oc. 4. × 375.

Fig. 28. Portion of cell nearly cut off at x.

Fig. 29. Portion of cell at x, which stains more deeply and resembles corpuscles (*cp'.*) of the body cavity.

Fig. 30. Corpuscles of different sizes completely separated from protoplasmic zone.


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PLATE III.

Figs. 31–45. Transverse sections of the alimentary canal from a single series of sections. Mayer's HCl carmine. Apochr. 4 mm. Compens. Oc. 4. × 230.

Fig. 31. 7th section of the series.
“ 32. 16th “ “ “
“ 33. 25th “ “ “
“ 34. 31st “ “ “
“ 35. 32d “ “ “
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“ 45. 103d “ “ “

Figs. 46–48. Transverse sections of alimentary canal from the region where it is bounded by two cells alone to show diminution in size toward the posterior end. Apochr. 4 mm. Compens. Oc. 4. × 230.

Fig. 46. Kleinenberg's hæmatoxylin.

Figs. 47, 48. Ehrlich's hæmatoxylin.

Fig. 49. Transverse section of alimentary canal to show the normal relation of the lumen to the cells. Kleinenberg's hæmatoxylin. 2. E. × 610.

Figs. 50, 51. Transverse sections of the œsophageal cell in the same series. Ehrlich's hæmatoxylin. 2. E. × 610.

Fig. 50. To show the relation of the nucleus to the chitinous tube.

Fig. 51. Two sections beyond the section in Fig. 50 to show disappearance of the chitinous tube.

Fig. 52. Lateral aspect of intestine. The two cells of the opposite side are not shown. Ehrlich's hæmatoxylin. 2. C. × 165.


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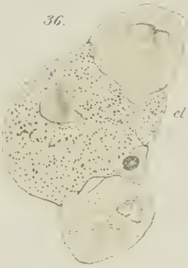
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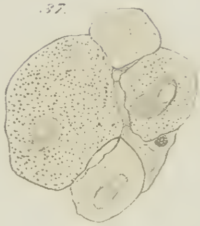
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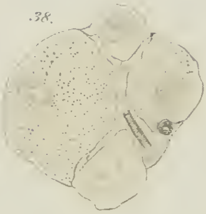
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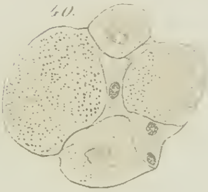
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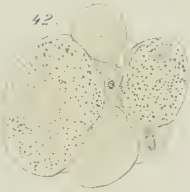
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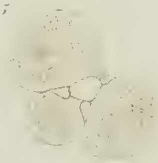
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PLATE IV.

Fig. 53. Posterior end of male viewed as a transparent object in clove oil. 2. C × 165.

Fig. 54. Wall of dorsal sac showing nuclei. Ehrlich's hæmatoxylin. Apochr. 4 mm. Compens. Oc. 8. × 725.

Fig. 55. Spermatozoa (unripe ?). Böhmer's hæmatoxylin. Apochr. 4 mm. Compens. Oc. 12. × 1,000.

Fig. 56. Posterior end of female viewed as a transparent object in clove oil. 2. A. × 95.

Fig. 57. Sagittal section through posterior end of female, showing slight development of anal ganglion. Ehrlich's hæmatoxylin. 2. A. × 95.

Fig. 58. Transverse section through middle of body of female filled with eggs. Böhmer's hæmatoxylin. 3. A. × 130.

Fig. 59. Transverse section through body wall of nearly mature female to show remains of cell layer (*) within the muscular layer. Böhmer's hæmatoxylin. 3. C. × 330.

Fig. 60. Section of immature egg. Ehrlich's hæmatoxylin. 3. D. × 540.

Fig. 61. Section through nearly ripe egg. Böhmer's hæmatoxylin. 3. D. × 540.

Fig. 62. Egg after contact with sea-water. Glycerine preparation. 3. D. × 560.

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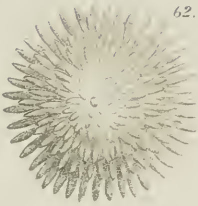

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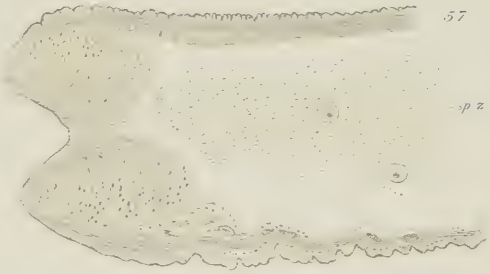

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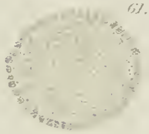

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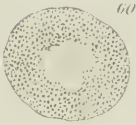

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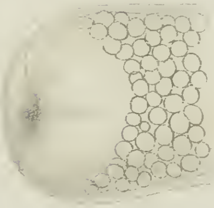

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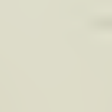

PLATE V.

Fig. 63. Ventral aspect of head with brain, viewed as a transparent object in clove oil. 2. C. × 160.

Fig. 64. Nucleus of dorsal cell showing enclosed body (x). Böhmer's hæmatoxylin. Apochr. 4 mm. Compens. Oc 8. × 680.

Fig. 65. Nucleus of dorsal cell. Kleinenberg's hæmatoxylin. Apochr. 4 mm. Compens. Oc. 8. × 680.

Fig. 66. More regular nucleus of dorsal cell. Ehrlich's hæmatoxylin. Apochr. 4 mm. Compens. Oc. 8. × 725.

Fig. 67. Oblique section through basal portion of dorsal cell where the process enters and divides. Böhmer's hæmatoxylin. Apochr. 4 mm. Compens. Oc. 8. × 725.

Fig. 68. Small nervous nuclei of brain. Ehrlich's hæmatoxylin. Apochr. 4 mm. Compens. Oc. 4. × 360.

Fig. 69. Nucleus of commissural cell showing enclosure similar to that of the dorsal cell. Böhmer's hæmatoxylin. Apochr. 4 mm. Compens. Oc. 4. × 360.

Fig. 70. Nucleus of large ganglion cell in anal ganglion. Böhmer's hæmatoxylin. Apochr. 4 mm. Compens. Oc. 8. × 725.

Fig. 71. Nuclei of cells in peripheral layer of anal ganglion. Ehrlich's hæmatoxylin. Apochr. 4 mm. Compens. Oc. 8. × 725.

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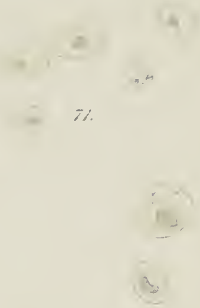

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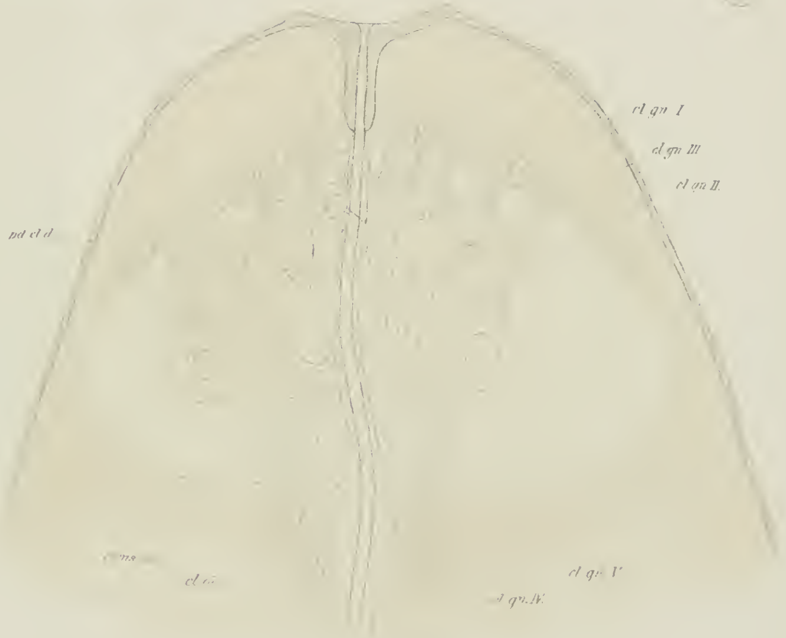

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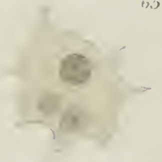

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PLATE VI.

Figs. 72–88. Successive transverse sections through the brain. The small nervous nuclei are represented by simple dots, the nuclei of the large cells as accurately as possible; the cell bodies are not represented.

Fig. 72 is the twelfth section from the apex of the head; each section is represented from its anterior face, and approximates 10 μ in thickness. Ehrlich's hæmatoxylin. 2. A. × 95.

Fig. 89. The posterior end of the male with anal ganglion and dorsal sac viewed as a transparent object in clove oil. Only a few of the numerous Gregarinida (*) in the body cavity are represented. 2. A. × 66.

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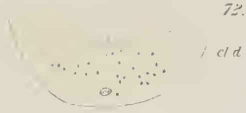

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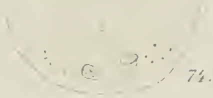

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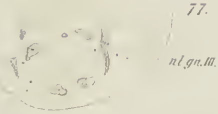

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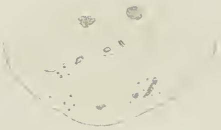

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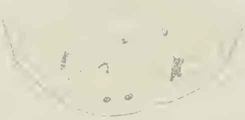

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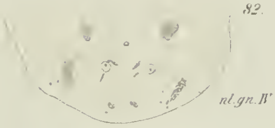

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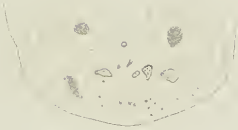

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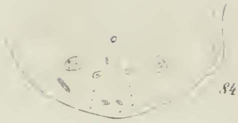

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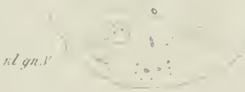

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PLATE VII.

Fig. 90. Sagittal section through posterior end of male, slightly lateral, showing large cells and processes in anal ganglion. Böhmer's hæmatoxylin. 1. C. × 180.

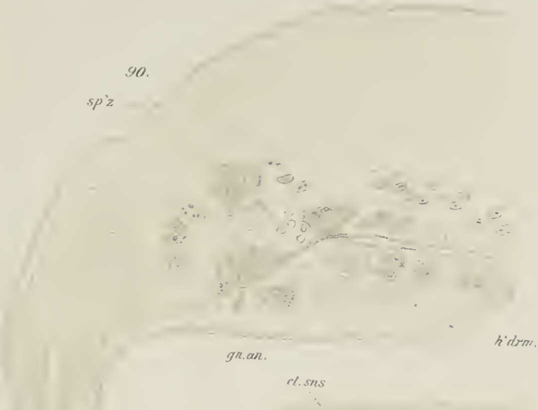
Fig. 91. Gregarinida from mass of spermatozoa. One in cross section is shown at *a*. Mayer's HCl carmine. 3. D. × 560.

Fig. 92. Transverse section, slightly oblique, from near the tip of the head, showing sensory cells, and nerve fibres passing up towards them. Ehrlich's hæmatoxylin. 2. C. × 230.

Fig. 93. Isolated sensory cells from front end of head. Ehrlich's hæmatoxylin. Apochr. 4 mm. Compens. Oc. 8. × 725.

Fig. 94. Diagrammatic representation of the relative size and position of the large ganglion cells in the brain. The extremes of variation in the position of the second pair (*cl. gn.* II.) are represented on the right and left of the figure. Dorsal aspect with the dorsal cells removed; the deep-lying cells appear fainter, cells which are nearer being more prominent. Drawing by A. G. Mayer.

Fig. 95. Oblique longitudinal section of posterior portion of the brain and the partition which cuts off the anterior chamber. The deepest and last portions of the processes of the dorsal cells are shown. Ehrlich's hæmatoxylin. Apochr. 4 mm. Compens. Oc. 8. × 725.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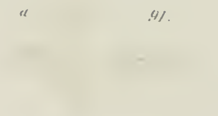
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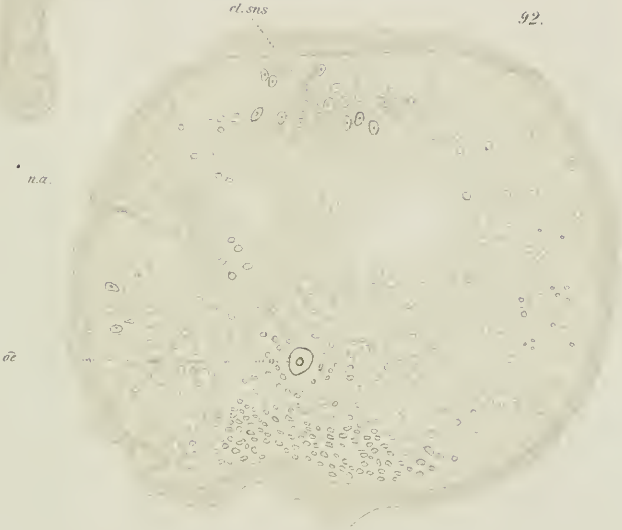
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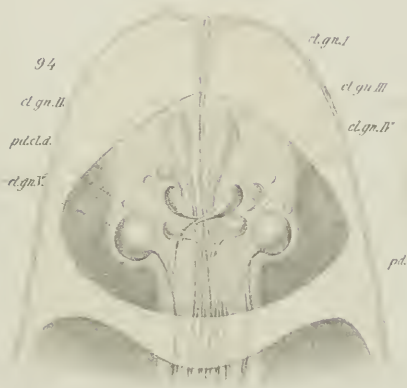
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PLATE VIII.

Fig. 96. Transverse section from posterior region of body of male. The dorsal margin is somewhat broken. Bismarck brown. 3. A. × 125.

Fig. 97. Longitudinal section of ventral nerve cord near the front end of the anal ganglion. Böhmer's hæmatoxylin. 1. C. × 180.

Fig. 98. Dorsal cell viewed as a transparent object in clove oil. The left half of the cell is occupied by a large vacuole. 2. D. × 290.

Fig. 99. Transverse section through dorsal cells and brain. The section is oblique enough to pass through the process of the first cell on the left, and of the second cell on the right. Mayer's HCl carmine. 2. D. × 290.

Fig. 100. Termination of process of right dorsal cell in Fig. 99 found 20 μ farther posteriad. Mayer's HCl carmine. Apochr. 4 mm. Compens. Oc. 4. × 360.

Fig. 101. Transverse section of ventral line with ventral nerve cord. Ehrlich's hæmatoxylin and eosin. Apochr. 4 mm. Compens. Oc. 4. × 250.

Fig. 102. Transverse section of dorsal line. Ehrlich's hæmatoxylin and eosin. Apochr. 4 mm. Compens. Oc. 4. × 250.

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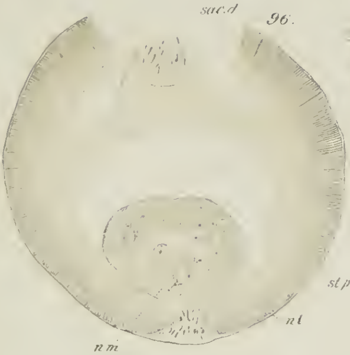

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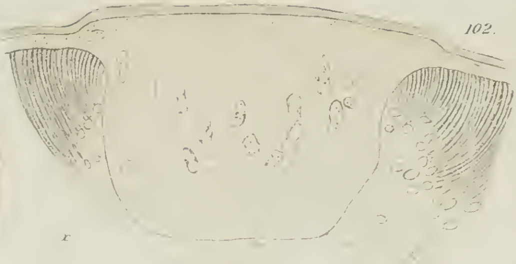

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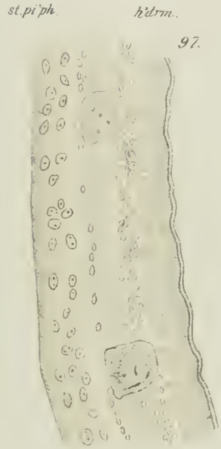

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No. 4. — *Studies from the Newport Marine Zoölogical Laboratory.*

XXIX.

Preliminary Note on some Modifications of the Chromatophores of Fishes and Crustaceans. By Alexander Agassiz.

In a former paper on the Development of Flounders,[1] I have called attention to the rapidity with which young flounders adapt themselves to their surroundings, and have shown how soon their pigment cells, when young, assume in a general way the coloring of the bottom on which they rest. I have since that time experimented occasionally upon the effect of a black and of a white bottom upon other fishes, and upon Crustacea in the young stages of which there were huge or highly specialized pigment cells (chromatophores).

I was surprised to find that in adult specimens of Gasterosteus, for instance, the coloration was soon modified by keeping the fish upon a black or upon a white tile. A number of Gasterosteus were taken which showed but slight individual differences, and might have passed as presenting no perceptible contrast in their general coloring (Figs. 1, 2). They were divided into two sets, each set placed in a glass dish, one upon a bottom of black tiles, the other upon white tiles.

At the end of three days, there was already a very striking contrast between the coloration of the two sets of specimens. Those placed upon the black tiles had retained their original coloration, while those upon the white tiles assumed a grayish tint. The pigment cells of the darker bright-colored specimens consisted of two kinds of chromatophores, fully expanded (Figs. 1, 2). The uppermost cells were highly dendritic, with closely packed thin ramifications of a dark chocolate color, with nearly black nuclear centre ; the lower chromatophores were more compact, with flatter and spreading ramifications a short distance from the centre. In the specimens which had become bleached, on the contrary, the chromatophores were reduced to mere dots, with

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[1] On the Young Stages of Bony Fishes. By Alexander Agassiz. I. The Development of Flounders. Proc. Am. Acad., Vol. XIV. p. 1. Boston, 1878–79.

here and there an amœbiform thread extending from the central nucleus (Fig. 3). If the bleached specimens were kept continuously upon the white tile for five to six weeks, they apparently lost the faculty of regaining their original coloring. When removed to a background of black tiles, specimens which had been submitted to the action of the light of the white tiles for only from three to ten days regained to a great extent their original coloration, though never its primitive brilliancy; while the specimens which had been bleached for a longer time seemed to have become permanent albinos, or grayish lighter colored specimens. The pigment cells no longer expanded and contracted under the influence of varying conditions of intensity of light, as they do when they have not been too long subjected to one set of strong influences.

Our common Ctenolabrus varies, as is well known, greatly in coloration. But the conditions which bring about the differences described are seen only in the young from the time they hatch until they are not more than from about four to five months old. The shade of coloring is brought about by the greater or less development of the pigment cells, which assume either the form of a thin grayish film, with an annular nucleus, the film consisting of comparatively short, broad amœbiform expansions, giving to the fish a gray appearance if spread uniformly over the surface, or of gray patches or bands if limited to special areas (Fig. 5). Should the black chromatophores be more concentrated, and its offshoots thinner but more numerous, and packed together as they are in Figure 4, the young fish would appear to have a much darker tint, and from the reduction of these chromatophores to mere dots, with the presence only of the larger black chromatophores on the upper edge of the alimentary canal, and near the tail, the fish assumes an entirely different aspect, being comparatively transparent and colorless.

Experiments made with the youngest stages of Ctenolabrus and of Platessa have shown the same results. A number of specimens of each species were picked out as soon as hatched, and placed respectively upon black and white tiles. The young of Ctenolabrus and of Platessa at these early stages have only black pigment cells, so that the effect of light is not complicated by the interference of other colored cells.

After ten days, the young of Ctenolabrus placed upon the white tiles were found to develop only into practically colorless stages, such as are figured in Figures 1, 2, and 4 of Plate XIV. of the Young Osseous Fishes, Part III.,[1] while those which were placed upon black tiles

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[1] Proc. Am. Acad., Vol. XVII. p. 271. 1882.

developed into young with well marked black pigment cells of the type of those of Figures 2 and 5 of the same plate.

With Platessa, the young kept on dark tiles passed into stages with well marked black pigment cells, while in the specimens kept on white tiles the pigment cells were reduced to a minimum, — to mere circular dots.

In the case of Hemitripterus americanus, in which the reddish pigment cells play a more important part, the young kept upon white tiles will assume the appearance of such types as are figured on Plate III. Figures 8, 9, of Agassiz and Whitman's Development of Osseous Fishes, Part I.,[1] while in those kept upon black tiles the black pigment spots develop in a marked manner, and form an upper layer of large regularly dendritic chromatophores on the flanks of the body. See Figures 10, 11, of the same plate. The yellowish-red colored cells are not as much affected by the color of the ground as was found to be the case in the colored cells of the young of Ctenolabrus.

The color of the fish is due to differently colored chromatophores placed on a lower level than the black pigment cells. These may be red, yellow, brown, blue, or other color, and by their combination and the greater or less prominence of a special set of chromatophores will give to the young fish its prevailing tint, which may be distributed in a general tone, or in patches and bands on the side of the body or head.

On keeping selected lots of young specimens of Ctenolabrus, probably two months old, of various coloring, upon black and white tiles (Figs. 8–16), the results were found to be similar to those obtained with the older Gasterosteus. Only the faculty of recovering their original color was evidently not so easily lost as in the case of the older Gasterosteus. This would seem to indicate that to retain a condition of coloring brought about or modified by surrounding influences, the young fish must remain exposed to them for a considerable time, and the modification will be more or less permanent, or of a greater or less degree, according to the age of the fish.

The young fishes placed upon black tiles retained their brilliant coloring, no matter whether red, yellow, brown, or blue chromatophores were present; and neither they nor the black pigment cells were modified by the light reflected from the black tiles (Fig. 16). On the other hand, the young fishes kept for ten days upon white tiles had lost, in proportion to their original dark tint, much of their dark color, the black pigment cells having become reduced in some of them to mere dots, in others

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[1] Mem. Mus. Comp. Zoöl., Vol. XIV. No. 1, Part I. 1885.

to faint nuclei, with their delicate radiating spokes indicating faintly the former extension of the dark chromatophores (Figs. 11–15). The colored pigment cells seem to be far less influenced by the color of the bottom upon which the young fishes are placed; they contract somewhat, but are never reduced in size as much, or in the same proportion, as are the black cells. (Compare Figures 9 and 16.) The question of heredity involved in the changes due to the growth of flounders from a symmetrical embryo to an unsymmetrical adult, are naturally suggested by the development of the flounder. They have an important bearing on the transmission of acquired character, and seem to have escaped the notice of most writers on the subject.

In the case of young Lobsters, while still pelagic, the changes in coloring were quite marked; they pass, during the first month of their growth, from green to brown, but thus far my attempts to change or modify their coloring by the action of differently colored bottoms have not been successful. Nor have I succeeded any better with the young embryonic stages of Crangon and Palæmon, in which the tail and thorax are marked by few large and prominent pigment cells. The Crustaceans were kept, during parts of several seasons, subject to very different influences of light and surroundings, but without producing any perceptible change in coloration.

December, 1892.

EXPLANATION OF THE PLATE.

Fig. 1. Pigmented area near the centre of the lateral line of adult Gasterosteus, showing the upper and the lower layer of chromatophores fully expanded.

Fig. 2. One of the chromatophores of the upper and the lower layer. The cell with expanded ramifications belongs to the upper layer. From the same area as those of Figure 1.

Fig. 3. Pigmented area of the same portion as that of Figure 1, taken from a fish which had been kept upon a bottom of white tiles, showing the contracted chromatophores.

Fig. 4. Expanded surface chromatophores of a pigmented band on the flanks of a young Ctenolabrus, measuring about 5 mm. in length.

Fig. 5. Expanded chromatophores of the opercular area of a young Ctenolabrus, somewhat older than the fish represented in Figure 4.

Fig. 6. Large single chromatophore near the tail of a young Ctenolabrus of the age of Figure 4, fully expanded.

Fig. 7. Chromatophores of a young Ctenolabrus taken from near the centre of the lateral line, showing the black cells contracted and closely packed together.

Figs. 4–7. From young fishes caught in the tow-nets and subsequently kept on bottoms of black and white tiles.

Fig. 8. Pigmented area of flank of a gray Ctenolabrus, which had been kept on white tiles for twelve days.

Fig. 9. A similar pigmented area from a young Ctenolabrus, which had been kept on a white tile bottom for ten days, and then placed for the same length of time on a black tile bottom. It had by no means recovered the dark appearance which the same area presented after being exposed to the action of light from a black tile for ten days. See Figure 16.

Fig. 10. Pigmented area exposed to the action of the light from a white tile bottom for ten days. The black cells alone show changes; the colored cells do not differ from those of similar areas exposed upon a bottom of black tiles.

Figs. 11–15. Different views of the same pigmented area in several young specimens of Ctenolabrus, after being exposed to the action of the light upon a bottom of white tiles for about thirteen days.

Fig. 16. The same pigmented area of a young Ctenolabrus, exposed upon a bottom of black tiles for ten days. The black pigment cells are intensely black, and the red cells somewhat more expanded than in Figure 10, and much less so than in the same areas exposed upon a bottom of white tiles for thirteen days. See Figures 11–15.

AGASSIZ. CHROMATOPHORES

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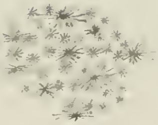

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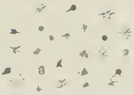

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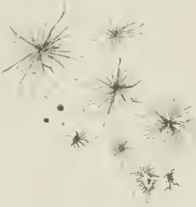

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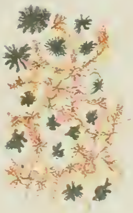

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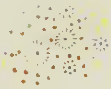

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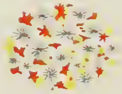

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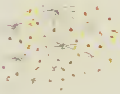

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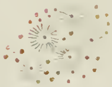

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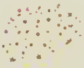

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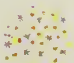

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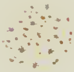

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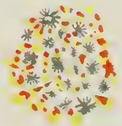

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B. Meisel lith Boston

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.*

III.

On a peculiar Type of Arenaceous Foraminifer from the American Tropical Pacific, NEUSINA[1] AGASSIZI. By A. GOËS.

AMONGST the vast number of remarkable forms from the deep-sea fauna which Mr. Alexander Agassiz brought home last year from his important and successful expedition in the United States Fish Commission steamer "Albatross," in the Pacific off Central America, the Galapagos Islands, and in the adjacent seas,[2] was found this stranger to the Foraminifera on record. Mr. Agassiz has had the kindness to send me for examination a large number of specimens, together with an extensive collection of other foraminiferous material, dredged during this cruise.

The most striking feature of Neusina is its stroma, which forms a strong network of bundles of very fine chitinous threads, measuring in thickness 0.003–0.006 mm., incorporated with a thin layer of finest sand and débris of shells. Although these inorganic constituents of the structure amount to about 80% of the weight of the whole after drying, the test preserved in spirit is to a certain degree flexible and flabby, but somewhat brittle, recalling somewhat the consistency of some fresh-water algæ belonging to the Nostoc family. It is only after drying and removing the sand grains and dust with a brush that the stroma comes to sight as a gray or yellowish flocculent felt. The meshes in the network measure in diameter from 0.05 to 0.08 mm. The test is leaf-formed, with outlines

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[1] From νέειν, to spin

[2] Comp. Letter and Report by Alexander Agassiz, in Bull. Mus. Comp. Zoöl. of Harvard College, Vol. XXI. No 4 (1891), and Vol. XXIII. No. 1 (1892); and the Memoirs of the Mus. Comp. Zoöl., Vol. XVII. No. 2 (1892), On Calamocrinus Diomedæ, Agass.

usually describing a triangular, fan-like, or reniform figure, with more or less strongly arcuated edge, the whole reminding one of a Fadina alga of 0.5 to 2 mm. in thickness. Sometimes the shape is that of a biauriculated leaf, produced much more in breadth than in height. The edge is often undulated in broad folds, and sometimes new individuals sprout from the broad side, forming irregularly shaped clusters of two or three individuals.

The chambers constitute arcuated, concentric, more or less complete bands, increasing in length with age, forming a fan-like growth, commencing with a pointed triangular juvenile stage. Some of the chambers do not extend from side to side, but stop short after a while, ending in an acute point on the broad side.

The two ends of the chambers are usually produced in a narrow, more or less compressed, hollow appendage, with thin walls, composed of parallel bundles of threads, which also are incrusted, but more sparingly, by sand and débris. The cluster-like appendages often divide into two or three terminal branches. The longest measure about 20 mm., with a diameter of 1 to 2 mm.; their wall is only 0.05–0.06 mm. thick. Forming a row along the lower edge of the test, they serve probably as fastenings to the bottom, where they often are entangled in masses of a Rhizammina. The chamber wall is thin, often wrinkled, and here and there pierced by irregularly formed pores of different size. In some places a faint striation running perpendicular to the chamber sutures across the chamber wall can be discovered, probably indicating the divisions into chamberlets. The interstice between the two side walls is crossed by numberless irregular partitions, forming masses of small chambers of different size and form, giving to the structure a sponge-like texture. The color is commonly sooty, with shades in dark olive; when dried, it becomes grayish clay-colored.

The largest specimens measure about 190 mm. in breadth. On account of their brittleness, specimens in perfect condition are rarely obtained; usually the early stage is detached and the border torn. The appendicular tubes are often wanting, or some scanty remnants only left. Among the whole assemblage of specimens from the "Albatross" expedition, I have not found a single one with an embryo stage.

Habitat. — Pacific: Lat. 1° 7′ N., Long. 8° 4′ W. (about 35 miles W. N. W. off Galeras Point), in 3,097 meters' depth (1,740 fathoms); olive-green ooze; temperature, +2°.2 Cent. (Albatross Exp. Stat. 3,399.)

Lat. 10° 14′ N., Long. 96° 28′ W. (about 300 miles S. S. E. from Acapulco); depth, 3,972 meters (2,232 fathoms); green mud; temperature, +1°.7 Cent. (Albatross Exp. Stat. 3,414.)

Lat. 14° 46′ N., Long. 98° 40′ W. (about 95 miles S. E. from Acapulco); depth, 3,344 meters (1,879 fathoms); brown mud, with Globigerina; temperature, +2°.2 Cent. (Albatross Exp. Stat. 3,415.)

Affinities. — In a valuable paper (*Note sur un Foraminifère nouveau de la Côte Occidentale d'Afrique,* Mém. Soc. Zool. de France, Tom. III. p. 211, 1890), Mr. Ch. Schlumberger has described a type, under the name Jullienella fœtida, which seems to have much in common with Neusina, the principal difference being the absence of the filamentous stroma, and the more simple and regular subdivision in chamberlets by the former, which also is provided with tubes *all around* the edge. Jullienella has been dredged by M. le Docteur Jullien off the Liberian coast in four to five meters' depth.

As far as we know, these two forms stand much isolated from others of that class on record, — recent as well as fossil, — and justly claim to be placed in a family by themselves.

Kisa, Sweden, April, 1892.

EXPLANATION OF THE PLATE.

Figs. 1, 2. Neusina Agassizi, nat. size.
Fig. 3. The edge of the last chamber; nat. size.
Fig. 4. Part of the surface, showing its wrinkles and pores; in reflected light. $\times \frac{11}{1}$.
Fig. 5. Transverse section, showing the partitions and the small irregular chamberlets, the former made up chiefly of ovoid silicious bodies; in transmitted light. $\times \frac{11}{1}$.
Fig. 6. Network of chitinous threads forming the stroma of the test, after removal of the sand. $\times \frac{40}{1}$.
Fig. 7. The lower part of an appendicular tube, cleared from sand, showing its structure of bundles of threads. $\times \frac{8}{1}$.
Fig. 8. Transverse section of such a tube. $\times \frac{8}{1}$.
Fig. 9. Colored sketch, from a fresh specimen, made on board the "Albatross" by M. Westergren.

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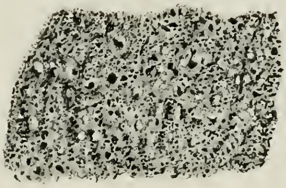

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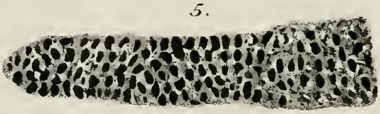

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B. Meisel. lith. Boston

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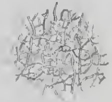

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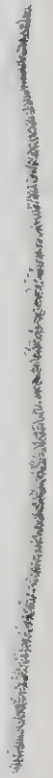

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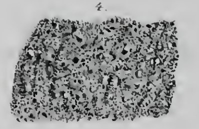

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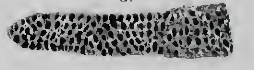

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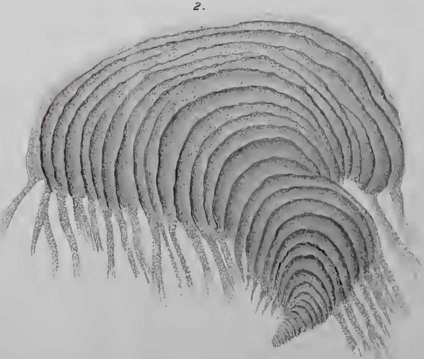

A Goes del

B Meisel lith Boston

No. 6. — *Reports on the Results of Dredging, under the Supervision of* ALEXANDER AGASSIZ, *in the Gulf of Mexico* (1877–78), *and in the Caribbean Sea* (1879–80), *and along the Atlantic Coast of the United States* (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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XXXIV.

Report on the Mollusca dredged by the "Blake" in 1880, including Descriptions of several new Species. By KATHARINE JEANNETTE BUSH.

THIS collection, although a small one, is of considerable interest, owing to the fact that it contains a number of very beautiful, and hitherto undescribed species, and also because the range of many of our Northern forms is extended much farther south.

There were about fifty small jars and bottles of unassorted material from thirty-two stations off the coast included between George's Bank, N. Lat. 41° 35′ 15″, W. Long. 65° 51′ 25″, and Charleston, South Carolina, N. Lat. 32° 25′, W. Long. 77° 42′ 30″, ranging in depths from 24 to 1,394 fathoms. These stations are mostly in depths between 100 and 1,000 fathoms, there being but six in less than 100 fathoms, and six below 1,000 fathoms.

Of the eighty-six species found, about thirteen are named and described as new, and five others, although supposed to be undescribed, are so badly worn and broken that they are only worthy of brief mention.

All the specimens have been carefully compared with the types or typical forms in the collection of the U. S. Commission of Fish and Fisheries.

References are only given to those species included in Professor Verrill's catalogues of deep-water Mollusca (Transactions of the Connecticut Academy of Arts and Sciences, Vols. V. and VI., 1882–1885), and Mr. Dall's reports on the "Blake" Mollusca (this Bulletin, Vols. IX., XII., and XVIII., 1881, 1886, and 1889). In some instances, where the name has been changed, a more complete synonymy is given.*

In order that the distribution of each species may be given as completely as possible, the range, as recorded in the Reports of the U. S. Commission of Fish and Fisheries, is included, and mention is also made of other known localities, north and south.

In giving the bathymetrical range, mention in most cases is made of the depths at which the species was found living, in addition to the extreme limit of range. When no distinction is made, it is to be understood that the specimens were taken alive.

At the end of this report, a list of the species is given, showing the relation of each to the Northern and Southern faunas.

My acknowledgments are especially due to Professor Agassiz for the privilege of preparing this paper, and to Professor Verrill for valuable advice and criticism.

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* Other books used for reference are the following: —

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Whiteaves, J. F. Reports on the Deep-sea Dredgings in the Gulf of St. Lawrence, 1871–74.

LIST OF STATIONS FROM WHICH MOLLUSKS WERE RECEIVED.

Station No.	Locality.		Depth, Temperature, and Nature of Bottom.			When collected.
	N. Lat.	W. Long.	Fath.	F.°	Materials.	
	East of George's Bank.					
302	41° 30′ 0″	66° 0′ 0″	73	42.5	yl. S., bk. Spk., Sh.	1880
303	41 34 30	65 54 30	306	40.5	gy. S., bk. Spk., M.	"
304	41 35 0	65 57 30	139	44	No specimen.	"
305	41 35 15	65 51 25	810	39	dk.-gy. M., S., St.	"
306	41 32 50	65 55 0	524	39.5	" "	"
307	41 29 45	65 47 10	980	38	dk.-gy. M.	"
308	41 24 45	65 35 30	1,242	38	"	"
	South of George's Bank.					
309	40 11 40	68 22 0	304	40.5	dk.-gy. M., S.	"
	South of Martha's Vineyard.					
310	39 59 0	70 18 45	260	42	gn. M.	"
	Off Charleston, S. C.					
313	32 31 50	78 45 0	75	61.5	fne. gy. S., bk. Spk.	"
319	32 25 0	77 42 30	262	45.5	crl. S.	"
321	32 43 25	77 20 30	233	53.5	glb. O.	"
	Off Cape Fear, N. C.					
325	33 35 20	76 0 0	647	39	"	"
326	33 42 15	76 0 50	464	39.5	"	"
	Off Cape Lookout, N. C.					
329	34 39 40	75 14 40	603	39.75	"	"
	Off Cape Hatteras, N. C.					
330	35 41 3	74 31 0	1,047	38.5	glb. O., C.	"
331	35 44 40	74 40 20	898	39	glb. O.	"
332	35 45 30	74 48 0	263	41.5	"	"
333	35 45 25	74 50 30	65		Cl.	"
	Off Delaware Bay.					
334	38 20 30	73 26 40	395	41	glb. O., C.	"
336	38 21 50	73 32 0	197	45	fne. gy. S., M.	"
337	38 20 8	73 23 20	740	39.5	glb. O.	"
338	38 18 40	73 18 10	922	39	"	"
339	38 16 45	73 10 30	1,186	39	"	"
	South of Martha's Vineyard.					
340	39 25 30	70 58 40	1,394	38	"	"
341	39 38 20	70 56 0	1,241	38	"	"
342	39 43 0	70 55 25	1,002	39	bl. C.	"
343	39 45 40	70 55 0	732	39.5	gn. S.	"
344	40 1 0	70 58 0	129	51	"	"
345	40 10 15	71 4 30	71	51	gn. M., brk. Sh., S.	"
346	40 25 35	71 10 30	43½	49	gn. M.	"
	Off Montauk Pt., L. I.					
347	40 59 0	71 22 30	24	60	crs. bl. S., yl. Spk.	"

CEPHALOPODA.

Argonauta argo Linné.

Verrill, Trans. Conn. Acad., V. pp. 364, 420, 1881; VI. pp. 247, 265, pl. 28, figs. 1, 1 *a*, 1 *b*, 1884.

Dall, Bulletin U. S. Nat. Mus., No. 37, pp. 174, 200, pl. 64, fig. 142 *b*; var. *americana*, pl. 43, figs. 1, 1 *a*, 1 *b*, and pl. 67, figs. 63, 63 *a*, 63 *b*, 1889.

A single fragment, Station 325, off Cape Hatteras, N. C., in 647 fathoms.

Several shells and many fragments have been taken by the U. S. Commission of Fish and Fisheries off the coast, from Martha's Vineyard to Chesapeake Bay, in 64 to 2,620 fathoms, and several living specimens at the surface.

Mr. Dall records this species as far south as the West Indies, and, doubtfully, from Brazil. He gives the varietal name *americana* to all found off our coast, because of their broader form and fewer radial folds and cardinal nodules.

In a series of perfect shells of moderate size, taken with the animal, I find marked variation in the prominence and number of the folds and nodules. Some of them could not be distinguished from authentic specimens of about the same size from Sicily, in the collection of the Peabody Museum of Yale University. It is only the large, full-grown specimens that seem to be narrow and more compressed in form.

GASTROPODA.

TOXOGLOSSA.

Pleurotoma (Drillia) Dalli Verrill and Smith.

Verrill, Trans. Conn. Acad., V. p. 451, pl. 57, figs. 1, 1 *a*, 1882; VI. p. 265, 1884.

Drillia ? Dalli Dall, this Bulletin, XVIII. p. 92, 1889; Bulletin U. S. Nat. Mus., No. 37, p. 98, pl. 60, fig. 66 *a*, 1889.

One living and one dead specimen, Station 345, south of Martha's Vineyard, in 71 fathoms.

A rare species, found by the U. S. Fish Commission off the coast, from Martha's Vineyard to Delaware Bay, in 94 to 188 fathoms; not living below 120 fathoms.

Two varieties of this species — *acloneta*, without transverse sculpture, and *cestrota*, with conspicuous sculpture — are recorded by Mr. Dall as found from Georgia to the West Indies, in 170 to 294 fathoms, dead.

Our specimens show marked variation in the development of the transverse sculpture, but there are none in which it is entirely wanting.

Pleurotoma (Drillia) amblytera, sp. nov.

Plate I. Figs. 5, 5 a.

Three living specimens and one dead, Station 313, off Charleston, S. C., in 75 fathoms.

Two living specimens were dredged by the U. S. Fish Commission in 1883, off Cape Hatteras, N. C., in 142 fathoms.

This species is closely related to the preceding, but has a stouter form, shorter and more rapidly tapered spire, ornamented with more conspicuous transverse ribs, with a narrower and less perceptible subsutural band, and a larger, more prominent apical whorl.

It also bears a superficial resemblance to *Drillia æpynota*, Dall (this Bulletin, XVIII. p. 96, pl. 36, fig. 10, 1889), but the fewer number of its whorls (the latter is described as having ten, yet the figure given shows only seven) and transverse ribs, with its more strongly marked striæ and conspicuous posterior sinus, will readily distinguish it.

The animal is drawn so far into the shell in all the specimens as to render the study of it impossible.

Shell consisting of eight whorls, rather thick, of a light yellow color, sometimes banded with reddish brown. The posterior sinus is nearly round, situated just below the suture, and has, in the best developed specimen, a thin, sharp edge rising a little above the surface of the shell, bending decidedly backward, then curving and nearly meeting in front. The outer lip rounds gradually to near the anterior end of the aperture, where it is slightly contracted, making a short, broad canal, then twisting abruptly backward produces a decided notch before joining the columella. A conspicuous varix is formed by the thickening of the last rib, beyond which the outer lip is thin, white, and sharp-edged. There is a prominent, tooth-like projection on the interior of the aperture, at the end of the varix, more conspicuous in some specimens than in others, and seen best in an end view. Interior of the aperture and inner lip white. Columella straight, with a conspicuous layer of enamel having a thin, free edge. Suture distinct, undulating. Subsutural band very narrow, concave, lapping well on the preceding whorl. Prominent, strong, oblique, rounded ribs, nine on the body whorl, separated by concave spaces of about the same width, cross the whorls from suture to suture, faintly defined on the subsutural band, and most prominent just below it. On the body whorl, these gradually fade away at the base of the siphon, and appear on the canal as conspicuous, much curved lines of growth. Microscopic striæ intersect the fine lines of growth, giving to the entire surface of the shell a peculiar crinkled appearance. Nucleus broad, blunt, smooth, somewhat shining, consisting of two and a half turns; the apical whorl large, rising very little above the succeeding one.

Length of the largest specimen, 15 mm.; greatest breadth, 6 mm.; length of aperture, 6 mm.

Pleurotomella Agassizii Verrill and Smith.

Verrill, Trans. Conn. Acad., V. p. 454, pl. 57, figs. 3, 3*a*, VI. p. 265, 1884.
Dall, this Bulletin, XVIII. p. 121, 1889.
Non Pleurotomella Sandersoni Dall, *loc. cit.*
Pleurotomella Agassizii Dall, Bulletin U. S. Nat. Mus., No. 37, p. 197, pl. 60, fig. 67, *non* figs. 71, 71 *a*, 1889.
Pleurotomella Agassizii var. *mexicana* Dall, this Bulletin, XVIII p. 121, 1889.
? *Mangilia Agassizii* var. *mexicana* Dall, Bulletin U. S. Nat. Mus., No. 37, p. 180, pl. 11, fig. 14, 1889.
Pleurotomella Agassizii var. *permagna* Dall, Proc. U. S. Nat. Mus., XII. p. 308, 1889.

Two living specimens and one dead, Station 305, east of George's Bank, in 810 fathoms. One dead, Station 325, off Cape Fear, N. C., in 647 fathoms. Three living (one young), Station 326, off Cape Fear, in 464 fathoms. One living and six dead (four young), Station 329, off Cape Lookout, N. C., in 603 fathoms. Two dead, Station 330, north of Cape Hatteras, N. C., in 1,047 fathoms. One living, Station 334, off Delaware Bay, in 395 fathoms. One living and two dead, Station 337, off Delaware Bay, in 740 fathoms. One living and one dead, Station 342, south of Martha's Vineyard, in 1,002 fathoms. One living, Station 343, south of Martha's Vineyard, in 732 fathoms.

A common species found by the U. S. F. C. from east of George's Bank to off Cape Hatteras, N. C., in 39 to 1,608 fathoms, not living below 1,539 fathoms.

Extending south as far as Tobago, in 202 to 880 fathoms (Dall). Living in 841 fathoms.

Mr. Dall gives the varietal name *mexicana*[1] to specimens of this species found in the Gulf of Mexico, on account of their being of small size, white, with faint color on the columella. In the hundreds of specimens from Northern waters in the F. C. collection there is great variation in form, elegance of sculpture, and purity of color. To an elongated form he gives the varietal name of *permagna*. This is a quite common form among our specimens, although I have found none that reach a length of 47 mm. Their lengths range from 30 to 40 mm.

We have the perfect young of this species in all stages of development from 5 mm. on, and I have carefully compared them with a series of *Pleurotomella Sandersoni* Verrill,[2] but do not agree with Mr. Dall in combining the two species. The large, inflated body whorl, abruptly tapered spire, small nucleus, and the comparative smoothness of the surface, are characters which ought sufficiently to distinguish the young of *P. Agassizii* from the latter, which is slender, gradually tapered, with large nucleus, and very prominent though delicate sculpture.

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[1] The figure quoted above was first published in this Bulletin, XVIII pl 11, fig. 14, as *Mangilia ipara* Dall, p. 115. Mr. Dall does not state whether the change was intentional or not.

[2] Trans. Conn. Acad., VI. pp 149, 266, pl. 31, figs. 3, 3*a*, 1884

Pleurotomella atypha, sp. nov.

Plate I. Fig. 3.

Two dead specimens, Station 325, in 647 fathoms, and one living specimen, Station 326, in 464 fathoms, off Cape Fear, N. C.

Shell rather large, solid, somewhat translucent, bluish white, with a comparatively smooth surface and little lustre. Spire unusually high, consisting of nine angularly shouldered whorls below the small, very acute, chestnut-brown nucleus. Aperture short, broad. Posterior sinus as broad as the subsutural band, rather shallow. Outer lip considerably inflated, curving gradually toward the columella without forming a decided canal. Columella nearly straight, curved slightly anteriorly, with a narrow, closely adhering strip of enamel. Suture distinct, undulating, slightly channelled. Subsutural band rather broad, oblique, somewhat concave, ornamented on the upper whorls with fine, distinct, curved riblets and lines of growth, the latter alone being visible on the two lower whorls. Just above the periphery, at the edge of the subsutural band, very narrow, sharp, slightly raised, oblique ribs, separated by very wide, slightly concave spaces, cross the whorls to the suture, and on the body whorl disappear just below the sutural line of the aperture. These ribs are most conspicuous at the shoulder, and vary considerably in different specimens, changing from the above narrow, sharp ones, with wide interspaces, to others broad and rounded, with narrower interspaces, the number on the body whorl varying from twelve to fifteen. The entire surface, except the nucleus and subsutural band, is cut by fine, shallow grooves separated by flattened spaces of unequal width ; these are deeper and coarser, or broader, on the lower part of the body whorl and canal, causing the spaces between them to appear as raised rounded threads. Nucleus long, very slender, consisting of four and a half finely reticulated light chestnut-brown whorls. The apical whorl is imperfect, but must have been very minute, judging from the size of the succeeding one.

Length of the largest specimen, destitute of the nucleus and one or two upper whorls, 30 mm. ; greatest breadth, 12 mm. ; length of aperture, 13.5 mm. ; its greatest breadth, 4 mm. A smaller specimen with a nearly perfect nucleus is 23.5 mm. long ; about 8.5 mm. broad ; width of the last nuclear whorl, 0.5 mm.

This species resembles in general appearance the elongated form of *Pleurotomella Agassizii* V. & S., but is quite different in detail. The most apparent distinguishing characters are its high, finely pointed spire and nearly smooth surface.

It is perhaps closely related to the much smaller *Pleurotomella filifera* Dall (this Bulletin, IX. p. 56, 1881 ; XVIII. p. 123, pl. 12, fig. 9, 1889). The figure quoted was evidently made from a specimen with an imperfect nucleus, as it shows but seven whorls.

Pleurotomella Jeffreysii Verrill.

Trans. Conn. Acad., VI. p. 411, pl. 44, fig. 3, 1885.

Non Pleurotoma (Defrancia) chariessa Watson, Linn. Soc. Journ., London, XV. p. 458, 1881.

Non Clathurella chariessa Watson, Chall. Voyage, Zoölogy, XV. p. 352, pl. 20, fig. 6, 1886.

Pleurotomella chariessa Dall, Bulletin U. S. Nat. Mus., No. 37, p. 191, pl. 46, fig. 3, 1889; this Bulletin, XVIII. p. 122, 1889.

? *Pleurotomella chariessa* var. *pistillata* Dall, Trans. Wagner Free Inst., III. p. 41, 1890.

Two perfect, though dead specimens, Station 308, east of George's Bank, in 1,242 fathoms. A rare species, first dredged by the U. S. F. C. in 1884, ranging from east of George's Bank to Chesapeake Bay, in 984 to 2,620 fathoms; not living in less than 1,525 fathoms. Mr. Dall records it as far south as St. Vincent, in 464 to 966 fathoms, dead.

In the F. C. collection there is nearly a complete series of this species, ranging in length from 10 to 52 mm. Among these there is considerable variation in their proportionate lengths. Two specimens, having the same number of whorls and the same width, vary in height, one measuring 38 and the other 43 mm.

Mr. Dall gives the varietal names *spica*, *phalera*, *tellea*, and *aresta*, to various deviating forms of this species found off the Southern coast. I do not agree with him in identifying this with *Clathurella chariessa* of Watson. That species is described as being about 21 mm. in length, and consisting of 10 whorls in all, of which 4½ form the nucleus. It is also said to have 20 oblique, transverse ribs on the body whorl. A perfect living young example of our species, measuring about 20 mm. in length, has but 4 whorls beside the nucleus, and but 15 ribs on the body whorl.

The figure given by Mr. Watson is certainly quite different from Professor Verrill's, especially in the degree of angularity of the shoulder, obliquity of the transverse sculpture, and in the form of the body whorl and canal.

Pleurotomella sp.

A badly worn and broken specimen, Station 329, off Cape Lookout, N. C., in 603 fathoms.

This shell bears a superficial resemblance to the young of *P. atypha*, with which it was at first combined, but after a careful study it proves to be quite different in detail. The other known species to which I notice its having any relation is *Leucosyrinx Sigsbeei* Dall (this Bulletin, XVIII. p. 76, pl. 11, fig. 10, 1889). It is impossible to decide definitely, without careful comparison of more perfect specimens.

It has a slender, elongated form, with obtusely shouldered whorls; wide, oblique subsutural band; a rather long, narrow aperture, ending in a decided canal. The shoulder of the whorls, situated at the periphery, is ornamented with rather broad, slightly angular, oblong, oblique nodules, thirteen on the penultimate whorl, separated by slightly concave, about equally wide spaces. The entire surface, except the subsutural band, is covered by raised, rounded, revolving threads of nearly uniform size, which extend over the shoulder a little way on the subsutural band, where they are a little finer and closer together than elsewhere.

Length, 22 mm.; breadth, 8 mm.; length of aperture, 10 mm.

Pleurotomella sulcifera, sp. nov.

Plate II. Fig. 4.

One living specimen, Station 325, off Cape Fear, N. C., in 647 fathoms.

Shell rather large, fusiform, rather thin, translucent white with very little lustre. It has a high, regularly tapered spire of six obtusely shouldered whorls, not counting the nucleus which is broken off, and a long, nearly straight columella and a broad, straight aperture occupying about half the length of the shell. Posterior sinus as broad as the subsutural band, shallow, slightly broken. Outer lip thin, curving very gently to join the columella with but a very slight bending in anteriorly, not forming a well-defined canal. Columella with a thin, narrow strip of enamel extending its entire length. Suture inconspicuous. Subsutural band rather broad, oblique, crossed by delicate slightly curved riblets, most distinct on the upper whorls. Narrow, oblique, angular ribs, fifteen on the body whorl, separated by rather deep, narrow spaces, cross the whorls, rising just above the periphery and not quite reaching to the suture; these are cut just above the middle by a broad, shallow groove, making them appear, especially on the body whorl, as two rows of nodules. In some positions of the shell there seems to be a second similar groove (scarcely discernible) below this one. The spiral sculpture is very irregular. On the body whorl, below the transverse ribs, there are from twenty-five to thirty shallow grooves, varying in width, and having between them flattened bands or threads. On the canal they are so close together that their interspaces appear like rounded threads; above these, about the middle of the whorl, they are very broad, and separated by equally broad flattened bands, while still above these, below the ribs, they are again narrowed and separated by flattened threads. On the ribs the grooves also vary considerably. On each side of the principal groove, a rather broad, flattened thread forms a slight crest on the summit of the ribs, and beyond the lower one of these there are two or three fine rounded threads. The principal groove is also interrupted by a rounded thread at about the middle, and two or three very faint ones above and below it. On the upper part of the ribs there are two or three unequal grooves. On the penultimate whorl there are four grooves below the principal one, separated by nearly equal spaces, with but a single rounded thread on the centre of the first or principal one. With the exception of the subsutural band, the surface is covered with microscopic striæ, which, in intersecting the inconspicuous lines of growth, give a peculiar crinkled appearance to the surface.

Length, 30 mm.; breadth, 12 mm.; length of aperture, 15.5 mm.; greatest breadth, 5.5 mm.

This species is easily distinguished by the character of its sculpture.

Pleurotomella leptalea, sp. nov.

Plate II. Figs. 5, 5 a.

One living specimen, Station 325, off Cape Fear, N. C., in 647 fathoms.

Shell of moderate size, rather stout, very thin and fragile, delicately tinted with brown below the chestnut-brown tip, consisting of four obtusely shouldered whorls besides the nucleus. Aperture long, rather broad, pinched in anteriorly, forming a moderately long, narrow canal. Outer lip badly broken, but, judging by the lines of growth, sweeps well forward from the posterior sinus, which is as wide as the subsutural band, and deepest next the suture. Columella very straight for this genus, with a narrow, very thin, closely adhering layer of enamel. Subsutural band broad, oblique, crossed by numerous very delicate curved riblets and lines of growth, most conspicuous just at the suture. At the angle of the shoulder just below the periphery there is, on the two upper whorls, a row of small nodules, which gradually disappear on the penultimate whorl and are entirely wanting on the last one. The spiral sculpture consists of narrow, shallow grooves separated by rather broad, flattened bands of nearly uniform width, which cover the entire surface except the subsutural band and nucleus. Those on the shoulder are a little closer together than elsewhere. Lines of growth rather indistinct. Nucleus large, consisting of four conspicuously reticulated, chestnut-brown whorls which increase in size very abruptly from the very small apical whorl.

Length, 12 mm.; breadth, 6 mm.; length of aperture, 7.5 mm.; greatest breadth, about 2.5 mm.

This species more closely resembles the young of *P. Emertoni* V. & S. (Trans. Conn. Acad., VI. p. 154, pl. 31, fig. 6, 1884) than any of the other known forms. It can, however, be readily distinguished by its more regularly coiled and less acute spire; less prominent transverse sculpture; and especially by the very different form of the aperture, which in *P. Emertoni* is very broad, without any clearly defined canal.

Pleurotomella Dalli, sp. nov.

Plate II. Figs. 2, 2 a.

One living specimen, Station 325, off Cape Fear, N. C., in 647 fathoms.

Shell of moderate size, rather slender, thin, white, with a waxy lustre, consisting of nine regularly coiled whorls, having a broad oblique subsutural band

and prominent transverse nodules, and on the body whorl conspicuous widely separated spiral threads. Spire about half the length of the shell, acutely conical in outline, ornamented with prominent nodules just above the sutures, and with a shining, pale yellowish brown tip. Aperture narrow, oblique. Posterior sinus deep, as broad as the subsutural band. Outer lip thin, reaching far forward, curving in anteriorly, forming a short, narrow canal, and joining the columella in a regular curve without any notch. Columella very strongly curved with a thin, ill-defined layer of enamel. Suture defined by a fine rounded thread. Subsutural band, crossed only by the very conspicuous, strongly curved lines of growth intersected by indistinct microscopic striæ, reaches to the periphery of the whorls, where prominent, nearly straight, oblong, angular, transverse nodules, fifteen on the body whorl, rise very abruptly and terminate just above the suture, and are separated by spaces about equal to their own width. On the body whorl, below the nodules, there are twelve conspicuous, raised, rounded, widely separated threads. The space between them measures about 0.5 mm.; on the canal it decreases slightly, so that the last four or five threads are a little nearer together. The lines of growth are clearly defined and, under the microscope, are everywhere intersected by indistinct striæ. Minute microscopic granules are scattered over the entire surface, scarcely discernible on the nuclear whorls. Apical whorl small, smooth, slightly raised above the next whorl, which, with the succeeding turn, forms the nucleus. These are ornamented with a fine, distinct peripheral keel, which under the microscope is found to be divided into minute beads. There is no operculum. The animal is drawn so far into the shell as to render the study of it impossible.

Length, 11 mm.; breadth, 5 mm.; length of aperture, 5.5 mm.

This is a very beautiful species, and quite distinct from any known form.

Mangilia leuca, sp. nov.

Plate I. Fig. 2.

One living specimen, Station 329, off Cape Lookout, N. C., in 603 fathoms.

Shell rather large for the genus, regularly fusiform, thin, translucent, bluish white, with a roughened surface of waxy lustre, and a shining tip of a delicate yellow tint. Spire about half the length of the shell, of seven decidedly shouldered whorls, besides the nucleus. Aperture long and narrow. Posterior sinus large and nearly round, commencing at the suture and reaching to the shoulder, cutting into the top of the varix formed by the thickening of the last transverse rib, thus showing a thickened border with the upper edge rounded but not raised above the surface of the shell, extending farther back than the inner edge and curving strongly with the lines of growth, nearly meeting in front; from this the thin outer lip reaches far forward over the aperture, leaving a very narrow opening. Near the anterior end it is pinched in slightly, then bends abruptly backward as though cut off obliquely, revealing the entire width of the canal, and, curving a little upward, forms a slight notch before joining the columella. The edge of the lip is rounded and crimped by the termination of the revolving threads. Columella with a slight sigmoid curvature and an inconspicuous layer of enamel. Suture distinct, undulating, slightly channelled. The concave subsutural band occupies about a third of the width of the upper whorls, and is crossed by fine indistinct lines of growth. Conspicuous, rather broad, angular, oblique ribs cross the whorls, scarcely evident on the subsutural band, but rise somewhat abruptly on its lower edge, forming a sharp shoulder at the periphery. There are eleven of these ribs on the body whorl, reaching to the base of the canal; these, with their equally broad, concave interspaces, are ornamented with about twenty-five conspicuously raised, uniform, rounded threads, pretty regularly separated, but a little crowded on the anterior end of the canal. On the penultimate whorl there are six of them, the first just above the shoulder and the last just above the suture. Lines of growth very indistinct. Nucleus small, shining, consisting of three and a half regularly coiled whorls, the lower one ornamented with a peripheral keel. The entire surface of the shell is covered with minute granules, closely crowded except on the nucleus, where they are somewhat scattered and discernible only under a high magnifying power.

Length, 15 mm.; breadth, about 6 mm.; length of aperture, about 7 mm.; breadth, about 2 mm.

I can find no description nor figure that bears any resemblance to this very elegant species.

Bela cancellata (MIGHELS) STIMPSON.

VERRILL, Trans. Conn. Acad., V. p. 475, pl. 43, figs. 10, 11; pl. 57, fig. 13, 1882.

One living specimen, Station 344, south of Martha's Vineyard, in 129 fathoms.

A Northern species recorded by the U. S. F. C. in small numbers from a comparatively few stations between Sable Island Bank and south of Martha's Vineyard, in 12½ to 547 fathoms; not living below 126 fathoms. It has also been recorded by Prof. Verrill from Eastport, Me., and by Prof. A. S. Packard from Labrador.

RHACHIGLOSSA.

Buccinum Sandersoni VERRILL.

Trans. Conn. Acad., V. p. 490, pl. 58, fig. 9, 1882.

One living specimen, Station 306, east of George's Bank, in 524 fathoms. One dead, Station 309, south of George's Bank, in 304 fathoms.

A rare species recorded by the U. S. F. C. from off Martha's Vineyard, in 156 to 264 fathoms; not living in less than 208 fathoms.

Buccinum cyaneum Bruguière.

Verrill, Trans. Conn. Acad., V. p. 492, pl. 43, fig. 5; pl. 58, fig. 11, 1882.

One living specimen, Station 303, east of George's Bank, in 306 fathoms.

A common Northern species found by the U. S. F. C. from north of George's Bank to southeast of Martha's Vineyard, in 26 to 471 fathoms.

Buccinum abyssorum Verrill and Smith.

Verrill, Trans. Conn. Acad., VI. p. 167, pl. 31, figs. 11, 11 *b*, 1884.

Over fifty living specimens, Station 308, east of George's Bank, in 1,242 fathoms.

A common deep-water species first found by the U. S. F. C. in 1883; ranging from east of George's Bank to off Cape Hatteras, N. C., in 49 to 1,434 fathoms; not living in less than 906 fathoms.

Sipho Stimpsonii Mörch.

Verrill, Trans. Conn. Acad., V. p. 499, pl. 57, fig. 24, 1882.

One living and five dead specimens, Station 329, off Cape Lookout, N. C., in 603 fathoms. Four living, Station 332, off Cape Hatteras, N. C., in 263 fathoms. One living, young (var. *liratulus* V.), Station 344, south of Martha's Vineyard, in 129 fathoms.

Recorded by the U. S. F. C. from Misaine Bank to off Cape Hatteras, N. C., in 16 to 471 fathoms.

Sipho pubescens Verrill.

Trans. Conn. Acad., V. p. 501, pl. 43, fig. 6; pl. 57, fig. 25, 1882.

One dead specimen, Station 309, south of George's Bank, in 304 fathoms. Over twenty living specimens, Station 310, south of Martha's Vineyard, in 260 fathoms. Over twenty living and twelve dead, Station 329, off Cape Lookout, N. C., in 603 fathoms. One dead, Station 332, off Cape Hatteras, N. C., in 263 fathoms. One living, Station 334, off Delaware Bay, in 395 fathoms. Over twenty living, Station 336, off Delaware Bay, in 197 fathoms.

A very abundant species found by the U. S. F. C. from off Misaine Bank to off Cape Hatteras, N. C., in 42 to 677 fathoms; not living in less than 57 fathoms or below 640 fathoms.

Sipho pygmæus (Gould) Verrill.

Verrill, Trans. Conn. Acad., V. pp. 501 and 505 (note), pl. 57, fig. 21, 1882.

One living specimen, Station 303, east of George's Bank, in 306 fathoms. Three living specimens and one dead, Station 310, south of Martha's Vineyard, in 260 fathoms. Over twenty-five living and dead, Station 332, off Cape Hatteras, N. C., in 263 fathoms. Nine living, Station 336, off Delaware Bay, in 197 fathoms. Nine living and twelve dead, Station 344, south of Martha's Vineyard, in 129 fathoms. One living, Station 345, south of Martha's Vineyard, in 71 fathoms. Two living, Station 346, south of Martha's Vineyard, in 44 fathoms.

A common shallow-water species recorded by the U. S. F. C. from St. Peter's Bank to off Cape Hatteras, N. C., in 10 to 1,004 fathoms.

Sipho obesus Verrill.

Trans. Conn. Acad., VI. p. 168, 1884.

One living specimen, Station 331, off Cape Hatteras, N. C., in 898 fathoms. One living, Station 340, south of Martha's Vineyard, in 1,394 fathoms.

A rare species found by the U. S. F. C. from Martha's Vineyard to off Cape Hatteras, N. C., in 102 to 859 fathoms ; not living in less than 707 fathoms or below 843 fathoms.[1]

Mr. Dall gives Florida as the most Southern limit of range of this species.

Sipho cælatus Verrill.

Trans. Conn. Acad., V. p. 506, pl. 57, figs. 19, 19 *a*, 1882.

Five living and ten dead specimens, Station 325, off Cape Fear, N. C., in 647 fathoms. Five living and four dead, Station 326, off Cape Fear, in 464 fathoms. Two living and four dead, Station 329, off Cape Lookout, N. C., in 603 fathoms. Five living, Station 334, off Delaware Bay, in 395 fathoms. Three living, Station 337, off Delaware Bay, in 740 fathoms. One dead, Station 343, south of Martha's Vineyard, in 732 fathoms.

Found in considerable numbers by the U. S. F. C. from east of George's Bank to off Cape Hatteras, N. C., in 75 to 1,537 fathoms; not living in less than 302 fathoms.

Sipho cælatus var. hebes Verrill.

Trans. Conn. Acad., VI. p. 172, 1884.

Five living and ten dead specimens, Station 329, off Cape Lookout, N. C., in 603 fathoms.

A few are recorded by the U. S. F. C. from east of George's Bank to off Chesapeake Bay, in 444 to 1,255 fathoms.

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[1] One very young living specimen is recorded from the U. S. F. C. Station 2272, off Cape Hatteras, N. C., in 15 fathoms.

Sipho cælatulus Verrill.[1]

Trans. Conn. Acad., VI. p. 172, 1884.

Plate II. Fig. 1.

Two living specimens and one dead, Station 305, east of George's Bank, in 810 fathoms. One dead, Station 307, east of George's Bank, in 980 fathoms. One living and three dead, Station 308, east of George's Bank, in 1,242 fathoms. Two dead, Station 339, off Delaware Bay, in 1,186 fathoms. One dead, Station 341, south of Martha's Vineyard, in 1,241 fathoms. One dead, Station 342, south of Martha's Vineyard, in 1,002 fathoms.

A common deep-water species found by the U. S. F. C. from east of George's Bank to off Cape Hatteras, N. C., in 326 to 1,356 fathoms.

Recorded by Mr. Dall, from off Jamaica, W. I., in 966 fathoms.

Neptunea despecta (Linné) Ad.

Verrill, Trans. Conn. Acad., V. p. 499, 1882.

One dead specimen, Station 309, southeast of Martha's Vineyard, in 304 fathoms.

A common, shallow-water, Northern species recorded by the U. S. F. C. from off St. Johns, Newfoundland, to south of Martha's Vineyard, in 34 to 471 fathoms; not living in less than 36 fathoms.

Murex (Pteronotus) pygmæus, sp. nov.

Plate I. Figs. 3, 4.

One living specimen, Station 319, off Charleston, S. C., in 262 fathoms.

Shell small, fusiform, rather thin, of a light yellow color. Whorls six, evenly and moderately rounded, ornamented with three high, thin foliaceous varices and covered with coarse revolving threads and microscopic striæ. Aperture nearly round, with a long, curved, tubular canal, and a smooth, lustrous interior. Outer lip with a slightly thickened edge, descending a little obliquely from the suture, forming a slight obtuse posterior angle, below which it is somewhat flaring and curves well round to the base of the canal, where there is another slight angle, then curves gradually outward to the end of the canal. Inner lip formed by a rather narrow, thin, lustrous layer of enamel closely adhering to the body whorl to just above the base of the canal, where it becomes detached and twists forward and over to meet the outer lip, nearly or quite

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[1] Mr. Dall, in this Bulletin, XVIII. p. 174, 1889, suggests that this species is the same as *Sipho Bocagei* Fischer, but gives no reference to description or figure. In the limited number of Mr. Fischer's papers at my command, I have been unable to find such a species, and therefore can express no opinion on the subject.

closing the canal its entire length. There is a tube corresponding to a former canal on the left of the present one for about half its length, which projects strongly outward at the end. Operculum thin, horny, amber-colored. Suture distinct, slightly channelled. Varices three, equally spaced, high, very thin, with an irregular slightly notched edge, the last one formed a little before the edge of the outer lip. Each stands a little in front of the corresponding one above, rises above the suture, laps a little on to the preceding whorl, then reaches high above with a re-entrant curve, the greatest height being in a line with the posterior angle of the aperture. When dry, the surface on the back of these and between them is without lustre, and is covered with microscopic revolving striæ crossed by inconspicuous lines of growth. There are also a few broad, widely separated, rather indistinct revolving threads, which are most apparent on the varices. These number about eight on the last varix, but the two or three lowest ones are almost imperceptible. The surface on the front of the varices is very lustrous, covered with the very thin, irregular edges of the several layers of growth; the upper revolving threads appear as broad shallow grooves. Nucleus large, of two smooth lustrous whorls, the apical one prominent and decidedly upturned.

Length, 16 mm.; breadth, including varices, 9.5 mm.; length of aperture and canal, 10.5 mm.; of canal, 5.5 mm.; greatest height of the last varix, 3.5 mm.

This is a very interesting species and quite unlike any hitherto described.

Trophon Verrillii, sp. nov.

Plate I. Fig. 16.

Two living and three dead specimens, Station 325, off Cape Fear, N. C., in 647 fathoms.

Shell of moderate size, thin, translucent, bluish white, slightly lustrous, consisting of five whorls besides the nucleus, with a rather high spire ornamented with numerous conspicuous lamellæ and revolving striæ, and a long, rather slender, nearly straight canal. Aperture very long, club-shaped. Outer lip thin, with the edge spreading outwards when forming a lamella, oblique above the shoulder, rendered slightly concave when there is a prominent spine on the shoulder, beyond which it is well rounded, curving abruptly in about the middle of the aperture, at the base of the canal, then continuing in a straight line, bending nearly at right angles to join the columella. Columella very decidedly twisted, curving outward from the point opposite the constriction of the outer lip, so that the canal is broad and open. Interior of the aperture very smooth and glassy. Suture distinct, undulating, slightly channelled. Conspicuous thin lamellæ cross the whorls, directed obliquely backwards from the suture to the periphery, below which they bend slightly forward, and on the body whorl continue to the end of the canal. The number varies from twelve to fourteen in different specimens. In some specimens these lamellæ rise into prominent spines at the shoulder, directed decidedly upward, but in others they are scarcely perceptible. The entire surface is covered with microscopic revolving striæ, more distinct in some specimens than in others, crossing the obscure lines of growth. Nucleus large, smooth except for the microscopic striæ, shining, consisting of one and a half turns, with a large, rather prominent apical whorl.

Length of the largest specimen, which is broken at the tip, 18.5 mm.; breadth, 8.5 mm.; length of aperture, 11 mm.; its breadth, about 3.5 mm.; length of canal, about 6.5 mm. Length of a smaller, perfect specimen, 14.5 mm.; greatest breadth, about 7 mm.; length of aperture, 9 mm.; its breadth, 2.5 mm.; length of canal, about 4.5 mm.

Trophon clavatus Sars, *T. abyssorum* Verrill and its variety *limicola* Verrill, *T. aculeatus* Watson, and *Boreotrophon* (*aculeatus* Watson, var.?) *lacunellus* Dall, are all related to the present species.[1] A careful study of their descriptions and figures, however, reveals marked differences in their size, number of whorls, character and number of lamellæ, and presence or absence of spiral sculpture. *T. aculeatus* Watson is doubtless most readily distinguished by the distinct angulation or keel at the shoulder of the whorls.

Anachis Haliæeti (Jeffreys).

Anachis costulata Verrill, Trans. Conn. Acad., V. p. 513, pl. 43, fig. 7, 1882.
Anachis Haliæeti Verrill, *op. cit.*, VI. p. 252, 1884.
Dall, Bulletin U. S. Nat. Mus., No. 37, p. 116, 1889.

One living specimen, Station 310, south of Martha's Vineyard, in 260 fathoms. One living, Station 336, off Delaware Bay, in 197 fathoms.

Common in the U. S. F. C. collection from Cashe's Ledge to off Cape Hatteras, N. C., in 48 to 1,537 fathoms; not living in less than 52 fathoms.

Astyris diaphana Verrill.

Verrill, Trans. Conn. Acad., V. p. 513, pl. 58, fig. 2, 1882.
Dall, this Bulletin, XVIII. p. 191, pl. 35, fig. 9, 1889; Bulletin U. S. Nat. Mus., No. 37, p. 118, pl. 35, fig. 9, 1889.

One living specimen, Station 321, off Charleston, S. C., in 233 fathoms.

A comparatively rare species found by the U. S. F. C. from south of Martha's Vineyard to off Cape Hatteras, N. C., in 64 to 487 fathoms; not living in less than 100 fathoms. Mr. Dall records it as far south as the Gulf of Mexico, in 196 fathoms, dead.

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[1] G. O. Sars, Moll. Reg. Arct. Norvegiæ, p. 249, pl. 15, fig. 12; pl. 23, fig. 14; pl. 9, fig. 17, 1878. Verrill, Trans. Conn. Acad., VI. p. 421, 1885. Watson, Chall. Voyage, Zoölogy, XV. p. 169, pl. 10, fig. 9, 1886. Dall, this Bulletin, XVIII. p. 205, pl. 15, fig. 4, 1889.

TÆNIOGLOSSA.

Natica clausa Brod. and Sowerby.

One living specimen, Station 303, east of George's Bank, in 306 fathoms.

Found by the U. S. F. C. in both shallow and deep water from off St. Johns, Newfoundland, to off Cape Hatteras, N. C., in 16 to 1,537 fathoms. Found also by the Stearns Expedition on the coast of Labrador, in 1 to 8 fathoms.

Lunatia heros (Say) H. & A. Ad.

One living and five dead specimens, Station 345, south of Martha's Vineyard, in 71 fathoms.

Recorded by the U. S. F. C. from east of Banquereau to off Cape Hatteras, N. C., from the shore to 238 fathoms. Also recorded, by Mr. J. F. Whiteaves, from the Gulf of St. Lawrence, and by Prof. A. S. Packard, from Labrador.

Lunatia Grönlandica (Möll.) Ad.

One dead specimen, Station 310, south of Martha's Vineyard, in 260 fathoms. Two dead specimens, Station 325, off Cape Fear, N. C., in 647 fathoms. One living, Station 332, off Cape Hatteras, N. C., in 263 fathoms.

Found in both shallow and deep water by the U. S. F. C. from off Cape Race, Newfoundland, to off Cape Hatteras, N. C., in 8 to 1,356 fathoms. Also found by the Stearns Expedition on the coast of Labrador, in 3 to 8 fathoms.

Crucibulum striatum (Say) H. & A. Ad.

Fourteen living specimens, Station 345, south of Martha's Vineyard, in 71 fathoms. One living, Station 347, off Montauk Point, L. I., in 24 fathoms.

A common shallow-water species found by the U. S. F. C. from the Bay of Fundy to off Cape Hatteras, N. C., from the shore to 231 fathoms; not living below 67 fathoms.

Recorded by Mr. Dall from off Sand Key, Florida, in 128 fathoms, dead.

Aporrhais occidentalis Beck.

One dead specimen, Station 309, south of George's Bank, in 304 fathoms. Nine dead specimens, Station 310, south of Martha's Vineyard, in 260 fathoms.

A very common species found by the U. S. F. C. from St. Johns, Newfoundland, to off Cape Hatteras, N. C., in 20 to 1,000 fathoms ; not living below 349 fathoms. Recorded by Mr. J. F. Whiteaves, from the Gulf of St. Lawrence, and found by the Stearns Expedition on the coast of Labrador, in 2 to 20 fathoms.

GYMNOGLOSSA.

Turbonilla Rathbuni VERRILL and SMITH.

VERRILL, Trans. Conn. Acad., V. p. 536, pl. 58, fig. 15, 1882.

Three dead specimens, Station 310, south of Martha's Vineyard, in 260 fathoms.

A rare species found by the U. S. F. C. from off Martha's Vineyard to off Cape Hatteras, N. C., in 64 to 547 fathoms; not living in less than 100 fathoms or below 365 fathoms.

RHIPIDOGLOSSA.

Calliostoma occidentale (MIGH.).

Three living specimens, Station 302, east of George's Bank, in 73 fathoms. One living, Station 307, east of George's Bank, in 980 fathoms. One living, Station 310, south of Martha's Vineyard, in 260 fathoms.

A Northern species found by the U. S. F. C. from northwest of Flemish Cap (Station 2697) to south of Martha's Vineyard, in 27 to 640 fathoms. Also found by Professor Verrill at Eastport, Me., and Grand Menan, N. B.

Calliostoma Bairdii VERRILL and SMITH.

VERRILL, Trans. Conn. Acad., V. p. 530, pl. 57, fig. 26, 1882.

Seven living specimens, Station 345, south of Martha's Vineyard, in 71 fathoms.

Recorded by the U. S. F. C. from off Martha's Vineyard to off Cape Hatteras, N. C., in 43 to 640 fathoms; not living in less than 64 fathoms or below 192 fathoms. Also recorded by Mr. Dall from the coast of Florida, in 100 to 200 fathoms, dead.

Margarita (Solariella) Ottoi PHILIPPI.

Margarita regalis Verrill, Amer. Journ. Sci., XX. p. 397, 1880; Proc. U. S. Nat. Mus., III. p. 378, 1880; Trans. Conn. Acad., V. p. 530, pl. 57, fig. 37, 1882; VI. p. 254, pl. 29, fig. 14, 1884.

Solariella Ottoi Dall, this Bulletin, XVIII. p. 381, 1889.

One living specimen, Station 305, east of George's Bank, in 810 fathoms. One dead, Station 306, east of George's Bank, in 524 fathoms. One living and two dead, Station 307, east of George's Bank, in 980 fathoms. One dead, Station 343, south of Martha's Vineyard, in 732 fathoms.

Recorded by the U. S. F. C. from east of George's Bank to off Cape Hatteras, N. C., in 63 to 1,594 fathoms; not living in less than 193 fathoms; and by Mr. Dall as far south as Grenada, in 416 fathoms, dead.

Mr. Dall has been able to decide definitely, by the comparison of authentic specimens, the question suggested by Mr. Jeffreys in 1883, as to whether the recent and fossil forms were not identical; but I notice that, in his more recent report on the "Albatross" mollusks (Proc. U. S. Nat. Mus., XII. p. 352, 1889), he retains *regalis* as a varietal name.

Margarita (Solariella) infundibulum WATSON, var. Diomedeæ VERRILL, nov.

Trochus (*Margarita*) *infundibulum* Watson, Journ. Linn. Soc., London, XIV. p. 707, 1879; Chall. Voyage, Zoölogy, XV. p. 84, pl. 5, fig. 5, 1885.

Solariella infundibulum Dall, this Bulletin, XVIII. p. 380, 1889; Bulletin U. S. Nat. Mus., No. 37, p. 164, 1889; Proc. U. S. Nat. Mus., XII. p. 349, pl. 9, fig. 3, 1889 (Anatomy).

Plate II. Figs. 10 and 11.

One living specimen, Station 308, east of George's Bank, in 1,242 fathoms. One living, Station 340, south of Martha's Vineyard, in 1,394 fathoms.

A rare and beautiful deep-water species first dredged by the U. S. F. C. in 1883, ranging from east of George's Bank to off Cape Hatteras, N. C., in 679 to 1,782 fathoms.

Mr. Dall extends the range as far south as Brazil, in 769 to 860 fathoms, dead.

This variety differs from the typical form described by Mr. Watson chiefly in having two, and sometimes three, sharply tuberculated carinæ on all the whorls except those of the nucleus, and also in having on the base four nearly equally spaced, finely crenulated carinæ, besides a fifth which defines the umbilicus and is more strongly crenulated than the others; in some specimens it is sharply tuberculated.

Professor Verrill has kindly permitted me to give the following description, which was prepared by him from specimens in the collection of the U. S. F. C., but has not as yet been published: —

"Shell white, iridescent, large for the genus, with an elevated conical spire, consisting of about eight whorls, which are well rounded and ornamented with two (rarely three) tuberculated carinæ. Suture rather deep, sometimes slightly chanelled. Base convex and swollen, with a large umbilicus and ornamented with five (rarely six) prominent spiral lines or carinæ, which are usually separated by concave interspaces of nearly equal breadth; when there are six carinæ the interspaces become unequal. The outermost carina coincides with the posterior edge of the lip; the innermost one forms the border of the umbilicus, and is usually surmounted by a series of small, blunt tubercles formed by the crossing of the lines of growth; the outer three or four carinæ are usually more or less distinctly crenulated where they are crossed by the lines of growth, which are very distinct, and have the form of raised, rounded ridges in the interspaces, and increase in prominence toward the umbilicus. Above the line of the suture on the lower whorls there are two, or sometimes three, prominent revolving carinæ, which are regularly covered with prominent, subacute tubercles or denticulations, which vary considerably in number, prominence, and thickness. In the more common form, with the larger tubercles, there are on the body whorl about twenty-five to thirty tubercles on each carina, in other specimens forty, and in one case there are as many as sixty very small ones. The interspaces are broad, flattened, or even concave when the carinæ are very prominent. The whole surface is usually crossed by numerous oblique, distinctly raised, unequal lines of growth, of which the more prominent, in crossing the carinæ, form the tubercles. On the upper whorls the lines of growth are less distinct than on the lower, and sometimes scarcely obvious except close to the carinæ; in such specimens the middle of the interspaces is nearly smooth and iridescent. The nucleus is prominent, the apical whorl being slightly upturned, rounded, smooth and white; the second and third whorls are crossed by raised transverse ribs, and the revolving carinæ become distinct on the third whorl. The umbilicus is large, deep funnel-shaped, showing the volutions, bordered by a distinctly tuberculated carina, and covered, on the inner surface, by very regular and prominent sharp lines of growth, which become crowded within. Aperture nearly round, except where slightly notched beneath the carinæ; columella lip slightly excurved over the upper part of the umbilicus. In fresh specimens the surface is sometimes partially covered by a very thin, brownish yellow epidermis, which easily peels off, leaving the shell beautifully iridescent; inner surface pearly white. Operculum circular, thin, pale yellow.

"Height, 22 mm.; breadth, 19 mm. Another specimen measures, in height, 21 mm.; breadth, 19.5 mm."

Ganesa sp.

VERRILL, Trans. Conn. Acad., VI. p. 201, 1884.

One dead specimen, Station 307, east of George's Bank, in 980 fathoms.

Puncturella sp.

A very much worn and broken specimen, Station 321, off Charleston, S. C., in 233 fathoms.

Although so imperfect, this specimen is of interest in being the only one of this genus in the collection, and also in being quite distinct from *P. noachina*.

It is rather low and broad, with the posterior slope slightly oblique, the beak prominent, curving well over, with about two smooth whorls standing out on the right side. The anterior slope is convex, with a long and rather broad, partly closed slit tapered to a narrow point at the upper end, and reaching well up on the beak. The sculpture consists of radiating, well rounded, alternately larger and smaller ribs, crossed and rendered somewhat nodulose by rather regular concentric lines or threads. Interior smooth, with plain margin.

HETEROPODA.

Atlanta Peronii Les.

Verrill, Trans. Conn. Acad., V. p. 529, 1882; VI. pl. 28, figs. 4, 4 *a*, 1884.

A fragment, Station 325, off Cape Fear, N. C., in 647 fathoms.

A not uncommon pelagic species recorded by the U. S. F. C. from east of George's Bank to off Cape Hatteras, N. C. Dead shells in 16 to 1,825 fathoms; living at the surface.

Extending south to Bermuda (Dall).

TECTIBRANCHIATA.

Scaphander nobilis Verrill.

Trans. Conn. Acad., VI. p. 209, pl. 32, figs. 18–18 *d*, 1884.

Two living and three dead specimens, Station 308, east of George's Bank, in 1,242 fathoms.

A rare deep-water species first found by the U. S. F. C. in 1883, ranging from east of George's Bank to off Delaware Bay, in 705 to 1,742 fathoms; not living below 1,434 fathoms.

Mr. Dall records this species from the Gulf of Mexico and off Tobago, in 880 and 1,639 fathoms, dead.

Scaphander puncto-striatus (Migh.) Ad.

Three living specimens and one dead (young), Station 303, east of George's Bank, in 306 fathoms. One dead, Station 305, east of George's Bank, in 810 fathoms. One living, Station 306, east of George's Bank, in 524 fathoms. Three dead (two young), Station 308, east of George's Bank, in 1,242 fathoms. One dead, Station 309, south of George's Bank, in 304 fathoms. Two living, Station 310, south of Martha's Vineyard, in 260 fathoms. Four dead (one young), Station 331, off Cape Hatteras, N. C., in 898 fathoms. Two living, Station

332, off Cape Hatteras, in 263 fathoms. Eighteen living and three dead (young), Station 336, off Delaware Bay, in 197 fathoms. One living, Station 338, off Delaware Bay, in 922 fathoms. One dead (young), Station 342, south of Martha's Vineyard, in 1,002 fathoms.

A very abundant species found by the U. S. F. C. from Flemish Cap to off Cape Hatteras, N. C., in 11 to 1,467 fathoms; not living below 1,356 fathoms.

Mr. Dall extends the range south to the Barbados, in 288 to 533 fathoms, dead.

Cylichna vortex Dall.

Utriculus (?) *vortex* Dall, this Bulletin, IX. p. 100, 1881; XVIII. p 47, pl. 17, fig. 3, 1889.

Non Cylichna (?) *Dalli* Verrill, Trans. Conn. Acad., V. p. 542, 1882; VI. p. 274, pl. 29, fig. 15, 1884.

One dead specimen, Station 305, east of George's Bank, in 810 fathoms. One living, Station 307, east of George's Bank, in 980 fathoms.

Found by the U. S. F. C. from east of George's Bank to off Chesapeake Bay, in 326 to 1,356 fathoms; not living in less than 984 fathoms, or below 1,290 fathoms.

In studying the specimens labelled *Cylichna Dalli* in the F. C. collection I found some confusion in the identification, and that two similar but distinct forms had been placed under that name: *Cylichna Dalli* Verrill and *Cylichna vortex* Dall.

The differences in the two species are clearly shown in the figures quoted above. *C. Dalli* is most readily distinguished by its "strongly excavated and sinuous" columella, which forms anteriorly a distinct fold or tooth-like projection where it joins the strongly curved outer lip; while *C. vortex* has a gently curved columella, passing "imperceptibly" into the outer lip without "twist or fold."

In this species the apical whorl is smooth, upturned, and sunken in a shallow pit formed by the two succeeding whorls, one rising a little above the other, with a slightly rounded sutural margin. In some specimens these are so closely coiled as nearly to conceal the nucleus, while in others each turn is visible. The following turns are more loosely coiled, and the outer lip joins the body whorl a little below the apex of the shell.

Some of the F. C. specimens are considerably larger than Mr. Dall's types, and more slender in proportion to their length.

One perfect specimen is 16½ mm. long and 8 mm. broad; another worn and broken one is about 29 mm. long and 13 mm. broad; while still another is 23 mm. long and 11 mm. broad.

A careful study of the radula and gizzard shows that the correct position of the species is with the *Cylichnæ*.

The radula consists of a series of strongly hooked, dark amber teeth, the lateral ones with broad curved bases and the marginal ones with simple straight bases, arranged in rows of five or seven on each side of the minute median tooth. In small specimens these hooks are distinctly roughened on the under surface by fine, raised, longitudinal lines. The three plates of the gizzard are club-shaped, with a yellow-white flattened exterior surface and a dark reddish brown convex interior surface, the greatest convexity situated beyond the middle, in the broader end, with a little flattened space in front defined by a lighter shade of color.

Diaphana (?) Lottæ, sp. nov.

Plate II. Figs. 8 and 9.

One dead specimen, Station 329, off Cape Lookout, N. C., in 603 fathoms.

Shell rather large, short and stout, abruptly tapered at the ends, truncate at the top with the two whorls of the spire showing in a shallow pit; translucent, yellowish white, with a slightly lustrous surface covered with distinct punctate spiral lines. The outer lip rises considerably above the level of the body whorl, arches well forward, and follows the curvature of the body whorl to near the base, where it is a little expanded, and joins the columella in a broad curve. The inner lip is formed by a rather wide, closely adhering layer of enamel, which is considerably thickened on the columella, spreading out over the umbilical region with a thick, free outer edge. The spiral lines are distinct and rather coarsely punctate, a little crowded on the apex of the shell, nearly uniformly separated to just below the centre (five to the millimeter), where there are two quite fine, widely separated ones, below which they become again coarser and considerably crowded on the base. Epidermis thin, very slightly tinged with yellow. Lines of growth inconspicuous.

Length of shell, 8 mm.; breadth, 5.5 mm.; length of aperture, 8.5 mm.

A smaller, somewhat worn specimen (No. 45,604), differing from the above only in having fewer spiral lines, was dredged by the U. S. F. C. in 1882, at Station 1142, off Martha's Vineyard, in 322 fathoms.

This species bears considerable resemblance to *Cylichna occulta* Migh. & Ad.; but that is a much smaller and more slender species, more gradually tapered toward the ends, with finer and more numerous spiral lines.

This species is named in honor of Miss Charlotte E. Bush, who has rendered valuable assistance in assorting and tabulating the specimens in this collection.

SCAPHOPODA.

Dentalium solidum Verrill.

Verrill, Trans. Conn. Acad., VI. p. 215, 1884, pl. 44, figs. 16, 17, 1885.

Three living specimens, Station 305, east of George's Bank, in 810 fathoms. Eight dead (seven young), Station 307, east of George's Bank, in 980 fathoms. One living and ten dead, Station 308, east of George's Bank, in 1,242 fathoms. One young, dead, Station 325, off Cape Fear, N. C., in 647 fathoms. One living, Station 331, off Cape Hatteras, N. C., in 898 fathoms. Three living, Station 338, off Delaware Bay, in 922 fathoms. Four living and one dead, Station 339, off Delaware Bay, in 1,186 fathoms. One dead, Station 341, south of Martha's Vineyard, in 1,241 fathoms. Four living and one dead, Station 342, south of Martha's Vineyard, in 1,002 fathoms.

A common deep-water species first found by the U. S. F. C. in 1883, ranging from east of George's Bank to off Cape Hatteras, N. C., in 662 to 1,825 fathoms. Mr. Dall also records it from off the coast of Brazil, in 1,019 fathoms, dead.

It is with considerable hesitation that I retain the name *solidum* for this species, as Mr. Dall states,[1] with much positiveness, that our species is identical with Mr. Jeffreys's types of *Dentalium candidum*. But the descriptions and figures of the two species are so markedly different in their principal characters, that I cannot accept the identification without question.

Our specimens are large (about 3 inches long), robust, thick, and strong, with numerous, very distinct lines of growth, and, toward the posterior half, with marked, but shallow, longitudinal striations, or small impressed grooves, separated by slightly convex spaces, varying in width, and have the anterior aperture large, circular, moderately oblique, with plain, thin, sharp edge, and the posterior one small, pear-shaped, with a rather deep notch on the dorsal side, and a shallower, more rounded one beneath (all of which characters seem to be constant even in the perfect young). If specimens labelled *D. candidum* in the Jeffreys collection are like these, I do not see how they can agree with the description given by Mr. Jeffreys in Ann. Mag. Nat. Hist., p. 153, 1877, or with the figure in Proc. Zoöl. Soc., London, pl. 49, fig. 2, 1882, which agrees well with the description, especially in the character of the longitudinal sculpture. Mr. Jeffreys states that his species is thin, opaque, about 1.75 inches long, with about forty fine and regular rounded longitudinal striæ (I should judge from the figure that he must have meant threads or ribs) disappearing towards the front margin, crossed by extremely numerous microscopic circular lines. The anterior end broad and jagged; the posterior abruptly truncated, without notch, groove, slit, or channel.

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[1] *Dentalium candidum* Dall, this Bulletin, XVIII. p. 422, 1889; Proc. U. S. Nat. Mus., XII. p. 294, 1889.

Mr. Dall's statement, that, judging from the figure, one would not anticipate the two species being identical, leads me to think that there may possibly have been some confusion in the labelling of the specimens, or there may be two species under the same name.

Dentalium occidentale, var. *sulcatum* Verrill (Trans. Conn. Acad., VI. p. 217, 1884) resembles, as already stated by Professor Verrill, the descriptions and figure of *D. candidum.*

Dentalium striolatum Stimp.

One living specimen, Station 329, off Cape Lookout, N. C., in 603 fathoms.

A very abundant species found by the U. S. F. C. from Flemish Cap to off Cape Hatteras, N. C., in 6 to 1,255 fathoms; not living in less than 35 fathoms.

Dentalium occidentale Stimp.

Verrill, Trans. Conn. Acad., V. pl. 42, figs. 16–18, 1882.

Nine living and seven dead specimens, Station 329, off Cape Lookout, N. C., in 603 fathoms. Four living, Station 336, off Delaware Bay, in 197 fathoms.

An abundant species found by the U. S. F. C. from east of Banquereau to off Cape Hatteras, N. C., in 26 to 1,356 fathoms; not living in less than 51 fathoms. Recorded by Mr. J. F. Whiteaves from the Gulf of St. Lawrence.

Siphodentalium vitreum M. Sars?

Verrill, Trans. Conn. Acad., V. p. 557, pl. 42, fig. 19, 1882.

One dead specimen, Station 325, off Cape Fear, N. C., in 647 fathoms.

A very rare species found by the U. S. F. C. from south of Martha's Vineyard to Chesapeake Bay, in 368 to 811 fathoms; not living below 368 fathoms. Also recorded by Mr. J. F. Whiteaves from the Gulf of St. Lawrence.

The above specimen has been broken and evidently repaired by the animal, so that it is somewhat distorted, and does not agree perfectly with authentic specimens of this species from the north.

PTEROPODA.

Cavolina tridentata (Forskål).

Verrill, Trans. Conn. Acad., V. p. 554, figs. 6, 7, 1882.

One dead specimen, Station 303, east of George's Bank, in 306 fathoms. One dead, Station 308, east of George's Bank, in 1,242 fathoms. A fragment, Station 321, off Charleston, S. C., in 233 fathoms. Four dead specimens, Station 325, off Cape Fear, N. C., in 647 fathoms. One dead, Station 336, off Cape Fear, N. C., in 464 fathoms. One dead, Station 329, off Cape Lookout, N. C., in 603 fathoms. One dead, Station 340, south of Martha's Vineyard, in 1,394 fathoms. One dead, Station 344, south of Martha's Vineyard, in 129 fathoms.

An abundant pelagic species found by the U. S. F. C. from east of George's Bank to off Cape Hatteras, N. C. Dead shells in 16 to 2,620 fathoms; living at the surface.

Extending south to the Republic of Buenos Ayres.

Cavolina uncinata (Rang).

Verrill, Trans. Conn. Acad., V. p. 554, 1882.

Two dead specimens, Station 321, off Charleston, S. C., in 233 fathoms. One dead, Station 325, off Cape Fear, N. C., in 647 fathoms.

A common pelagic species found by the U. S. F. C. from east of George's Bank to off Cape Hatteras, N. C. Dead shells in 16 to 1,859 fathoms; living at the surface.

Extending south to Brazil.

Cavolina longirostris Les.

Verrill, Trans. Conn. Acad., V. p. 555, 1882.

One dead specimen, Station 321, off Charleston, S. C., in 233 fathoms.

A very abundant pelagic species recorded by the U. S. F. C. from east of George's Bank to off Cape Hatteras, N. C. Dead shells in 15 to 2,574 fathoms; living at the surface.

Extending south to Brazil.

Cavolina gibbosa (Rang).

Verrill, Trans. Conn. Acad., VI. p. 213, 1884.

Two dead specimens, Station 325, off Cape Fear, N. C., in 647 fathoms.

A rare pelagic species recorded by the U. S. F. C. from south of George's Bank to off Cape Hatteras, N. C. Dead shells in 193 to 2,620 fathoms; living at the surface.

Extending south to the Republic of Buenos Ayres.

Diacria trispinosa (Les.).

Verrill, Trans. Conn. Acad., VI. p. 275, 1884.

Three dead specimens, Station 321, off Charleston, S. C., in 233 fathoms. Two dead, Station 325, off Cape Fear, N. C., in 647 fathoms. Two dead, Station 326, off Cape Fear, in 464 fathoms.

A common pelagic species recorded by the U. S. F. C. from Sable Island Bank to off Cape Hatteras, N. C. Dead shells in 15 to 2,620 fathoms; living at the surface.

Extending south to the Republic of Buenos Ayres.

Clio pyramidata Linné.

Verrill, Trans. Conn. Acad., V. p. 555, 1882.

Four dead specimens, Station 321, off Charleston, S. C., in 233 fathoms. Two dead, Station 325, off Cape Fear, N. C., in 647 fathoms.

A rather common pelagic species recorded by the U. S. F. C. from off Nova Scotia to off Cape Hatteras, N. C. Dead shells in 16 to 2,033 fathoms; living at the surface.

Extending south to the Republic of Buenos Ayres.

LAMELLIBRANCHIATA.

Cuspidaria glacialis (Sars) Dall.

Neæra glacialis Verrill, Trans. Conn. Acad., V. p. 562, pl. 44, fig. 10, *a*, *b*, 1882.
Cuspidaria glacialis Dall, this Bulletin, XII. pp. 294, 303, 1886; XVIII. p. 444, 1889; Bulletin U. S. Nat. Mus., No. 37, p. 66, 1889.

One living specimen, Station 310, southeast of Martha's Vineyard, in 260 fathoms. Seven living, and five valves, Station 332, off Cape Hatteras, N. C., in 263 fathoms. Nine large living and four dead specimens, Station 336, off Delaware Bay, in 197 fathoms. Two living, Station 344, south of Martha's Vineyard, in 129 fathoms.

A common species found by the U. S. F. C. from west of St. Peter's Bank to off Chesapeake Bay, in 6 to 828 fathoms; not living below 568 fathoms. Also dredged in the Bay of Fundy.

Mr. Dall extends the range south to the Gulf of Mexico, in 1,467 fathoms; dead.

Cardiomya sp.[1]

A single left valve, Station 321, off Charleston, S. C., in 233 fathoms.

This specimen is badly broken, but shows an oblique, inflated form, with a very short, ill-defined, upturned rostrum, and a nearly smooth, slightly lustrous surface. On the posterior end there are several rather inconspicuous angular ribs. Two principal ones diverge from the beak to the margin. The upper one defines the rostrum, and has above it three fine, little raised radiating lines, which commence about half-way down from the beak and reach to the end of the rostrum. The second or lower rib has two or three shorter ones above and below it, which commence, as the lines on the rostrum, half-way down from the beak, and extend to the margin, which they make a little fluted. These ribs appear as shallow grooves on the interior of the valve. The rest of the surface is crossed only by indistinct, unequal lines of growth.

Length, 9 mm; height, 7 mm.

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[1] Dall, this Bulletin, XII. p. 296, 1886.

This species, which is quite distinct from any of our Northern forms, seems to be most nearly related to *Cardiomya costellata* Deshayes[1]; but is too imperfect to identify with certainty.

Myonera paucistriata Dall.

Dall, this Bulletin, XII. p. 302, 1886; XVIII. p. 445, 1889; Bulletin U. S. Nat. Mus., No. 37, p. 68, 1889; Proc. U. S. Nat. Mus., XII. p. 283, pl. 13, fig. 12, 1889.
Non Neæra paucistriata Bush, Trans. Conn. Acad., VI. p. 473, 1885.

Plate II. Fig. 18.

A badly smashed but living specimen, Station 325, off Cape Fear, N. C., in 647 fathoms.

Recorded by Mr. Dall as ranging from off Cape Fear, N. C., to off Tobago, in 193 to 880 fathoms; living in 339 to 464 fathoms.

I regret having to call attention to the inaccuracy in the synonymy of this species. Specimens from shallow water off Cape Hatteras, N. C., were forwarded to me from Washington under the manuscript name of *Neæra paucistriata* Dall, which name I accepted for my paper, quoted above, without question. The true *Myonera paucistriata* proves to be a quite different species.

The shallow-water species is small, with an oblique, inflated form, and a well developed, upturned, gaping rostrum. It is ornamented on the posterior half with three or four conspicuous, divergent, radiating ribs, and a few faint riblets, crossed by numerous concentric undulations, which are most clearly defined on the anterior half of both valves. It should be placed under the subgenus *Cardiomya*, and may possibly be the *C. costellata* of Deshayes, recorded by Mr. Dall from the same locality.

Periploma abyssorum Verrill. (?)

Plate II. Figs. 12 and 13.

The broken left valve[2] of a young specimen, Station 332, off Cape Hatteras, N. C., in 263 fathoms.

A very large, new, and rare species recorded by the U. S. F. C. from east of Banquereau to off Chesapeake Bay, in 101 to 1,255 fathoms; not living in less than 906 fathoms.

Professor Verrill has kindly permitted me to give the following description, which was prepared by him from specimens dredged by the U. S. F. C., but has not as yet been published: —

"Shell large, broad, rather depressed, thin and delicate, but not very translucent, nearly equivalved, gaping somewhat posteriorly, the posterior end being bent a little to the right. The beaks are considerably behind the middle,

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[1] Dall, this Bulletin, XII. p. 297.

[2] This fragment is hardly worthy of mention, but in the characters which are preserved agrees fairly well with the young of the above mentioned species in the F. C. collection.

acute, and turned directly inward, with a long, narrow ligamental furrow on the posterior side, which on the inner surface extends far inward in a transverse direction, as a narrow dark brown groove with a raised margin on each side. The antero-dorsal margin is a little convex, and broadly arched anteriorly, with a wave-like inbending of the margin below corresponding to a broad shallow depression extending from the umbos to the edge. The ventral margin is very broadly and evenly rounded, separated from the posterior region by a distinct, wave-like incurvature, corresponding to a double furrow running from the posterior side of the beak to the margin. The posterior region is a little prolonged and subtruncate at the end. The postero-dorsal margin slopes from the beak and is nearly straight, joining the posterior margin in a rounded angle.

"The cartilarge pit is moderately large, thick and strong, spoon-shaped or ovate, and curved obliquely backward, with the cartilage area in the form of a wedge-shaped depression; the plate is supported by a broad, thin rib, which runs from its inner surface inward and somewhat backward for a considerable distance; another much smaller rib runs from its posterior surface backward to the margin, leaving a triangular cavity between it and the principal rib. The pallial sinus is moderately large and deep, extending directly backward from the posterior tip, tapering and terminating in a bluntly rounded end. The inner surface, somewhat pearly and slightly concentrically waved, is also marked with rather indistinct radiating lines. The external surface is covered with rather conspicuous and narrow, unequal, concentric grooves and lines of growth; anteriorly there is a broad shallow transverse undulation, while posteriorly a narrow shallow depression, defined by two distinct furrows, curves from the beak to the posterior ventral margin; farther back a small, distinctly raised ridge extends from the posterior side of the beak to the posterior end; the area between this and the dorsal margin is covered by numerous fine radiating lines, not distinctly visible without a lens. The epidermis is thin and closely adherent, with irregular, raised, fibrous, concentric lines in some parts, especially on the posterior area.

"Length, 40 mm.; height from ventral margin to beak, 31 mm.; breadth, 16 mm.; length from beak to anterior end, 23 mm.; to posterior end, 15 mm.; length of cartilage plate, 3 mm.; length of internal rib, 9 mm.; its greatest breadth, 2 mm.; length of pallial sinus, 18 mm.; its breadth in middle, 8 mm."

Periploma fragilis (Totten).

Anatina papyratia Totten, Am. Journ. Sci., XXVIII. p. 347, pl. fig. 1, *a*, *b*, *c*, *d*, 1835.
Periploma fragilis Conrad, Am. Journ. Conch., II. p. 106, 1866.
Anatina papyracea Gould, Invert. Mass., Binney's ed., p. 66, fig. 382, 1870.
Periploma papyracea Verrill, Invert. Anim. Vineyard Sd., p. 379, pl. 27, fig 197, 1874; Trans. Conn. Acad., VI. p. 277, 1884.
Periploma fragilis Dall, this Bulletin, XII. p. 306, 1886; Bulletin U. S. Nat. Mus., No. 37, p. 64, pl. 59, fig. 7, 1889.

Nine living specimens and two valves, Station 344, south of Martha's Vineyard, in 129 fathoms.

A rather common shallow-water species, rare in deep water, recorded by the U. S. F. C. from Eastport, Me., to off Delaware Bay, in 5 to 321 fathoms. Also found by the Stearns Expedition on the coast of Labrador, in 10 to 15 fathoms, and recorded by Mr. Whiteaves from the Gulf of St. Lawrence, and by Mr. Dall as far south as the West Indies ; bathymetrical range not given.

Mr. Dall, in his recent report, calls attention to the fact that the true *P. papyracea* Say is quite distinct from the Northern form described by Mr. Totten, and given the provisional name *Anatina fragilis*.

Abra æqualis Say.

Verrill, Trans. Conn. Acad., V. p. 568, 1882.

A somewhat worn left valve, Station 321, off Charleston, S. C., in 233 fathoms.

Recorded from Stonington, Conn., in the stomachs of cod (Linsley).

A Southern species, detached valves of which are recorded by the U. S. F. C. from off Cape Hatteras, N. C., in 13 to 48 fathoms ; and one living specimen in 14 fathoms. Recorded by Mr. Dall as far south as the Gulf of Mexico ; bathymetrical range not given.

Macoma sabulosa (Speng.) Mörch.

One living specimen, Station 310, south of Martha's Vineyard, in 260 fathoms.

A common species found by the U. S. F. C. from off St. Johns, Newfoundland, to off Cape Hatteras, N. C., in 6 to 1,255 fathoms ; by Prof. A. S. Packard and the Stearns Expedition on the coast of Labrador, in 1 to 15 fathoms; and by Mr. Dall on the coast of Florida as *M. proxima ;* bathymetrical range not given.

Cyprina Islandica (Linné) Lam.

One living specimen, Station 347, off Montauk Point, L. I., in 24 fathoms.

A common species found by the U. S. F. C. from the Bay of Fundy and off Nova Scotia, to off Cape Hatteras, N. C., in 7 to 264 fathoms; not living below 128 fathoms. Recorded by Mr. Whiteaves from the Gulf of St. Lawrence.

Astarte undata Gld.

One valve, Station 303, east of George's Bank, in 306 fathoms. Six living and eight dead specimens, Station 345, south of Martha's Vineyard, in 71 fathoms.

A very common species found by the U. S. F. C. from the Bay of Fundy to off Cape Hatteras, N. C., in 7 to 480 fathoms. Recorded by Mr. Whiteaves from the Gulf of St. Lawrence.

Astarte crenata Gray.

Astarte crebricostata Gould, Invert. Mass., Binney's ed., p. 126, fig. 440, 1870.
Astarte lens Verrill, Am. Journ. Sci., III. p. 287, 1872.
Astarte crenata Verrill, Proceed. U. S. Nat. Mus., III. p. 399, 1880.
Astarte lens Dall, Bulletin U. S. Nat. Mus., No. 37, p. 46, 1889.

Two dead specimens, Station 303, east of George's Bank, in 306 fathoms. One dead, Station 304, east of George's Bank, in 139 fathoms. Four living and one dead, Station 306, east of George's Bank, in 524 fathoms. Three living, Station 309, south of George's Bank, in 304 fathoms. Fifty living, Station 310, south of Martha's Vineyard, in 260 fathoms. One dead, Station 321, off Charleston, S. C., in 233 fathoms. One dead, Station 333, off Cape Hatteras, N. C., in 65 fathoms. One valve, Station 343, south of Martha's Vineyard, in 732 fathoms. Two valves, Station 344, south of Martha's Vineyard, in 129 fathoms. Three living, Station 345, south of Martha's Vineyard, in 71 fathoms.

A very common species found by the U. S. F. C. from northwest of Flemish Cap to off Cape Hatteras, N. C., in 7 to 677 fathoms; not living below 640 fathoms. Recorded by Mr. Whiteaves from the Gulf of St. Lawrence, and by Mr. Dall as far south as Cape Florida.

Venericardia granulata Say.

Verrill, Trans. Conn. Acad., VI. p. 258, 1884.

Three valves, Station 345, south of Martha's Vineyard, in 129 fathoms. Two living, Station 347, off Montauk Point, L. I., in 24 fathoms.

A very common species found by the U. S. F. C. from off Cape Race, Newfoundland, to off Cape Hatteras, N. C., in 7 to 435 fathoms ; not living below 250 fathoms. Found by the Stearns Expedition on the coast of Labrador, in 10 fathoms.

Loripes lens Verrill and Smith.

Verrill, Trans. Conn. Acad., V. p. 569, 1882; VI. p. 259, 1884.

Nineteen living and fourteen dead specimens, Station 344, south of Martha's Vineyard, in 129 fathoms. Three dead and one valve, Station 345, south of Martha's Vineyard, in 71 fathoms.

Recorded by the U. S. F. C. off Cape Cod and Martha's Vineyard, in 5 to 231 fathoms ; not living in less than 58 fathoms, or below 190 fathoms.

Extending south to Grenada, in 321 to 464 fathoms ; living in 321 fathoms (Dall).

Lucina Blakeana, sp. nov.

Plate II. Figs. 16, 17.

One living specimen was found at Station 326, off Cape Fear, N. C., in 464 fathoms.

Shell of moderate size, a little longer than high, moderately convex, with a well-marked posterior undulation, rather thin, translucent white under a conspicuous light yellow epidermis. Umbos white, central, prominent, smooth near the beaks, which are small, pointed, curved strongly forward. Lunule long, rather broad, lanceolate, smooth, well excavated, so that the anterior dorsal margin is straight and slopes obliquely from the beaks. From this the margin rises slightly, curves well forward, forming a prominent, well-rounded anterior end before joining the broadly and regularly rounded ventral margin. Posterior dorsal margin long, sloping, nearly straight, forming a rounded angle where it meets the posterior ventral margin, which is distinctly incurved, corresponding to a slight but well-marked furrow extending from the umbos. The ligamental area is wide, sunken, tapering regularly towards either end, with a conspicuous ligament extending half its length. The surface is covered by irregular concentric lines and ridges, which, on the umbos, are nearly uniform in size and about equally separated, but below become very irregular and are covered with a thin light yellow epidermis decidedly wrinkled by the conspicuous lines of growth, most evident on the ends of the valves; in the centre it forms several (six in the type specimen) conspicuous, distant lamelliform ridges, the last one very near the edge. Interior bluish white, slightly lustrous, with numerous microscopic radiating striæ, most clearly defined near the margin, and a conspicuous concentric ridge situated half-way between the margin and the pallial line. Scars clearly defined. Hinge plate rather broad and well arched, with two prominent divergent, curved, cardinal teeth in the right valve, and a single thick, equally prominent one in the left valve. The anterior tooth in the right valve is more than twice as thick as the posterior, and has a well-marked central groove; the posterior one is situated directly beneath the beak, and is thin, curved, with the concave surface forward and the summit broadly rounded; the tooth in the left valve is about equal in size to the anterior one in the opposite valve, and also has a rather deep, central groove.

Length, 31 mm.; height, 27.5 mm.; thickness, about 13.5 mm.

This species has been carefully compared with authentic specimens of *L. filosa*, *borealis*, *Pennsylvanicus*, and *Jamaicensis*, but is quite distinct from all of them. It is readily distinguished by the irregular concentric sculpture, conspicuous epidermis, large lunule, long, broad, nearly straight ligamental area, and conspicuous ligament.

Cryptodon sp.

A broken left valve, Station 326, off Cape Fear, N. C., in 464 fathoms.

Although only a fragment, this differs so decidedly in form and sculpture from any of the species known to me, that it seems worthy of description. Its outline is much more angular than that of *C. ovoideus* Dall from the same locality.[1]

The ventral margin is too badly broken to judge of its outline, but the upper part of the valve is entire and shows an exceedingly high, narrow, angular, inflated form, with a small though prominent umbo and very sloping dorsal margins. Beak small, curved well forward over an exceedingly small, slightly sunken lunule, bordered by an inconspicuous ridge. The postero-dorsal margin is very long, straight (though strongly concave in an end view), and sloping, and is four and a half times the length of the lunular area. A single very deep narrow groove extends across the valve from the beak to the posterior ventral margin. In front and back of this there is a scarcely discernible undulation of the surface, and another equally slight one just back of the lunular ridge. Umbo nearly smooth and lustrous; the rest of the surface is roughened by the conspicuous, strongly curved lines of growth. Color, yellowish white. Interior bluish white, with a slightly lustrous frosted surface, which, under the microscope, appears covered with minute shallow pits. The exterior groove forms a conspicuous interior ridge. The ligamental groove is rather narrow, straight, sunken, running nearly the entire length of the postero-dorsal margin. At the end of the ligament, just beneath the beak, there is a prominent angular tooth-like process.

Length of lunular area, 2 mm.; of posterior dorsal margin, 9 mm.

Diplodonta turgida VERRILL and SMITH.

VERRILL, Trans. Conn. Acad., V. p. 569, pl. 58, fig. 42, 1882; VI. pl. 30, figs. 10, 11, 1884.

Fragments, Station 345, south of Martha's Vineyard, in 71 fathoms.

A rare species, only disunited valves of which have been found by the U. S. F. C. from south of Martha's Vineyard to off Cape Hatteras, N. C., in 27 to 167 fathoms.

A single valve, off Grenada, in 170 fathoms (Dall).

Yoldia thraciformis (STORER) STIMP.

Five dead specimens and one valve, Station 332, off Cape Hatteras, N. C., in 263 fathoms. Twenty living and four dead, Station 336, off Delaware Bay, in 197 fathoms.

A common species recorded by the U. S. F. C. from the Bay of Fundy and west of St. Peter's Bank to off Cape Hatteras, N. C., in 16 to 906 fathoms; and by Mr. Whiteaves from the Gulf of St. Lawrence.

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[1] *Cryptodon ovoideus* Dall, Proc. U. S. Nat. Mus., XII. p. 263 (no description), pl. 14, fig. 3, 1889.

Yoldia sapotilla (Gould) Stimp.

Over fifty living specimens, Station 344, south of Martha's Vineyard, in 129 fathoms. Six living and three dead, Station 345, south of Martha's Vineyard, in 71 fathoms. Four living and two valves, Station 346, south of Martha's Vineyard, in 44 fathoms.

A common species found by the U. S. F. C. from the Bay of Fundy and west of St. Peter's Bank to off Martha's Vineyard, in 4½ to 1,054 fathoms; not living in less than 8 fathoms, or below 428 fathoms. Also recorded by Mr. Whiteaves from the Gulf of St. Lawrence, and by Professor Packard from Labrador.

Yoldia lucida Lovén.

Leda lucida Jeffreys, Brit. Conch., V. p. 173, pl. 100, fig. 1, 1869.
Yoldia obesa Gould, Invert. Mass., Binney's ed., p. 155, fig 463, 1870.
Verrill, Invert. Anim. Vineyard Sd., p. 396, 1874.
Portlandia lucida Sars, Moll. Reg. Arct. Norveg., p. 37, pl. 4, figs. 8 *a*, 8 *b*, 1878.
Leda lucida Jeffreys, Proc. Zoöl. Soc., London, p. 578, 1879.
Yoldia lucida Verrill, Trans. Conn. Acad., V. pl. 44, fig. 1, 1882.

One living specimen, Station 305, east of George's Bank, in 810 fathoms.

A small species found in considerable numbers by the U. S. F. C. from the Bay of Fundy and northwest of Flemish Cap to off Cape Hatteras, N. C., in 22 to 2,620 fathoms.

Recorded by Mr. Whiteaves from the Gulf of St. Lawrence.

Yoldia callista, sp. nov.

Plate I. Figs. 9 and 10.

One living specimen, Station 321, off Charleston, S. C., in 233 fathoms.

This is a very small species, with a smooth, shining surface, covered with very fine microscopic lines of growth. It is narrow, nearly regularly ovate in outline, with small beaks, curved well forward, and situated at about the anterior third. Exteriorly the shell resembles a minute *Callista.* The anterior dorsal margin is somewhat concave, the posterior decidedly convex; while the ends are narrowed and nearly evenly rounded to meet the regularly curved ventral margin. Epidermis wanting. The interior has also a very shining surface with plain margins. The hinge margin is rather wide and thin, with six distinct well-separated teeth before and nine behind the beak. Cartilage pit minute, triangular, situated directly below the beak.

Length, 2.5 mm.; height, about 2 mm.

This species bears considerable resemblance to the young of *Y. regularis*, described by Professor Verrill (Trans. Conn. Acad., VI. p. 228, 1884), but the latter is very much broader and more oval in outline, with broadly rounded ends and the dorsal margins evenly convex. The most striking differences are in the smaller number of teeth, and in the size and position of the cartilage pit, which in *Y. regularis* is very large, and situated a considerable distance behind the beak.

Leda quadrangularis Dall.

This Bulletin, XII. p. 253, pl. 8, fig. 6, 1886; Bulletin U. S. Nat. Mus., No. 37, p. 42, pl. 8, fig. 6, 1889.

A single right valve, Station 321, off Charleston, S. C., in 233 fathoms.

This specimen is broken away on the posterior ventral margin, but in general outline agrees well with Mr. Dall's figure. There is, however, a marked difference in the number of teeth; besides the principal ones, six before and eight behind the beak, as mentioned by Mr. Dall, there are four minute ones on either side of an exceedingly narrow (microscopic) smooth space (not a pit) directly beneath the beak. The hinge margin is also remarkably wide and strong in my specimen.

From Cape Hatteras, N. C., to Cuba, in 683 to 1,568 fathoms, dead (Dall).

Leda acuta Conrad.

Leda unca, Verrill, Trans Conn. Acad., V. p. 572, pl. 58, fig. 41, 1882.
Leda acuta Verrill, *op. cit.*, VI. p. 259, pl. 30, fig. 15, 1884.
Dall, this Bulletin, XII. p. 251, pl. 7, figs. 3*a*, 3*b*, 8, 1886; XVIII p. 438, 1889; Bulletin U. S. Nat. Mus., No. 37, p. 44, pl. 7, figs. 3, 8; pl. 45, fig 15; pl. 64, fig. 140, 1889.

One living, Station 345, south of Martha's Vineyard, in 71 fathoms.

Found by the U. S. F. C. from south of Martha's Vineyard to off Cape Hatteras, N. C., in 43 to 225 fathoms; not living in less than 63 fathoms, or below 155 fathoms.

Also recorded by Mr. Dall as far south as the West Indies, in 54 to 80 fathoms, dead.

Leda pernula (Müll.).

Verrill, Trans Conn. Acad., V. p. 572, 1882; VI. p. 280, pl. 30, figs. 14, 14 *a*, 1884.

One living, Station 331, off Cape Hatteras, N. C., in 898 fathoms.

A rare species found by the U. S. F. C. from off Cape Race, Newfoundland, to off Chesapeake Bay, in 25 to 479 fathoms.

Malletia obtusa (M. Sars) Mörch.

Verrill, Trans. Conn. Acad., VI. p. 226, 1884.

Three valves, Station 307, east of George's Bank, in 980 fathoms. Fragments, Station 325, off Cape Fear, N. C., in 647 fathoms. Two valves, Station 340, south of Martha's Vineyard, in 1,394 fathoms. One dead, Station 341, south of Martha's Vineyard, in 1,241 fathoms.

A common deep-water species first found by the U. S. F. C. in 1883, ranging from east of George's Bank to off Cape Hatteras, N. C., in 516 to 1,781 fathoms; not living in less than 525 fathoms.

Arca pectunculoides Sc.

Verrill, Trans. Conn. Acad., V. p. 573, pl. 44, fig. 6, 1882.
Dall, this Bulletin, IX. p. 121, 1881; XII. p. 240, pl. 8, fig. 5, 1886; Bulletin U. S. Nat Mus., No. 37, p. 42, pl. 8, fig. 5, 1889.

Twelve living specimens (six very large), Station 310, south of Martha's Vineyard, in 260 fathoms. Seven valves, Station 321, off Charleston, S. C., in 233 fathoms.

An abundant species found by the U. S. F. C. from the Bay of Fundy and northwest of Flemish Cap to off Chesapeake Bay, in 11 to 965 fathoms. Recorded by Mr. Whiteaves from the Gulf of St. Lawrence, and by Mr. Dall from St. Vincent, in 292 to 1,568 fathoms; living in 292 fathoms.

Macrodon asperula Dall?

This Bulletin, IX. p. 120, 1881; XII. p. 244, pl. 8, figs. 4, 4 *a*, 1886; Bulletin U. S. Nat. Mus., No. 37, p. 42, pl. 8, figs. 4, 4 *a*, 1889.

A right valve, Station 321, off Charleston, S. C., in 233 fathoms.

The valve is very badly worn, and, although agreeing very closely with Mr. Dall's description and figures, is referred to this species with some doubt.

Extending south to the West Indies, in 310 to 1,568 fathoms, dead (Dall).

Limopsis minuta (Phil.).

Verrill, Trans. Conn. Acad., V. p. 576, 1882.

Plate I. Fig. 8.

One dead specimen, Station 307, east of George's Bank, in 980 fathoms. Seven living specimens, Station 310, south of Martha's Vineyard, in 260 fathoms. Two valves, Station 321, off Charleston, S. C., in 233 fathoms.

A very common species found by the U. S. F. C. from the east end of Banquereau to off Cape Hatteras, N. C., in 64 to 2,221 fathoms; not living in less than 155 fathoms.

Extending south to Grenada, in 30 to 850 fathoms; living in 30 fathoms (Dall).

Pecten Clintonius Say.

Verrill, Trans. Conn. Acad., VI. p. 261, 1884.

One valve, Station 333, off Cape Hatteras, N. C., in 65 fathoms. Five living specimens, Station 345, south of Martha's Vineyard, in 71 fathoms. One living, Station 346, south of Martha's Vineyard, in 44 fathoms. Three living (one large and two small), Station 347, off Montauk Point, L. I., in 24 fathoms.

A common species found by the U. S. F. C. from the Bay of Fundy and St. Peter's Bank to off Cape Hatteras, N. C., in 7 to 813 fathoms; not living in less than 9 fathoms, nor below 146 fathoms. Recorded by Prof. A. S. Packard from the coast of Labrador.

Pecten vitreus (Gmel.) Wood.

Verrill, Trans. Conn. Acad., V. p. 581, pl. 42, fig. 21, 1882.

Twenty living specimens, Station 306, east of George's Bank, in 524 fathoms. Three living, Station 307, east of George's Bank, in 980 fathoms. Thirteen living, Station 309, south of George's Bank, in 304 fathoms. Two valves, station 310, south of Martha's Vineyard, in 260 fathoms. One living, Station 336, off Delaware Bay, in 197 fathoms.

An abundant species found by the U. S. F. C. from east of Banquereau to off Cape Hatteras, N. C., in 57½ to 1,537 fathoms; not living in less than 100 fathoms.

Amusium (Propeamusium) Pourtalesianum, var. **striatulum** Dall.

Dall, this Bulletin, XII. p. 212, 1886; Bulletin U. S. Nat. Mus., No. 37, p. 34, 1889. *Amusium lucidum*, var. *striata* Jeffreys, Proc. Zoöl. Soc. London, p. 562, 1879.

A fragment, Station 321, off Charleston, S. C., in 233 fathoms.

Extending south to St. Vincent, in 138 to 424 fathoms, dead (Dall).

This is a fragment of a very delicate shell, having a lustrous interior surface and about ten internal ribs, which terminate in rounded points or knobs a considerable distance within the margin, and are distinctly visible on the exterior surface, which is also lustrous and covered with microscopic concentric lines, and, on the upper half of the valve, with slight radiating striæ.

In these characters it seems to agree with Mr. Jeffreys's description of *A. lucidum*, var. *striata*, but, according to Mr. Dall's enumeration of specimens, should receive the name as given above.

Limæa subovata (Jeff.) Monteros.

Verrill, Trans. Conn. Acad., V. p. 580, 1882.

One valve, Station 329, off Cape Lookout, N. C., in 603 fathoms.

A common deep-water species recorded by the U. S. F. C. from Flemish Cap to off Cape Hatteras, N. C., in 45 to 1,362 fathoms; not living below 1,290 fathoms.

Anomia aculeata Müll.

One living specimen, Station 345, south of Martha's Vineyard, in 71 fathoms.

An abundant species found by the U. S. F. C. from the Bay of Fundy and Flemish Cap to off Cape Hatteras, N. C., in 4 to 640 fathoms; Stearns Expedition, on the coast of Labrador, in 8 to 15 fathoms.

MOLLUSCOIDEA.

BRACHIOPODA.

Terebratulina septentrionalis (Couth.).

One living specimen and one valve, Station 310, south of Martha's Vineyard, in 260 fathoms.

An abundant species found by the U. S. F. C. from the Bay of Fundy and St. Peter's Bank to south of Martha's Vineyard, in 7 to 1,081 fathoms; not living below 677 fathoms. Recorded by Mr. Whiteaves from the Gulf of St. Lawrence.

Atretia gnomon Jeff.

Verrill, Trans. Conn. Acad., VI. p. 445, 1885.

One living specimen, Station 329, off Cape Lookout, N. C., in 603 fathoms.

Found by the U. S. F. C. in 1884, off Martha's Vineyard and Delaware Bay, in 1,525 to 1,594 fathoms.

Extending south to Florida Straits; bathymetrical range not given (Dall).

LIST OF SPECIES

ENUMERATED IN THE PRECEDING PAPER.[1]

The species in Italics are additions to the fauna of the Atlantic coast. Those with *s* before them are Southern species; those with an asterisk, Northern species which range as far south as Cape Hatteras, N. C.; and those with a dagger, Northern species which reach farther south.

CEPHALOPODA.

*Ommastrephes illecebrosus (Les.) V.
†Mastigoteuthis Agassizii V.
Chiroteuthis Bonplandi D'Orb. (?)
†Rossia sublevis V.
†Heteroteuthis tenera V.
†Argonauta argo Linné.
†Octopus Bairdii V.
s Octopus lentus V.
Octopus sp.
Eledone verrucosa V.

GASTROPODA.

Toxoglossa.

†Pleurotoma Dalli V. & S.
s Pleurotoma amblytera Bush.
†Pleurotomella Agassizii V. & S.
s Pleurotomella atypha Bush.
†Pleurotomella Jeffreysii V.
s Pleurotomella sp.
s Pleurotomella sulcifera Bush.
s Pleurotomella leptalea Bush.
s Pleurotomella Dalli Bush.
s Mangilia leuca Bush.
Bela cancellata (Migh.) Stimp.

Rhachiglossa.

Buccinum Sandersoni V.
Buccinum cyaneum Brug.
*Buccinum abyssorum V. & S.
†Sipho Stimpsonii Mörch.
†Sipho pubescens V.
*Sipho pygmæus (Gld.) V.
†Sipho obesus V.
*Sipho cælatulus V.
†Sipho cælatus V.
†Sipho cælatus, var. hebes V.
Neptunea despecta (Linné) Ad.
s Murex (Pteronotus) pygmæus Bush.
s Trophon Verrillii Bush.
*Anachis Haliæeti (Jeff.).
†Astyris diaphana V.

Tænioglossa.

*Natica clausa Brod. & Sower.
*Lunatia heros (Say) H. & A. Ad.
†Lunatia Grönlandica (Möll.) Ad.
†Crucibulum striatum (Say) H. & A. Ad.
*Aporrhais occidentalis Beck.

Gymnoglossa.

*Turbonilla Rathbuni V. & S.

Rhipidoglossa.

Calliostoma occidentale (Migh.).
†Calliostoma Bairdii V. & S.
†Margarita (Solariella) Ottoi Phil.
†*Margarita (Solariella) infundibulum* Watson, var. *Diomedeæ* V.
Ganesa sp.
s Puncturella sp.

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[1] With the exception of the Cephalopods, which were taken, with Professor Verrill's permission, from his report on the "Blake Cephalopods," published in this Bulletin, Vol. VIII., 1881.

HETEROPODA.

†Atlanta Peronii Les.

TECTIBRANCHIATA.

†Scaphander nobilis V.
†Scaphander puncto-striatus (Migh.) Ad.
†Cylichna vortex Dall.
†*Diaphana Lottæ* Bush.

SCAPHOPODA.

†Dentalium solidum V.
†Dentalium striolatum Stimp.
†Dentalium occidentale Stimp.
†Siphodentalium vitreum M. Sars.?

PTEROPODA.

†Cavolina tridentata (Forskäl).
†Cavolina uncinata (Rang).
†Cavolina longirostris Les.
†Cavolina gibbosa (Rang).
†Diacria trispinosa (Les.).
†Clio pyramidata Linné.

LAMELLIBRANCHIATA.

†Cuspidaria glacialis (Sars) Dall.
s*Cardiomya* sp.
sMyonera paucistriata Dall.
**Periploma abyssorum* V. (?)
†Periploma fragilis Totten.
sAbra æqualis Say.
†Macoma sabulosa (Speng.) Mörch.
*Cyprina Islandica (Linné) Lam.
*Astarte undata Gld.
†Astarte crenata Gray.
*Venericardia granulata Say.
†Loripes lens V. & S.
s*Lucina Blakeana* Bush.
s*Cryptodon* sp.
†Diplodonta turgida V. & S.
*Yoldia thraciformis (Storer) Stimp.
Yoldia sapotilla (Gld.) Stimp.
*Yoldia lucida Lovén.
s*Yoldia callista* Bush.
sLeda quadrangularis Dall.
†Leda acuta Conrad.
*Leda pernula (Müll.).
†Malletia obtusa (M. Sars) Mörch.
sMacrodon asperula Dall.
†Arca pectunculoides Sc.
†Limopsis minuta (Phil.).
*Pecten Clintonius Say.
*Pecten vitreus (Gmel.) Wood.
sAmusium (Propeamusium) Pourtalesianum, var. striatulum Dall.
†Limæa subovata (Jeff.) Mont.
*Anomia aculeata Müll.

MOLLUSCOIDEA.

BRACHIOPODA.

Terebratulina septentrionalis (Couth.).
†Atretia gnomon Jeff.

REFERENCES TO DESCRIPTIONS AND NOTICES OF ADDITIONAL SPECIES FIGURED ON THE ACCOMPANYING PLATES.

Adeorbis supranitidus Wood, var. *Orbignyi* Fischer, Dall, this Bulletin, XVIII. p. 278, 1889.

Astyris pura Verrill, Trans. Conn. Acad., V. p. 515, 1882.

Cingula Sandersoni Verrill, *op. cit.*, VI. p. 241, 1885.

Cocculina reticulata Verrill, *op. cit.*, p. 426.

Limopsis plana Verrill, *op. cit.*, p. 441.

Mangilia eritima Bush, Trans. Conn. Acad., VI. p. 456.

Mangilia quadrata Reeve, var. *quadrata* Dall, *op. cit.*, p. 113.

Marginella aureocincta Stearns, Proc. Bost. Soc. Nat. Hist., XV. p. 22, 1873; Dall, *op. cit.*, p. 139.

Marginella Smithii Verrill, *op. cit.*, pp. 420, 452.

Nucula trigona Verrill, *op. cit.*, p. 438. (Name preoccupied.)

Nucula Verrillii Dall, *op. cit.*, p. 248; Proc. U. S. Nat. Mus., XII. p. 257, pl. 14, fig. 4, 1889.

Pandora Carolinensis Bush, *op. cit.*, p. 474.

Scala leptalea Bush, *op. cit.*, p. 465; Dall, *op. cit.*, p. 309. (*Scalaria* preoccupied.)

Skenea lirata Verrill, *op. cit.*, V. p. 529, 1882; VI. p. 452, 1885.

Trophon abyssorum Verrill, and var. *limicola* Verrill, *op. cit.*, p. 421.

Peabody Museum of Yale University.

INDEX.

The names in Italics are those which are synonyms, or cited for comparison, or not included in the body of this work.

PLATE I.

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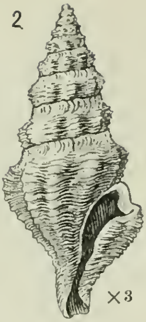

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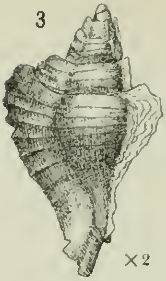

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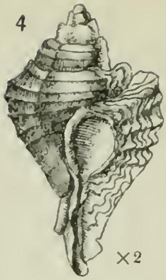

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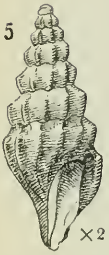

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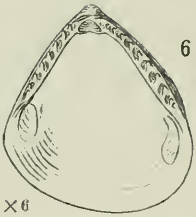

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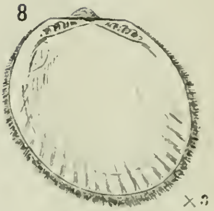

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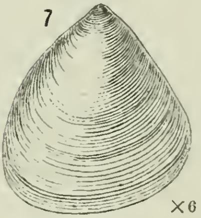

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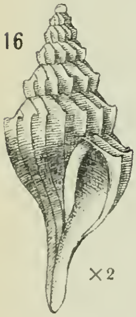

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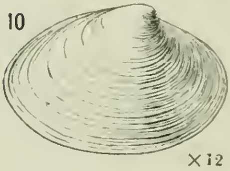

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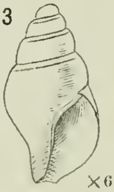

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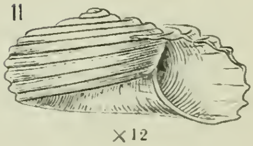

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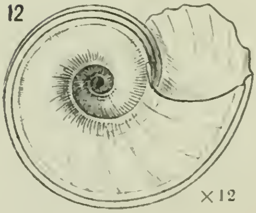

Photo. Lith. by L. S. Punderson, New Haven

EXPLANATION OF PLATES.

I am indebted to Prof. A. E. Verrill for permission to use in these plates some of the drawings prepared from specimens in the collection of the U. S. National Museum, by Mr. J. H. Blake.

PLATE I.

Fig. 1. *Mangilia eritima* Bush (*Mangilia quadrata* Reeve, var. *quadrata* Dall). Front view; × 6 diameters. Off Cape Hatteras, N. C., U. S. F. C. Station 2280, in 16 fathoms, 1884. Page 240.

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Figures 2, 9, and 10 were drawn by Mr. J. H. Emerton; Figures 3 to 5*a* and 16, by Mr. W. F. Hopson; and the others, by Mr. J. H. Blake.

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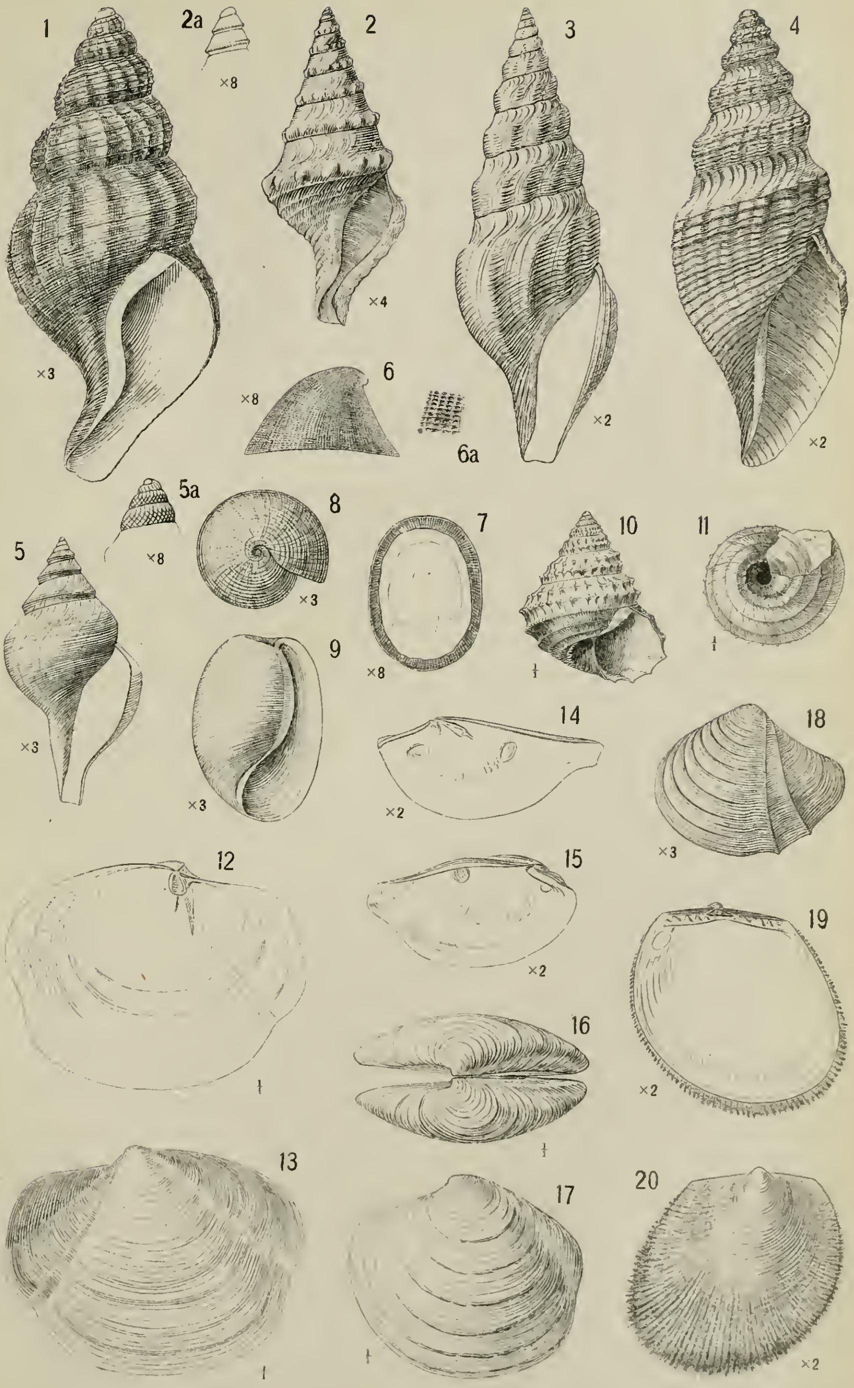
Figures 2, 2*a*, 3, 5, 5*a*, 8, 9, and 16–18 were drawn by Mr. J. H. Emerton; Figure 4, by Mr. W. F. Hopson; and the others, by Mr. J. H. Blake.



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BULLETIN

OF THE

MUSEUM OF COMPARATIVE ZOÖLOGY

AT

HARVARD COLLEGE, IN CAMBRIDGE.

VOL. XXIV.

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1893.

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CONTENTS.

No. 1. — *On Urnatella gracilis.* By C. B. Davenport.[1]

Contents.

I. Introduction.

In November, 1851, the late Dr. Leidy published, in the Proceedings of the Academy of Natural Sciences of Philadelphia, a notice of "what I suspect to be the cœnœcium of a new genus of Polyzoa; although I have never been able to detect the polypides if such exist." He gives three figures of the "cœnœcium," consisting of a series of urn-shaped segments placed so that the base of one segment rests on the mouth of its proximal neighbor. To this new genus he gives the name Urnatella, with a genus diagnosis, which three years later ('54, p. 191), after discovery of the polypide, was revised to read as follows: "Cœnœcium consisting of a series of segments up to eighteen in number, and forming free, semi-erect, curved stems, attached only by the base of the lowest segment. Segments excepting the three last ones simple, urniform; the antepenultimate and the penultimate oblong, with simple or compound branches of the same form; the last segment or active polyp is campanulate, and is supplied with cylindrical, ciliated arms arranged in a circle around the mouth." He finds that several stems arise from a common base. There are fourteen tentacles.

In 1856 Allman (pp. 117–119) referred to the discovery of Leidy, and published a pencil sketch of Urnatella furnished by Leidy. This is the

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

first published drawing of the calyx and young branches. Allman was inclined to refer this genus to the Pedicellinidæ.

In 1870 Leidy recorded further observations on Urnatella, and in 1884 he published in a thin quarto, with a single plate, everything which he had found out about its anatomy and physiology. The main points of these papers will be brought out in connection with the organs to which they refer.

Finally, Mr. Edward Potts, in a note to one of the editors of the American Naturalist (April, 1891), states that he has succeeded [as did Leidy] in obtaining in the spring rejuvenated heads from the headless stems of Urnatella gathered the preceding fall.

Various writers have called attention to the imperfections in our knowledge of this aberrant form. Ehlers ('90) has made many suggestions concerning the anatomy of Urnatella, which, being purely hypothetical, require to be settled by observation. Leidy himself was impressed with the importance of a better knowledge, and he had intended, he says ('84, p. 6), to make a thorough investigation of it. "Other occupations, and the want of a ready supply of the necessary material, have prevented my intention, and I am now led to communicate what I have learned of the animal with the view that some of my younger countrymen and co-laborers, under more favorable circumstances, may be induced to do what I had hoped and wished to do." To supplement the work of Professor Leidy is the object of the present paper, which has been largely inspired by his.

In 1884 Leidy remarked upon the absence of Urnatella from its former haunts. Apparently nothing had been seen of it since that time, until, in 1889, I opened correspondence with Mr. Edward Potts of Philadelphia upon the subject. In the summer of 1890 Mr. Potts and I thoroughly examined the waters of the Schuylkill River, both above and below the Fairmount dam, but without finding any trace of Urnatella. In September, 1891, Mr. Potts found many stocks in the bed of the temporarily emptied Schuylkill Canal, below Flat Rock dam, and kindly forwarded some of these, living, to me at Cambridge. In July, 1892, Mr. Potts and I re-examined in vain the Schuylkill River at Fairmount dam, and finally, on July 4, made dredgings in the Schuylkill at Flat Rock dam, near Shawmont Station, Pennsylvania. We found no trace of Urnatella in the quiet waters above the dam, but in the turbulent waters immediately below the overflow almost every stone brought from the bottom bore stocks, and some were almost completely covered on one face with luxuriant growths. One barrel-hoop dredged from the mud was completely covered with headless stems. As many stones as we could carry were packed in moist paper or in jars, and transported safely several miles. A few days later, stones with living stocks of Urnatella and parts of the barrel-hoop with headless stems were transported in a pail of water to Cambridge. Upon arrival at Cambridge it was found that nearly all the heads had dropped off. The stocks were kept in running water for three months, during which time those which had lost their calyces did not regenerate them; whereas the stocks on the barrel-hoop did regenerate their heads, but did not bud very luxuriantly.

I cannot close this introduction without expressing thanks to my friend Mr. Potts, who, filled with love for the science, has unselfishly supplied me with material, hospitably received me into his household during my stay in Pennsylvania, and worked with me beyond his strength in our dredging operations on the Schuylkill in order to further a study of this animal.

The later studies included in this paper were made in the Embryological Laboratory, under the direction of Dr. E. L. Mark.

I propose to describe first the anatomy of the adult, and, in the second place, the non-sexual reproduction and regeneration, so far as I have been able to determine them. In each section of the paper I shall give first my own observations on Urnatella; secondly, compare them with those of others on Urnatella or other Endoprocta; and, finally, give my conclusions upon or interpretation of any difficult points.

II. Anatomy.

For the purposes of description we must distinguish the stalk and the calyx.

1. *The Stalk.*

The stalk is an elongated, filamentous structure, composed of a number of segments, lying one beyond the other. The number of such segments varies from one to several, according to the age of the stalk. Leidy counted as many as eighteen. I have never counted more. Looked at with a hand lens, the stem is seen to be composed of alternating translucent and opaque rings, of which the former occupy the middle zone of each segment; the latter have an intersegmental position. The surface of the stalk in the translucent zone is thrown into circular folds, and small processes appear scattered over its surface, more abundantly on the more distal segments (Plate I. Fig. 6).

An optical longitudinal section of the living stalk (Plate I. Fig. 7) shows that it consists of a thick cuticula, within which is a mass of ill-defined tissue. The cuticula is thicker and more opaque in the basal segments, thinner and more transparent in the distal ones. Each of the basal segments often contains a mass of globular, highly refractive bodies, which may be forced out from the segment by crushing the latter (Plate I. Figs. 4, 5). Isolated by this means they are seen to be of the most varied size, and to resemble yolk spherules. Besides these granules, one finds lying near the cuticula in all but the oldest segments a fibrillated layer consisting of elongated, spindle-shaped, highly granular cells in the midst of the yolk spherules (Plate I. Fig. 7), and, finally, one or several flickering bodies reminding one by their motion of the *cirri*[1] of flame cells. In the dark zones optical sections reveal indications of a transverse septum.

A more accurate insight into the histological structures is gained from thin sections of the stalk.

The *cuticula* appears in two conditions, which are not sharply separated, but pass into each other through intermediate conditions. The one kind (Plate I. Fig. 4, *cta.*) occurs in the middle zone of each segment. It is transparent and flexible, and becomes thicker in passing from the distal to the proximal segments. It stains in hæmatoxylin, and is then seen to be composed of laminæ, for it appears in section distinctly striated (Plate I. Fig. 4 ; Plate II. Fig. 16). The other kind of cuticula occurs chiefly at the constrictions between segments, but it extends over the two ends of the segments also, and even over the middle zones of the segments, as an outer cuticula (Plate II. Fig. 8, *cta'.*). It forms, moreover, the septa between adjacent segments. It does not stain in hæmatoxylin, is more highly refractive than the first kind, and has a yellowish color by transmitted light. Where it passes over into the first mentioned kind of cuticula, it becomes distinctly striated, and gradually loses its specific characters, gaining those of the first kind, of which it is probably only a modification. It is the presence of these two kinds of cuticula that causes the superficial appearance of alternating light and dark zones on the stem. These two kinds of cuticula do not correspond to the inner and outer cuticulas which Ehlers ('90, pp. 16, 17) describes for Ascopodaria. Two layers with the characters of those of Ehlers appear not to exist in Urnatella.

The *ectoderm* (Plate II. Figs. 11, 10, 16) diminishes in thickness from

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[1] I employ the word "cirrus" in the sense in which it is used by Bütschli for Ciliata (cf. Bronn's Thierreich, Protozoa, p. 1324).

the distal end of the stalk, where it is a layer of cuboidal cells, to the base, where its cells are extremely flattened, so that the layer is hardly distinguishable. Even near the base of the stalk, however, the ectoderm is a relatively thick layer on each of the surfaces of the transverse septa.

The *axial portion* of the stalk presents very interesting histological conditions. In a young individual whose stalk comprises a single segment only (Plate II. Fig. 15) the axial portion contains a closely packed mass of cells, which stain deeply, contain few vacuoles, and are slightly elongated in the direction of the axis of the stalk. At a later stage one finds the plasma of some of these cells undergoing a metamorphosis. Such cells appear filled by a vacuole in which lie numerous highly refractive granules. A little later all of the axial cells have become greatly elongated in correspondence with the elongation of the stalk. Many of them appear almost completely vacuolated. A cross section of the stalk at such a stage of development is shown in Plate II. Figure 9, where the centre is filled with a network of cell boundaries enclosing clear spaces. This condition is very striking in longitudinal sections through the region of the septum, where the long vacuolated cells may be seen extending from one segment into the other.

According to Ehlers ('90, pp. 18–22), the stolon of Ascopodaria shows a condition of the axial portion similar to that here described; but in the stalks which support the calyces there is a considerable amount of intercellular substance, and I find the same thing in Pedicellina. In Urnatella, on the contrary, such intercellular substance appears only in the older stalks.

The *musculature* of the adult stalk is situated immediately within the ectoderm, and is found in all segments running from one septum to the other. On cross section of the stalk it appears as a circle of radially elongated, highly refractive bodies, placed close to the ectoderm (Plate II. Fig. 9, *mu*). Each elongated body has, at a certain focus, a darker periphery and a lighter central line. With the highest powers the darker periphery can be resolved into a single row of bodies, which appear as bright spots at the highest, as dark spots at the lowest focus (Plate II. Fig. 16, *mu*). These I interpret as fibrillæ.

The fibrillæ develop in the protoplasm of the axial cells. In their earliest stages one sees them forming a single row on the outer edges of the more peripheral cells (Plate II. Fig. 17, *mu*). Later they are formed on the two lateral edges also (Fig. 11). Additional lateral (or, in relation to the stalk, radial) rows of fibrillæ are next formed in each cell, the new rows appearing nearer the centre of the cell than those already formed (Fig. 10). Finally, in the adult, the nucleus of the cell, which has been pushed centripetad by the multiplication of fibrillæ, comes to lie opposite several pairs of radial rows or sheets of fibrillæ. These sheets always occur in pairs, the components of the pairs being separated by a narrow clear space, and the pairs by broader spaces.

As I have said, this musculature occurs throughout the entire stalk up to the base of the calyx (Plate III. Fig. 19, *mu.*). I do not understand on what ground Ehlers states ('90, p. 146) that in Urnatella "der Muskelmantel in den gleichmässig dicken Stengelgliedern nicht deren ganze Länge erfüllt."

There is a considerable difference between my description of the structures of the muscle fibres and that of Ehlers ('90, pp. 25–28) for Ascopodaria. In the latter case, the muscle cells are placed three to five deep, instead of in one peripheral series, as in Urnatella. Moreover, in Ascopodaria the fibrillæ lie in two thick peripheral bands on the sides of each muscle cell ; whereas in Urnatella several muscle bands (each consisting of a single row of fibrillæ) belong to each cell.

The differences between the two genera are easily explained by assuming an increase in the number of muscle cells in Ascopodaria, so that they can no longer lie in a single peripheral series, and that the fibrillæ bands have become greatly crowded together, so that one band is not equivalent to a single band of Urnatella, but to all of the bands of Urnatella which have arisen on one side of the cell. The stalk musculature of Ascopodaria is thus more highly developed than that of Urnatella.

Ehlers mentions the resemblance between the muscle fibres of Ascopodaria and those of Nematodes, especially the Cœlomyaria.

I have referred above to vibratile movements in the living stalk. Stained sections show, placed more or less abundantly throughout the stalk, elongated spaces terminating blindly at one end in structures which must be regarded as flame cells (Plate II. Fig. 12, *cl. flm.*). Such a flame cell is spherical in form, stains slightly, possesses a large nucleus, and gives off into the elongated space *cl. tb.* the well known cirrus (*Wimperflamme*).

The form of the cirrus in all cases examined was conical, the axis of the cone being usually thrown into a sigmoid curve. Where the cirrus arises from the cell, it is slightly constricted, then enlarges suddenly, forming a thickened ring. Distal of this ring the cirrus tapers gradually to a fine point. That the cirrus is composed of a number of agglutinated cilia is indicated by the presence of longitudinal striæ. I believe that the flame cell closes the lumen of the tubule at this point.

Concerning the space into which the free end of the cirrus projects I can only conclude, from comparison with other cases where a flame cell occurs, that this must represent the lumen of an excretory tubule. I have not, however, been able in any instance to trace an individual tubule to any considerable distance, or until it opens into any other organ. One thing seems fairly certain, there is no morphological difference between those elongated clear spaces into which the cirri project and the elongated vacuolated cells to which reference has already been made. I am therefore inclined to regard it as probable that they are one and the same thing. The vacuolated cells are developed by the breaking down of the plasma of the elongated cells of the young stalk. Before the metamorphosis is completed, one finds cells filled with clear contents, in which lie scattered granules (Plate II. Fig. 15, *cl. tb.* left). Finally, even these seem to disappear (Fig. 15, *cl. tb.* right). Since the tubules agree in size with these elongated, later vacuolated cells, I conclude that their lumina are intracellular. Since the so called vacuolated cells — many of which at least are, according to my view, tubules — pass uninterruptedly from one segment to the next through the central opening of the septa, there may easily exist continuous tubules running from the basal segments into the calyx.

The only excretory tubules which have been heretofore mentioned as occurring in Endoprocta are the pair which lie in the calyx and open into the atrium between mouth and rectum. Farther on, I shall have occasion to inquire into the probable significance of the facts here recorded.

In specimens of Urnatella gathered in the fall and examined while living, I found the basal segments filled with yolk granules (Plate I. Fig. 4). Even in stocks collected in July, the basal segments contained a greater or less amount of yolk. In passing from the distal towards the proximal end of the stalk, one can trace the development of this yolk, and since this is a matter of some general interest I have paid a little attention to it.

If we examine one of the middle segments of a stem whose basal segment is full of large yolk spherules, we shall find reserve stuff forming in some of the elongated cells. It appears as a fine granulation throughout the whole cell, except immediately surrounding the nucleus (Plate II. Fig. 13). Not all of the cells appear thus granular, for others are at this stage vacuolated. Still later (Fig. 14) many of the fine granules appear to have fused into larger ones, and these are separated by clear spaces. The cells have enlarged very greatly (those in Figs. 13 and 14 being equally magnified), and their boundaries seem to be at some points discontinuous. Finally, in the basal segment we find all trace of cell boundaries lost, and the central space filled by a mass of large and small yolk globules, nuclei, and protoplasmic débris (Plate II. Fig. 8).

The series of stages in the formation of yolk, which are shown in successive segments of the same stalk, points to the conclusion that yolk is in this case formed inside of the cell by a fusion of many excessively small granules, — a conclusion similar to that reached by Stuhlmann ('87, p. 23) for the eggs of a Teleost. Hand in hand with the development of yolk there seems to go a diminution in the amount of protoplasm, which therefore seems to be broken down in the process. The details of this process resemble remarkably those of the formation of the yolk in the statoblast of Phylactolæma, for an accurate description of which we are especially indebted to Braem ('90, p. 76).

Urnatella is quite unique, so far as I know, among all Endoprocta in the storage of food material in its stalk. This is doubtless of high physiological importance, as I shall try to show later.

Septa occur at the constrictions between segments, and separate the latter from one another. They are composed of a circular fold of ectoderm, whose free edge surrounds a small opening, through which spindle-shaped vacuolated mesenchymatous cells pass. The adult condition is easily interpreted by reference to the development, an early stage in which is shown in Figure 24 (Plate IV.). Between the layers of the ectodermal fold a perforated disc of cuticula — continuous at its outer edge with the superficial cuticula — becomes laid down. This cuticular disc increases in thickness with increasing age.

The most distal septum, which separates stalk and calyx, is more complicated than the others. The complication is due to the fact that mesenchymatous cells have placed themselves in and above the opening of the septum, and have flattened themselves out perpendicularly to the axis of the stalk, while still allowing the vacuolated cells to pass at their margins into the calyx from the stalk. Thus the transversely flattened mesenchymatous cells appear to send out horizontal processes between the tubular cells (Plate IV. Fig. 25).

The flattened cells which lie above the opening of the septum are seen, in longitudinal section of the stalk, to be arched over the opening. It results from this that the smaller, lower cells lie partly enclosed by the larger upper ones (Plate III. Fig. 18).

A septum between stalk and calyx agreeing even in detail with that just described for Urnatella has been described and figured by Ehlers for Ascopodaria. Such a highly complicated septum seems indeed to be common to the Pedicellinidæ, which in this respect appear more nearly allied to Urnatella than does Loxosoma, in which such septa are absent.

In Pedicellina Benedeni also, which has a segmented stalk, the segments are separated from one another, according to Fœttinger ('87, pp. 301–303), by perforated septa.

2. *The Calyx.*

Under this heading I shall treat successively of the body wall (including the lip of the atrium, and the tentacles), the atrium, the alimentary tract, the body cavity, the nephridia, the sexual organs, and the nervous system.

A good idea of the external form of the expanded calyx may be gained from Leidy's figures. My own, having been drawn chiefly from preserved material, show the polypide for the most part in a retracted condition (cf. Plate I. Fig. 2). When thus retracted, the atrial opening does not lie at the apex of the calyx, but is thrown sharply over towards the oral aspect (Plate III. Fig 18).

The body wall is composed of a single layer of excessively thin epithelium, — the ectoderm, — which has secreted a thin cuticula. This cuticula is thickened in places, producing papillæ, which are irregularly scattered over the calyx. At the lip of the atrial opening, as the passage into the atrium in the retracted condition may be called, the ectoderm is thicker than elsewhere, and folds back upon itself until it reaches the base of the lophophore. This backward-reflected portion I shall call by the name *kamptoderm,* for although its homology with the kamptoderm of Ectoprocta may not be entirely beyond doubt, I cannot see any important difference between the two structures, either in their adult relations or in development. As in the Ectoprocta, so here the polypide is formed in the retracted state, and the atrial opening does not break through until a late stage is reached.

In Ectoprocta the line of union of the kamptoderm and body wall, i. e. the lip of the atrial opening, is marked by a thickened ring composed of elongated ectodermal cells, at the base of which lie the fibres of a sphincter muscle. This organ constitutes the "Randwulst" of Phylactolæmata or the "Diaphragma" of Gymnolæmata. Does an organ homologous with this occur in Urnatella? It is in keeping with the more primitive organization of the Endoprocta that, although a corresponding region exists and sphincter muscles are found here, it has not become so distinctly differentiated from the rest of the body wall as has the *Randwulst* of Phylactolæmata. This region may be designated the lip of the atrium.

When the tentacles are expanded, — a secondary condition, as the development of the calyx shows, — the lip of the atrium forms a circular ridge lying at the base of the tentacles (Plate IV. Fig. 26, *spht. atr.*). When the tentacles are drawn in tightly, the lip of the atrium becomes puckered. Two of the folds resulting from this process are shown cut across in Figure 19 (Plate III.) above the middle of the atrium.

The *tentacles* of Urnatella in three cases in which I counted them on transverse sections, as well as on the entire animal, numbered twelve; in one case, thirteen. In addition to these numbers, Leidy ('84, p. 10) found sixteen (usually) and fourteen. In the specimen with thirteen tentacles, the odd one was placed on the anal aspect of the calyx in the median plane. It appeared shorter than the others. In one case with twelve tentacles, observed fully expanded, the two tentacles of the anal aspect lying nearest the median plane appeared shorter than the remaining ones. Leidy does not refer to this point, and his figures afford no satisfactory evidence as to the occurrence of this condition in his specimens.

The tentacles are each composed of a cylinder of columnar epithelium surrounding a narrow central region which is filled with mesenchymatous tissue. In addition, on each of the lateral aspects of the tentacle there is a muscle, composed of one to three fibres lying side by side (Plate IV. Fig. 27, *mu. ret. ta.*). The epithelium is ciliated on the lateral and inner faces of the tentacle.

The *atrium* is bounded by the tentacular corona on all sides. The floor of the atrium passes into the mouth in the oral region, and rests upon the rectum in the aboral region. At the centre there opens into it an elongated pocket, the cloaca. The lateral angles of the mouth are prolonged aborally, and form two grooves which open into the atrium along the lateral margins of the floor (Plate III. Fig. 19, *sul. atr.*). These, which may be called the *atrial grooves*, approach each other and become shallower as they pass aborally upon the atrial wall, until they disappear in the median line above the rectum. The epithelium lining the grooves is ciliated.

This "atrial groove" exists also in Pedicellina echinata according to Nitsche ('69, pp. 21, 22), and, according to Ehlers ('90, pp. 52, 53, 59, 60), in his Ascopodaria macropus also. Its function, as has been frequently pointed out, must be to carry the particles of food from the bases of the tentacles towards the mouth.

The mouth is limited on the side towards the anus, and separated from the cloaca by a fold, which may be designated the *inner lip*. This represents the organ often referred to as the epistome, — a term which implies an homology with the organ of the same name in Phylactolæmata. This organ is of greatest size in Rhabdopleura and Loxosoma among Endoprocta, where it is elevated far above the general level of the floor of the atrium. It is less marked in the Pedicellinidæ. In Urnatella it is not at all evident, because its upper edge is not higher than the roof of the rectum which forms the actual floor of the atrium behind. If, on the contrary, the cloaca extended underneath the rectum, as it does in the Pedicellinidæ, causing a great space between it and the intestine, and thus making the roof of the *intestine* the floor of the atrium, the inner lip would appear as a very prominent organ (cf. Fig. 18).

On the outer edge of the mouth, and forming the "outer lip," is a prominent horizontal fold of the oral part of the atrium (Fig. 18, *loph. atr.*). This fold extends aborally, running parallel with, and forming the outer wall of the "atrial groove" (Fig. 19). The fold gradually becomes less pronounced towards the aboral aspect of the atrium until (in Fig. 18) it forms only a slight swelling of the atrial wall over the rectum.

Alimentary Tract. — As in other Endoprocta, so in Urnatella one can distinguish four regions in the alimentary tract: œsophagus, stomach, intestine, and rectum. The wall of the alimentary tract is composed throughout of a ciliated epithelium, except in the so called hepatic cells of the upper wall of the stomach. In this exception Urnatella agrees with other Pedicellinidæ, but for Loxosoma Harmer makes no such exception.

I find a highly refractive basement membrane lying at the base of the digestive epithelium. This stains deeply in hæmatoxylin, so that it can be seen with a low power as a distinct line surrounding the alimentary tract. Such a condition, described by Nitsche ('69, p. 19) for Pedicellina, has been denied by Ehlers ('90, p. 72) to exist in Ascopodaria.

There is an indication of a specialized intestinal (sphincter) muscle surrounding the opening leading from intestine to rectum, as well as at the anus. The structure in question, which appears in section (Fig. 18, *spht.*) as highly refractive and deeply staining areas on either side of the opening, seems to lie in the epithelial wall of the alimentary tract.

Since elsewhere in the calyx of Urnatella, and in other Bryozoa, muscles arise from mesodermal tissue, I am inclined to believe that, notwithstanding their position, they are formed from mesenchymatous cells which have crowded in between the epithelial cells.

The free surfaces of the epithelial cells are different in the various regions of the alimentary tract. On the wall of the œsophagus they run out into tolerably close-set and long cilia, which become longer towards the deep end of the œsophagus, and project into the stomach at its cardiac end (Fig. 18, *œ.*). Along the lateral and lower sides of the stomach one finds longer sparsely distributed cilia, and at their base a close-set layer of short rods (Stäbchen). Around the pyloric opening of the stomach there is a ring of elongated cilia. The intestinal epithelium bears chiefly short, stout, and close-set *Stäbchen.* The cilia of the rectum are confined to the upper wall, and are of medium length, and sparse. These are omitted in Figure 18.

The position of the mouth has been already defined. It leads into a broad *œsophagus*, constantly narrowing as it descends until it opens into the stomach at the lower (oral) end of the latter. Its wall consists of a columnar epithelium, some of whose cells are vacuolated, especially at the base of the epistome. The inner wall of the œsophageo-gastric opening is provided with a valve-like process, covered, like the opposite wall, with large cilia.

The pear-shaped stomach is lined below and laterally by a cuboidal or short columnar epithelium, above by a highly granular, more or less vacuolated, non-ciliated epithelium, whose free ends are ragged, sending processes into the lumen of the organ. These constitute the so called hepatic cells. Their granules stain deeply in hæmatoxylin. In the epithelium of the lateral and lower walls of the stomach deeply staining cells alternate irregularly with less deeply staining ones (Fig. 18). These cells are also full of small vacuoles.

The stomach is separated from the intestine by a circular ridge, formed of elongated cells bearing long cilia, — the pyloric valve.

The cells of the conical intestine are cuboidal, and possess a thick external and internal membrane, which stains deeply in hæmatoxylin. The passage into the rectum is restricted.

The epithelium of the rectum is composed of flattened cells. Its lower wall is closely applied to the upper wall of the intestine, the two walls being separated by the basement membranes of the two cell layers.

The anus lies, as already stated, on the aboral wall of the cloaca. At this point the wall of the rectum becomes continuous with the floor of the atrium above and the aboral wall of the cloaca below. The cells surrounding the anal opening are slightly larger than their neighbors. Lying apparently in the basement membrane is the anal sphincter already mentioned.

Under the term *body cavity* I include the space lying between the alimentary tract and the outer body wall and atrium. This space, which is much reduced in the retracted condition of the polypide, contains indifferent mesenchymatous tissue, tubular cells, muscles, the excretory and sexual organs, and the nervous system.

The body cavity is bounded by no other epithelium than the ectoderm of the body wall and atrium, and the entoderm of the alimentary tract; that is to say, there is no mesoderm.

The indifferent mesenchymatous cells have been seen to best advantage in the end of a regenerating stalk shown in Figure 3. Here the cells, which were studied while living, could be seen migrating on the inner surface of the ectoderm, and extending through the central region. Such wandering cells were filled with highly refractive granules.

The tubular cells of the body cavity lie chiefly at the base of the calyx, near its attachment to the stalk. In this region also I have seen in the living animal a flickering ciliate movement, and in the sectioned animal flame cells.

I have been able to distinguish only two systems of muscles in the body cavity of Urnatella, — the sphincter of the atrium, and the muscles of the tentacles.

The sphincter of the atrial opening (Plate III. Fig. 18, Plate IV. Fig. 26, *spht. atr.*) is composed of circular fibres lying in the lip of the atrium. Taken together, the fibres form a folded sheet, U-shaped on cross section, the convexity of the U being directed upwards. The function of this muscle is, of course, to constrict the atrial opening, and thus to protect the tentacles and parts below.

The tentacular muscles consist of the pair to each tentacle already mentioned. These run from the apex of the tentacle to the base, where they diverge to the right and to the left, and, after breaking up into many branches, pass through the ectoderm to become inserted upon the cuticula of the body wall. Leidy ('84, p. 10) saw these tentacular muscles.

Differentiated muscles do not seem to be abundant in the calyx of any of the Endoprocta. Tentacular muscles are unknown in other species. On the other hand, Ehlers ('90, pp. 64, 65) has described two systems for Ascopodaria which I have not seen in Urnatella, namely, lateral wall muscles and transverse muscles, the latter running from the right to the left wall. The fibres of these muscles also break up into branches before making their attachments.

Excretory Organs. — The chief excretory apparatus in Urnatella lies in the calyx below the ectodermal floor of the atrium (Plate III. Fig. 18, Plate IV. Fig. 22, *nph.*). It consists of a pair of tubules which unite proximally and open by a single pore into an unpaired cavity, which in turn opens into the atrial chamber at about the centre of its floor. This unpaired cavity is the one I have proposed to call the *cloaca.*

From its opening into the cloaca the unpaired tract of the excretory tubules, which may be designated *efferent duct,* runs oralwards and downwards, and then divides, the two tubules following the posterior wall of the œsophagus. Finally, the tubules turn back upon themselves, running outward and towards the rectum. The whole excretory apparatus has thus the form of the Greek letter Υ.

Each tubule ends blindly in a flame cell which bears the characteristic cirrus, exactly similar to that found in the stalk (page 6). Figure 22 (Plate IV.) shows the end of the tubule of the left side. The plane of this section was such that it cut the posteriorly reflected region of the excretory tubule of the left side throughout all but the middle of its extent. At the middle line the tubules of both sides sink below the plane of the section, so that it is the efferent duct which is cut at *nph.* in the median plane.

One of the youngest individuals in which I have found a nephridium is that from which the section Figure 29 (Plate IV.) was drawn. The efferent duct (*neph.*) appears to be composed of two elongated cells placed end to end. Running through the midst of these is a poorly marked lumen, partly filled by a granular substance. This and one or two other similar cases seem to me to support strongly the view of the intracellular nature of the lumen of the nephridium.

The evidence derived from the adult condition is less satisfactory, but points to the same conclusion. Thus one finds on cross section of the tubules that the lumen is not sharply limited like the exterior of the tubule. In fact, one sometimes finds delicate threads traversing the lumen (Plate III. Fig. 21, *a–c*). In one of these sections two nuclei are cut across, which in so far militates against my conclusion that the lumen runs inside of single cells placed end to end. But I believe these to be the nuclei of two adjacent *overlapping* cells.

On account of the evidence just presented, I regard the nephridium of Urnatella as having an intracellular lumen and ending blindly in a flame cell, and am thus brought into complete agreement with the results obtained by Harmer from Loxosoma. His conclusion ('85, p. 279) that the Endoproct nephridium is probably to be regarded as a head kidney, like that of Trochophores, seems to me to be justified. A further discussion of this topic must be deferred till towards the close of this paper.

The nephridium opens, as already stated, not directly into the vestibule, but into a pocket of it, the *cloaca* (Plate III. Fig. 18, Plate IV. Fig. 28). The wall of the cloaca consists of a layer of cuboidal epithelium which is perforated by three openings, — the anus, and the proximal openings of the efferent duct and of the vas deferens.

The cloaca is an organ which does not occur in any other Endoproct. Its existence here is due to the unique position of the rectum and anus, and of the opening to the vas deferens. In Loxosoma the last is very far removed from the opening of the nephridia. In the Pedicellinidæ the two openings are less distant from each other. In the male of P. Benedeni (Fœttinger, '87, Plate X. Fig. 16), the anus and the openings of the nephridium and vas deferens are quite near together; but in the female the oviduct of that species opens far distant from the other organs.

Sexual Organs. — Curiously enough, I have not found among all the individuals sectioned any ripe females. All the mature individuals of the lot collected by me on July 4th from the Schuylkill appear to have been males. In no individual did I notice any difference in the position of the ducts, such as obtains between the two sexes in Pedicellina Benedeni, — no trace of an incubatory chamber between rectum and the floor of the vestibule.

In the male organs two parts may be distinguished, — testis and vas deferens. The testis (Plate IV. Fig. 23) is a paired ovoid body lying between rectum, intestine, and the floor of the atrium. In the figure given one observes spermatozoa in various stages of development, the wall of the sac constituting the germinative epithelium.

The vas deferens (Plate III. Fig. 18, Plate IV. Fig. 28) is an unpaired U-shaped tube, the concavity of the U being turned oralwards. The wall consists of a cuboidal epithelium which is ciliated, at least at the proximal end of the tube.

The vas deferens of Urnatella resembles in form that of P. Benedeni (Foettinger, '87, Plate X. Fig. 15), which in turn seems to be more complicated than that of Ascopodaria.

Nervous System. — I have been able to make only a superficial study of this system. The main ganglion (Plate III. Fig. 18, Plate IV. Figs.

22, 29, *gn.*) lies between vas deferens and nephridium, is elongated transversely, and slightly constricted in the median plane. One can distinguish a central region composed of fine fibres running transversely, and a cortical region of cuboidal, deeply staining cells with large clear nuclei. I have not succeeded in tracing any peripheral fibres from this ganglionic mass, as Ehlers has done in another Endoproct.

III. Non-sexual Reproduction.

1. *Architecture of the Stock.*

Urnatella forms stocks by budding. As in other Bryozoa, the buds are normally produced in a very regular manner. I believe that I have determined the law in part, although it has exceptions, as the law of budding in every Bryozoan stock has. As Leidy has stated, several vertical stalks may arise from the same horizontal plate. A single stalk may remain unbranched, giving rise to new individuals at its distal end only, or it may give rise to branches which come off irregularly from a few segments. Usually only one branch arises from a single segment, but occasionally two do so (Plate V. Figs. 35, 38).

The length of these branches and the number of their segments decrease towards the distal end of the main stalk, and the conclusion seems justified that it is only at the distal end that they are formed. Excepting for these occasional branches, the lower segments of the stalk are bare of any branches or polypides. The distal end, however, is usually crowded with polypides so thickly as to make it difficult to count them or to determine their points of attachment (cf. Plate V. Fig. 30).

A very casual observation, however, shows that the buds from the main stalk are of two kinds; first, those which have given rise to a linear series of segments at the distal end of which is a calyx, and these are what I have called *branches;* and, secondly, those consisting of a *stolon*-like process, from one surface of which arise calyces resting upon a stalk of usually one segment only. The surface of the stolon upon which such polypides are placed is a definite one, namely, that which is turned towards the distal end of the main stalk. The budded branches and also the stolons are grouped upon the oral side of the adult stalk.

In the clearest cases, in young or not too richly branched stocks, I find the branch arising on the oral surface of the segment, and between two stolons, which are therefore more nearly lateral (Plate V. Figs. 37, 38, 40, 42).

One may therefore say that *usually the branches are median and oral, the stolons lateral.* Again, the branches give rise, like the primary stalk, to two kinds of buds, branches and stolons. The stolons give rise only to stalks of one segment each, bearing a calyx distally. These calyces are so placed that their oral surface is directed towards the distal end of the stolon. I have not found more than two individuals borne upon a stolon.

I have previously ('91, p. 72) tried to show how all buds in the stocks of Bryozoa are to be referred back to embryonic tissue lying at the tips or margin. In Endoprocta, however, the extreme tips seem to be occupied by a polypide, and the embryonic tissue lies in a zone at the base of the latter. This difference may be regarded, however, as only apparent, and the two conditions harmonized by conceiving the polypide in Endoprocta retracted into the stalk, below the zone of embryonic tissue, — the condition realized in Ectoprocta. The distal part of the stalk will then become terminal, constituting an apical ring of embryonic tissue surrounding the secondary atrial opening thus produced. From the oral portion of this ring new buds — branches and stolons — are, as in Plumatella, proliferated; and this process is repeated for each segment. At (or near) the apices of these incipient branches and stolons lies a mass of embryonic tissue which gives rise in the one case — branches — to the stalk, the polypide, and the *Anlage* of new buds; and in the other — incipient stolons — to the stolon and the *Anlage* of the individuals which bud forth from it. The differences between the branch and the stolon are, however, more apparent than real, as a comparison of the diagrams Figures 59 and 60 (Plate VI.) will make clear. In one case (Fig. 59) the mass of embryonic cells in any segment does not grow out far beyond the youngest individual produced from it; in the other case (Fig. 60) there is a considerable growth beyond the youngest individual. Thus in the latter case a long stolon is produced, in the former it remains at a minimum.

As I have already stated, in most cases, particularly in young vigorous stocks, one meets with the condition which may fairly be called typical, in which from one segment three buds — one median (branch) and two lateral (stolons) — arise. This typical condition may be expressed by the formula on the next page.

This formula will be understood by reference to the diagrams on Plate VI., of which it is a symbolic expression. The letters represent in all cases calyx-bearing individuals, the asterisks gemmiparous tissue. The capital A stands for the individual which forms the main stem under consideration. The $\circledast$ immediately below it represents the embryonic mass situated at the tip of the stalk, from which all the gemmiparous tissue distributed throughout the stock has taken its origin. As the stalk has grown, there have been left behind the embryonic masses represented by $\ast$. Three of these have arisen together, and the process has been repeated as often as segments have been formed. The separation of the segments is represented in the formula by a dash. Between every two dashes the same budding process is repeated.

$$
\begin{array}{ccccccc}
 & & & A & & & \\
 & & & \circledast & & & \\
 & \ast & & \ast & & \ast & \\
\cline{4-4}
 & \ast \times a & & a & & a \times \ast & \\
 & & & \times & & & \\
 & & & \ast & & & \\
\cline{4-4}
 & \times & & & & \times & \\
\ast \times b & \times \times a & & a & & a \times \times & b \times \ast \\
 & \times & & \times & & \times & \\
 & & \times & \times & \times & & \\
 & & & b & & & \\
 & & & \times & & & \\
 & & & \ast & & & \\
\end{array}
$$

The median embryonic masses ($\ast$) give rise to the individuals a, b, and c, and leave with each a dowry of embryonic tissue represented by ×. Each of these individuals a, b, and c, with its embryonic mass ×, now acts exactly like A $\circledast$. The lateral embryonic masses act precisely as do the median ones.

The typical condition expressed by the foregoing formula is not often perfectly realized, for the simple reason that the stock would thereby become too crowded. The more frequent modifications are the absence of the median bud, the absence of one or both of the lateral buds (stolons) and, occasionally, the apparent substitution of a branch for a stolon.

The foregoing formula is one of the most complicated that it is necessary to make for Bryozoa, for nowhere else are the embryonic masses so abundant relative to the polypides, or, in other words, nowhere else are so many embryonic masses borne by one individual. It is quite common among other species to find three embryonic masses arising from one; but here the formation of triple masses is repeated as often as the number of segments in the stalk. This fact raises the question of the significance of these segments, and leads us to discuss the subject.

2. *Segmentation of the Stalk.*

Leidy ('84, p. 9) did not fail to call particular attention to the division of the stalk of Urnatella into segments, and recognized their successive production "through the process of division, very much in the same manner as in the production of the proglottides of tape-worms from a *scolex*."

The phenomena of segmentation must have a special interest on account of the relation of segmentation and strobilization. I shall treat under this subject, first, of the phenomena of segmentation in Urnatella; secondly, of the probable origin and significance of the process in this genus; and, thirdly, I shall examine critically Leidy's comparison.

The transverse septum, which is the first indication of the separation of the stalk into segments, begins to be formed at about the time that the lateral buds arise, and immediately below them. It arises, as already stated (page 8), as a ring-like fold of the ectoderm, whose free edge encloses a circular orifice, through which the interiors of the two segments which are being formed are continuous (Plate IV. Fig. 24). By continued growth of this fold the diameter of the orifice diminishes, never wholly closing, but leaving a space for the passage of the tubular cells, to which reference has already been made (page 7). In this process the sheath of longitudinal muscles, which originally ran immediately inside of the ectoderm continuously from the base of the calyx to the last fully formed septum, becomes discontinuous at the place of the ingrowing fold, and the separated ends of the muscle fibres become attached to their respective faces of the septum.

In order to discover the significance of this process of segmentation we must first study its distribution throughout the Endoprocta. Usually the calyx is borne upon an unsegmented stalk. Such is the condition, for example, in Loxosoma, Pedicellina echinata, P. Americana, and Ascopodaria. In other cases, Gonopodaria (Ehlers, '90, p. 146) and P. Belgica (Fœttinger, '87, p. 301), there is a poorly expressed and highly variable segmented condition. In Arthropodaria (Pedicellina) Benedeni the stalk is distinctly and regularly segmented, there being partitions and slight external constrictions. Finally, in Urnatella we find the segmented condition still more sharply expressed.

There is a suggestive parallelism between the formation of segments and the production of buds. While with one exception all species with unsegmented stalks produce no buds, and none have yet been described as occurring on Gonopodaria and P. Belgica, budding does occur to a slight extent on Arthropodaria, and still more profusely on Urnatella. There is one genus, however, Barentsia (Vigilius, '84^a, p. 86), which buds sparsely and has an unsegmented stalk. Here, however, as in Urnatella (Plate VI. Fig. 58) and Arthropodaria (?), there is a septum between the branches and the main stalk.

Finally, in all Pedicellinidæ which have been studied carefully there is a septum between the stalk and calyx.

One may bring these scattered facts of distribution of the septum into some sort of unity by saying that in the Pedicellinidæ every calyx and every lateral branch (where such exists) is partly cut off from communication with the interior of the mother stalk by septa. This is effected by the production of these organs at the place of junction of the calyx and the lateral buds to the stalk, and in some cases also by the partial division of the stalk itself into compartments by septa. The transverse septa must have either a morphological or a physiological significance. They might be regarded as a part of the wall of zoœcia, equivalent to the zoœcia of Paludicella, and therefore to be morphologically equivalent to the septa of Paludicella. On this hypothesis each segment of the stalk of Urnatella would be an (incomplete) individual. The idea of the individuality of the segments would seem to be sustained by the fact that each gives rise to similar buds, and that apparently any segment has the capacity of regenerating the lost calyx, or end of the primary stalk. On the other hand, dissepiments might be regarded as structures which had grown across the originally unsegmented stem to fulfil some need of the organism. Comparative anatomical studies seem to me to favor the second view. In Loxosoma, and in most marine Pedicellinidæ, we find a stalk without dissepiments. In other forms dissepiments are few and variable in number, in still others they are constant in occurrence, and from the segments arise buds. Finally, in Urnatella, the segments are separated by the dissepiments, each becomes more individualized, and has the capacity of giving rise to buds having the same arrangement. The differentiation of the separate segments has gone so far that one can hardly see in the stalk of Urnatella, resembling a string of beads, the assumed smooth cylindrical stem of its Pedicellina-like ancestors.

If we seek for an explanation of the dissepiments, I think it is to be found in the protection of the stock against the influx of water and destroying organisms at the time of the loss of calyx or lateral branches, which would make regeneration impossible. This is the same hypothesis which I offered in a former paper ('91, p. 40) to account for the formation of a septum in Ectoprocta.

In favor of this hypothesis are not merely the need of such an apparatus on account of the frequent loss of the calyx and the lateral branches through accident, and the fitness of this mechanism for the function, but also the existence of the special mechanism of radiate cells, covering over the opening in the dissepiment between the calyx and stalk, — a dissepiment which will be most useful in the manner indicated by this hypothesis, owing to the delicacy of the calyx and its liability to accident. When the lateral branches or the terminal calyx become detached from the parent stem, we find that the pore in the septum, remaining behind as a part of the wall of the stalk, has become sealed by a cuticular plug. So also Ehlers ('90, p. 22) in Ascopodaria. In this case we can see the utility of the dissepiment, and can infer its value in those positions where it is not certain, but only possible, that it may be called into play. My conclusion then is, that the dissepiments have a purely physiological meaning, possessing a protective function, and that the segments of the stem are only physiological divisions of a primitively undivided stalk, which have perhaps no other significance than that they are parts separated by the dissepiments.[1]

It follows naturally from the foregoing hypothesis, that the segmentation of the stalk has succeeded, rather than preceded, the condition of bud formation from the stalk, it being rendered desirable owing to the greater danger to mutilation to which the stalk is exposed. From this standpoint we can see why buds should be produced on each segment in a similar manner. The relative profuseness of budding in Urnatella is explainable on other grounds.

Examining more closely the relation of this process to the production of proglottides in a tape-worm, — accepting the view that the production of proglottides is fundamentally a process of continual regeneration of lost parts, — there seems to be an important difference in this, that the growth of the stock of Urnatella is limited, more than ten or twelve segments being rarely formed, while an indefinite number of proglottides are produced. The limited growth of the Urnatella stem seems to indicate that the production of segments is not the production of new parts,

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[1] Freely branching stocks of Hydroids have septa interpolated at the base of the hydranth, which is peculiarly liable to fall off, and sometimes in the middle of the stems. The occurrence of such similar structures throughout the two most profusely branching groups of Metazoa is further evidence for the validity of the physiological explanation of them which I have offered.

but the division, progressing towards the calyx, of an originally simple stalk into a number of parts, — that the growth of the Urnatella stalk is limited just as that of the Pedicellina stock is limited, and for the same reason.

3. *Orientation of the Individuals.*

The orientation of the individuals of the stock seems to be here, as in Ectoprocta, a very definite one. In Pedicellina and its close allies, as well as in Urnatella, the young individuals budded from the parent stalk face the same way as the polypide of the parent stock. Seeliger ('90, p. 571) has pointed out that in all the species of Loxosoma the orientation of the buds with reference to the parent is definite, but different from that found in Pedicellina. The orientation of the buds in Loxosoma (which arise, as in Pedicellina, on the oral side of the mother) is the reverse of that of the mother. Thus it comes about that the oral aspect of the buds in the Pedicellinidæ is turned towards the periphery of the stock, that of Loxosoma towards the centre. This is the same difference which has been found to prevail between the buds of Phylactolæmata and Gymnolæmata, and as in this case, so in Endoprocta the differences may be harmonized by a different method of expression. *In all Endoprocta the oral aspect of the buds is turned towards the centre of proliferation.* For in Loxosoma new individuals are produced between the next older and the parent stock, the centre of proliferation remaining in the parent stock, while in Pedicellina it migrates away upon the end of the stolon. The typical condition in Loxosoma is represented by the formula

a b c d * A;

that of Pedicellina by

* d c b a A,

in which the asterisks represent gemmiparous tissue.

The general statement of the relation of the aspects of the buds to the proliferating region is the reverse of that which I have given for Ectoprocta ('91, p. 82), which reads, "In both Phylactolæmata and Gymnolæmata, the *anal* aspect is turned towards the gemmiparous region." It is important to note, however, that this difference corresponds to a difference in respect to the part of the alimentary tract which is formed by the principal pocket of the atrium, for this in Ectoprocta gives rise to the posterior part of the elementary tract; in Endoprocta, on the contrary, to the anterior part. The differences in the process of budding in the two groups can be harmonized, and at the same time the physiological nature of the differences indicated, by putting the statement thus: — In all Bryozoa, the formation of the alimentary tract begins at that end which is turned towards the gemmiparous region (cf. page 28).

The problem of the difference in the method of development of the alimentary tract in Ectoprocta and Endoprocta, is the same as that of the differences in the development of the alimentary tract of Triploblastica in general.

As is well known, the midgut in Triploblastica is produced by an invagination whose mouth — the blastopore — comes to be in some cases at the anterior part of the tract, in others at its posterior part. This variation in the method of formation has been explained by the hypothesis that the blastopore represents the opening into the gastro-vascular cavity of Cœlenterates, which is functionally both mouth and anus; and that as we find a physiological separation of the opening in many Cœlenterates, so a morphological separation of the gastrula-opening into mouth and anus by concrescence of the lips of the blastopore in the mid-oral line, has occurred in the ontogeny of Triploblastica. In some cases both mouth and anus arise by this process, in other cases only one organ, the other arising secondarily, or (preferably) later. The part which arises later might be regarded as a new formation, or, following Caldwell ('85, p. 23), as derived from a part of the entoderm which had become separated from the greater part in the separation of the two extremities of the elongated lip of the blastopore to permit the placing of mouth and anus at opposite poles of an elongated animal.

The application of these facts and their explanations to the facts of the formation of the alimentary tract in the Bryozoan polypide is evident. Gastrulation takes place not in the act of first invagination of the inner layer of the bud, but in a secondary invagination from the bottom of the first formed sac. The blastopore does not lie on the surface of the body wall, but has been carried below the surface, and its position is indicated by the plane of separation of alimentary tract and atrium, where the roof of the gut and the floor of the atrium have been produced[1] by concrescence of the lips of the blastopore. The atrium then is in no way lined by entoderm; it is merely a precociously developed, protecting pocket of the body wall, which occurs in that region in which invagination of the entoderm is to take place. The primary atrial opening is not at all the blastopore, as some authors have called it.

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[1] Compare Seeliger, '89^a, pp. 181, 182; so also in Paludicella, see my earlier paper, '91, p. 19, and probably in Phylactolæmata, cf. Kræpelin, '92, p. 33.

My conception of the relation of the processes of atrium formation and gastrulation will be more easily understood if we compare the formation of the polypide with the early stages in the development of the egg of Sipunculus, as given by Hatschek ('83, pp. 78–81). Here gastrulation occurs only in the depths of the invagination at the vegetative pole; the more superficial part of the cavity is the trunk amniotic cavity. This corresponds to the atrium of Bryozoa, and, like it, is lined by ectoderm.

The concrescence of the lips of the blastopore takes place slightly differently in Endoprocta and Ectoprocta, so that in one case the blastopore persists in the region of the permanent mouth, and the proctodæum appears later; whereas in the other case the blastopore persists in the region of the permanent anus, and the stomadæum arises later.

In all Bryozoa, however, the main ganglion arises in the region of concrescence, precisely as the ventral nerve cord is now known to do in most invertebrates. Thus additional support is given to the idea that the ganglion of Bryozoa is a *subœsophageal* one.

4. *Histology of the Buds.*

The *histological structure* of the branches is exactly like that of the parent stalk. The minute structure of the stolons deserves a word of description. The base from which the individuals arise is filled with mesenchymatous cells, which at the distal, growing end are closely packed and deeply stainable (Plate VI. Figs. 51, 57, *sto.*). Some of the cells are differentiated into muscle fibres, which run up into the stalks of the individuals that have arisen from the stolon (Fig. 57, *mu.*). The epithelium at the distal end of the stolon is composed of cuboidal or slightly elongated cells. At the base of the stolon the epithelial cells are greatly elongated and closely packed together (Figs. 51, 57, *cl. sec.*).

At the point of attachment to the parent stem the stolon is considerably constricted, the epithelium forming an inward fold surrounding a small opening through which the parenchymatous tissue of the bud and the mother stalk are continuous (Plate VI. Fig. 58, *di. sep.*). Between the layers of this circular fold is secreted a cuticular disk, perforated at its centre.

5. *Formation of New Stocks.*

The development of Urnatella from the egg has never been seen, and I was naturally anxious to get embryological material. On looking over my preserved material I found no trace of eggs, although there were many ripe males. I have no direct knowledge, therefore, as to whether

I was too early or too late for embryological material, although from some indirect evidence drawn from what follows I am inclined to think I was too early.

The youngest stocks found I obtained in large numbers, and they were of almost exactly the same age. Moreover, they agreed with the youngest stages found by Leidy and figured by him ('84, Plate I. Figs. 5, 6, 7). I have represented some of these in Plate V. Figures 31, 32, and, enlarged, in Plate II. Figure 15, and Plate V. Figure 46.

I have already (pages 3–6) called attention to some of the characters of the stalks of these young individuals. It remains to mention the "basal plate" of such stocks.

Unlike its condition in the adult, the "basal plate" is a relatively large organ of elongated cylindrical form (Plate II. Fig. 15). Its outer epithelium consists of sharply demarked cells, cuboidal above, columnar below. This epithelium has given rise to a cuticula thin and dense above, and thicker and less refractive below. The columnar cells are somewhat less deeply stained than those at the end of the "basal plate" farthest from the two stalks. Their nuclei lie at their inner ends. The outer part of the cell contains spherical masses of granules. On the whole, it stains less deeply than the inner end. Finally, one always finds particles of dirt closely adherent to the under and lateral aspects of the basal plate.

These facts I interpret as follows. The columnar cells of the under side are glandular, and secrete a sticky substance which causes the adherence of the surrounding particles of dirt, and thus serves to *anchor* the young stock.[1] The tissue of the interior of the "basal plate" is remarkable, and difficult of interpretation from sections alone. In such sections one sees bands running through the middle region and crossing at various angles. Each of these "bands" is a nucleated cell, and probably represents a muscle fibre (cf. Plate V. Fig. 46). One sees also fibres having a different appearance running radially from the base of the stalk to the columnar cells of the "basal disc" over quite a long stretch (Plate II. Fig. 15). In addition to these protoplasmic structures there are long clear spaces which are bounded by thin membranes and contain occa-

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[1] Seeliger ('90, p. 573) finds in Pedicellina a glandular differentiated zone on the base of the stolon, where it comes in contact with foreign bodies. This, he says, can be traced unbroken through the entire length, especially in young stocks, consisting of few individuals. The foot gland of Loxosoma is an organ fulfilling a function similar to that of the glandular cells of the stolon, but an homology of the two organs can hardly be maintained.

sional nuclei. These are the tubular cells already referred to. Some of them contain the agglutinated cilia characteristic of flame cells, and they arise from large cells, which must indicate the beginnings of the excretory tubules of the stalk already mentioned.

What is the meaning of the fact that no younger stages than these occur, although such and all older stages are abundant? Have these young stocks been derived from fertilized eggs, or have they some other origin?

I have already referred to the fact that the great mass of the buds of any Urnatella stock are found at the upper end of the parent stalk. The lower and middle parts of the stalk possess few buds, although they once constituted the upper end of the stalk. What has become of the buds which have been lost? Leidy asked this question, and the facts led him "to suspect that the branches are spontaneously and habitually detached from the parent stem, to become elsewhere attached, and thus form new colonies." I have evidence that raises the suspicion of Leidy to as near certainty as can be obtained by use of the morphological method. *The "youngest stocks" are derived from the stolons of the parent stalk, which habitually become free for the purpose of founding new stocks.*

To establish this proposition it will be necessary to show, (1) identity of structure between old lateral buds and young stocks, and (2) the scar of attachment of the young stock to the parent stalk (cf. Plate VI. Fig. 58). Of identity of structure there can be no question. Often it would have been quite impossible to distinguish between young stocks and "stolons" which had been violently broken off from the parent stalk and were lying loose in the bottle, were it not for a single criterion, namely, the young stocks had dirt adhering to their lower surface. An application of the second criterion leads to the same positive result. In series of thin sections of young stocks one can always find at one side of the median plane the scar of former attachment, which appears as a thickening of the cuticula into which ectodermal cells may sometimes be seen penetrating (Plate V. Fig. 47). We have here, then, a method of non-sexual propagation quite similar to that obtaining in Loxosoma, where the buds habitually drop off, so that this genus is commonly said not to be stock-producing. This resemblance must be regarded as being purely a physiological one, and not in the least implying any closer relationship of the two genera.

I have already expressed my belief that the stolons are thrown off regularly *for the purpose* of founding new stocks. On this assumption we can account for the rapid growth of the embryonic tissue giving rise to a stolon-like body, which will become a basis of support for the new stock, the "basal plate." One can thus account for the thickened cells of the under side of the stolon, which appear before detachment (Plate VI. Figs. 51, 57). The question remains, Do the median branches play a similar *rôle* to the stolons? I do not think they do, for the reasons, (1) that, having no basal plate, they are not physiologically fit for forming new stocks; (2) that I have found no new young stocks having one parent stem with one or two generations of budded individuals, — the condition of the median branches; (3) that, on the contrary, one often finds such median branches persisting on even the lower segments of the stock. (Plate V. Figs. 35, 39, 40. Compare Leidy, '84, pp. 8, 9, Plate I. Fig. 4.) Since the median branches frequently persist as a part of the parent stock, — they are not produced in the first place on every segment, — I conceive their function to be the increase of the number of proliferating points in the stock itself.

Starting with the young stock, one can find all stages of growth up to the most complicated conditions (Plate V. Figs. 33, 36, 43, 44). During the growth of the stock the basal plate gradually undergoes changes. The parenchyme becomes filled with yolk globules (Plate V. Fig. 49), and the cuticula becomes thick and dark.

Concerning the morphological significance of the basal plate a few words must be said. I regard this as a stolon morphologically equivalent to the stolon of the Pedicellinidæ. In the latter group, as is well known, the individuals are budded from the upper side of a repent cylindrical stolon, which constantly produces new buds at the growing end, and which becomes separated into segments by the formation of transverse dissepiments. There is no such stolon in the adult Urnatella, which is sharply separated from the Pedicellinidæ by this single character. The presence of a stolon in the young stock indicates a derivation from an ancestral condition possessing a stolon in the adult.

If, however, the "stolon" of the young Urnatella stock is homologous with that of the Pedicellinidæ, we ought to find it, sometimes at least, giving rise to more individuals than two, and perhaps becoming segmented. Both of these conditions are occasionally fulfilled. Leidy observed that three, four, or even five stems may arise from a common "basal plate." I have observed only three with certainty. Two cases of this are shown in Plate V. Figs. 48 and 49. In the first of the two cases distinct perforated dissepiments were observed dividing the stolon (basal plate) into three segments, out of each of which a single stalk arose.

6. *Formation of the Individual.*

Recent careful studies on the formation of the individual in other Endoprocta, especially by Seeliger ('89ᵃ), render a detailed study of this process less necessary. There are a few points concerning the physiological rather more than the morphological features of this process which I have attended to in this case in order to test certain conclusions which I had arrived at from the study of the earliest stages of budding in Ectoprocta.

First, the budding regions are areas of cuboidal cells, with relatively large nuclei and deeply staining plasma. Such a condition is found in both the ectoderm and mesoderm of the proliferating region (Plate VI. Figs. 50, 57). The relative enlargement of the ectodermal cells, and at the same time a bending of the whole layer outward, give rise to the first fundament of the new individual. The musculature of the new individuals is certainly not derived directly from that of the old stalk, for this takes no part in the outbending. Upon the apex of the cylindrical protuberance thus formed the polypide is produced. The details of this process I have not followed.

Secondly, the position and time of origin of the buds arising from the stalk are very definite. They make their appearance in a zone lying in the lower part of the segment (Plate VI. Figs. 50, 58–60), and shortly after the formation of the dissepiment which lies just below.

One of the questions the re-examination of which most interested me was that of the origin of the alimentary tract, since this is stated to arise differently in Endoprocta and Ectoprocta.

In an optical section of the whole bud (Plate VI. Fig. 53), it could be seen that the atrium was connected with the young alimentary tract at the oral end only. The same thing is shown in the series of transverse sections, Figures 54–56, in which the distal (anal) part of the atrial chamber is not confluent with the rudiment of the alimentary tract which touches its floor, Figure 54, but the two organs are confluent at the proximal (oral) part, Figure 56. Figure 52 is from an optical longitudinal section of the bud shown in Figure 53, taken in a plane perpendicular to that of Figure 53. Here the alimentary tract, *st.* (Fig. 52 ; *ga.* Fig. 53) is being constricted off from the atrium.

Like the young bud, the growing tip of the stolon possesses an ectoderm consisting of large cuboidal cells (Plate VI. Fig. 57). The mesenchymatous tissue also consists of thickly crowded, undifferentiated, and deeply staining cells (Figures 51, 57).

7. *Regeneration.*

Like other Endoprocta, Urnatella has the capacity of regenerating its lost calyces. Leidy ('84, p. 13) had already observed this process, and Potts and I have (as previously mentioned) seen the same thing. Figures 3 and 2 (Plate I.) show some of the phenomena of regeneration. The formation of a new terminal calyx seems to be preceded by the formation of the stalk part of the new terminal individual. This new formation takes place in one of the segments near the distal end of the parent stalk. The terminal dissepiment of the segment, cutting it off from the outside world, is completely closed in its centre by a cuticular plug. This cuticular dissepiment (Fig. 2, *di. sep.* at the left) becomes torn off from the lateral cuticula of the segment along one edge, sometimes, as in the figure, remaining attached at the opposite edge. I have given on Plate I. (Fig. 3) a drawing of such a regenerating stalk before the polypide has budded from its wall. The outer body wall has evidently taken the initiative in the process, and mesenchymatous cells have migrated in. The drawing (Fig. 3) was made from the living animal, and the mesenchymatous cells could be seen changing form like an amœba. The amœboid cells also contained highly refractive granules, which I regard as food material. These granules were seen moving about in the cells as the latter changed in form.

One striking feature of the young segment was the presence of two flickering organs, which I now fully believe to be flame cells with their tufts of fused cilia. I have elsewhere ('91, p. 39) called attention to the part played by amœboid cells in Paludicella on the nutrition of the young buds. I believe that the amœboid cells here have the same function.

Leidy ('84, p. 13) has suggested that the segments of Urnatella might function as statoblasts to preserve the species during the winter. Of the correctness of this suggestion I have no doubt. The ease with which regeneration occurs from the old segments, and the fact that in stalks in which the calyces have been for a long time lost one sees the cirri of the flame cells still flickering, show that the tissue surrounded by the thick cuticula of the segments has a great capacity for retaining life, and, under favorable conditions, for reproducing lost parts. In their *rôle* as statoblasts, the segments need the yolk stored up in their cells during the summer.

IV. AFFINITIES OF URNATELLA.

From the frequent opportunity that I have had successfully to compare the organs of Urnatella, even in detail, with those of Pedicellina and allied genera, there remains no doubt in my mind of its close relationship to those forms. Arthropodaria, especially in its segmentation of the stem and the associated budding process, seems most closely to resemble Urnatella. In three points of importance, however, Urnatella differs from other Pedicellinidæ, namely : (1) in the possession of a cloaca (and absence of a brood-sac ?) ; (2) in the presence of water or excretory canals in the stem and calyx, — which are so striking that they could hardly have been overlooked if they occurred in other Pedicellinidæ; and (3) in the absence of the stoloniferous type of budding.

As for the last difference, however, I have tried to show that there is a stolon from which the individuals of the Urnatella stock arise, although it is small. Whether this rudimentary condition of the stolon is an ancestral or a degenerate character is doubtful ; I have been inclined to consider it the latter.

In regard to the first difference, I must point out that in the male of Arthropodaria there is a condition resembling that found in Urnatella, for in the former genus (Foettinger, '87, Plate X. Fig. 8) the anus, vas deferens, and excretory tubule open near together.

The second difference concerns a very important set of organs, and if they should be shown to be indeed absent in Arthropodaria Benedeni, it would lead us to conclude that in one respect at least, perhaps owing to physiological needs, Urnatella has retained a more ancestral condition than its near allies.

V. AFFINITIES OF THE BRYOZOA.

There are three prevailing views concerning the relationship of the Bryozoa to other groups. According to one view (most recently and ably defended by Ehlers) they find their nearest allies in the Gephyrea ; according to the second view, they have sprung from the lower worms, — from Rotifer-like ancestors. The third view (that of Hatschek) assumes that Ectoprocta and Endoprocta are in fact not closely related, but that the former should be placed near the Gephyrea, the latter close to the Rotifera.

The reasons for this difference of opinion are not far to seek. Those who have begun their studies with the Ectoprocta, particularly with their anatomy, have been struck by their resemblance — especially in the possession of a body cavity and of a tentacular corona — to the Gephyrea, and particularly to Phoronis. Those, on the contrary, who have devoted their studies chiefly to the Endoprocta, and especially to the development of that group, have urged the second view. The third view seeks to reconcile the two conflicting theories. I favor the second of the views given above because of certain considerations which follow.

I propose first to show the untenableness of the third view. It would then be nearly sufficient, in deciding between the two remaining views, to show that the Endoprocta are the more primitive group of Bryozoa; but in addition to this, I shall offer positive evidence of derivation of the Bryozoa from the lower worms.

The chief argument for the diphyletic origin of Bryozoa rests on these three important differences between Ectoprocta and Endoprocta: (1) that of the tentacular corona, which includes within it the anus in one case, and leaves it outside in the other; (2) that of the body cavity, which is absent in one case and present in the other; and (3) that of the kidney, which is a pronephridium in Endoprocta and (it is alleged) a metanephridium in Ectoprocta.

I have, in an earlier paper ('91[a], p. 103), shown that the difference in relations of the anus to tentacular corona is completely and satisfactorily explained by the study of the development of the polypide, in which the closure of the tentacular corona between mouth and anus is effected only at a relatively late stage.

Concerning the second of these differences, Ehlers ('90, pp. 152, 154) has already well argued that it cannot be so fundamental, since other unquestionably closely allied groups (e. g. Hirudinea and Chætopoda) differ similarly. Moreover, the difference between the "body cavity" of Gymnolæmata and Endoprocta is one of degree, not of kind, for in both cases we have to do with parenchymatous tissue more or less completely filling the primary body cavity. The existence of spaces in the midst of the parenchyme of Gymnolæmata may be accounted for (following Harmer, '85, p. 64, see also Lang, '88, p. 77) on the physiological ground of the necessity of a space into which the polypides can retract. In Phylactolæmata this parenchyme has become, in part, a very definite "cœlomic epithelium," although, as I have pointed out ('90, p. 128), showing traces of its parenchymatous origin.

Upon the alleged differences in the kidney, no argument can be based, simply because the existence of an excretory tubule in Ectoprocta is very uncertain, being at present not even probable.

A fourth difference, which I do not remember to have seen mentioned, concerns the position of the sexual glands. In Endoprocta they arise on the polypide and are connected with the atrium by a special duct. In Ectoprocta they arise on some part of the body wall. In all cases, however, they arise from the mesenchymatous tissue, or its equivalent, the cœlomic epithelium. The exact position is not significant, for even within the group of Phylactolæmata we find the testis arising sometimes on the funiculus (Plumatella), sometimes on the body wall (Cristatella), and in neither case at the same place with the ova.

On the other hand, the resemblances between Ectoprocta and Endoprocta are striking: in both a curved alimentary tract, with tentacles of similar histological structure; in both, an atrium originating in the same manner; the central nervous system in both alike in position, form, structure, and development; in both the polypide originating in comparable ways, involving the same problem of the relation of the germ layers to the organs of the bud. Moreover, there must remain unmentioned many minor resemblances which individually are not very significant, but which, occurring together, furnish a most powerful argument to the mind of one studying the animals themselves.

. Hatschek's view seems to me, therefore, untenable, and it remains to inquire whether the Bryozoa have been derived, accompanied by degeneration, from an Annelidan ancestry, through Gephyrean-like forms,[1] or whether they represent a persisting low type. As we have seen, the first hypothesis must be relinquished, if it can be shown that the Endoprocta are the more ancestral type.

In any group of sessile, colonial animals, we should expect the more ancestral type to retain more distinctly its individuality, to possess in a more marked degree features belonging to a free, non-colonial life, and in a less marked degree those belonging to a sessile, colonial one. Thus in its development the group will lose certain characters and gain certain others.[2] A well marked individuality accompanied by a simple

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[1] As is well known, Hatschek ('83, p. 69) has long maintained that Phoronis and the Sipunculaceæ have not been derived from Annelids as the Echiurida have, but from unsegmented ancestors; and this view has become very widely accepted. Ehlers, however, seems to adhere to the older view. Whatever the truth may be in regard to this matter, the validity of my argument based on embryology and comparative anatomy concerning the absence of close relationship between Phoronis and Bryozoa is not affected.

[2] Lang ('88) has shown, by an instructive analysis, that in sessile animals locomotor and sense organs, the nervous system, and the musculature tend to degenerate, and that the tentacles and protective coverings become more important.

method of budding (Loxosoma); a relatively poorly developed, incompletely retractile lophophore; a complicated system of sense organs and nerves (Loxosoma); sexual and excretory ducts; a typical larval (trochophore) form, — these distinguish the Endoprocta. On the other hand, the Ectoprocta are marked by a loss of individuality (existence of cœnocœl, Phylactolæmata), by a highly complicated lophophore provided with means for complete retraction, by absence of a complicated nervous system (small ganglion of Gymnolæmata), by absence (?) of sexual and excretory ducts, and by abbreviated larval life (passed within the body of the mother).

Stronger than this argument is the fact that in the development of the tentacular corona and of the alimentary tract — at first without a cœcum — Ectoprocta pass through stages more nearly resembling the adult Endoprocta condition than their own adult condition does.

These facts seem to me to prove, if morphological principles can be relied upon, that Endoprocta are nearer the ancestral form of Bryozoa than Ectoprocta.

Admitting that the Endoprocta are more ancestral than the Ectoprocta, I cannot conceive how any one can maintain a close relationship with Phoronis. For the line connecting mouth and anus is in Endoprocta ventral, while the corresponding line in Phoronis is dorsal, as Caldwell ('83, p. 372) has shown, and the kidney is a metanephridium. These facts far outweigh, in my opinion, similarities in tentacular corona, epistome, and bent alimentary tract.

The absence of a true body cavity, and the existence of a water or excretory system ending in flame cells, point conclusively to an origin of Bryozoa from the lowest worms. For such an excretory system is found elsewhere only in Platyhelminthes, Rotifera, and in a modified form in Nemertines (Bürger, '91). On the other hand, the existence in the stalk of epithelial (in addition to mesenchymatous) muscles looks like an advance beyond Rotifera and Platyhelminthes. But it does not follow that such muscles existed in the ancestors of Endoprocta; they may have been produced by causes similar to those by virtue of which they occur in Nematodes.

Hatschek ('77, p. 528) suggested, and Harmer ('85, p. 11, 35) has since shown, that the ganglion of the Endoprocta is to be regarded as a subœsophageal ganglion. Zelinka's ('91, p. 337) discovery of a subœsophageal ganglion in Rotifers is interesting in this connection, as making more probable the assumption necessary for the preceding view, that the ancestor of Rotifers and Endoprocta possessed such an organ.

One cannot refrain from noticing the similarity in the relations of the "under lip" of Rotifers (Zelinka, '91, Taf. III. Fig. 55) and the epistome of Bryozoa (cf. also the foot of Mollusks).

Zelinka has also shown (p. 397) that in Callidina at an early stage two lateral folds appear on the ventral side of the embryo, enclosing between them the mouth and under lip. These folds extend along about one half of the length of the embryo. Later they become relatively shorter, and finally form the lobes of the wheel organ. They have also precisely the position of the lophophoric ridges of Ectoprocta at an early stage, as I have figured it ('91, Fig. 25), lying on each side of the mouth and ganglion. They have also the same relations as the ridges from which the gill filaments arise in Lamellibranchs. Lankester's ('74, p. 80) view of the homology of the tentacles of Bryozoa and gill filaments of Lamellibranchs is thus strengthened.

Finally, there is between Rotifers and Endoprocta a striking similarity in the position of anus and urogenital ducts, which in Urnatella, as in Rotifers, open into a common cloaca on the subœsophageal aspect between mouth and anus. Such a resemblance is especially striking in footless genera like Asplanchna (which, however, has no anus, cf. Masius, '91, fig. 1) and Hertwigia (L. Plate, '85, Fig. 7), — genera resembling more nearly the ancestral form, since the foot, lying behind the anus, must be considered as a secondarily produced appendage.

To sum up: The embryological as well as the anatomical evidence seems to sustain the view that Bryozoa are closely related to Rotifers, the two groups having sprung from an ancestor which was common to them and Mollusks also; that after the Rotifer stem had branched off, the common Mollusco-Bryozoan stem produced tentacles on the lateral ridges; that the two groups then soon separated, the Mollusca to undergo an extensive and complicated development, the Bryozoa to remain at a low level. The chief changes which the Bryozoa have experienced are (1) the acquiring of a body-cavity through the relative decrease in amount of the mesenchyme, that which remains forming an epithelium (Phylactolæmata); (2) the loss (?) of the protonephridia and sexual ducts in Ectoprocta; (3) the loss of the epistome (Gymnolæmata); (4) the loss of the preoral ganglion; (5) the acquiring of a cœcum (Ectoprocta); (6) the multiplication of methods of reproduction, by regeneration, by budding (without and with stock-formation), by division of stocks, and by statoblasts.

Cambridge, September 27, 1892.

SUMMARY.

The segmented stem of Urnatella consists of a two-layered cuticula; an outer epithelium (ectoderm) consisting of cells flattened except at the transverse septa and at the distal end of the stalk; and an axial portion consisting of elongated cells, many of which are vacuolated, and surrounding which there is no intercellular substance. (Pages 4, 5.)

The musculature of the stalk consists of radial sheets of fibrillæ, several of which develop in a single cell. (Pages 5, 6.)

Many of the vacuolated cells of the stalk end in flame cells like the water or excretory tubules of Platyhelminthes. (Pages 6, 7.)

Yolk is developed in the cells at the base of the stalk, first as fine intercellular granules, which later fuse, this process being accompanied by cell degeneration. (Pages 7, 8.)

The lip of the atrium contains a sphincter, and resembles in its relations the "margined thickening" of Ectoprocta. (Pages 9, 10.)

The epithelium of the tentacles encloses a parenchymatous core. A pair of muscles is present. (Page 15.)

The alimentary tract resembles that of the Pedicellinidæ, except that the lower wall of the rectum and the upper wall of the intestine are in close contact. (Pages 11, 12.)

The nephridial tubules end blindly in flame cells, and open into a cloaca, into which open also anus and the vas deferens. (Pages 14,15.)

Two kinds of buds arise from the Urnatella stalk; "branches," which are typically median, and "stolons," typically lateral. (Page 16.)

The segmentation of the stalk is probably an adaptation to the process of budding, which is accompanied by a greater liability of the wall of the stock to rupture, and therefore by a greater need of separation of the stalk into compartments. (Page 20.)

In all Endoprocta the oral aspect of the buds is turned towards the centre of proliferation, and in all Bryozoa the aspect in which that end of the alimentary tract which arises from the principal outpocketing of the atrium lies is turned towards the gemmiparous zone. (Pages 22, 23.)

The youngest stocks found consisted of a stolon bearing two individuals. This has been derived from the "stolons" of the parent stalk, which habitually become free for the purpose of founding new stocks. (Page 26.)

Urnatella is, structurally, one of the Pedicellinidæ and most nearly resembles Arthropodaria Benedeni. (Page 30.)

The Bryozoa have probably been derived from Rotifer-like ancestors. (Page 34.)

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ANALYTICAL INDEX

TO DAVENPORT '90, '91^{a}, AND THE PRESENT PAPER.[1]

The Roman numerals refer to these three papers in the order of publication. The Arabic numerals refer to pages. Topics are arranged alphabetically, except under "Groups," where the main divisions are arranged according to an adopted zoölogical system. Under "Organography" letters are placed after certain page numbers to designate the standpoint from which the organ is treated. The letters apply to all the page numbers between them and the next preceding letter. These letters have the following significations: **A**, Anatomy; **F**, Function; **H**, Histology; **O**, Ontogeny; **P**, Phylogeny.

AUTHORS.

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[1] See "Literature Cited," p. 36.

BIOLOGY.

BUDDING, GENERAL.

BUDDING, SPECIAL.

HISTOLOGY.

PHYSIOLOGY.

REGENERATION.

RELATIONSHIPS.

EXPLANATION OF PLATES.

All figures were drawn with the aid of a camera lucida, from preparations of Urnatella gracilis, unless otherwise stated.

PLATE I.

ABBREVIATIONS.

atr.	Atrium.	*di. ba.*	Basal disk.
cic.	Scar of fallen-off bud.	*di. sep.*	Transverse septum.
cl. flm.	Flame cell.	*gm.*	Bud.
cl. mi.	Migratory cell.	*mu.*	Muscle fibre.
cta.	Cuticula.	*nl.*	Nucleus.
cx.	Calyx.	*pli. crc.*	Circular folds.
cx. rgn.	Regenerating calyx.	*vt. gran.*	Yolk granules.

Fig. 1. Regenerating stalk of Urnatella, viewed as an opaque object. × 96.

" 2. Optical section of the same. × 96.

" 3. Optical section of the distal end of a stalk of Urnatella which is probably about to regenerate, from living animal. × 410.

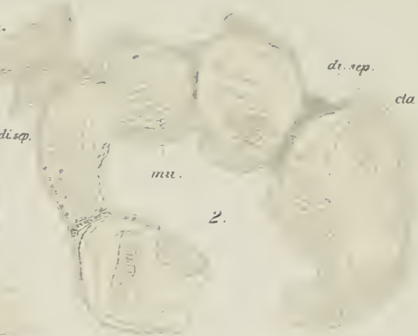
" 4. Optical section of the proximal urn of the stalk of Urnatella. Showing thick cuticula and yolk granules. × 165.

" 5. Contents of proximal urn, obtained by crushing. Moving cilia were visible. Nuclei in some of the yolk granules. × 320.

" 6. Stock of Urnatella viewed as opaque object. Three stems arising from the basal disk. Buds and regenerating terminal calyces. × 36.

" 7. Optical section of stalk of Urnatella. × 96.


cta.
pli.crc.
1.
cx.
di ba


cta.
di.sep.
cta.
di.sep.
mu.
2.
atr.
di.ba.


cl.mi.
cl.flm
cta
cl.mi
cl.flm.
mu
3.


vt.gran.
4.
cta.


nl
5.


gm.
cx rgn.
di ba
6.

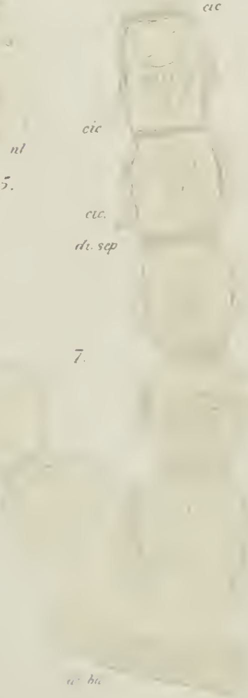

cic
cic
cic.
di. sep
7.
vt.gran
di ba

PLATE II.

ABBREVIATIONS.

atr.	Atrium.	*gn.*	Ganglion.
cl. flm.	Flame cell.	*in.*	Intestine.
cl. hp.	Hepatic cells.	*ms'drm.*	Mesoderm.
cl. sec.	Secreting cells.	*mu.*	Muscle fibre.
cl. tb.	Tubular cells.	*nl.*	Nucleus.
cta.	Cuticula.	*nph.*	Nephridium.
cta.'	Outer cuticula.	*œ.*	Œsophagus.
cta.''	Inner "	*of. atr.*	Atrial opening.
di. ba.	Basal disk.	*pa'chy.*	Parenchyme.
di. sep.	Dissepiment.	*rt.*	Rectum.
ec'drm.	Ectoderm.	*vt.* or	Yolk granules.
ga.	Stomach.	*vt. gran.*	

Fig. 8. Longitudinal section through proximal part of stalk of Urnatella. Third stage in the formation of yolk granules. × 610.

" 9. Cross section through distal segment of stalk, showing ectoderm and parenchymatous tissue inside. × 405.

" 10. Third stage in the development of the stalk muscles. Zeiss, $\frac{1}{18}$ oil immers., Oc. 2. × 1350.

" 11. Second stage in the development of the stalk muscles. × 1350.

" 12. Termination of excretory tubule of stalk in flame cell. The position of the calyx is above. × 305.

" 13. First stage in development of yolk in stalk. × 610.

" 14. Second stage in development of yolk in stalk. × 610.

" 15. Median section through young stalk (age of Fig. 31 in Plate V.). × 165

" 16. Fourth stage in the development of the stalk musculature. × 1350.

" 17. First stage in the development of the stalk musculature. × 1350.

DAVENPORT – URNATELLA Pl. II

PLATE III.

ABBREVIATIONS.

an.	Anus.	*mu.*	Muscle fibre.
atr.	Atrium.	*nph.*	Nephridium.
clc.	Cloaca.	*œ.*	Œsophagus.
cl. cls.	Closing cell of septum.	*pd.*	Stalk.
cl. hp.	Hepatic cells.	*rt.*	Rectum.
cta.	Cuticula.	*spht.*	Sphincter between intestine and rectum.
di. sep.	Dissepiment.		
ga.	Stomach	*spht. atr.*	Atrial sphincter.
gn.	Ganglion.	*sul. atr.*	Atrial groove.
in.	Intestine.	*ta.*	Tentacle.
kmp'drm.	Kamptoderm.	*va. def.*	Vas deferens.
loph. atr.	Atrial ridge.		

Fig. 18. Median section of calyx of Urnatella. Camera drawing made from several adjacent sections. × 405.

" 19. Section through plane of line "Fig. 19" on Fig. 18. × 96.

Figs. 20, 20^a. Longitudinal and cross sections through chief nephridium of calyx. × 610.

" 21^a, 21^b, 21^c. Three sections taken across nephridium of one individual at different places, to show nature of the lumen and wall. Fig. 21^a nearer the distal end of tubule. Fig. 21^c, third section from mouth of tubule, at point of union of two nephridia into one. × 700.

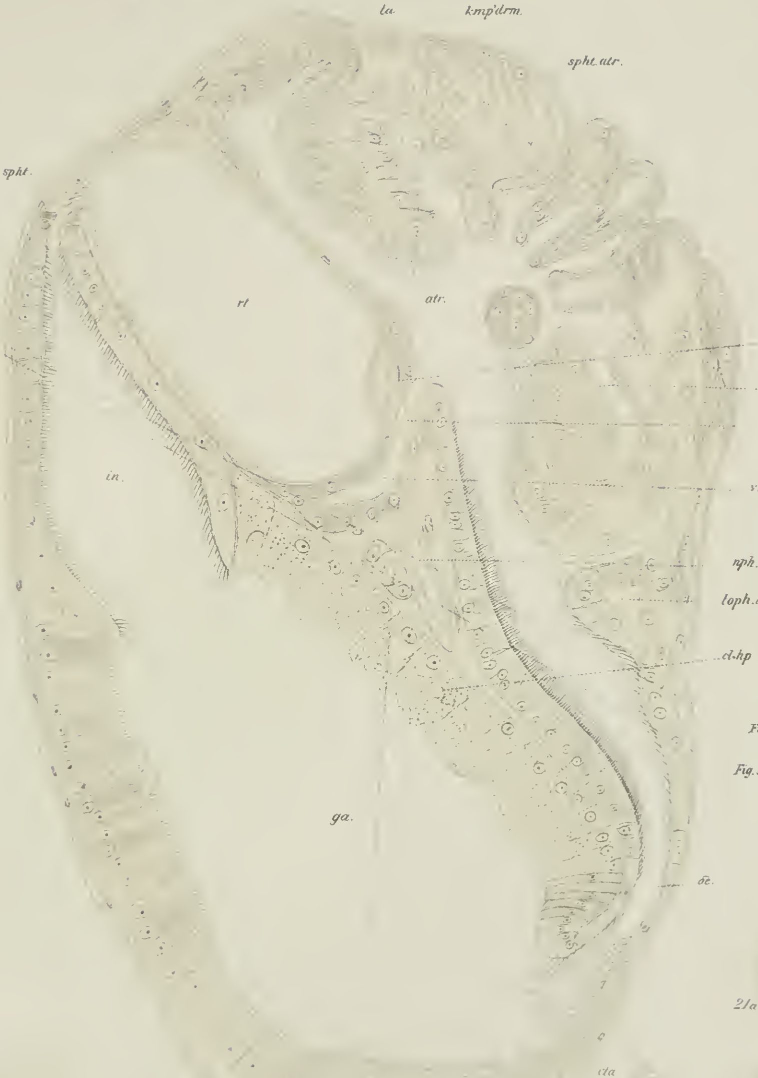
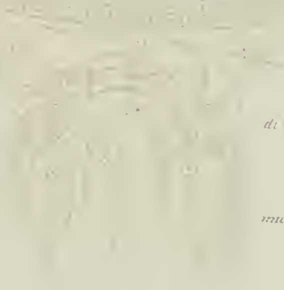


Fig. 23

Fig. 22.

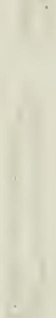
21a.

19



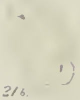
18.

Fig 19



20a

20



21b.

21c

PLATE IV.

ABBREVIATIONS.

an.	Anus.	*mu.*	Muscle fibre.
atr.	Atrium.	*mu. ret. ta.*	Retractor muscle of tentacle.
clc.	Cloaca.	*neph.* or *nph.*	Nephridium.
cl. cls.	Closing cell.		
cl. flm.	Flame cell.	*œ.*	Œsophagus.
cl. tb.	Tubular cell.	*pa'chy.*	Parenchyme.
cta.	Cuticula.	*rt.*	Rectum.
di. sep.	Dissepiment.	*spht. atr.*	Atrial sphincter.
ec'drm.	Ectoderm.	*sp'z.*	Spermatozoa.
gn.	Ganglion.	*te.*	Testis.
int.	Intestine.	*va. def.*	Vas deferens.

Fig. 22. Section through calyx at level indicated by line "Fig. 22" in Fig. 18 × 405.

" 23. Section through calyx above the last at level indicated by line "Fig 23" in Fig. 18. × 405.

" 24. Longitudinal section through young stalk showing development of septum. × 405.

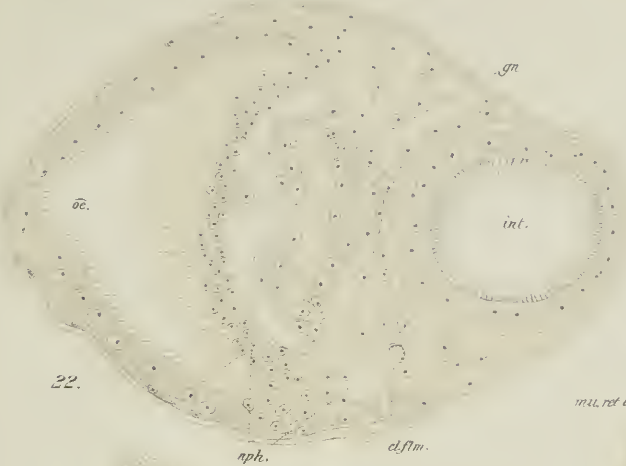
" 25. Transverse section through closing cells at base of calyx. Section passes through a flame cell at the left. The lower part of the section lies below the dissepiment, the position of which is indicated by the line *di. sep.* × 670.

" 26. Longitudinal section through tentacle and atrial sphincter. × 405.

" 27. Two adjacent tentacles cut transversely near their bases. × 405.

" 28. Part of nearly median section of calyx, passing through cloaca and vas deferens. × 405.

" 29. Median section through nephridium aud adjacent organs of young calyx to show the development of the nephridium. × 1000.



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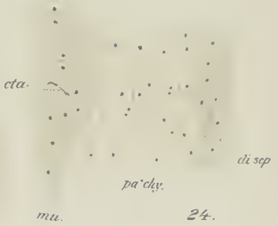

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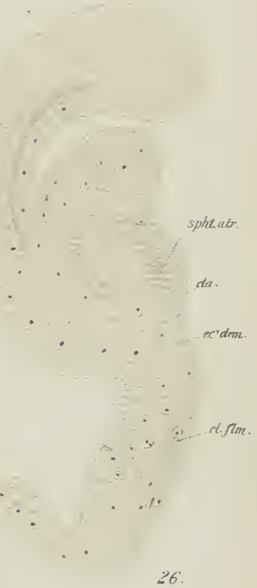

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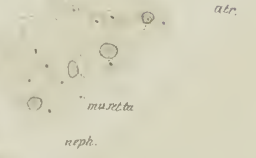

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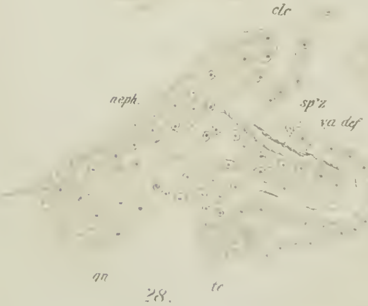

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PLATE V.

ABBREVIATIONS.

An.	Anal aspect.	*Or.*	Oral aspect.
cic.	Scar of fallen bud.	*or.*	Mouth.
cl. sec.	Secreting cell.	*pd.*	Stalk.
di. ba.	Basal disk.	*rt.*	Rectum.
ec'drm.	Ectoderm.	*sto.*	Stolon.
mu.	Muscle fibre.	*vt.*	Yolk spherules.

Fig. 30. Distal end of a richly branching stock of Urnatella, seen from the right side. × 56.

Figs. 31–45. Views of Urnatella as solid object (exc. Fig. 33). All × 18½.

" 31, 32. "Youngest stage" of Urnatella stock. Cf. Plate II. Fig. 15.

Fig. 33. View of somewhat older stage, as transparent object. Disk adhering to stolon.

Figs. 34, 35. Young stalks with median buds.

Fig. 36. Entire stock of Urnatella, — three stalks arising from one basal disk. "Median buds" arising.

" 37. Stalk with two lateral buds and one median.

" 38. Stalk with profuse lateral budding on the median buds. Anal view. branches displaced to the right and left. From segment c′ two lateral buds and one median have arisen; from c, two lateral buds, one of which has given rise to two individuals, the other to only one.

" 39 Stalk with branches, — oral view. Remnant of a median branch on segment F. From c′ two lateral (?) buds; from K a stolon with two individuals, and from L two stolons, the left with two individuals, the right with one.

Figs. 40, 41. Branching stocks with median and lateral buds.

Fig. 42. Typical lateral buds, each with two individuals. A median bud on next younger segment.

Figs. 43, 44. Right and left views of the same stock. The number of individuals is indicated in the diagram accompanying the figures (Fig. 44^a).

Fig. 45. Left view of part of stock. Two stolons and one median branch from segment B (Fig. 45^a).

" 46. Optical section of "youngest stage" of Urnatella stock. Stolon with two individuals arising therefrom. × 120.

" 47. View of cuticula and ectoderm at end of a stolon in a stock of the "youngest stage," showing scar of former attachment to parent stock. × 405.

" 48. Optical section of the basal plate of a stock showing three individuals arising from it, and its division into three segments. × 52.

" 49. Three individuals arising from an older basal plate. × 52.


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PLATE VI.

ABBREVIATIONS.

atr.	Atrium.	*i.*	Inner layer of bud.
cl. sec.	Secreting cell.	*mu.*	Muscle fibre.
cx.	Calyx.	*or.*	Mouth.
di. sep. or *di. sp.*	Dissepiment.	*spht. atr.*	Atrial sphincter.
		st.	Stomach.
ex.	Outer layer of bud.	*sto.*	Stolon.
ga.	Stomach	*ta.*	Tentacle.
gm.	Bud.		

Fig. 50. Surface view of stem stained in Czokor's cochineal and studied in clove oil. Showing the deeply stained protoplasm and crowded condition of nuclei indicating the position of an incipient bud. × 318.

" 51. Lateral bud drawn as transparent object after staining, showing stolon and secreting cells (*cl. sec.*). × 98.

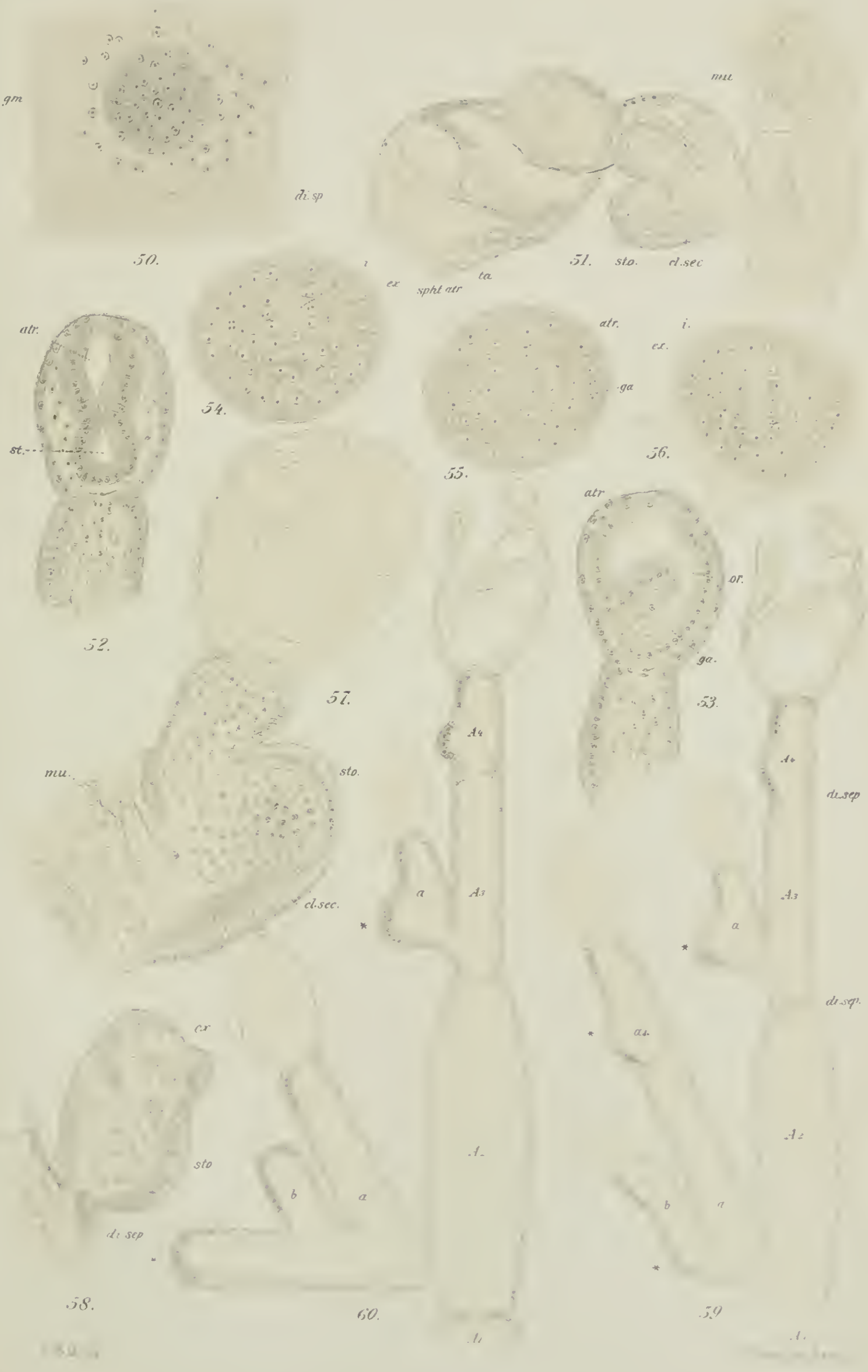
Figs. 52, 53. Two optical sections from different aspects of the same bud stained in Czokor's cochineal and studied in clove oil. Showing formation of alimentary tract. × 225.

" 54–56. Three transverse sections across a young bud, showing the development of the alimentary tract. Fig. 54 nearest the tip; Fig 56 nearest the base. × 405.

Fig. 57. Enlarged view of lateral bud showing stolon and secreting cells (*cl. sec.*). × 205.

" 58. Stalk of young lateral (?) bud showing method of attachment to adult stalk. × 285.

Figs. 59, 60. Two diagrams showing relation between the two methods of budding in Urnatella. The shaded cells indicate probable position of embryonic tissue.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No. 2. — *Note on the Carotids and the Ductus Botalli of the Alligator.* By C. B. Davenport.[1]

The carotids of the Alligator, as is well known, usually present in the adult an unsymmetrical condition. From the right aortic root two branches (*a* and *b*) arise close together. Of these, one goes to the left, the other to the right side of the body. The left vessel (*a*) gives rise first to a large artery (1) running on the dorsal side of the œsophagus to the head; secondly, to a smaller one (2) running alongside the neck, sending branches to the œsophagus, trachea, and muscles of the body wall, and anastomosing behind the occiput with a branch of 1; and, thirdly, to a vessel (3) going to the fore limbs. Other smaller vessels we may for present purposes neglect. The right vessel (*b*) gives rise to all that the left does excepting the equivalent of 1.

Concerning the homology of these vessels with those of other Reptiles and of Birds, there has been much difference of opinion. Rathke ('57, p. 91) designated the vessels *a* and *b* arteria anonyma. He called 1 art. subvertebralis, and from embryological data he interpreted it (as defined in the preceding paragraph) as follows. The right and left common carotids arise separately, and later fuse along the middle of their extent, but remain separate at their proximal and distal ends. Secondarily, the right proximal root degenerates, and is thus absent in the adult.

By "common carotid," Rathke implies an homology with a vessel of this name in Lizards. The latter is morphologically equivalent to the *ventral distributing trunk* between the third and fourth arterial arches in Rathke's well known type scheme of the arterial arches. The unfused distal ends of the common carotids each branch at the occiput to form vessels homologous, in his opinion, to the internal and external carotids of Mammals.

Fritsch ('69, p. 705) later maintained that the a. subvertebralis is an a. carotis primaria, i. e. produced by a drawing out of the a. anonyma,

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

and hence essentially unpaired, — a view which Hoffmann in Bronn's Thierreich, Reptilia, unfortunately adopts.

Van Bemmelen ('88, pp. 114, 115) combats the view of Fritsch, and brings forward additional instances of the persistence of the right proximal root of the a. subvertebralis in embryos. At the same time he points out that Rathke's a. subvertebralis must be regarded as equivalent to the dorsal collecting trunks of the anterior branchial vessels, and therefore to the aa. carotides internæ of Rathke's general scheme. The vessels designated in my description above by the numeral 2 — called by Rathke a. collateralis colli — are, on this hypothesis, to be regarded as aa. carotides externæ (ventral distributing trunks of anterior branchial vessels).

Mackay ('89, pp. 126–136) more than any other has contributed by his embryological and comparative anatomical studies to an interpretation of the carotids of the Crocodilia. The vessels *a* and *b* are, according to him, the parts of the ventral distributing trunks which lie between the fourth and third arches, and correspond to the common carotids of Rathke's general scheme. The morphologically paired vessels (1) are the combined internal, or, better, " dorsal " carotids. The part designated in Figure 1 by 1^a is thus homologous with the third visceral (first branchial) vessel. The part designated by $1^b + 1^{b'}$ has arisen by fusion of the dorsal collecting trunks of the three anterior branchial vessels through a part of their extent. The vessels marked 2 and 2′ (Fig. 1) are external or " ventral " carotids, — these vessels being represented in Birds also, where the so called common carotids are in reality " dorsal " carotids, not equivalent to the common carotids of Lizards. Mackay's results, which thus confirm and extend van Bemmelen's, seem conclusive, not only because he has traced the development of the homologous vessels in Birds, but because he has found one instance — like that of Brandt ('72, p. 307) long ago — in which the dorsal collecting trunk persists between the third and fourth arches. It is connected with the third arch near the proximal (posterior) end of the a. subvertebralis, and is thus far removed from Rathke's so called " a. carotis interna " of the head region. The hypothesis that the a. collateralis colli of Crocodiles is homologous with the a. carotis externa of Lizards, receives additional support from the fact that, as in Birds, the a. subclavia arises near the point at which the a. collateralis colli is formed by the division of the true a. carotis communis (*a* and 1).

The conclusions of Mackay have been recently confirmed by the researches of Hochstetter ('90).

In view of the interest attaching to this subject, I have thought it not wholly superfluous to put on record still another example of the persistence of the right root of the a. subvertebralis, — especially since so perfect a root from so old a specimen has not been heretofore mentioned, and since no figure of this condition at any stage has, to my knowledge, been heretofore published.

The specimen in question was one which was being used for study in the class in Vertebrate Anatomy by one of my pupils, Mr. H. O. Marcy. The Alligator was about 28 cm. long. The arteries had been injected from the heart, and a very evident branch, Figure 1, $1^{a\prime}$, was shown, fully injected, running from the right common carotid, *b*, to the a. subvertebralis $1^{a} + 1^{b\prime}$. Thus the whole carotid system had a very symmetrical aspect. The branch in question ($1^{a\prime}$), which must be regarded as the proximal end of the right dorsal carotid, was injected throughout its whole length. It measured 0.7 mm. in diameter, the corresponding measurement of the left root being 1.0 mm. The two trunks passed dorsally, encircling the trachea and œsophagus, and met near the median plane, dorsal to the œsophagus and immediately beneath the vertebral column.

I add also figures of two cases of persistent ductus Botalli, completing the VI. or pulmonary arch. Some trace of this condition appeared upon most of the individuals examined. In one case shown (Fig. 3), the injection filled only the dorsal and ventral ends of the ductus, the middle region remaining as a white cord. In the other case (Fig. 2), the pulmonary end only was injected.

Finally, in a simple diagrammatic lateral view (Fig. 4), built up on the system of Rathke's diagrams, as improved by Boas ('87), I have indicated the chief neck-arteries of the Crocodilia. In this diagram, the usually occurring arteries are drawn in heavy lines; those occurring less regularly or abnormally, in fine lines; those absent, in dotted lines. I have introduced as the II. arch the anastomosis between 1^{c} and 2 (Fig. 1), thus adopting van Bemmelen's ('88, p. 115) suggestion; but I must repeat his caution, that this is only a rather probable, but by no means demonstrated homology.

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EXPLANATION OF FIGURES

ABBREVIATIONS.

ao.	Aorta.	*ad mu. lar.*	To muscles of larynx.
art. pul.	Pulmonary artery.	*mu. pct.*	Pectoral muscles.
dt. Bot.	Ductus Botalli.	*œ.*	Œsophagus.
ad œ.	To œsophagus.	*tr.*	Trachea.

a. Left arteria anonyma, Rathke = ventral distributing trunk between IV. and III. arterial arches.

b. Right ditto.

1. Arteria subvertebralis colli, Rathke = a. carotis dorsalis, Mackay = third arterial arch and dorsal collecting trunk anterior to III. arch. In this vessel three regions may be distinguished : —

1^a. Left vessel of the posterior paired portion, the fellow of which on the right side ($1^{a\prime}$) is usually lost, but in Figure 1 persists.

$1^b + 1^{b\prime}$. Fused portion of 1. (The leader should be continued to the vessel covered by the œsophagus in Fig. 1.)

1^c. Left vessel of anterior paired (unfused) portion.

2. Left collateralis colli, Rathke = a. carotis ventralis, Mackay = ventral distributing trunk anterior to III. arch.

2′. Right ditto.

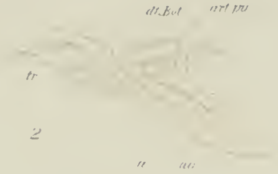
3. Left a. subclavia = secondary or persistent subclavian (cf. Mackay).

* Anastomosing branch between 1^c and 2 (= II. arterial arch ?).

Fig. 1. Ventral aspect of head and neck regions of Alligator Mississippiensis, 28 cm. long. Part of the œsophagus and trachea are represented lying above (ventral to) the median artery.

Figs. 2 and 3. Lateral views of the arterial arches to show two cases of persistent ductus Botalli.

Fig. 4. Diagram, showing in side view the relation of the arterial arches of Crocodilia to the type. Heavy lines represent normal vessels; lighter lines, abnormally occurring vessels; dotted lines, vessels wholly absent in adult.



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No. 3. — *On the Eyes, the Integumentary Sense Papillæ, and the Integument of the San Diego Blind Fish* (*Typhlogobius californiensis,* Steindachner). By W. E. Ritter.[1]

The work the results of which are embodied in the present paper was begun and well advanced at Harvard University, and has been completed at the University of California.

I wish here to express my warmest appreciation of the many kindnesses received at the hands of Prof. E. L. Mark, not only during my residence in Cambridge as a student under him, but particularly since leaving there. I have also to thank Prof. C. H. Eigenmann both for specimens sent me from San Diego while I was working in Cambridge, and for valuable information and suggestions about collecting the fish during my visit to San Diego last summer.

Typhlogobius californiensis was first described by Dr. Franz Steindachner. The species is the type of the genus, and thus far is the only one known. Steindachner's ('79, pp. 142, 143) description of the eyes is as follows: "Die winzig kleinen, wie Punkte durchschimmerenden Augen, liegen hoch am Seitenabfalle des Kopfes gegen Ende des ersten Viertels der Kopflänge; ihre Entfernung von einander steht der Schnauzenlänge nach und beträgt circa $\frac{1}{6}$ der Kopflänge." According to this author the genus resembles Crystallogobius, Gill, from which it differs in its dentition and abortive eyes.

Miss Rosa Smith ('81, pp. 19–21), — now Mrs. C. H. Eigenmann, — unaware that the fish had been described by Steindachner, redescribed it, making for it, as the Vienna ichthyologist had done, a new genus, the name of which was derived from the rudimentary condition of its eyes. *Othonops* was the generic name given it by Miss Smith, and this term, signifying as it does "veiled or obscured eyes," is, so far at least as the younger individuals are concerned, undoubtedly more nearly true to the facts, as the sequel will show, than is the name chosen by Steindachner, *Typhlogobius* signifying "blind goby." The specific name chosen by Miss Smith was *eos*. She says: "This species is most closely related to

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

Crystallogobius nilssoni (Düb. & Ker.) Gill (*Gobiosoma nilssoni* Günther, Cat. Fishes Brit. Mus., III. 86), a species found on the coast of Norway, from which it is distinguished generically by the obsolete eyes. . . . The eyes are large and conspicuous in *C. nilssoni*."

With reference to the integument of the head and its tactile organs, this author says: "On the under side of the head the skin (in a preserved specimen) lies in irregular folds, which conform generally to the outlines of the lower jaw, the outer folds reaching the gill openings. Between the lower lip and these folds there is a series of papillæ which has its origin a short distance behind the corner of the mouth, the series being slightly separated close behind the symphysis of the lower jaw by two small, rounded flaps. The papillæ number about fourteen on either side of the flaps. On the superior surface of the snout, extending posteriorly half as far as the termination of the maxillary, the skin is finely wrinkled, and there is on either side a conspicuous flap, which seems to conceal a nostril." The largest specimen examined by Miss Smith was 2¾ inches in length.

The same author ('90, p. 181) publishes a note made by her at San Diego, July 3, 1882, on the tenacity of life exhibited by this species, which is so characteristic of it that I quote the passage nearly entire: "Three specimens were secured and were placed alive in a two-quart tin pail along with seaweeds, polyzoa, hydroids, living mollusks, a sea-cumber, and a number of small fishes and crabs. The living forms in the pail were so crowded and so short of water that all of the fishes except the three pink blind fish had died before I reached home, the drive of twelve miles being over a hilly road for some distance. . . . When returning from La Jolla and other points along the seabeach, I have frequently carried home the tide-pool species alive in this manner, and invariably the Oligocottus analis, one of the small Cottidæ, was more tenacious of life than any of the other species. At this time, however, Oligocottus expired with the rest, leaving the blind fish to claim the honor of being the most hardy of the smaller species of the region. This species is scaleless and exceedingly slippery. I took one of these examples from the pail, when, like an eel, it slipped through my fingers into a barrel of rain water standing near, swimming around in the barrel several times. I then removed it to a clean shallow dish into which I had poured half a cupful of sea sand, together with the small amount of dirty sea water which had covered the medley of animate beings before mentioned. Typhlogobius, still active, tried to bury itself in the sand, but the dish was too shallow, and several efforts proved unavailing. . . .

It was still quite active five hours after it was removed from among the dead fishes. How much longer it may have been able to survive I do not know, as I then killed it with alcohol."

In a paper on the "Point Loma Blind Fish and its Relatives," Prof. C. H. Eigenmann ('90, pp. 65–71) has given some very interesting facts on the habits of the species, and also the only account, so far as I am aware, of some of the profound structural changes that have been induced in it by its peculiar way of living.

The fact that the fishes pass their lives under stones in crab holes, or buried in the sand, must of course have been known by every one who had collected them; but as Prof. Eigenmann has had much better opportunity to study their habits than has any one else who has written on the subject, his account is quite full, and so interesting that I reproduce a considerable portion of it.

About San Diego the fish has been found at Point Loma only; it has been taken, however, at Encenada. Its habitat is consequently, so far as known, quite limited. The crustacean in the holes of which and with which it lives is a burrowing carideoid, which has the same pink color as the fish; but while the crustacean is found throughout the entire bay region, the fish is its companion only at Point Loma. Another species of the Gobiidæ, belonging to the genus Clevelandia, also frequents the holes of the same crustacean along with Typhlogobius.[1]

"Sometimes the fishes [other than the blind fishes?] live quite out of water on the damp gravel and sand under rocks. . . . In the bay the gobies habitually live out of the holes, into which they descend only when they are frightened, while at Point Loma they never leave their subterranean abode, and to this fact we must attribute their present condition."

It is not the eyes alone that have undergone modification. The whole frontal region of the skull has been profoundly changed; the scales have entirely disappeared, the color has been reduced, and the spinous dorsal has been greatly diminished in size. "The skin, and especially that of the head, has become highly sensitized."

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[1] I find Clevelandia in San Francisco Bay at West Berkeley; and here it often enters holes in the mud with a species of Crangon. In this case the holes are not, I think, dug by the crustacean. The general appearance and actions of the two animals are so similar that at a little distance it is very easy to mistake the one for the other. The color of the two is absolutely indistinguishable as they rest at the bottom of the shallow tide-pools; and it is so like the dark brown mud of the bottom on which the animals are found that it is with great difficulty that they are seen when not in motion.

In a specimen about 0.9 of an inch long the color cells were well formed, and the membranes of the fins were thin (in the adult the fins are very thick in proportion to their height). The movements of the fish at this age were similar to those of the other gobies, and not at all sluggish, like those of the adult. In the adult, says Eigenmann, "the color has been reduced."

The eyes have suffered the greatest change of all. In the small specimen just mentioned they were quite evident, and apparently functional. "Objects thrust in front of them are always perceived, but the field of vision is quite limited. With age the skin over the eyes thickens, and they are scarcely evident externally. As far as I could determine they do not see at this time, and certainly detect their food chiefly, if not altogether, by the sense of touch."

"The lens is large in proportion to the size of the eye, which does not materially differ in size in the smallest and largest specimens examined. The optic nerve is slender and long as compared with that of any of the other gobies." Because of lack of facilities for histological work, Prof. Eigenmann did not study the minute structure of the eyes. All his attempts to get material for studying the development were unsuccessful, though artificial fertilization was tried, and many visits were made to Point Loma in search of eggs and embryos. The spawning time is June and the latter part of May.

During the last of June and the first of July, 1891, I was able to spend several days at San Diego, but at that time it was impossible to get specimens of the blind fish, a thing which I had greatly hoped to do. From Dr. Eigenmann's experiences I had thought it quite possible that at this time I might also be so fortunate as to get embryonic material of the species. On arriving at San Diego my hopes were at once annihilated, however, as I found that the fish could be caught only at the very low tides, and at this time of the year these tides come in the night. I arranged, however, with two local collectors, Mr. L. C. Bragg and Mr. O. N. Sanford, to have all the specimens they could obtain, as soon as the tides would permit of their being collected, sent to me at Berkeley. By this means I secured twenty-two specimens, the most of them apparently fully grown, though two were considerably smaller than any I had previously studied, and these were all carefully preserved in Perenyi's fluid.

Through the kindness of the officers of the Pacific Coast Steamship Company's steamer "Pomona," twelve specimens were sent to me in July from San Diego alive. Only four of these were living, however, when they reached me, and only one was in perfect health. This one was kept in an aquarium of about four gallons of water until February 10, 1892. I can fully confirm the statements of other writers concerning the extreme tenacity of life exhibited by these fishes. During the last two months that this specimen was kept, the water was not changed nor aerated in any way, nor was food given to the fish ; and I may say that it did not, so far as I could determine, take food at all during the time of its confinement, except the small quantity naturally contained in the water. Worms were placed in the aquarium, but had to be removed, untouched so far as I could see, to prevent contamination of the water by decomposition. When the fish was killed, it was to all appearance as well and as lively as it had been at any time during its captivity.

Experiments for the purpose of determining whether the eyes in this individual still performed their proper function were not very satisfactory. Very frequently when the water was suddenly illuminated by a strong light thrown into the aquarium, standing in a dark room, the fish was found to be moving about at the bottom with considerably more than its wonted activity. This activity would continue for only a short time, when the fish would either move more slowly or would settle down and become quite still. As the movements were almost always rather slow and infrequent when the fish could be seen, I am inclined to interpret this behavior as indicating that the fish was sensitive to the light. However, repeated attempts to produce conditions that would cause it to choose between light and darkness, if it had the power of such choice, were without positive results. On the whole, both from these observations on the living fish, and from the structural conditions to be hereafter described, I am of the opinion that the power of perceiving light is not wholly lost, even in the adult. The specimen kept alive was 32 mm. long, or about 20 mm. shorter than the largest ones that I have seen.

The pink color mentioned by all those who have written of this fish is a quite striking feature in its general appearance. It is not at all due to pigment in the integument, but to the extreme richness of blood-vessels situated in the sub-epidermal connective tissue, as will be shown later. It disappears entirely in preserved specimens, the color becoming a dull opaque white, particularly in large individuals. In small individuals, however, the color of the dorsal side of the head and body is quite dark from the presence of brown pigment. The causes to which these different colors, under different conditions of development and treatment, are due, are of considerable significance, and I shall speak of them more fully later on. It is not my purpose to give an account of the general structure of the fish in this paper. I must, however, call attention to the far reaching modifications that have been brought about by its peculiar habits, not in the eyes merely, but in many other structures. As already mentioned, Dr. Eigenmann has shown that the "entire frontal region of the skull has been profoundly changed." He has also shown that the fins of the adult are much thicker, more fleshy, and shorter, in proportion to the size of the body, than in the young. My observations fully confirm these statements.

In the smallest specimens that I have seen, 19 mm. long, the eyes are distinctly visible without dissection. In some of the preserved specimens of this and somewhat larger size, the lens is also clearly seen in surface views; while in other specimens it is not so distinct, and in some is scarcely seen at all, though it is probably always present in all these younger individuals.

The eyes are situated wholly on the dorsal aspect of the head, and very near together (Plate I. Figs. 1, 2). Their distance backward from the tip of the nose is also short as compared with the length of the fish. Thus in the specimens 19 mm. long this distance was 0.95 mm., or one twentieth of the entire length of the fish. In large individuals, especially while living, the eyes are visible from the surface, but appear as scarcely more than black specks deeply buried in the tissue. In many cases they cannot be seen at all in preserved specimens.

The epidermis immediately over the eyes does not differ essentially, either in the smaller or the larger individuals, from what will be described further on as existing in other portions of the dorsum and sides of the head and body. The mucous cells are present here as elsewhere, and they are as numerous and as large as in adjacent regions. The average thickness of the epidermis is $50\,\mu$ in the smallest specimens studied; $63\,\mu$ in a specimen 60 mm. long, and $76\,\mu$ in a specimen about 65 mm. long, thus showing a gradual increase in thickness with the increasing size of the animals. In the smallest specimens the sub-epidermal tissue over the eye is not differentiated into a dermal and subdermal layer. The connective tissue in this region is arranged in several strands which unite with one another at various angles, thus bounding wide spaces (Plate III. Fig. 17, *spa.*). In this specimen (Fig. 17) the space between the epidermis and the sub-epidermal tissue is quite wide, and is continuous over the entire eye, and for a considerable distance beyond. This space may be in part artificial; but even if so, the connection between the epidermis and the immediately underlying tissue must have been exceptionally frail, since separations of this kind are rare in adjacent regions.

The thin layer of tissue next to the lens — in fact closely applied to it in many cases (Figs. 5 and 17, *crn.*) — is part of a layer that envelops the entire eye, in many places lying close upon the pigmented layer of the retina. The portion in the region of the retina is undoubtedly the sclera, and will hereafter be designated as such. The portion in the region of the lens may be regarded as representing all there is of a cornea excepting its epithelial layer; but on this subject I shall speak further presently. The strands of connective tissue that have been spoken of as intervening between the epidermis and the eye in the smaller specimens are distinctly fibrous, and contain numerous small, much flattened connective-tissue nuclei. These strands are directly continuous with the sub-epidermal connective tissue of the surrounding regions, and are not largely continuous with the sclera, though in part they are (Fig. 17 α).

In addition to the small flattened connective-tissue elements in these bands of connective tissue, a few much larger cells are found (*cl. con't.*). They have distinct round nuclei, and each nucleus has a nuclear membrane and a nucleolus. The membraneless cell body is drawn out into one or more processes, usually two or three, which become lost among and are apparently continuous with the fibres of the connective-tissue strands in which the cells are situated. They are probably embryonal connective-tissue cells concerned in the production of the thick layer of this tissue that intervenes between the eye and the epidermis in older specimens (Plate II. Fig. 6). In this older specimen (Fig. 6) a large number of nuclei are seen, in part immediately over the eye, and consequently in the same position as the cells regarded as embryonal connective-tissue cells in the young specimens; but they are mostly at one side of the eye (Fig. 6, *con't. tis.*), and although some of them are undoubtedly cells of connective-tissue character, at the same time many of them are certainly not of this nature, but are probably leucocytes. As shown in Figure 6, there is over the eye in the large specimens a well defined dermal layer, *drm.*, which usually remains adherent to the epidermis when the latter is removed. This layer is nearly structureless, though fine fibres are not uncommon in it. In the specimen shown in Figure 6, the entire thickness of the tissues over the eye is about 392 μ, of which 103 μ is epidermis and 289 μ sub-epidermis. About midway between the epidermis and the eye there is a thin stratum of formed connective tissue (*st. con't.*), much denser than the surrounding tissue; and immediately beneath the dermal layer is a layer of comparatively coarse fibres arranged in bundles running more or less nearly parallel with one another. Among these bundles are blood-vessels and numerous cells, mostly of the kind that I have regarded as leucocytes. The remaining portion of the tissue in this region is composed of rather fine uniform fibres, containing very few cellular elements. I have said that the eye-enveloping portion of the connective-tissue capsule that is immediately over the lens probably represents the cornea, excepting its epithelial layer. When, however, we bear in mind the method of development of the cornea, — as first clearly made out by Kessler ('77, pp. 83–94), and now understood by all embryologists, excepting in so far as this author believed it to contain, besides its epithelial layer, elements derived from the ectoderm; and when we remember, further, that in the cornea of the normal adult eye, the substantia propria, together with the membrana elastica anterior and the membrane of Descemet, make up its entire thickness, excepting its conjunctival (i. e. epithelial) layer, the interesting question arises whether in such an eye as is represented in Figure 6 the layer *crn.* should be regarded as representing the whole cornea, or merely the membrane of Descemet. Should the latter interpretation be adopted, then it would follow that the tissue intervening between this and the dermal layer would be the substantia propria greatly thickened, and the dermal layer (*drm.*) would be the membrana elastica anterior of the cornea; and what I have called embryonal connective-tissue cells (Fig. 17, *cl. con't.*) might then be regarded as corneal corpuscles. However, I hardly think this the right view of the matter, since, as already pointed out, the tissue over the eye is mostly continuous with that of the adjacent regions other than the sclera. It is possible that the strands seen at α, Figure 17, give some support to such an interpretation. But whatever view may be taken, it seems to me that we are justified in regarding the conditions here presented as evidence against Kessler's statement that a portion of the cornea, besides its epithelial layer, is derived from the ectoderm. This author's account of the development of the cornea in Triton is in substance as follows.

The first trace of it to appear is a thin layer of hyaline substance on the inner surface of the ectoderm over the eye. This appears at a time when the cavity of the lens vesicle has wholly disappeared, and the retinal layers have begun to be differentiated. (See the author's Figure 60.) This layer is held to be secreted from the ectoderm. The succeeding steps may best be given in the writer's ('77, pp. 89, 90) own words: "Wenn die zuerst vorhandene hyaline Schicht eine gewisse Dicke (Figg. 60 und 61) erreicht hat, wird dieselbe vom Hornblatt abgedrängt durch eine zweite an dieses sich anbildende hyaline Schicht; in das zwischen beiden Schichten entstehende Interstitium dringt von der Peripherie her eine einzellige Lage der spindelförmigen Kopfplattenelemente, die sich vorher schon in einen spitzen Winkel gegen das Hornblatt am Rand der Corneaanlage gestellt hatten, ein (Fig. 62); sobald dieselben von allen Seiten her im Pol der Cornea zusammentreffen, ist die erste hyaline Schicht von der unterdess zu der gleichen Dicke entwickelten zweiten vollständig gesondert. Ebenso wie die erste durch die zweite, wird dann die zweite durch eine dritte neu sich bildende Schicht vom Hornblatt und darauf durch eine zweite einwandernde Lage von Kopfplattenelementen von der dritten Schicht isolirt; diese wieder vom Hornblatt durch eine vierte neue Schicht und von letzterer durch eine dritte Zellenlage u. s. f." It would thus appear that a very intimate connection is brought about between the ectoderm itself, the relatively large portion of the substantia propria derived from it, and the mesodermal elements of the cornea; and it should be especially noticed that this process goes on at a comparatively late stage of development, — viz. at a time when the retinal layers are being differentiated, and after the pigmented portions of the eye are well formed; in short, at a stage only a very little earlier than that at which development is arrested in the eye of Typhlogobius. If such a process had ever taken place here, it seems almost certain that we should see some indications of it in such a stage as is shown in Figure 17 (Plate III.). But, on the contrary, what we do find is no connection between the epithelium over the eye and the immediately underlying tissue, or at least almost none, and no indication of a hyaline layer on the inner surface of the epithelium. While, on the other hand, in older specimens (Plate II. Fig. 6) the epidermis and the sub-epidermal tissue are in close connection, there being no interruptions or spaces at all, and we have here a well defined nearly structureless layer closely adherent to the epidermis.

There is considerable individual variation in the size of the eye. In three specimens, 50 mm., 60 mm., and 63 mm. long, the diameters, measured parallel to the long axis of the head, were respectively 0.44 mm., 0.46 mm., and 0.47 mm.; the diameters transverse to the long axis of the head in the last two of these were, respectively, 0.39 mm. and 0.47 mm. In another specimen 63 mm. long, the diameter transverse to the head was 0.372 mm.; the diameter parallel to the long axis of the head was not measured in this specimen. This last measurement was made on the section, while the measurements in the case of the first three were made with the eyes in place in the head, the head having been cleared in clove oil. It is undoubtedly true, that some of the difference in size between the last mentioned eye and the first three was due to shrinkage in it during its passage through the paraffine. I have made numerous measurements of the same eyes before embedding and after cutting, and have always found the sections somewhat less in diameter than the whole eyes, even when all precautions had been taken to prevent shrinkage. But certainly shrinkage cannot account for the great difference found here between the eye measured in section, and the one of an individual of the same length measured in the head. This small eye, I should add, was the only one that I have found in which the lens was wholly absent. This eye will be described later on. In a specimen 25 mm. long the axial diameter of the eye was 0.28 mm., and its equatorial diameter was 0.45 mm. In a specimen 19 mm. long the diameter in the long axis of the head was 0.28 mm., and transverse to this it was 0.39 mm. It appears from these measurements that the eye does increase somewhat with the increase in size of the animal, though it is true that, in view of the obvious individual variation in size in specimens of nearly the same length, not enough of the smaller specimens have been studied to determine definitely how much this increase amounts to.

A sclerotic coat, well defined from the surrounding connective tissue, is always present, though in some places its fibres, both singly and in bundles, leave their concentric course and pass off into the connective tissue, and thus bring about an intimate connection between the two. In some places the connective-tissue fibres not belonging to the sclera, but in its vicinity, are seen to have taken on a concentric direction even at a considerable distance from the eye, and to have become more numerous and more closely packed than is the case with the subcutaneous connective tissue in general. There is thus brought about a fusion to some extent of the eye bulb with the tissue in which it is embedded. This statement applies especially to the eye the section of which is shown in Figure 6. In most sections numerous flattened connective-tissue cells are found in the sclera; and in all the eyes that I have sectioned the sclera is cartilaginous in the region corresponding to the ora serrata of the retina. The cartilaginous layer is usually only one cell thick, but occasionally it is two or more cells thick (Figs. 5, 6, and 12). In many specimens the cartilage does not extend entirely around the eye in the equatorial zone, and in no case have I seen it extend more than half-way back to the entrance of the optic nerve. No indication of ossification of the scleral cartilage, as is common in bony fishes, has been seen. No trace of an argentea is to be found. All the pigment is of the same dark brown granular variety, and, when seen by reflected light, never gives the white, silvery color that is characteristic of the crystalline material of the argentea.

The choroid is exceedingly rudimentary, and in many specimens I have been unable to detect its presence at all. In the eye from which Figure 13 was drawn (Fig. 13, *chr.*), — a specimen the eyes of which, as will be seen further on, are better developed in several respects than is usual in these eyes, — it is more distinctly seen than in any other case that I have studied. Here the layer of pigment is very thin; it is interrupted at short intervals, and cannot be traced for more than one third of the distance through which it would normally extend. Whether this pigment should be regarded as representing the lamina suprachoroidea, or as belonging to the choroid proper, it is impossible to say.

In a few instances (Figs. 13, 14, 15, *chr. cpl.*), a layer of cellular tissue has been found at the proximal pole of the eye, extending for a variable distance toward the anterior rim of the optic cup, but rarely reaching it. This layer is always closely applied to the outer surface of the pigmented layer of the retina, and in some sections it seems to be continuous with the pigment of the choroid. In some places (Fig. 15, *chr. cpl.*) the tissue has very much the nature of formed connective tissue, while in other places (Figs. 13 and 14, *chr. cpl.*) the cells are spherical or elliptical, with indications at times of blunt processes, and with distinct nuclei. Where cells of this kind occur, the layer is somewhat thicker than where the structure is more characteristically that of connective tissue; and in several instances blood corpuscles (Fig. 13, *cp. sng.*) are found scattered here and there in these thicker portions of the layer, indicating the presence of capillaries. I identify this layer as the chorio-capillaris.

A conspicuous structure in all the specimens studied is a thick, usually short, somewhat lenticular mass of pigment occupying a position usually at the proximal pole of the eye, at or near the entrance of the optic nerve, by which it is pierced in some cases (Figs. 14, 15, etc., *gl. chr.*). This mass is concentric with the surface of the retina, but is always separated from it by a short though somewhat variable interval. In some places the cellular layer just described in part occupies this space, and in some places the thin layer of choroid pigment is seen to enter the same space. The mass always lies within the sclerotic, and is always composed entirely of pigment. I have been unable to find any cellular or other protoplasmic elements in it. This body I interpret as representing the "choroid gland." The evidence for this is principally in the position which it occupies, and very little in its structure. It is true that this body may contain a small amount of pigment in the normal eye, as I find to be the case in Clevelandia, yet its characteristic structure consists, as is well known, in its richness in blood-vessels; but, as already said, none of these occur in Typhlogobius. Its position — viz. at the proximal pole of the eye at or very near the entrance of the optic nerve, and between the chorio-capillaris and the sclerotic — is, however, strong evidence in favor of regarding it as the "choroid gland." This structure is described in text-books (Wiedersheim, '86, p. 412) as being situated in the normal fish eye between the argentea and the pigmented layer of the choroid. The fact that no argentea is present in the eye of Typhlogobius weakens somewhat the force of the evidence that I have used to support the assumption that I have made with reference to the significance of the pigment mass described. But its relation to the chorio-capillaris and the pigment layer of the choroid are the same as that of the "choroid gland"; as is also its relation to the sclera, with the exception that no argentea is interposed between the two. Of course it is impossible to say that, were the argentea developed, it would lie between the sclera and the pigment mass, rather than between the latter and the pigmented layer of the choroid. We however have as much reason to suppose it would occupy the former position as the latter.

The pigment layer of the retina is exceedingly thick. In a specimen about 50 mm. long, the entire thickness of the retina including the pigment layer was 0.108 mm., and that of the pigment layer was 0.07 mm.; while in a specimen of Clevelandia of about the same length, the entire thickness of the retina including the pigment layer being 0.13 mm., the thickness of the pigment layer was only 0.037 mm.; that is, in Typhlogobius the thickness of the whole retina is to the thickness of the pigment layer as 1.5 : 1, while in Clevelandia the corresponding ratio is 3.5 : 1. In Gasterosteus, I find that about the same proportion holds as in Clevelandia, whereas in the perch (H. Müller, '57) the proportion is at least not less, and in the salmon a year old (Hoffmann, '83) the proportion is 6+ : 1.

The layer is composed wholly of pigment of the dark brown granular variety. I have searched in vain for cellular elements within it. In most specimens the pigment is a very uniform mass; but occasionally one finds an eye in which very distinct and perfectly round nodules of pigment occur. Some of these are so clear-cut and smooth in outline that they have the appearance of perfectly round cells wholly transformed into pigment, though they are considerably larger than any cells, even blood corpuscles, that are found in the eye (Plate II. Fig. 13, *glb. pig.*). They probably merely signify that the pigment tends to segregate in such nodules during its formation. On the inner surface processes of pigment project down among the rods, as in normal eyes, excepting that in most instances they are relatively much shorter and less distinct; in some specimens they scarcely appear at all (Plate II., Figs. 5 and 13 *pr'c.*). The greater portion of the thickness of the layer pertains to the region between the bases of these processes, i. e. the terminals of the rods, and the outer surface of the layer. And it is hence in this portion that the increase in thickness over that found in normal eyes has taken place; for in the latter, this region is relatively thin. I am at a loss to know from what source this pigment has come. As already said, no cellular elements are to be found in the layer, so it is quite certain that they have completely degenerated into pigment. I shall return to this question in the comparative part. The layer thins out rapidly as it approaches the ora serrata, and is frequently thrown into an equatorially directed fold (Plate II. Figs. 5 and 13, *), which may extend entirely around the eye, but more commonly is confined to one side of it.

Immediately in front of the thinned out region just mentioned, the pigment thickens again somewhat, to form the pigmented portion of the iris. This structure, though always present, varies greatly both in form and size. In a majority of specimens the pigmented portion constitutes the entire iris; and in all cases it forms by far the greater portion of it. The dense pigment is entirely the same in structure as that in the pigment layer of the retina. In the few cases where a cellular portion is present, it is in small quantity, and appears to be of the nature of connective-tissue cells and fibres. Neither blood capillaries nor epithelium have been detected in this region (Figs. 5, 13, and 17, *ir.*). It frequently happens that the outer surface of the iris is in contact with the inner surface of the cornea (see figures), and it is thus made to appear as though the iris has a considerable part in addition to its pigment; this, however, is undoubtedly only an appearance caused by the inner border of the iris having been thrust outward by some artificial means, — probably by the lens being in most cases moved outward, for this body is very loosely held in its place. In a few specimens a trace of the ligamentum pectinatum is present, though in most cases no trace of it exists. The short blunt processes of pigment occasionally seen projecting toward the lens (Plate III. Fig. 17, β) remind one of the ciliary processes, but it is extremely doubtful if they should be so interpreted. They are situated too far from the ora serrata and too near the free edge of the iris. They are probably in some way merely incidental to the extensive pigmentation of the iris.

In no instance are the layers of the retina in Typhlogobius as fully differentiated as in the normal eyes of fishes. I will first describe them as they are found in the majority of specimens, beginning with the innermost layer, and will afterwards speak of the cases that show deviations from the common condition.

An internal limiting membrane, distinct from the layer of nerve fibres, I have been unable to find. Corresponding with the exceedingly rudimentary condition of the optic nerve, the layer of nerve fibres is very thin, even in the immediate vicinity of its entrance, where, in the normal retina, it reaches its greatest thickness. In many sections only fragments of it are to be seen ; and for considerable areas no traces at all are found. It is possible that its absence is due to its having been broken away during the preparation of the sections ; but, however that may be, it is certain that, wherever present, the layer is very thin (Plate II. Fig. 5, Plate III. Figs. 18 and 21, *st. fbr. opt.*). The next layer, viz. that of the ganglion cells (Figs. 18 and 21, *cl. gn.*), is always distinct, and is from one to three or four cells in thickness. As a rule only the nuclei are distinguishable ; but occasionally the cell bodies can be made out. Examined under high powers and with careful focusing, some of these are found to possess one or more processes (Fig. 18, *cl. gn.'*). A nuclear membrane can usually be seen, as can also one to several darkly stained particles within the nuclei. The nuclei are in general very nearly spherical, though there is a tendency for them to become elliptical with the longer axis radially directed.

The inner reticular layer (*st. rtl. i.*) is well developed in all cases, and is essentially the same in structure as in the normal eye, though I have not detected any of the fibres running parallel with the surface of the retina that are found in normal fish eyes. Within this layer the radial fibres of Müller (*fbr. Mü.*) can usually be made out, though they appear to be few and indistinct.

The remaining portion of the retina, as far as to the external limiting membrane, is never fully differentiated into the layers that are found in the normal eye between this membrane and the inner reticular layer ; and in many specimens scarcely any indication of a differentiation can be seen. About the average condition is shown in Figure 18, *st. rtn.'*, where a layer of nuclei (*st. nl. i.*) about two or three deep may be distinguished next to the inner reticular layer. These are slightly larger, on the average, than are the more superficially situated nuclei (*st. nl. ex.*), and they also stain somewhat more deeply. Usually each nucleus has a centrally placed nucleolus, and a not very distinct nuclear membrane. These nuclei undoubtedly represent the inner nuclear layer, though whether the entire layer or only its spongioblasts, it is impossible to say.

Following this layer there is usually a single layer of nuclei (*st. rtl. ex.*) that are considerably smaller and less distinct than those of the layer last described. Not only are the nuclei themselves here smaller and less distinct than those of the layers on either side of them, but spaces (*st. rtl. ex.'*) are seen at intervals in which there are no nuclei at all. It seems quite certain that the outer reticular layer is represented by these spaces.

Finally, outside of this layer follows another of nuclei about one or two deep (*st. nl. ex.*) that are again somewhat larger and more distinctly stained than those in the layer last described. No difference between them and those of the inner nuclear layer can be discovered, excepting, as said above, that they are slightly smaller, and stain a little less deeply. They are undoubtedly the nuclei of the rods, i. e. the outer nuclear layer, though I have been unable to trace a connection between them and the rods, and it is somewhat surprising that they are slightly greater in diameter than the rods.

The external limiting membrane (*mb. lim. ex.*) is usually quite distinct.

The rods are well — probably normally — developed, but I have searched in vain for cones. In the retina shown in Figure 18, they are quite variable both in length and diameter, being in a few instances knobbed at the outer ends (*bac. cla.*). It is, however, quite possible that both this appearance and the shortness of some of them are due to artificial causes, but the variation in diameter could scarcely be so explained.

With a single exception, to be described more minutely hereafter, the lens has been present in all the specimens studied in detail.

It differs in no way in structure from the lens in normal fish eyes that I have examined; i. e. it appears entirely homogeneous and structureless after preservation in alcohol, Perenyi's fluid, or picro-nitric acid. It is held in position very loosely, and consequently is easily displaced; it is frequently found, in prepared specimens of the eye, pushed entirely out of its proper situation into the somewhat yielding connective tissue which lies immediately over it. No trace of a suspensory ligament seems to be present, nor have I been able to find a processus falciformis.

In a single instance, viz. in the eye portions of which are shown in Figures 13 and 21, and which has already been spoken of as showing in several respects a higher state of development than any other specimen studied, I find close behind the iris, within the cavity of the eye, a few strands of tissue containing a few small nuclei, which may possibly be regarded as the hyaloid membrane, though I do not feel at all certain that this is their nature. In the same specimen a very few blood corpuscles are also found close behind the lens within the eye chamber. With this single exception I have been unable to find a trace of tissue within the chamber.

The optic nerve, although exceedingly slender, is always present, so far as my observations have gone. A very striking fact in connection with it is the thick sheath of pigment that surrounds it in its passage through the retina (Figs 6, 13, and 15, *pig.'''*). This sheath invests the nerve very closely, no space existing between it and the latter; however, in its course through the retina, a considerable non-pigmented space is sometimes seen between its outer surface and the pigment of the retina; indeed, in a majority of cases the outer boundary of the sheath can be traced entirely through the retinal pigment.

These facts make me incline to the opinion that this sheath really belongs to the nerve, and has arisen by the pigmentation of the outer portions of it. The fact that in many cases it continues on without interruption through the cellular portion of the retina, nearly to its inner surface (Plate II. Figs. 6 and 13), gives considerable confirmation to this view. It would seem, however, were this the right interpretation, that we should find a rather more gradual disappearance of the pigment in passing, on a section, from the main mass of the wall of the sheath to the unpigmented portion of the nerve, than we do; but the inner surface of the sheath is not quite as sharply defined as its outer surface is.

On account of the position of the eyes, far anterior to the brain, and near the anterior extremity of the head, the optic nerves are very long.

The muscles of the eyeballs (Fig. 8) are also very long and slender, and are probably always present, though I have not been able to detect them in the sections in all cases; but in eyes dissected out and cleared in glycerine or clove oil, or slightly stained in Schneider's acetic acid carmine, I have always found them. Figure 8 is a camera drawing from a glycerine preparation, showing all the muscles excepting the internal oblique, and also the nerve.

I will now describe certain eyes that present exceptions to the conditions already described. The first will be the eye that shows the maximum development; the second, eyes that show the minimum development and the maximum degeneration.

The specimen that shows the greatest development has already been mentioned (page 61) in connection with the choroid and the hyaloid membrane, and the reader is referred to the statements there made concerning these structures.

The most interesting evidence of unusual development is found in the greater differentiation of the layers of the retina; and it is in the greater distinctness of the outer nuclear (*st. nl. ex.*) and outer reticular (*st. rtl. ex.*) layers that the difference chiefly consists (Fig. 21). Whereas the former is ordinarily, as in Figure 18, only one or two cells thick, (exclusive of the cells *st. rtl. ex.*), in this instance it is three or four cells thick; but more significant than its greater thickness is the fact that the deepest cells (*nl. ba.*) are arranged in a regular layer one cell thick, and closely packed.

What this layer of nuclei represents will be pointed out in the comparative part; it may be said here, however, that it probably does *not* belong to the outer nuclear layer. Although the external reticular layer even here does not present a well defined boundary either internally or externally, — particularly not internally, — the irregular areas which have already been mentioned as being destitute of nuclei in the average specimens (Fig. 18, *st. rtl. ex.'*) are here considerably more distinct (Fig. 21, *st. rtl. ex.*), both as to thickness and frequency of occurrence. In fact, the layer may be regarded as having the characteristic structure of the normal eye, excepting that it contains a considerable number of scattered nuclei, and is without distinct limitation internally. The rods also seem to be better developed in this specimen than in others. In many of them what has the appearance of an indistinct structureless nucleus may be seen occupying the extremity of the fourth of the rod nearest the external limiting membrane (Plate IV. Fig. 22, *a* and *b*). This one fourth probably represents the inner member of the rod. In some cases the nuclear-looking structure terminates on the side directed toward the distal end of the rod with a well defined straight line, but in other cases the whole has a round or elliptical form. This portion of the rod takes stain slightly, but it is the only portion that does. The substance of the remaining portion is uniformly opaque-glassy in appearance, excepting that numerous pellucid spots exist in it. These are considerably more distinct in some rods than in others, and occasionally they form a regular row through the whole length of the outer member (Fig. 22, *c*). They are mostly confined to the outer members, but in some rods a single one of unusual distinctness is found in the inner member.

I now pass to the least developed and most degenerate eyes. Perhaps the specimen most interesting in this respect is the one shown in Figure 6. In this the lens is entirely absent, a continuation of the pigment layer of the retina extending without break entirely over the space that this structure should occupy. The series of sections of this eye is complete, and every section is as perfect as the one from which Figure 6 was drawn; so there can be no possibility that the absence of the lens is due to artificial causes, or that an error in observation has been made. I should add, also, that I have an equally complete series of sections of the other eye of the same individual, and this shows the same structure in every particular. Over a portion of the outer moiety, the pigment is disposed in a double layer (Fig. 7, *pig.'* and *pig.''*). The outer of these layers is more directly continuous, both in thickness and direction, with the pigment layer of the retina. The inner layer presents a considerably thickened mass, *pig.''*, irregularly lenticular in form. From the appearance shown in this figure, one is tempted to regard this pigment mass as a remnant of the lens, the thinner portion of the layer at its edges, which connects it with the pigment layer of the retina, representing the iris. It is very doubtful, however, if such is the case. With such an interpretation the outer pigment layer (*pig.'*) would seem to represent the inner layer of the cornea; and this would afford an explanation, not obvious otherwise, of the continuity of the layer over the pupil. But there are several difficulties in the way of these convenient interpretations. In the first place, the pigment mass under consideration is found on examining the entire series of sections to be very irregular in form, and, as shown in Figure 6, to become confluent with the outer pigment layer (*pig.'*) in some portions of the eye; in the second place, as is shown in the figures, and has already been mentioned, the outer layer is directly continuous with the pigment layer of the retina, which of course it should not be if it belongs to the cornea; and, in the third place, the inner layer of the cornea is itself present and not pigmented (Figs. 6 and 7, *crn.*).

Concerning the condition of the retina in this eye I speak with considerable hesitation, because of a fear that its peculiarities may be due to artificial causes. I should say, however, that the specimen was hardened in chromic acid, and that all the tissues around the eye are well preserved. If the retina is macerated, it is because the preserving fluid failed to penetrate through the pigment layer in which it is wholly incased. Consequently, I shall not dwell at length on the subject, nor insist much on the significance of the structure described. Figure 19 is a rather highly magnified view of a meridional section of the retina near the ora serrata. It will be seen that only the layer of ganglion cells, the inner reticular layer, and undifferentiated layer are here distinguished. The inner reticular layer does not differ from that found in ordinary eyes. But with the other layers the case is quite different. The nuclei are much less closely packed than in other eyes, the intervening spaces being occupied by a few scattered fibres. The nuclei appear to be of two quite distinct kinds. One kind (*leu'cy.*) is somewhat larger than the other, stains considerably less deeply, is less refractive, and shows no trace of a membrane. In the other kind, the nuclei are smaller, *cl.*, *cl.'*, *cl.''*, stain deeply, and are refractive in such a way that in focusing through them they take on the three different appearances shown in the figure; i. e. when seen at a high focus they appear uniformly dark, as at *cl.*; at a deeper focus the appearance is that of a disk with a dark line at its circumference, a light yellow zone (represented in white in the figure) inside of this, and a uniformly dark spot in the centre, *cl.*; at a still deeper focus the appearance is that of a dark ring with a light centre, *cl.''* A few of these latter have two or three longer or shorter processes, but by far the larger number of them are spherical, or nearly so.

No rods are present in these eyes, though this portion of the retina is so ragged and formless that it is impossible to say whether they have ever been developed or not. It is quite possible that the larger bodies, in which, however, no nuclei are visible, are leucocytes.

Another interesting exceptional case is that presented by the section of the eye shown in Figure 12. It will at once be seen that the point of chief interest lies in the double layer of pigment that is situated behind the lens within the cavity of the eye. The outermost of these layers is in close contact with the posterior surface of the lens, while the innermost is in close contact with the inner surface of the retina. I cannot, however, satisfy myself that either layer is developed at the expense of the parts to which they are respectively adjacent. It is true that the line of contact between the lens and its pigment layer is not a sharp one, there evidently being a gradual disappearance of the pigment here. The lens, however, shows no flattening on this side, as it would were the pigment layer formed at its expense; but more than this, the pigment layer extends on either side beyond the lens, its outer edge becoming on one side (the lower one in the figure) continuous with the inner layer of pigment, and on the other side with the pigment layer of the retina. The connection with the outer is shown rather indistinctly in the section figured, but much more distinctly in some of the other sections of the series, as is also the fact that at places the iris is entirely cut off from the retinal pigment. If, then, these layers of pigment have come neither from the lens nor the retina, the only other structures in this region that they could come from are the vitreous body and the hyaloid membrane. In other respects this eye does not differ appreciably from the usual structure already described, with this exception, that the undifferentiated layer of the retina shows somewhat less differentiation than usual. I have studied these sections in vain to find convincing evidence of actual degeneration within the retinal elements themselves, in addition to the pigmentation.

I now present a table showing some of the results of measurements that have been made of the retina, lens, and optic nerve : —

	Two Specimens, each 19mm. long.		Spec. 50mm. long.	Spec. 60mm. long.[1]	Spec. of Clevelandia.
	1	2	3	4	5
	mm.	mm.	mm.	mm.	mm.
Entire retina (including pigment layer) . . .	.095	.075	.110	.145	.136
Pigment layer	.055	.046	.063	.078	.042
Nerve fibre layer	.0029	.0014	.0043	.0058	.05
Ganglion cell layer	.004	.0029	.0072	.0058	.05
Inner reticular layer	.013	.0058	.0116	.018	.021
Undifferentiated layer	.017	.001	.0203	.0317	
" Undifferentiated layer " of Nos. 1, 2, and 3 :					
Outer nuclear layer				.0058	.016
Basal nuclei in outer nuclear layer . . .				.0029	.0029
Inner nuclear layer (including outer reticular layer)				.0023	
Outer reticular layer					.0018
Tangential cell layer					.0029
Inner nuclear layer					.029
Diameter of lens		.205			.784
Thickness of optic nerve at entrance to retina				.011	.117
Length of rods				.032	

Perhaps the most important thing that these measurements reveal is the fact that the eyes are subject to great variation, as well in the pro-

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[1] The same specimen from which Figures 13 and 21 were drawn.

portion of their constituent parts as in their size and degree of differentiation in different individuals.

It is quite probable that some of the differences in thickness between the retinas of different individuals is due to the fact that measurements have been made on sections not quite meridional in direction. Care has been taken, however, in each instance to avoid this source of error. But in the case of the one giving a thickness 0.145 mm. greater than that of the normal retina in Clevelandia, the sections are so cut that none are quite meridional. As may be gathered from Figure 13, this eye is so flattened in its axial direction that the retina is almost disk-shaped; and from this fact it was possible so to cut the retina that none of the sections would be entirely perpendicular to its surface. The sections *are* so cut obliquely, though the deviation from the perpendicular is certainly not sufficient to account for the great difference in thickness that is shown. But the difference in proportion between corresponding layers in different retinas cannot be explained, even in part, as due to artificial causes. In one of the specimens 19 mm. long, the ratio between the inner reticular layer and the whole retina is 1 : 7, while in the other it is 1 : 13.

From the measurements here given alone, it might be concluded that there is a gradual increase in thickness, and a constantly advancing differentiation in the retina, with increase in the size and age of the animals. Such a conclusion is not warranted, however, when the whole number of specimens and stages that have been studied by me is considered, though it must be admitted that, in view of the obviously wide range of individual variation, the number of specimens examined has not been sufficiently large to justify an unqualified denial that such is the case. All that can be said with positiveness is, that, notwithstanding the fact that the thickest and most fully differentiated retina has been found in a specimen much larger — and therefore presumably older — than the smallest studied, yet several still larger individuals have shown retinas thinner and less differentiated than those of the smallest individuals; and, further, that in one instance at least one of the smallest individuals shows in the distinctness of the outer reticular layer as great a degree of differentiation as any retina examined. It would be a very interesting and significant thing, if, owing to a retardation in development, differentiation of the retina should continue throughout the entire life of these fishes; since we know quite well that normally the fish eye becomes functional and differentiated at an early period in development (Balfour and Parker, '82, pp. 371 and 384; Ryder, '84, p. 500; Hoffmann, '83).

It is exceedingly desirable to ascertain what law, if any, controls the variations of functionless organs. Having now before us the facts relating to the structure of the eye, we may pass to some reflections on their significance when considered from a comparative and a developmental point of view.

First of all, I will speak of the pigment layer of the retina. This has the greater interest since, according to R. Wright (Wiedersheim, '86, p. 427), in the retina of the "blind fish Chologaster papilliferus there is no pigmented epithelium."

It has already been shown that in Typhlogobius this layer is always thicker, relatively, than in the normal fish eye, being thicker than the entire remaining portion of the retina. I am in considerable doubt as to how this thickenning has taken place. The first explanation that suggested itself to me was that the choroid had become wholly converted into pigment and fused with the pigment lamella of the retina. However, the dense and uninterrupted character of the pigment of the layer, and the evenness of its external surface, at once threw grave doubts in the way of this explanation, and the more because of the rather meagre development of the choroid in the normal eye of bony fishes. Then, as the choroid was found on further study to be present outside of this layer, the only remaining alternative was to suppose the latter to be wholly derived from the proximal wall of the primitive optic vesicle; i. e. to represent the pigment lamella of the retina. We may possibly suppose that the proximal wall of the primitive optic vesicle never became thinned out as it does in normally developing eyes; but the fact that this process takes place very early — in bony fishes, at least, by the time the differentiation of the retina has begun — is quite a serious objection to such a supposition. But even if this were the case, it is hardly possible to believe that this layer was ever as thick as we find the pigment layer in the adult fish to be. We seem forced to suppose that for some reason the layer has actually increased in thickness concomitantly with the retardation in the development of the eye, or, it is quite possible, with the *degeneration* of this particular part of it.

I would call attention to the comparison of Typhlogobius with Clevelandia in this regard. From the figure of the retina of the latter, it will be seen that the retinal pigment appears in two quite well marked layers, an outer and an inner, the two being connected at short but somewhat irregular intervals by crossbeams or processes (Fig. 20, *ex.*, *i.*, and *m.*). From this it seems that the inner extremities of the processes of the retinal pigment layer, which in normal eyes, and particularly in many teleostean eyes, project far down among the rods and cones, have here become fused together to form a continuous inner layer, *i.*

So far as I have been able to determine, this condition is peculiar to Clevelandia, at least to the extent in which it is here seen. The interesting question now arises whether we have here the beginning of a process that would, under conditions that have brought about the changes seen in the Typhlogobius retina, ultimately result in a similar thick, solid retinal pigment layer; this being effected by a still further fusion of the cross rods of pigment now seen. As already pointed out, it is certain, both from Dr. Eigenmann's observations and my own, that Clevelandia spends some time at least in holes in the ground.[1]

The only doubt existing concerning the identification of the layers of the retina is with reference to what I have called the outer reticular layer (Plate III. Figs. 18 and 21, *st. rtl. ex.*), and the layer of nuclei (Fig. 21, *nl. ba.*) that has been designated by the non-committal term of "basal nuclei," *basal,* i. e., with reference to the outer nuclear layer. On comparing Figure 21 with Figure 20, the section of a Clevelandia retina, there will be little doubt of the correspondence of layer *nl. ba.* in the two cases; but at the same time the entire absence of layer *ful.* (Fig. 20) will be noticed in Figure 21. These two layers together seem to correspond to W. Müller's ('74, pp. 60 and 61, Taf. XIII. Figs. 4 and 7) layer of tangential fulcrum cells. This layer is described by this author as being composed in Petromyzon of "zwei Etagen grosser quadratischer Zellen, zwischen welchen eine Schicht ganz flacher, in faserartige Ausläufer sich fortsetzender Zellen gelagert ist." The layer is said, in the same connection, to be subject to much modification in the different families of fishes, in which alone it is well developed; but the Percidæ and the Cyprinidæ are mentioned as teleostean groups in which the layer with both its "Etagen" is present. According to this interpretation the external granular layer of M. Schultze, called in this paper the external reticular layer and by Krause ('76) the membrana fenestrata, is not present in either Clevelandia or Typhlogobius; and it is instructive to note that Krause does not find this

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[1] I may here add an observation recently made, which indicates that the time thus passed hidden from the light is not inconsiderable. On some of my visits to the beach at West Berkeley I have found the fish very numerous in the tide-pools, while at other times hardly any are seen. Whether their absence is due entirely to their having gone into the holes I am not sure; but however that may be, at such times I have occasionally found them by digging. I am not yet able to say whether their disappearance is in any way correlated with conditions of the weather as regards sunshine.

layer in Perca fluviatilis. Its position would be between the external nuclear layer and the layer *nl. ba.* (Figs. 20 and 21). The outer of the two "Etagen" of Müller's tangential fulcrum cells appears to correspond to Krause's membrana perforata, and likewise to M. Schultze's basal plexus, and the inner to Krause's stratum lacunosum; this would make the layers *nl. ba.* and *st. rtl. ex.* of the Typhlogobius retina the membrana perforata and the stratum lacunosum, respectively. An objection to this interpretation is possibly presented by Hoffmann's account of the development of the Salmon retina. His Figures 10, 11, and 12 (Taf. V.) show that what he calls the tangential fulcrum cells become differentiated quite early, certainly as early as the stage of development represented by the partially developed retina of the adult Typhlogobius. But judging from the position of this layer in relation to the inner nuclear layer and the layer that he regards as the outer granular layer, it would seem that his tangential fulcrum cells correspond to the inner "Etagen" only of what Müller designates by that name. But according to my interpretation these cells are not present in Typhlogobius, unless they be represented by the scattered cells in layer *st. rtl. ex.* The chief point to be made in this discussion of the homologies of the retinal layers is this. In the most differentiated retina, even though all the layers found in the normal adult fish eye may be marked out, the differentiation is much less complete as regards the zone between the two nuclear layers than it is in the normal eye of a closely related genus; while in a majority of individuals development is arrested at a considerably earlier stage.

In view of the almost universal statement that the rods and cones are the latest of all the parts of the retina to be developed, it would, I think, hardly be expected that the rods should be as complete as they are in these eyes. O. Hertwig ('90, p. 402) says, "Of all parts of the retina the remarkable rods and cones are the latest developed." Hoffmann ('83, p. 68) says, "According to all other authors [Löwe excepted] they [the external members of the rods and cones] arise latest of all the retinal elements in the different animals; and it is likewise so in bony fishes." It would certainly seem that the testimony of the eyes of Typhlogobius is against the absolute correctness of these statements.

The recent papers of Hess ('89), Kohl ('89), and Schlampp ('91 and '92) together with the somewhat older contributions to the same subject by Leydig, Kadyi, Ciaccio, and others, make possible a detailed comparison of the eyes of Typhlogobius with those of Proteus anguineus and Talpa europea.

On the whole, it appears that the eye of Proteus is more rudimentary than that of either Typhlogobius or Talpa. The most distinct indication of this is in the absence of the lens in the adult animal.

With reference to it Schlampp says ('92, p. 555): "Die Linse [in Proteus] wird gleichzeitig mit der Einstülpung der primären Augenblase angelegt, wächst in den sekundären Augenbecher hinein, wo sie bei der Larve noch in der Gegend des vorderen Augenpoles zu finden ist. Sie kommt aber über die zellige Struktur der embryonalen Linse nicht hinaus, erleidet vielmehr durch Nichtgebrauch alsbald eine Rückbildung, so dass sie bei ganz jungen Thieren an Grösse und Zellmasse schon bedeutend reducirt ist, im späteren Leben aber resorbirt wird und spurlos verschwindet."

The lens is present in Talpa, though it retains its embryonic cellular structure throughout life, wholly according to Hess ('89, p. 8), partly at least according to Kohl ('89, p. 385) and others. In this regard, then, it is more rudimentary than the lens of Typhlogobius. The choroid is present in Proteus, consisting, according to Kohl ('89, p. 406) "aus mehreren Zellenlagen mit reichlichem Pigment, das sich stets in zwei Lagen anordnet, von denen bald die eine, bald die andere die grössere Stärke besitzt. Die innere derselben repräsentirt das vielfach (so auch Hess) schon zur Retina gerechnete Pigmentepithel." It also contains blood capillaries according to both Kohl and Hess. As regards the choroid and the pigment lamella of the retina, it would seem, according to these statements, that the eye of Typhlogobius, with its exceedingly rudimentary choroid and greatly thickened pigment lamella, is somewhat more rudimentary — it may be even degenerate — than that of Proteus; though it must be borne in mind that the choroid is comparatively feebly developed in normal teleostean eyes.

In Talpa the choroid reaches a relatively slight development, and has little pigment, while the pigment layer of the retina is highly developed (Hess, '89, pp. 3 and 4). In this regard it more nearly agrees with Typhlogobius than does Proteus. The iris, considerably thickened with pigment, the ligamentum pectinatum, ciliary body, and ciliary muscle, are all present, though reduced, in Talpa, according to Hess.

With regard to the retina of Proteus, Schlampp's statement in his summary is as follows: "Die Retina breitet sich, Mangels des central Glaskörperraumes, nicht flächenhaft aus, sondern wird eine solide Kugel, welche axial von Sehnerven durchzogen wird. In ihrem histologischen Baue weicht sie nicht wesentlich von der Netzhaut der Amphibien ab, die Endapparate erreichen aber die endgültige Form nicht."

Also according to Kohl ('89, p. 407), the nerve-fibre layer, the ganglion-cell layer, the inner and outer nuclear layers, and the inner reticular layer are present. Regarding the outer reticular layer and the optic cells he says: "Zwischen den beiden Körnerschichten habe ich die aüssere reticuläre Schicht (Zwischenkörnerschicht) immer durch eine fortlaufende, oft gar nicht so schmale Spalte repräsentirt gefunden. . . . Die Sehzellen, die sich mit Picrocarmin meist sehr schön färben lassen, zeigen ungemein mannigfache Formen: bald ganz flach, bald nahezu kreisrund. Oefter fand ich vollkommen entwickelte Zäpfchen, niemals jedoch auch nur annährend stäbchenartige Gebilde. Die Hemmung in der Entwicklung ist eben auch hier schon so früh eingetreten, dass eine ausgesprochene Stäbchen- und Zapfenschicht nicht mehr zur Ausbildung kommen konnte."

Of the retina in Talpa, Hess says that the nerve-fibre layer is very thick near the entrance of the optic nerve, and that the inner reticular layer contains cells; he quotes Leydig and Kadyi to the effect that the optic cells consist exclusively of rods, and he adds ('89, p. 5), "Ueber die anderen Retinaschichten ist Besonderes nicht hervorzuheben." Kohl ('89, p. 384), however, states that "Zäpfchen sind stets vorhanden: oft vereinzelt, oft sehr zahlreich und die Stäbchen nahezu verdrängend. Bei einem Exemplar zeigen die Sehzellen noch jene Form, die sich bei Embryonen eines gewissen Alters findet, und noch nicht erkennen lässt, ob die betreffenden Zellen sich zu Stäbchen oder zu Zäpchen weiter entwickeln werden." It thus appears that the three retinas have reached about the same stage in development; that of Proteus being probably on the whole the most rudimentary, and that of Typhlogobius, at any rate as represented by the one shown in Figure 21, the least so.

As regards the vitreous body, Schlampp finds that it is entirely absent in the eye of Proteus; while Kohl ('89, pp. 406 and 407) finds a structure which he regards as the hyaloid membrane, or "the membrana limitans interna, the only representative of the vitreous body in the Proteus eye." Hess and Kohl both describe the vitreous body as present in Talpa, and, according to the latter, it contains numerous blood-vessels. It will be remembered that no trace of this structure has been found in the eye of Typhlogobius, with possibly a single exception.

All are agreed at present, it appears, that the optic nerve is present in both Proteus and Talpa, though Hess quotes Semper as stating that it is entirely degenerated in Talpa. I find no account, however, of its ever having in either of these animals a pigment sheath in its passage through the retina, such as occurs in Typhlogobius. But it is interesting to notice in this connection Kohl's description of this portion of the nerve in Proteus. He ('89, p. 408) writes : " Beim Durchgang des Opticus zeigen die Zellen der Retina ein eigenthümliches Verhalten. Ihre Kerne werden sehr langgestreckt und sie ordnen sich um den Nerv in 1-2 dichten Lagen dergestalt an, dass sie schon kurz vor dem Eintritt des Opticus in die aüssere Körnerschicht und auf der ganzen Strecke, die derselbe sich durch die Körnerschichten hinzieht, eine Art fester Röhre um ihre bilden." It is quite possible that the pigment sheath described in the Typhlogobius eye may have been preceded by such a cellular sheath as this ; but if so, my conjecture that it is derived from the nerve itself, and not from the surrounding retina, would be, of course, erroneous. It is also worth mentioning that Berger ('81, p. 262) has described pigmented fibres arising from the choroid as passing through the optic nerve in some fishes.

We have not yet sufficient knowledge of the minute structure of the eye of any of the other blind vertebrates, Myxine and its allies excepted, to make possible further detailed comparison. With reference to the eyes of the Myxinidæ, it should be said that, from the investigations of J. Müller ('35–41), and, later, W. Müller ('74, pp. 7–15), we know that they are far more rudimentary than in any other vertebrate whatever, unless we admit the exceedingly problematical pigment spot at the anterior end of the nerve cord of Amphioxus to be homologous with the eye. It is, however, instructive to notice wherein the eyes that we have been considering may be regarded as passing along the same degenerative road over which the Myxinoid eye has passed, and in what respects they might seem to be on different roads. The eye of Myxine is buried in the tissue of the head in much the same way as in the other forms, excepting that, in addition to the layers of skin and the connective tissue by which it is covered, there is also a layer of muscle over it, and it is immediately surrounded by a sort of capsule containing in its substance much fat. As the foregoing pages have shown, there is no indication of either the muscle layer over the eye or the fatty layer around it in Typhlogobius, Proteus, or Talpa ; but it is of course entirely beyond our power to say that there never could be such structures.

Neither lens nor eye muscles, nor anything that can properly be regarded as a cornea, sclerotic, or iris, are present in the eye of Myxine. The primitive optic vesicle never becomes wholly obliterated, and the retina reaches only a very rudimentary degree of differentiation. W. Müller ('74, p. 14, and Fig. 3, Taf. XI.) recognizes in it, however, the internal limiting membrane; the inner reticular layer (called by him the neurospongium), and scattered in this the ganglion cells; the inner nuclear layer (called by him the ganglion retinæ); the rudiments of the rods and cones; and the radial fibres. Krause's remarks on the eye of Myxine are interesting. He ('86, p. 19) says: "Sein Auge würde zu den *perotischen* rückgebildeten, wie das von Proteus anguineus zu rechnen sein, und man kann die rudimentär entwickelte Retina deshalb nicht zur Construction phylogenetisches Aufbauten benutzen." It appears to me that the most interesting fact concerning the Myxinoid eye, at least from a comparative point of view, is the entire absence of pigment in it. I may here say that I have made some sections of the eye of a member of this family found at Monterey, Cal., and named by Lockington ('78, p. 793) Bdellostoma stoutii, and can confirm the statements made on this point by all other observers. I have so far found no trace of pigment in the eye. The proximal layer of the primitive optic vesicle remains distinctly cellular throughout life, as always stated, but no pigment appears either in it or in the mesodermal tissue immediately surrounding the eye. If, as seems certain with the rudimentary eyes of the three forms that we have been considering, an increase of pigment is an incident to the gradual diminution in functional importance and structural completeness, I can see no very satisfactory explanation for the absence of pigment in the Myxinoid eye, if we are to suppose, as I take it for granted we must, that it too is the result of arrested development.

Wyman ('54, p. 395; '54^a, p. 18; see also Putnam, '72, pp. 18, 19) has made us acquainted with the eye of Amblyopsis spelæus as far as he was able to with the methods of morphological investigation of his time. And it is altogether probable that all he has made known concerning this species holds good for Typhlichthys subterraneus, since the two forms are so nearly alike that systematists are not fully agreed that they should be considered as separate species.

According to Wyman, the eye of Amblyopsis has "a sclerotic coat, a choroid coat, a layer resembling the retina, a lens, and a nerve." His notes, published by Professor Putnam, give somewhat more of detail as to the structure of these several parts. He says: "Under the microscope, with a power of about twenty diameters, the following parts are satisfactorily made out: . . . 2d, a layer of pigment cells for the most part of a hexagonal form, and which were most abundant about the anterior part of the eye; 3d, beneath the pigment a single layer of colorless cells, larger than a pigment cell, and each cell having a distinct nucleus; 4th, just in front of the globe a lenticular-shaped, transparent body, which consisted of an external membrane containing numerous cells with nuclei." The pigment layer he regards as representing the choroid, and the layer of colorless cells within — and it should be particularly noticed that it is according to both his description and figures a *single* layer — as representing the retina. It is very desirable, indeed, that these eyes should be studied anew with modern methods of preservation and by means of sections; for, if Wyman's account of the structure proves to be correct, we have here a most interesting deviation from the three forms best known and already compared. It may be supposed that his statement concerning the cellular condition of the lens is correct; for this involves merely the observation that a given structure is composed of cells, while his statement concerning the retina involves an observation as to how the cells in a given cellular structure are disposed, — two quite different matters, as every histologist knows. In this particular the lens of Amblyopsis corresponds, then, to that of Talpa; but in the latter animal the retina is fairly well differentiated, and even in Proteus, where the lens is wholly wanting in the adult, the retina is differentiated to a considerable extent. If Wyman is correct in supposing that the retina in Amblyopsis is represented by a single layer of cells, then we have a condition corresponding more nearly to that found in Myxine than in any other known vertebrate, although even here the retina proper is far from being a single cell layer, but the eye of this latter form has no trace of a lens.

Cope ('64, p. 232) remarks with regard to the blind Silurid, Gronias nigrilabris, that in no case has he found anything representing the lens. Whether a considerable number of specimens were examined with reference to this point, the author does not state; but from the general character of the fish and its eyes, as described, it appears to me quite probable that, as Packard suggests, further examination will lead to the discovery that the lens is not entirely absent.

I cannot refrain from saying at this point a few words on the question which, in reality, induced me to undertake the study of the eye of Typhlogobius, viz. the question of the actual degeneration of functionless organs. There is a belief prevalent among zoölogists, though to just what extent I am unable to say, that, if a structure undergoes degeneration in ontogeny it does so in the reverse order of its phylogeny. It would appear that a degenerating vertebrate eye with its great complexity of organization, this complexity having been taken on by degrees through a long course of evolution, would furnish an excellent test of this belief. The eye here studied throws very little light on the question, however, — scarcely as much as does that of other known functionless eyes. But when we consider together the facts presented by the eyes of Myxine, Typhlogobius, Proteus, and Talpa, and possibly also Amblyopsis and Gronias, this much seems quite certain: that the lens disappears before the retina; and that, where degeneration takes place at all in ontogeny, the lens is affected first and most profoundly, as seen in Proteus, and probably also exceptionally in Typhlogobius. Supposing the somewhat doubtful instance of a degenerating retina presented by the eye shown in Figure 19 to be genuine, we still have reason to believe that its degeneration has been preceded by that of the lens, since the latter body is undoubtedly absent in this specimen. There can scarcely be a doubt, from physiological reasons, that the retina is considerably older, phylogenetically, than the lens, even though it can hardly be said to be so ontogenetically.

The Integumentary Sense Organs.

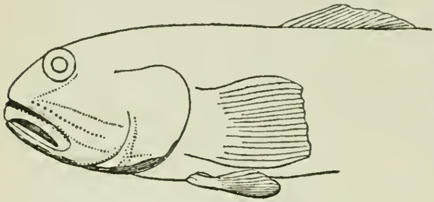
At present I treat this subject no further than pertains to the question whether the loss of sight in Typhlogobius has been compensated by an unusual development of the sense of touch, leaving the consideration of any morphological significance that the sense papillæ may have with the hope that they may be studied developmentally at some future time.

From the testimony of numerous writers, there is no doubt that compensations for such loss by the super-development of the other special senses, hearing, smell, and touch, are common among animals both invertebrate and vertebrate. For a discussion of this subject see Packard ('86, pp. 123–130).

My conclusion with reference to the tactile sense in Typhlogobius is, that in all probability it not only has not increased, but has actually diminished *pari passu* with the diminution of the power of sight. The reasons for this conclusion are that several — at least four — genera of the Gobiidæ closely related to Typhlogobius are as well provided with tactile papillæ as is the blind fish, these organs being considerably more numerous and more widely distributed on different parts of the body in the other fishes than in Typhlogobius. The genera to which I refer are Gobius, Gobiodon, Lepidogobius, and Clevelandia. The last two I have examined myself. The arrangement and distribution of the papillæ of Typhlogobius are shown, except for a few scattering ones to be spoken of shortly, in Plate I. Figure 3, *pap.*

There are two series near the edge of each side of the lower jaw, running parallel with it. The series of one side do not quite unite, anteriorly, with those of the opposite side, the interval between their ends being occupied by a slight prominence in the epidermis. Posteriorly the series extend beyond the angle of the mouth and turn upward somewhat to terminate about on a level with the mouth opening; the rows nearer the median line, however, extending slightly farther than the ones nearer the edges of the jaws (Fig. 3). The papillæ of the inner series are considerably larger than those of the outer series, there being about six of the former to thirteen of the latter. The larger ones are on the average about 0.08 mm. in diameter, though the size varies considerably. The papillæ of the outer series are situated on a quite prominent ridge, while the inner ones are, on the contrary, in a shallow furrow. These ridges and furrows are, however, apparently a part of the longitudinal foldings in the integument that are characteristic of this region of the head, rather than structures expressly for the accommodation of the sense buds. Another series of papillæ is found on each side of the head above the mouth, and having very nearly the same direction as those below, though inclining toward the latter somewhat in their course backward. These extend anteriorly to near the tips of the fleshy knobs shown at †, Figure 1. The papillæ above the mouth are of about the same size as the smaller ones on the lower jaw. Still another series is found on each side of the head on the operculum, extending however at a right angle, or nearly so, to the series already described (Fig. 3). These are also of the smaller variety. The number in both this and the upper-jaw series is more variable that in the lower-jaw series, though the transverse series never extend far on to the top of the head.

In Lepidogobius and Clevelandia both lower-jaw series are present, and have precisely the same arrangement and form as in Typhlogobius; and in addition papillæ are numerously present on various parts of the head and body where they do not occur in Typhlogobius. Thus on the head of Lepidogobius there are at least several hundred in addition to the ones on the lower jaw. On each side of the head, beginning at a point a little above the mouth and somewhat nearer its angle than the end of the snout, four rows take their origin and diverge irregularly. The row nearest the mouth bends downward somewhat as, in its backward course, it reaches the angle of the mouth, and it extends, as do all the rows, considerably farther back of the angle of the mouth than it does in front of that point. The uppermost row of the four runs upward to near the posterior and lower quadrant of the eye, where it takes a trend more directly backward, and extends for a considerable distance back along the dorsal limit of the operculum. The other two rows are situated considerably nearer the lower than the upper row, and are nearer each other than either is to the uppermost or the lowermost row. They also run very nearly parallel with each other. The lower one of these two middle rows contains the fewest and largest papillæ of the head, those of the inner mandibular series excepted. There are about twenty-five papillæ in the lower row, nineteen in the next, thirty-five in the third, and fourteen in the fourth.



Head of Lepidogobius, showing the distribution of the tactile Papillæ. × 1½.

Many of the papillæ of this species are distinctly excavated on their summits, and in such a way as to show such an arrangement as is described by Solger ('80, p. 375) to exist in the lower jaw of Gobius minutus. The excavations are in the form of grooves, or creases, which extend entirely across the summit of each papilla, each groove being somewhat broader in its middle than at the ends. In some of the rows these grooves are directed lengthwise of the row, while in others they have a direction crosswise of it. There is some variation in the direction of the grooves in the papillæ of the same row, and considerably more in some rows than in others; but the constancy in some of them is noticeable. In the larger papillæ the grooves are much more pronounced than in the smaller ones, in many of these latter the excavation being a pit rather than a groove. In the lower-jaw series of this species, the grooves of the inner rows extend crosswise to the axis of the head, and those of the outer row lengthwise, thus corresponding to the condition found by Solger in Gobius minutus.

In addition to the four series thus described, there are numbers of papillæ scattered on other portions of the head, particularly about the tip of the snout and on the opercular apparatus; in these regions they are particularly numerous on the suboperculum. Also on each side of the body, beginning immediately behind the pectoral fins, there are about thirteen transverse series, containing from five to ten papillæ each; and still lower down are from five to seven additional transverse series, extending well down on the ventral surface of the body. It is possible that these lateral series are derived from a segmentally arranged type; but if to they have certainly deviated greatly from the typical arrangement, as they also vary both in the number of series and in the number of papillæ in each series. The papillæ here are considerably smaller, on the whole, than those of the head. There are, finally, a number of papillæ scattered around the bases of the fins, both pectoral and pelvic.

In Clevelandia there are about twenty-five transverse series on the sides of the body very uniformly segmentally arranged, being situated on the inter-myotomic septa. The series contain an average of about five papillæ each, though the number varies considerably. I have worked out the precise arrangement of the series on the septa, — for not quite all the septa have papillæ, — and of the number of papillæ to each series in a considerable number of specimens, as it has appeared to me that this may have considerable morphological significance. It is not necessary for my present purpose, however, to give the results in detail. It is worthy of mention that the transverse series on the body of Clevelandia are situated in shallow ditches, the anterior wall of these being deeper and more abrupt than the posterior. In no case have I been able to find the papillæ situated in canals, or in grooves that approach canals, as is so common in fishes, and is said to be the case in Gobius niger, by Merkel ('80, p. 28). All writers agree, however, that in the genus Gobius by far the greater portion of the papillæ are free on the surface of the body (F. E. Schultze, '76; Merkel, '80; Solger, '80). We know from the last two of these authors that both the genera Gobius and Gobiodon have free transverse series of papillæ on the sides of the body. With reference to this subject, Solger ('80, p. 378) says: "Bei Gobius konnte ich 'Querreihen von 3–7 Organen' constatiren; auf Beziehung der Organreihen zur Metamerie des Leibes achtete ich damals leider noch nicht. Auch Gobiodon hat am Rumpfe freie Seitenorgane, die in Querreihen auf Coriumpapillen stehen und höchst wahrscheinlich durchweg segmental angeordnet sind." And Merkel ('80) shows three of these series in his Figure 4, Taf. IV.

It being, then, evident that so many of the near relatives of Typhlogobius are provided with sense papillæ on the sides of the body, the question at once arises whether any are found in the corresponding region on the blind fish. Very naturally it was to the smallest specimens in my possession that I turned to begin the search for them. On each of the two individuals 19 mm. long, papillæ were found on the sides of the body, and on one of them a few on the head, besides in the regions where they occur regularly In one of these the papillæ on the right side of the body were distributed in what I regard as representatives of nine of the transverse series described in Clevelandia. The first and second series behind the pectorals were represented by one papilla each; the third and fourth, by three papillæ each; the fifth, sixth, and seventh, by two each; and the eighth and ninth, by one each. The series were evidently segmentally arranged, though not all were on consecutive segments; thus between the third and fourth series were two myotomic plates; between the fourth and fifth, four plates; between the fifth and sixth, two plates; between the sixth and seventh, one plate; and between the eighth and ninth, two plates.

Figure 25, Plate IV., shows the arrangement of a group of papillæ on the right side of the head of this same individual. As seen by the figure, seven of these papillæ were much larger than the remaining ones, and were situated on quite prominent ridges of the skin.

Although the papillæ have been diligently searched for on the sides of the body of other specimens, they have been found on the two small ones only. The question at once arises, Are the papillæ absent from the larger ones because they have degenerated and completely disappeared during the life of the individual? All the evidence I have on this point is contained in the facts presented. That the papillæ have been found only on the two small specimens examined, and that they have not been found on any of the numerous large ones, certainly suggests very strongly an affirmative answer to the question. It must be said, however, that a considerable percentage of my larger specimens are not so well preserved but that the papillæ may possibly have been present in them and escaped detection. But some of them are well preserved, and were the papillæ present they would, I am sure, have been found.

That the sense papillæ are less numerous on Typhlogobius than on several, at least, of its near allies, is evident. The question may now be asked, Is it not possible that, although there has been no compensation for the loss of sight by an increase in number of the tactile papillæ, such a compensation has been brought about by a higher development of the individual papillæ themselves? So far as structural evidence is concerned, this is certainly far from probable. Figures 23 and 24 (Plate IV.) show sections of two papillæ of the inner mandibular series of Typhlogobius; and for the purpose of comparison a section of a papilla from the same region in Lepidogobius is given in Figure 26. Between Figures 24 and 26 there is considerably less difference than may often be seen between sections of different papillæ of the same animal. Thus the sense cells proper (*cl. sns.*), which are very regular in their arrangement in Figure 26, are quite irregular in Figure 24; but Figure 23 agrees much more closely in this particular with Figure 26 than with Figure 24. Indeed, the difference is due to the position and direction of the section, both arrangements being found on sections of one and the same papilla at times. The cuticular spikes, so distinctly seen on the sense cells in Figure 23, are much less distinct in any of the Lepidogobius sections examined; but they are only exceptionally seen with such clearness in sections of the blind fish papillæ. It will be noticed that a considerable space (*tt.*) exists in Figure 26 between the sensory cells and the underlying nuclei of the supporting cells, in which there are no nuclei; and that such a space does not appear, at least conspicuously, in either of the figures from Typhlogobius. This, however, is not a difference of material significance, since in many sections of the papillæ of the blind fish such spaces do exist. In Figure 24, it will be observed that a blood-vessel, *va. sng.* (the leader from which has been misplaced in the engraving), penetrates far into the interior of the papilla. A similar vessel is present in Figure 26, though it does not extend quite so far into the base of the papilla, nor have I in any case found it to do so in this species, though it is true I have not examined as large a number of sections of Lepidogobius as of the blind fish; but the difference, if distinctive of the two forms, is nevertheless insignificant. Neither as regards the mantle cells (*cl. mt.*), nor the relation of the papilla to the epidermis, — i. e. its extending entirely through the thickness of it, — nor the way in which the nerve approaches and enters the papilla, nor the character of the immediately underlying subepidermal tissue, is there the slightest characteristic difference to be made out between the two species in such papillæ as are represented in Figures 24 and 26.

In only one point a difference may possibly exist between them, though I have not yet been able fully to satisfy myself of this. By Figure 23 it will be seen that the papilla is wholly and deeply buried in the epidermis, only a small pore (*po.*) communicating with the outer world. The apparent bridge across the pore near the papilla is probably a point of contact merely, as adjacent sections show. The whole appearance is as though the papilla had been withdrawn into the epidermis; for not only is the latter much thickened immediately around the papilla, but the inverted hopper-shaped outline which the inner surface of the epidermis shows immediately under the papilla in most cases where the latter reaches out freely to the surface (as in Figures 24 and 26), is here entirely obliterated. Another fact that seems to favor the view that the papilla has been withdrawn, is the very distinct flask-shaped excavation in the summit of the papilla itself, seen in Figure 23 (*fos.*), while in the sections represented in the other two figures no such excavations are present.. A natural explanation for this would seem to be that, on being drawn in, the middle portion of the papilla with the sense cells had been more depressed than the mantel cells. This may be the true explanation, but in one instance I have found the excavation in the papilla, even though the papilla itself protrudes through the epidermis, even more distinctly than in Figures 24 and 26 ; yet it should be mentioned that in this exceptional instance the papilla is considerably narrower in proportion to its length than those shown in the figures just referred to, or than they usually are. I have searched in vain for muscle fibres that could bring about such a withdrawal, and have no other evidence than that presented that it takes place ; nor have I often found the papillæ thus buried, and never in Lepidogobius. Leydig ('79, p. 25) has suggested the probability of the contractility of the cellular elements of the papillæ as the cause of an apparently similar condition in Acerina cernua.

A word should perhaps be spoken at this point on the possibility of the loss of sight being compensated by a higher development of the organs of hearing or smell. This subject lies outside of the purpose of the present paper, and I have given only superficial attention to it. The ears examined in dissected specimens mounted in glycerine do not appear unusually large. The minute structure I have not examined ; but from this morphological evidence, taken with the fact that all my efforts to get from my single living specimen responses to sounds of various kinds were unavailing, I am inclined to believe that the sense of hearing is not largely developed.

My sections of the snout show the olfactory epithelium to be very well developed, though apparently not more so than in other bony fishes, and certainly not so highly as in some of the long-tailed amphibia that I have examined.

What we know about the compensatory development of the tactile organs in other vertebrates with rudimentary eyes may be summed up as follows. It is well known from the writings of Tellkampf, Wyman, Leydig, Putnam, Wright, and others, that the tactile papillæ are well developed on the head and sides of the body of both Amblyopsis and Typhlichthys. According to Packard ('86, p. 127), Tellkampf regarded these papillæ "as without doubt increasing the tactile sense." I have not seen this paper of Tellkampf's, and do not know whether his meaning would be that the tactile sense is increased as compared with what it was in the same species before it was deprived of sight, or merely that it is great as compared with other bony fishes. Leydig also believes that the tactile organs perform such a compensatory office ('83; see also Wright, '84, p. 272). Packard ('86, pp. 127, 128) gives extracts from several letters of Dr. John Sloan that are interesting in this connection. Although the writer does not expressly state his belief that the sense of touch has been highly developed for the purpose of compensating the lack of sight, he still gives very convincing evidence of its extreme acuteness from personal observation on the fishes in their native surroundings. It should also be noticed that he specially tested their powers of hearing and the effect of light upon them, and to both he says they "manifested total indifference." Sloan's observations were on Amblyopsis. Wyman ('72, p. 19) has described the ear of this species as being "largely developed" in all its parts, and Cope ('72, p. 410) found the sense of hearing "evidently very acute." As to the question whether the sense papillæ in Amblyopsis and Typhlichthys are in reality developed as a compensation for the loss of sight, the testimony furnished by Chologaster is of the greatest importance. Although this genus was discovered and named by L. Agassiz in 1843, its characters were best made known by Putnam. He ('72, pp. 22, 23) says: "In the genus Chologaster we have all the family characters as well expressed as in the blind species, though it differs from Amblyopsis and Typhlichthys by the presence of eyes, and the absence of papillary ridges on the head and body, and by the longer intestine and double the number of pyloric appendages, as well as by the position of the ovary."

In 1881, S. A. Forbes ('82, p. 3) discovered a fish in Southern Illinois which he identified as belonging to the genus Chologaster, but representing a new species. With reference to the point that we are now considering, the author writes: "The most important and interesting peculiarity of this species indicates a more advanced stage of adaptation to a subterranean life than that of its congeners. On all the surfaces of the head appear short rows of peculiar tubercles. . . . When thus exposed [by being freed from the adjacent epidermis], they closely resemble the papillæ of Amblyopsis in form and size, and are similarly cupped at the tip." Again (p. 5) he says: "The extraordinary development, in only a part of the genus, of a special sensory apparatus peculiarly useful to a fish unable, for any cause, to see, points the same way, [i. e. to the supposition that this genus has a shorter subterranean history than Amblyopsis,] and gives evidence of a *progressing* adaptation of these fishes to their unusual abode. The intermediate relation of the sensory tubercles of Chologaster to the much smaller ones of young fishes and the permanent papillæ of Amblyopsis, points out the evident origin of the last through the permanency and higher evolution of structures evanescent in the young." This is probably the clearest case furnished by vertebrates of the loss of sight being recompensed by a higher development of the tactile sense.

As regards the tactile papillæ in the Cuban blind fish (Lucifuga), Putnam ('72, p. 9), who examined a specimen sent to the Museum of Comparative Zoölogy by the discoverer of the fish, Professor Poey, says: "In the Cuban blind fish we find ciliary appendages on the head and body quite distinctly developed, evidently of the same character as those of Amblyopsis, and answering the purpose of tactile organs. . . . There are eight of these on the top of the head, . . . and quite a number arranged in three rows on each side of the body, showing that the tactile sense is well developed in these fish."

This, so far as I am aware, is all that is known on the subject, and can be regarded as furnishing nothing more than a probability that touch papillæ have been here developed to compensate the fish for sightless eyes. The writer just quoted remarks further, that it is singular that the barbels on the jaws, so commonly found in the Cod family and its allies (to the latter of which the Cuban fish belongs), are entirely wanting. As is well known, Lucifuga is a cave dweller, and consequently the conditions which have produced its rudimentary eyes are more similar to those that have produced the corresponding change in Amblyopsis than to those that have had the same effect on Typhlogobius. And this fact may strengthen the probability above referred to; for, from the difference in conditions of life, Amblyopsis and Lucifuga are in all probability much more active than Typhlogobius, and this would make the tactile sense more useful to the first two species than to the last one.

We will now notice the condition of the blind deep-sea fishes with reference to the touch papillæ. The three forms described by Günther ('80), Typhlonus nasus, Aphyonus gelatinosus (p. 548), and Ipnops murrayi (p. 585), are all without barbels, and, so far as known, other special tactile structures. The two genera first named belong to the same family as Lucifuga, and consequently the remarks made concerning the absence of barbels in the latter will apply in a measure to these genera, and with reference to Lucifuga receives more force by the statement of Günther that they "are Brotula organized for a subterranean life" (p. 547); and in the genus Brotula, which has eyes, the snout is provided with barbels.

Through the kindness of Mr. C. H. Townsend, naturalist of the United States Fish Commission Steamer "Albatross," I have been able to examine, though somewhat superficially, a specimen of Ipnops, — probably the same species as the one above mentioned, — and, so far as I could discover, Günther's statement that it is "deprived of organs of sight and touch" ('87, p. 190) is strictly correct. The same author makes the following as a general statement on this subject: "Special organs of touch are not more generally developed in deep-sea fishes than in the littoral fauna. . . . As such may be considered . . . the more or less detached rays of the pectoral fin of . . ., and especially of Bathypterois, which possesses but rudimentary eyes." ('87, p. xxxi.) And in another connection the same author (p. 722) says: "Beyond that depth [two hundred fathoms] small-eyed as well as large-eyed fishes occur; the former having the want of vision compensated by tentacular organs of touch, whilst the latter have no such accessory organs."

I have not been able to find any direct statements concerning tactile papillæ on the several species of blind Silurids of South America mentioned by Günther (Packard, '86, p. 107), nor have we any knowledge that such structures are found on Gronias, the blind representative of the same family from Pennsylvania.

The Integument.

I was led to a study of the integument by the question having arisen as to why the quantity of pigment should have *diminished* in it, while under the same conditions of life it had *increased* in the eyes. That such diminution had taken place in the skin was inferred from the generally much lighter appearance of the largest preserved specimens as compared with the smallest. In the latter, the whole dorsal portion of the body and head is covered with a great number of distinct pigment cells (Fig. 1), while the large specimens never present anything like so conspicuous a pigmentation; and in the majority of cases they appear, on cursory observation, to be almost white.

Closer examination shows, however, that the pigment is in reality present in large specimens as well as in small ones, in quantity almost, if not quite, as great in the one case as in the other; but that it becomes disguised in the former case, and in a manner that will appear presently.

Figures 9 and 10, Plate II., are from sections of the integument and immediately underlying tissues of the dorsum of the head of two individuals, 19 mm. and 72 mm. long respectively. It will be noticed that the epidermis does not differ essentially in thickness or structure. In Figure 9 it is about 0.028 mm., while in Figure 10 it is slightly thinner, though in reality it should be a little thicker, some shrinkage having taken place here. With the sub-epidermal connective tissue (*con't. tis.*), however, the case is quite different. In Figure 9 its thickness is 0.056 mm., while in Figure 10 it is about 0.025 mm., over the pigment; and it will be seen that in both the pigment (*pig.*) is situated in the deepest stratum of the connective tissue, adjacent, or very nearly so, to the muscles (*mu.*).

Within the sub-epidermal layer, in all the larger specimens, there is found a dense and intricate network of blood-vessels and capillaries. In general, the vessels of this network appear to run quite uniformly in one plane, situated about midway between the epidermis and the pigment layer. In many places, however, they will be seen, in sections, to approach very close to the epidermis, or at least to its basement membrane, which is at times quite distinct. These vessels are shown in Figure 10 (*va. sng.*); also in Figures 4 and 11 as surface views from nitric acid glycerine preparations. Their walls are so thin as to be scarcely distinguishable from the surrounding connective tissue. Indeed, in parts of many sections their presence can be detected only by the blood-corpuscles, which are very different in appearance from the connective-tissue cells, owing to their larger size, more elliptical outline, distincter nuclei, and slightly yellowish homogeneous non-stainable (in hæmatoxyline at least) cell protoplasm. The connective-tissue layer in which these vessels are situated is somewhat different from either the layer above or that below it: its fibres are more closely compacted together, it contains more cellular elements, and it takes stain rather more readily than do the adjacent layers. I am inclined to believe that many of these cellular elements are leucocytes. I may here add that the blood-vessels shown in Figures 4 and 11 are none of them of capillary fineness, since in none of them are the blood corpuscles arranged in a single row, as is characteristic in capillaries. The capillaries are still smaller, and from the method of preparation and delineation are not shown here.

It is unquestionably to the presence of this highly developed vascular network that the pink color of the living fishes is due; and it is undoubtedly by this, in part, but mostly by the much thickened sub-epithelial connective tissue, that the pigment is disguised in the preserved specimens.[1]

And now as to the reason for this highly vascular condition of the skin, which is certainly unusual, as I have convinced myself by examining the integument of several other bony fishes, both by sections and by the same methods of treatment that were used in preparing the specimens shown in Figures 4 and 11.

I will consider the several explanations that have suggested themselves, in the order in which they have occurred to me.

When I first saw the living specimens, I supposed their pink color to be due to the fact that the pigment had disappeared from the skin on account of the constant darkness in which the fishes live; and that, it having thus become somewhat translucent, no scales whatever being present, whatever of vascularity there might be in the tissues of the body wall became visible through the integument. This explanation lost all its force, of course, as soon as it was noticed that the pigment is present in large as well as in small specimens, and that the blood-vessels are situated *between* the pigment layer and the epidermis, and not *under* the former. I would not be understood to mean by this that the pigment layer is so dense that it would much obscure the vascular-layer were it superficial to the latter.

The next hypothesis that presented itself to me was suggested by the fact mentioned by Dr. Eigenmann, that the crustacean with which the fishes so constantly live is also of the same pink color. Have we here a case of protective resemblance? An entirely satisfactory answer to this question cannot be given until we know more of the habits of the fish in its native conditions of life, and also of the structure and habits of the crustacean in company with which it lives. So far, however, as our present knowledge enables us to see, there are some quite serious obstacles in the way of this supposition. It is probable that the fish

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[1] I may add, that on examining several large specimens preserved in alcohol exclusively, I find that the pigment is very distinctly seen on the whole dorsal surface, without removing the skin. As the epidermis in these specimens is quite loose as compared with that of specimens preserved in picro-nitric, picro-sulphuric, or Perenyi's fluid, I explain the greater distinctness of the pigment by supposing that in the alcoholic specimens the sub-epithelial connective tissue has shrunken more by dehydration than it has in the other methods of fixation, and also more than has the epidermis.

has adopted its present mode of life as a means of escape from its enemies, so that protective coloration could be of no use, and consequently natural selection would have no power to establish the color.

It is true that there are recorded a few cases of animals that are apparently protectively colored, which at the same time depend upon concealment to escape their enemies; e. g. the caterpillar of the moth Mania typica (A. R. Wallace, '89). But these are certainly very exceptional; and if the law of natural selection is to be held as applying to them at all, we are compelled to assume that either the coloration must have been produced in some other way than through it, or that neither the color protection nor the concealment is adequate in itself to effect the degree of protection necessary for the preservation of the species. On this supposition, it is possible that natural selection has been operative in producing the color; but Dr. Eigenmann ('90, p. 68) tells us that Typhlogobius "never leaves its subterranean abode"; and the extent to which the eyes are reduced affords very strong proof in confirmation of this statement. Again, on physiological grounds, it would seem that had the color been produced for the mere purpose of the color alone, it would have been effected by a deposition of pigment, and not by such an enormous increase in the quantity of blood-vessels and blood; for certainly the former would have been more economical.

And this brings me to what I believe to be the true explanation of the condition. I believe it to be for the purpose of cutaneous respiration. Says Prof. N. Zuntz ('82, p. 114): "Wo auch immer das Blut mit der Atmosphäre oder mit gashaltigem Wasser in Contact kommt, muss, in derselben Weise wie in der Lunge, ein auf Ausgleich etwaiger Spannungsänderungen hinzielender Diffusionsstrom der Gase auftreten." The conditions for such a diffusion seem to be present here. That cutaneous respiration takes place as a normal process in many vertebrates, both terrestrial and aquatic, is generally admitted by physiologists.[1] For the present purpose I need only to consider in some detail what is known about the process in some of the aquatic forms.

Spallanzani (1803, pp. 71, 114) was the first to show that the frog by means of respiration through the skin continues to live for a long time in air after the extirpation of the lungs. W. F. Edwards ('24, pp. 41–62) confirmed Spallanzani's results, and added the observation that this

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[1] For a discussion of this question, see the larger works on physiology, and particularly Milne-Edwards, '57, pp. 632–635, and Hermann, '82, pp. 114–117.

animal would continue to live in water as well as in air, particularly in flowing water at a low temperature.

Berg ('68) investigated the same subject, and, while confirming the results of his predecessors so far as the fact of cutaneous respiration is concerned, concluded that the quantity of carbonic acid gas exhaled is less than that found by Regnault and Reiset. Less attention appears to have been given to the subject of cutaneous respiration in fishes than to the same process in amphibians and mammals; though Spallanzani, and later Humboldt and Provençal ('11, p. 86), found it to occur in these animals to a slight extent.

Quincaud ('73, p. 1143) found that an eel of 530 grams' weight absorbs 0.58 c.c. of oxygen in an hour through the skin.

With this attempted explanation of the color of Typhlogobius the question at once arises, Is this color peculiar to this fish, or is it common to all others that live habitually excluded from the light as this one does? If all the other blind fishes have the same color, and from the same cause, viz. from the vascularity of the integument, then we should have to suppose the same explanation to apply to all; and this would diminish its probability, though of course it would not necessarily wholly invalidate it. In speaking of the color of blind fishes, Professor Putnam ('72, p. 8) gives a list of seven partially or wholly sightless genera of the family Siluridæ, found in various parts of South America, Africa, and Asia. Of their color he says: "All the other members of this family [Siluridæ] having rudimentary or covered eyes are also dark colored; while the blind fish of the Mammoth Cave and of the caves of Cuba are nearly colorless." Concerning the color of Gronias nigrilabris, already mentioned in other connections, Cope ('64, p. 232) says: "The color of the upper surfaces, tail, fins, barbels, and under jaw is black; sides varied with dirty yellow, abdomen and thorax yellowish white." And this author remarks in the same connection that the "dark pigment of the skin of this animal comes off upon the hands in handling it."

Concerning the color of the several species of the three blind, or nearly blind, groups of the Gobiidæ other than Typhlogobius, I gather the following from Günther ('61, pp. 133–138).

In the characterization of the group Amblyopina the eyes are spoken of as "very small, and more or less hidden." No mention is made in this connection of the color, though the name Amblyopus roseus (Cuv. and Val., XII. 164), as applied to the whole genus Amblyopus, is given in a foot-note. Of the eight species enumerated one is said to have "eyes inconspicuous," color "greenish olive (in spirits)"; the color of another is "greenish," no mention of the eye; another is "rose-colored," no mention of the eye, nor statement as to whether this is the color in life or in spirits; a fourth is "brownish with darker spots, . . . eye small and indistinct"; another, "eyes invisible," no mention of color. Of the remaining three, no mention is made of either the eyes or the color, but for the name in one species *rubicundus* is given as a synonym. Of the genus Trypauchen two species are described, one of which is characterized as "reddish (during life), brownish (in spirits)," the other as "uniform rose-colored." No mention is here made of the condition of the eyes, and I know them to be rudimentary only by the list of blind fishes given by the same author (Packard, '86, p. 107).

In the characterization of the genus Trypauchenichthys the eyes are said to be "very small, scarcely visible," and the only species described is "rose-colored (Bl.)." Nothing is given to indicate that these fishes live particularly excluded from the light. The genus Amblyopus is said to be "confined to the coasts, estuaries, and fresh waters of the East Indies, extending northward to China and Japan; one species from the west coast of South America." The genus Trypauchen is from the "East Indian Seas" and the "fresh waters of Borneo," and Trypauchenichthys is from "rivers of Borneo."

We are not informed whether the several shades of red here mentioned are due to pigmentation; but from the facts that there *are* several shades, that in some of the species the color seems to persist in the alcoholic specimens, and that the fishes come in a category many of which — particularly of the related genus Eleotris, with eyes normally developed, inhabiting much the same regions — are of similar shades of color, it appears probable that such is the case.

Perhaps the most interest attaches to the color of the Mammoth Cave blind fishes and those of the caves of Cuba; for these are without any question completely deprived of the influence of light. Cope ('72, p. 410) speaks of Amblyopsis spelæus as swimming "in full sight like white aquatic ghosts"; in his original description of Typhlichthys subterraneus, Girard ('59, p. 63) gives its color as a "uniform dull yellowish white tint"; and both these species as well as the Lucifuga are referred to by Putnam as being "nearly colorless," as already mentioned. Also Jordan and Gilbert ('82) describe both Amblyopsis and Typhlichthys as "colorless," and in the same way Günther ('80, p. 618), who regards the two as belonging to the same genus, speaks of the body as colorless.

I have dwelt thus at length on this question of color in other blind fishes because Eigenmann ('90, p. 68) has said with reference to the color of Typhlogobius that "in its pink color and general appearance this fish much resembles the blind fishes inhabiting the caves of Southern Indiana." I suppose this to refer to Amblyopsis, as there is not to my knowledge any other blind fish known from the caves of this region. Whether Eigenmann's statement about the color of the Indiana fishes is to be taken as opposed to those quoted from other writers or not, the most significant fact for our purpose is that there is certainly no such degree of vascularity in the integument of Amblyopsis as is found in Typhlogobius. I have had opportunity to examine a well preserved alcoholic specimen of this species, obtained by Professor Mark from Professor Putnam. I prepared fragments of the skin in the same way that had been employed in studying that of Typhlogobius, and found the blood-vessels here to be even less abundant than in the integument of the Clevelandia and Lepidogobius that I have examined.

The most serious objection, I think, to the supposed respiratory function of the skin lies in the thickness and density of the epidermis, and the fact that the entire surface is thickly beset with the slime-secreting cells (see Figs. 9, 10, and 17). I do not believe, however, that the epidermis here would offer greater resistance to the interchange of gases than would that of the frog; certainly, as regards the integumentary glands and their products, the frog's skin can hardly be more favorably constructed for a respiratory function than that of the blind fish. When we remember the dense cuticular layer that covers the entire surface of such animals as the earth-worm, where all the respiration must be carried on through the body wall, this obstacle does not seem so great. Moreover, in Cobitis fossils, where intestinal respiration is well known to take place to a considerable extent, although it was long supposed that no epithelium was present in the region of the intestine, — in which from the richness of the blood-vessels the respiration is supposed to be carried on, — Lorent has shown not only that there is an epithelium present, but that it consists of two layers, a superficial layer of flat polyhedral cells, and beneath this a layer of stratified cylindrical epithelial cells, among which are scattered beaker cells (Wiedersheim, '86, p. 572).

Of course the ultimate test of my theory must be made by physiological experimentation, and I hope to be able to do this before long. I cannot suppose gill respiration to be to any great extent supplanted by integumentary respiration, since the gills appear to be normally developed. It is necessary, then, to suppose that the latter method supplements the former; and this may have become necessary from the peculiar mode of life of the animals. It is quite certain that the water of the small holes under stones, in which they live, would contain less aerating oxygen than would that of the open sea; and consequently a greater absorbing surface would be essential in order to effect a normal aeration of the blood.

Summary.

The facts observed and the conclusions reached may be summed up as follows.

The Eyes.

1. In the smallest examples studied the eyes, though very small, are distinctly visible even in preserved specimens, — so distinctly that the lens is plainly seen. In the largest examples, on the other hand, they are so deeply buried in the tissue as to appear even in the living animals as mere black specks, while in preserved ones they are in many cases wholly invisible.

2. Neither in small nor in large specimens does the epidermis over the eye differ in thickness or structure from that of adjacent regions. In the large individuals the much greater thickness of the tissue here is brought about by an increase in the sub-epidermal connective tissue, the growth of which can be seen taking place in the embryonal connective-tissue cells that are found here.

3. As is the case with rudimentary organs generally, the eye is subject to great individual variation in size, form, and degree of differentiation.

4. The only parts of the normal teleostean eye no traces of which have been found are the argentea, the lamina suprachoroidea, the processus falciformis, the cones of the retina, the vitreous body proper, the lens capsule, and in one specimen the lens itself.

5. In the parts present the rudimentary condition of the organ is seen in the very slight development of the choroid, no cellular elements being present in this excepting in the chorio-capillaris, and here to a quite limited extent, the rest of that layer being composed exclusively of pigment; in the fact that the choroid gland is composed entirely of pigment; in the fact that the iris, though of fully the normal thickness, is almost entirely of pigment, there being on its outer surface in some specimens a small amount of cellular material, which probably represents the ligamentum annulare; in the great proportional thickness of the pigment layer of the retina and the entire absence in it of anything except-

ing pigment; in the incomplete differentiation of the layers of the retina, there being in some individuals scarcely more than a trace of the external reticular layer separating the two nuclear layers, and there being in no specimen studied a retina sufficiently developed to enable one to homologize with certainty the layers marked out; in the minute size of the optic nerve, and the fact that it is ensheathed in a thick layer of pigment for nearly its entire course through the retina; and, finally, in the small size of the motores oculi.

6. The surest evidences of actual degeneration are found, first, in the greatly augmented quantity of pigment in all the portions that are at all pigmented in the normal eye; and, secondly, in the presence of pigment in regions where none is found in the normal eye, as in the hyaloid membrane (Plate II. Fig. 12, *pig.''*).

No undoubted instances of degenaration through the breaking down and dissolution of the tissue without the formation of pigment, such as have been described particularly by Looss, have been found, though in a single specimen (the one in which no lens is present) a process of this nature may be taking place.

7. On comparing the eyes of all blind vertebrates that have been most carefully studied, we find that, in the several degrees of incompleteness of development represented by the different species, all may, in a general way, be said to be passing along the same degenerative road. There are apparently, however, a few interesting exceptions to this. The most marked of these exceptions is found in the entire lack of pigment in the eyes of the Myxinidæ, whereas in all other rudimentary eyes an increase of this substance over what exists in normal eyes is found.

8. The eyes of blind vertebrates furnish very little evidence on the question whether structures in undergoing actual degeneration in ontogeny follow the reverse order of their phylogeny. The little that may be regarded as bearing on this point is without much doubt of an affirmative character. This is found in the breaking down and resorption of the lens, — habitually in Proteus, and probably occasionally in Typhlogobius, — possibly in the excess of pigment in the iris and pigment layer of the retina, and particularly in its occasional presence in the hyaloid membrane of the Typhlogobius eye, while no evidence of actual degeneration in the retina appears in connection with these. The possible case of a degenerating retina in Typhlogobius is neglected in this consideration, since, as pointed out, the lens being absent in the same eye, it is immaterial whether it be considered or not.

The Integumentary Sense Papillæ.

1. These have been considered only so far as pertains to the question whether they have been developed to compensate the rudimentary condition of the eyes; and it is concluded that such is not the case.

2. The facts that lead to this conclusion are the presence in several closely related genera — four at least — of the tactile papillæ with the same distribution as those of Typhlogobius, and in addition to this, on parts of the body where they are not found at all in Typhlogobius, excepting in the smallest specimens; and that the papillæ that are present in Typhlogobius are not more highly developed than those of corresponding regions in related genera.

3. In comparing the several species of blind fishes with a view to determining under what conditions the tactile sense does become developed to compensate the loss of sight, it is concluded that, while the greater activity of the cave blind fishes might explain their more highly developed tactile papillæ, this cannot be affirmed as a general law, since other blind fishes (as some at least of the deep-sea forms and probably also the blind Silurids) are without tactile papillæ, while we have no reason to suppose them less active than the cave fishes. It is necessary to have more knowledge than is yet possessed of the mode of life of the various blind forms before this question can be fully answered.

The Integument.

1. This structure has been studied with reference to the pigment contained in it, and the pink color of the living fishes.

2. Very nearly if not fully as much pigment is present in the largest as in the smallest specimens, the lighter color of the former being due to the obscuration of the pigment by a thickening of the sub-epidermal tissue between the pigment and the epidermis.

3. The pink color of the living animals is due, in great part at least, to a highly abnormal development of blood-vessels in the sub-epidermal portion of the integument.

4. So far as it has been possible to determine, this vascularity of the skin is unique in this fish.

5. The most probable explanation found of this condition is that it is for the purpose of cutaneous respiration.

University of California, Berkeley,
July 4, 1892.

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EXPLANATION OF PLATES.

All the figures except 20 and 26 are drawn from Typhlogobius californiensis, Steind.

ABBREVIATIONS.

bac.	Rods of the retina.
bac. cla.	Knobbed or club-shaped rods.
chr.	Choroid.
chr.-cpl.	Chorio-capillaris.
cl., cl.′, cl.″	Refractive cells of retina as they appear at different foci.
cl. con't.	Cells in connective tissue.
cl. gn.	Ganglion cells.
cl. gn.′	Ganglion cells showing processes.
cl. mt.	Mantle cells.
cl. sns.	Sense cells.
con't. tis.	Connective tissue.
cp. sng.	Blood corpuscle.
crn.	Cornea.
crt.	Cartilaginous portion of sclera.
drm.	Derma.
ec'drm.	Ectoderm.
ex.	Outermost portion of pigment layer of retina.
fbr. Mü.	Müller's fibres.
fos.	Flask-shaped pit in papilla.
ful.	Tangential fulcrum cells.
glb. pig.	Pigment nodules, clusters, balls, etc.
gl. chr.	Choroid gland.
gl. muc.	Mucus glands.
i.	Innermost ends of the processes of pigment layer of retina fused together.
ir.	Iris.
leu'cy.	Leucocytes in retina.
lig. ann.	Non-pigmented elements of the iris, ligamentum annulare.
lns.	Lens.
m.	Middle portion of the processes not fused together.
mb. li.n. ex.	Membrana limitans externa.
mu.	Muscle.
nl. ba.	Basal nuclei. (See p. 65.)
n. opt.	Optic nerve.
n. pap.	Nerve to papilla.
ob. ex.	External oblique muscle.
or. ser.	Ora serrata.
pap.	Papilla.
pig.	Pigment.
pig.′	Pigment behind cornea.
pig.″	Pigment in place of lens (Fig. 7) and (Fig. 12) hyaloid membrane (?).
pig.‴	Pigment surrounding optic nerve.
pig. rtn.	Pigment of retina.
po.	Pore in epidermis.
pr'c.	Processes of the pigmented layer of the retina.
rt.	Rectus muscles.
rtn.	Retina.
scl.	Sclera.
set. cl. sns.	Bristles of sense cells.
spa.	Spaces in the connective tissue over the eye.
spng-bl.	Spongioblasts.
st. bac. con.	Layer of rods and cones.
st. con't.	Stratum of formed connective tissue.
st. fbr. opt.	Optic fibre layer.
st. lac.	Stratum lacunosum.
st. nl. ex.	External nuclear layer.
st. nl. i.	Internal nuclear layer.
st. rtl. ex.	External reticular layer.
st. rtl. ex.′	Non-nucleated spaces in *st. rtn.′*, the beginning of external reticular layer.
st. rtl. i.	Neurospongium (inner molecular layer) = inner reticular layer (preferable).
st. rtn.′	Undifferentiated layer of retina.
tt.	Non-nucleated tract between sense cells and mantle cells.
va. sng.	Blood-vessels.

PLATE I.

Fig. 1. View of the dorsal side of the head of an individual 19 mm. long, showing the distribution of the pigment cells, the folds of the skin, and the eyes. × 18.

" 2. Similar view of an individual about 55 mm. long. × $2\frac{1}{2}$.

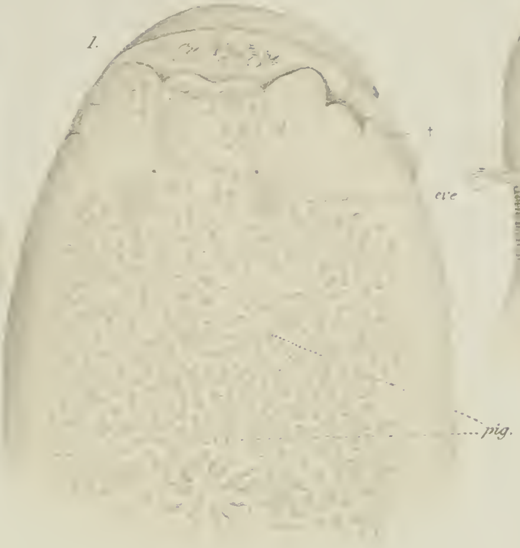
" 3. An individual of the same size seen from the ventro-lateral side. × 2.

" 4. Nitric-acid glycerine preparation of integument from the dorsum of the head of a specimen 72 mm. long, showing the blood-vessels and the pigment cells. — Surface view. × 59.

RITTER - EYES OF TYPHLOGOBIUS CALIF PL. I.

2.

1.



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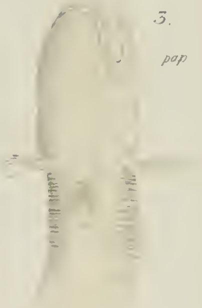

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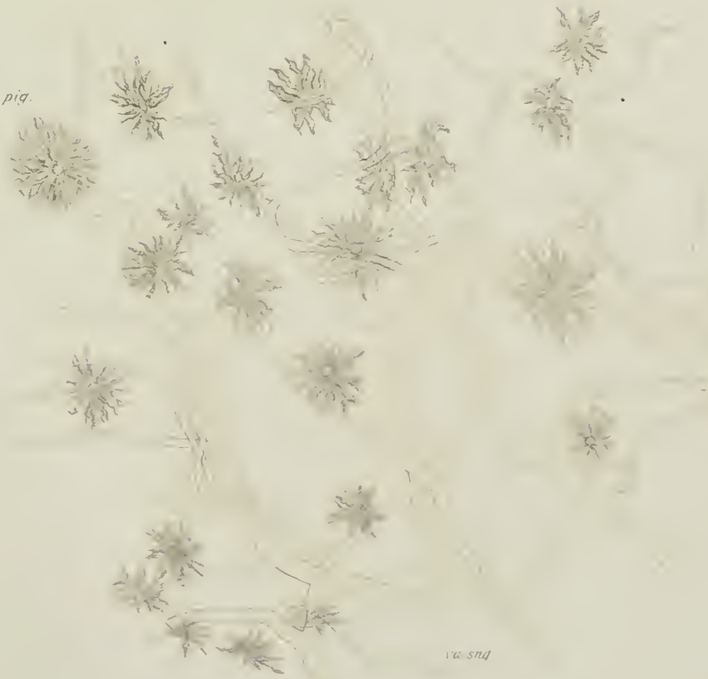

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PLATE II.

Fig. 5. Meridional vertical section of an eye from a specimen about 50 mm. long. × 150. The fold in the pigment layer of the retina is indicated at *. (See text, p. 63.)

" 6. Meridional section of an eye without a lens. Specimen 63 mm. long. × 88.

" 7. The section, not quite meridional, is from the same eye from which Figure 6 is taken, and is given to show the pigment mass (*pig.''*) in the place of the lens. Consequently only the pigmented portion of the eye is drawn. × 115.

" 8. A dissected acetic-acid glycerine preparation to show the eye muscles and optic nerve. × 60.

" 9. Section of the integument from the dorsum of the head perpendicular to the surface, from an individual 19 mm. long. × 450.

" 10. Section similar to the one shown in the preceding figure, but from an individual 72 mm. long. × 450.

" 11. Preparation similar to the one shown in Figure 4 (Plate I.), but from the side of the body. × 63.

" 12. Section, not quite meridional, from an individual 60 mm. long. × 115.

" 13. The pigmented portion of the retina and choroid, from the same eye. × 230. The fold in the pigment layer of the retina is indicated at *. (See text, p. 63.)

" 14. A small portion of the pigment layer of the retina, and the choroid gland with the optic nerve passing through it. Specimen 63 mm. long. × 300.

" 15. A small portion of the retina, showing the optic nerve passing through it. Same eye as that shown in the preceding figure. × 300.

" 16. The iris and the adjacent parts; same eye as that shown in Figure 5. × 350.

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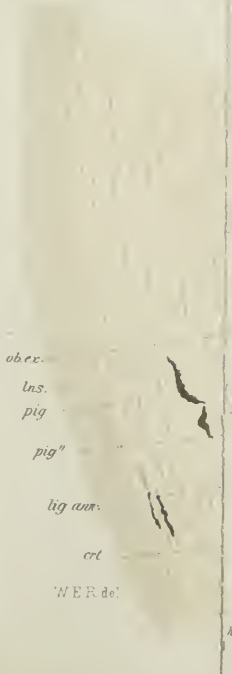

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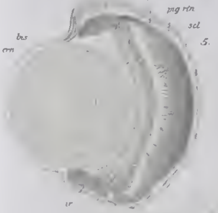

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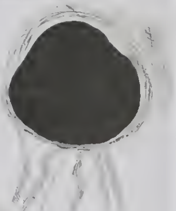

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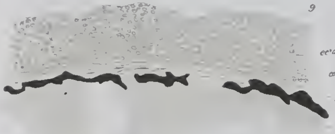

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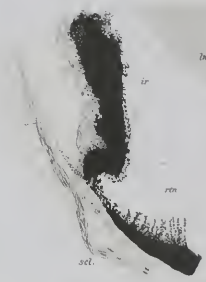

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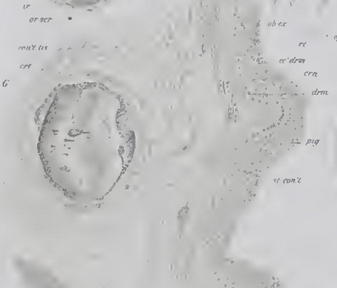

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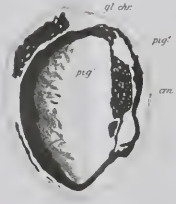

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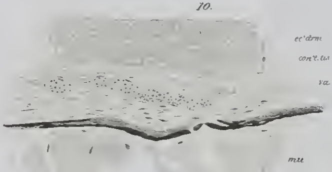

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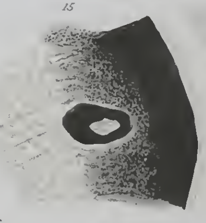

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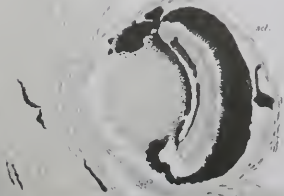

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PLATE III.

Fig. 17. Meridional vertical section of the eye of a specimen 19 mm. long. × 230. *α*, connective-tissue strands (see text, pp. 57, 58); *β*, ciliary processes ? (see text, pp. 63, 64).

" 18. Small portion of the retina of the eye shown in Figures 5 and 16. × 980.

" 19. A small portion of a section of the retina near the ora serrata from the eye having no lens. × 700.

" 20. Section of the retina of *Clevelandia*.

" 21. A small portion of the retina of the eye shown in Figure 13. × 350.

RITTER — EYES OF TYPHLOGOBIUS CALIF. PL. III.

W. E. R. del. E. Meisel lith. Berlin

PLATE IV.

Fig. 22. Rods from the same eye as the preceding (Fig. 21); *a′*, *b′*, outer members; *a″*, *b″*, inner members; *c*, portion of outer member showing the more transparent round spots. × 720.

" 23. Section of a tactile papilla from the median lower-jaw series of a specimen about 50 mm. long. The section is not quite parallel to the long axis of the papilla, and this accounts for its appearing not to extend fully through to the deep surface of the epidermis. × 720.

" 24. Section of another papilla of the same series, same specimen as the preceding. × 350 about.

Note. — The leader from *va. sng.* has neither the right direction nor sufficient length to reach the blood-vessel in the axis of the papilla.

" 25. Diagram showing the arrangement and relative size of the papillæ found on the right side of the head of a specimen 19 mm. long.

" 26. Section of a papilla of the median lower-jaw series of *Lepidogobius*. × 340.


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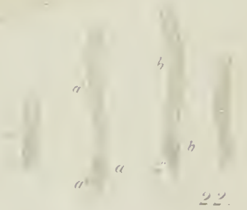
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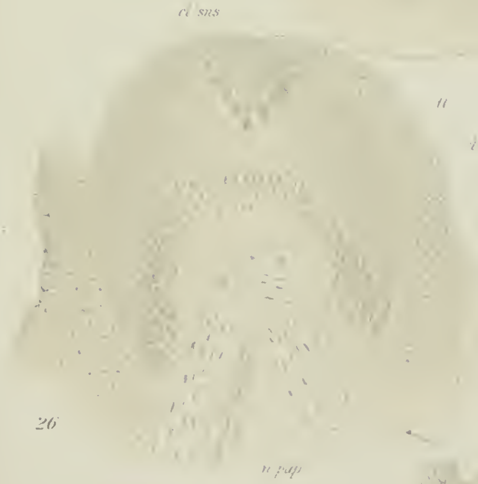
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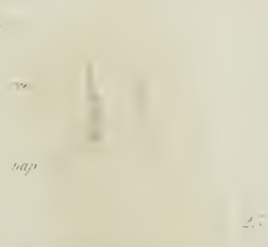
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No. 4. — *Reports on the Dredging Operations off the West Coast of Central America to the Galapagos, to the West Coast of Mexico, and to the Gulf of California, in charge of* ALEXANDER AGASSIZ, *carried on by the U. S. Fish Commission Steamer "Albatross," during* 1891, Lieut.-Commander Z. L. TANNER, U. S. N., Commanding.

[Published by Permission of MARSHALL MCDONALD, U. S Fish Commissioner.]

IV.

Vorläufiger Bericht über die erbeuteten Holothurien. Von HUBERT LUDWIG.

DIE Holothurien-Ausbeute der im Frühling 1891 unter der wissenschaftlichen Leitung von A. Agassiz stattgefundenen Fahrten[1] des Vereinigten-Staaten-Dampfers Albatross, welche sich auf den östlichen tropischen Theil des Stillen Oceans erstreckten, ist eine so ungemein reiche, dass es sich verlohnt einen vorläufigen Bericht über deren Inhalt zu geben. Die im Manuscript fertig vorliegende ausführliche Abhandlung wird von 19 Tafeln begleitet in den Memoirs of the Museum of Comparative Zoölogy at Harvard College, erscheinen.

Die Sammlung umfasst im Ganzen 46 Arten aus 28 Gattungen. Neu sind darunter eine Familie, eine Subfamilie, acht Gattungen, 30 Arten und drei Varietäten.

Von besonderem Interesse dürfte der Nachweis einer Übergangsgruppe der Aspidochiroten zu den Elasipoden sowie die Entdeckung einer seltsamen, dem pelagischen Leben angepassten Form sein.

In systematischer Reihenfolge sind die Untersuchungsergebnisse der einzelnen Familien die folgenden.

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[1] Vgl. über diese Fahrten, Bull. Mus. Comp. Zoöl., Vol. XXI. No. 4, 1891, u. Vol. XXIII. No. 1, 1892.

I. ASPIDOCHIROTAE.

Ausser einigen längst bekannten littoralen Arten (*Holothuria languens* Sel., *pardalis* Sel., *maculata* [Br.], *marenzelleri* Ludw., *vagabunda* Sel.) wurden zahlreiche Exemplare des interessanten, von Théel beschriebenen *Pseudostichopus mollis* aus Tiefen bis zu 1823 Faden erbeutet, deren Untersuchung verschiedene Ergänzungen zu den Angaben jenes Forschers gestattet, namentlich aber eine Änderung der Gattungsdiagnose nothwendig macht. Die veränderte Diagnose lautet:

(19—)20 Fühler; Keine Fühlerampullen; Steincanal mit der Körperwand verbunden; Bauch abgeflacht; Ambulacralanhänge in Form ungewöhnlich kleiner, schwer zu bemerkender Füsschen, die mehr oder weniger deutlich in Längsreihen geordnet sind; Genitalschläuche in zwei Büscheln (einem rechten und einem linken); After in einer senkrechten Furche, ohne Kalkzähne; Haut ohne Kalkkörper.

Ferner ist die bis jetzt nur durch Théel bekannte Gattung *Paelopatides* in mehr als 70 Exemplaren der *P. confundens* Théel vertreten. Auch diese Form, deren Fühler einen peltato-digitaten Character haben, zeichnet sich durch den Mangel der Fühlerampullen aus. Ihre nähere Untersuchung und Vergleichung lehrt, dass *P. agassizii* Théel mit *confundens* zu vereinigen ist und dass die neuerdings von Walsh beschriebene angebliche Elasipoden-Art: *Benthodytes gelatinosa* in die Gattung *Paelopatides* gehört. Doch muss die Diagnose dieser Gattung dahin erweitert werden, dass sie auch Arten mit nur 15 Fühlern umfasst. In dem Besitze von nur 15 Fühlern reiht sich an *Paelopatides gelatinosa* (Walsh) eine neue Art: *P. suspecta*.

Durch den Mangel der Fühlerampullen schliessen sich an die Gattungen *Pseudostichopus* und *Paelopatides* drei neue Gattungen an: *Synallactes*, *Mesites* und *Meseres*, welche mit jenen zu einer besonderen Unterfamilie der Synallactinae vereinigt werden. Die übrigen Aspidochiroten werden zu einer Unterfamilie der Holothurinae zusammengefasst.

Die Gattung *Synallactes* ist durch zwei Arten: *S. alexandri* n. sp. und *S. aenigma* n. sp. vertreten und durch folgende Merkmale characterisiert: (18—)20 Fühler; keine Fühlerampullen; Steincanal mit der Körperwand verbunden; Bauch abgeflacht; Füsschen des Bauches und Papillen des Rückens in Längsreihen geordnet und auf die Radien beschränkt; Genitalschläuche in zwei Büscheln (einem rechten und einem linken): After nicht in einer Längsfurche und ohne Kalkzähne; Kalkkörper in der Haut und in den Ambulacralanhängen vorhanden.

Von der neuen Gattung *Mesites* liegt nur eine Art: *M. multipes* n. sp.

vor. Die Diagnose der Gattung lautet: (18—) 20 Fühler; keine Fühlerampullen; Steincanal an, aber nicht in die Körperwand tretend; Bauch etwas abgeflacht; kleine, gleichartige, zahlreiche Füsschen sind über den ganzen Körper gleichmässig vertheilt; Genitalschläuche nur in einem (linken) Büschel; After ventral oder subventral, ohne Auszeichnung; Kalkkörper in der Haut und in den Füsschen vorhanden.

Die Merkmale der neuen Gattung *Meseres* mit der einen Art: *M. macdonaldi* n. sp. sind die folgenden: 15 Fühler; keine Fühlerampullen; Steincanal?; Körper niedergedrückt mit abgeflachter Bauchseite, deren Rand ringsum von einer einfachen Reihe feiner Füsschen wie von einem Randsaume besetzt ist; ausserdem unregelmässig (?) über den ganzen Körper vertheilte Füsschen (? Papillen); Genitalschläuche in zwei Büscheln (einem rechten und einem linken); After ventral, ohne Auszeichnung; Haut ohne Kalkkörper.

Die Unterfamilie der Synallactinae umschliesst demnach Formen, welche in dem Mangel der Fühlerampullen, im Verhalten des Steincanals und, wie hier hinzugefügt werden kann, auch in dem Fehlen eines Wundernetzes von den Aspidochiroten zu den Elasipoden hinüberleiten und so die schon vor einiger Zeit von mir geäusserte Ansicht bestätigen, dass die Elasipoden Abkömmlinge von Aspidochiroten sind.

II. ELASIPODA.

1) **Psychropotinae.** Die sechs vorliegenden Arten sind mit Ausnahme einer einzigen, der *Benthodytes sanguinolenta* Théel, sämmtlich neu. Eine gehört ebenfalls zur Gattung *Benthodytes: B. incerta.* Die vier anderen vertheilen sich auf die Gattungen *Psychropotes: Ps. raripes* und *Ps. dubiosa* und *Euphronides: E. tanneri* und *E. verrucosa.*

Euphronides tanneri n. sp. schliesst sich nahe an die typische Art der Gattung: *E. depressa* Théel an, unterscheidet sich aber durch die grössere Zahl der Rückenpapillen und durch stärkere Bedornung der vierarmigen Kalkkörper. Auffallend ist ihr Reichthum an Kalkkörpern in den inneren Organen, namentlich in der Wand der Genitalorgane, des Darmes und der Darmblutgefässe. *Euphronides verrucosa* n. sp. unterscheidet sich von *E. depressa* und *E. tanneri* schon durch die zahlreichen Warzen, mit welchen der Rücken des Rumpfes und Saumes übersät ist; dazu kommt eine geringere Abflachung des Körpers, eine geringere Breite des Saumes, eine andere Zahl der Fühler und Rückenpapillen sowie Form und Grösse der Kalkkörper.

Psychropotes raripes n. sp. ist durch die geringe Zahl (7—8) der freien

Füsschen in den seitlichen ventralen Radien gekennzeichnet. Die Diagnose der neuen Art lautet: Körper gestreckt, ohne den Schwanzanhang etwa 4½ mal so lang wie breit. Schwanzanhang nahe am Hinterende des Rückens entspringend, mehr als halb so lang wie der Körper und mit einfacher, abgerundeter Spitze endigend. 18 Fühler. Rücken jederseits mit fünf bis sieben winzigen Papillen. Bauch nur vorn und hinten von einem deutlichen Randsaume begrenzt, dagegen an jeder Seite mit einer Reihe von sieben bis acht grossen Füsschen. Kalkkörper: vierarmige, nach aussen convexe Kreuze von gedrungener Gestalt mit sehr kräftiger Bedornung der Aussenseite. *Psychropotes dubiosa* n. sp. besitzt wie *Ps. loveni* Théel nur zehn Fühler, dagegen sind die Füsschen der Flanken nicht zu einem zusammenhängenden Saume vereinigt, sondern durch kurze Zwischenräume getrennt.

Benthodytes incerta n. sp. kann nur vorläufig und bedingungsweise zur Gattung *Benthodytes* gestellt werden, da der ungünstige Erhaltungszustand der zwei vorliegenden Exemplare eine sichere Entscheidung nicht gestattet. *Benthodytes sanguinolenta* Théel ist in nicht weniger als 25 Exemplaren vertreten. Die bis jetzt unbekannt gewesenen Weibchen dieser Art zeichnen sich durch eine bei Echinodermen unerhörte Grösse ihrer deutoplasmareichen Eier aus, deren Durchmesser sich bis auf 2 mm. beläuft; das 0.26 mm. grosse Keimbläschen kann man mit blossem Auge wahrnehmen. Der Blinddarm dieser Art hängt (im Gegensatze zu der Angabe Théel's) zweifellos an der Cloake und ist der Kieme der sogenannten Lungenholothurien homolog. Die Längs- und Quermusculatur der Körperwand ist im Sinne einer Bilateralsymmetrie in den einzelnen Radien und Interradien ungleich ausgebildet.

2) **Deimatinae.** Von den acht erbeuteten Arten sind nur zwei bekannt; die übrigen sind neu und geben zugleich zur Aufstellung von drei neuen Gattungen Veranlassung. Die beiden bekannten Arten sind einmal die sehr variable *Oneirophanta mutabilis* Théel und zweitens die *Pannychia moseleyi* Théel; letztere liegt aber in Exemplaren vor, die nicht ganz mit dem Arttypus übereinstimmen und deshalb eine besondere Varietät: *henrici* darstellen. Von den neuen Arten bekannter Gattungen schliesst sich *Deima pacificum* n. sp. am nächsten an das westindische *Deima blakei* Théel an. *Oneirophanta affinis* n. sp. unterscheidet sich von *O. mutabilis* namentlich durch eine andere Anordnung der Rückenpapillen und andere Gestalt der Fühler und macht eine Erweiterung des Théel'schen Gattungsbegriffes nothwendig. *Laetmogone theeli* n. sp. unterscheidet sich durch ihre grössere Fühlerzahl (20 statt 15) von allen bisher bekannten *Laetmogone*-Arten.

Die neue Gattung *Scotodeima* mit der gleichfalls neuen Art *setigerum* nimmt eine Zwischenstellung zwischen den Théel'schen Gattungen *Oneirophanta* und *Orphnurgus* ein; ihre Diagnose lautet: 20 ziemlich grosse Fühler; in jedem seitlichen ventralen Radius eine Doppelreihe grosser Füsschen und darüber eine Reihe langer, schlanker, nicht zurückziehbarer Papillen (Flankenpapillen); eine Doppelreihe ähnlicher Papillen (Rückenpapillen) auf jedem Radius des Rückens; mittlerer ventraler Radius mit einigen verkümmerten Füsschen; Kalkkörper: vierarmige Kreuze und Umbildungen derselben.

Die neue Gattung und Art *Laetmophasma fecundum* gehört in die rädchenführende Gruppe der Gattungen *Pannychia, Laetmogone, Ilyodaemon* und schliesst sich durch ihre Kalkkörper am engsten an *Pannychia* an, unterscheidet sich aber durch die reiche Entwicklung von Ambulacralpapillen auf der Bauchseite. Diagnose von *Laetmophasma:* 16—20 ziemlich grosse, nicht zurückziehbare Fühler; in jedem seitlichen ventralen Radius eine einfache Reihe grosser Füsschen; Rücken und Bauch mit zahlreichen Papillen übersäet; Kalkkörper ähnlich wie bei *Pannychia.*

Die dritte neue Gattung endlich, *Capheira,* mit der ebenfalls neuen Art *C. sulcata,* kann nur vorläufig und mit einigem Zweifel bei den Deimatiden in der Nähe von *Ilyodaemon* untergebracht werden. Sie deutet darauf hin, dass auch einige *Holothuria*-Arten (*H. thomsoni, lactea, murrayi*) von den Aspidochiroten zu den Elasipoden hinüberleiten und lässt sich folgendermassen characterisieren: 30 (?) Fühler; Bauchseiten und Rücken mit zahlreichen, gleichartigen, feinen Füsschen bedeckt, die an den Flanken noch dichter stehen; mittlerer ventraler Radius ohne Füsschen; Kalkring aus fünf Radial- und zehn Interradialstücken gebildet; Kalkkörper: Stühlchen.

3) **Elpidiinae.** Aus der Unterfamilie der Elpidiinen liegen nur drei Arten vor, von denen zwei neu sind und die dritte eine Varietät einer bekannten Art darstellt. Von der typischen *Peniagone vitrea* Théel unterscheidet sich die neue, als *setosa* bezeichnete Varietät unter Anderem durch einen feinen Stachelpelz, der durch die Aussenfortsätze der Kalkkörper gebildet wird. Die zur Gattung *Scotoanassa* hinüberleitende *Peniagone intermedia* n. sp. schliesst sich in der Anordnung der Füsschen und der Ausbildung eines hinteren Randsaumes, welcher die hintersten Füsschen aufnimmt, sowie auch durch den Mangel freier Rückenpapillen an die *Peniagone challengeri* Théel an, ist aber verschieden von ihr durch die Körperform und durch die Form und Stellung des Nackensegels. Von der seltenen, bis jetzt nur nach einem einzigen Exemplare bekannten

Gattung *Scotoanassa* liegen mehrere Exemplare und Bruchstücke vor, welche zur Aufstellung einer neuen Art *Scotoanassa gracilis* zwingen, deren Diagnose die folgende ist: Körper etwa dreimal so lang wie breit, nach hinten etwas verjüngt. Vordersaum (= Nackensegel) und Hintersaum durch einen Seitensaum verbunden; Vordersaum mit vier Zipfeln, von denen zwei vorwärts, zwei seitwärts gerichtet sind; Hintersaum zu einem unpaaren, nach hinten gerichteten Zipfel verlängert. Mund ventral und schräg nach hinten gestellt, am Ende eines kurzen, nach hinten abgeknickten, vordersten Rumpfabschnittes. Endscheibe der (10?) Fühler rundlich mit zahlreichen, winzigen Papillen. Füsschen gross, nur unten an den Seitentheilen des Hintersaumes angebracht, jederseits in der Zahl fünf. Haut sehr zart, etwas durchscheinend; ihre vierarmigen Kalkkörper zahlreich, aber zart und mit schlanken, nur sehr schwach bedornten Aussenfortsätzen, die fast doppelt so lang sind wie die gleichfalls nur sehr schwach bedornten Arme selbst.

III. PELAGOTHURIIDAE.

Unter allen vom Albatross erbeuteten Formen ist eine merkwürdige Art am auffälligsten und interessantesten, welche sich in Bau und Lebensweise so sehr von allen bisher bekannten Holothurien unterscheidet, dass sie nicht nur als Vertreter einer neuen Gattung sondern auch einer neuen Familie betrachtet werden muss. Sie führt ein pelagisches Leben und zeichnet sich in bemerkenswerthester Weise durch die Ausbildung eines besonderen Schwimmapparates aus, der in einer am Rande in lange Strahlen ausgezogenen Scheibe besteht, welche im Umkreis des Fühlerkranzes angeordnet ist und in seiner Form etwa an die an ihrer Basis durch eine Schwimmhaut verbundenen Arme mancher Tintenfische erinnert. Ich beschränke mich hier darauf eine kurze Diagnose der Familie, Gattung und Art zu geben und daran einige Worte über die Verwandtschaft des wunderbaren Thieres zu knüpfen, bei dessen Anblick man zunächst an manches Andere eher als an eine Holothurie denkt.

Familie **Pelagothuriidae.** Füsschen (und Ambulacralpapillen) fehlen. Mund und After terminal. Körper drehrund, rings um den Fühlerkranz zu einer dünnen, an ihrem Rande zu langen Strahlen ausgezogenen Scheibe ausgebreitet. Die Fühlercanäle entspringen aus den wohlentwickelten Radialcanälen und entsenden an der Fühlerbasis je einen (wahrscheinlich einer Fühlerampulle homologen) Canal in die Scheibe; diese Scheibencanäle verlaufen in radiärer Richtung zur Peripherie der Scheibe und treten in je einen Strahl des Scheibenrandes ein um ihn bis zur Spitze zu durchziehen. Längsmuskeln der Körperwand einfach; Rückziehmuskeln fehlen; Quermusculatur in den Radien unterbrochen. Weder Kiemenbäume, noch Wimperorgane, noch Cuvier'sche Organe sind vorhanden. Genitalorgane rechts und links vom dorsalen Mesenterium.

Pelagothuria n. g. 13—16 Fühler und ebenso viele Scheibencanäle sind vorhanden. Die Fühler sind am Ende zweitheilig und ebendort mit winzigen Papillen besetzt. Keine Spur eines Kalkringes. Steincanal in der Einzahl, dicht vor dem Genitalgang zur Haut aufsteigend und direct nach aussen mündend. Jederseits ein traubenförmiges Genitalorgan, das linke oft viel kräftiger entwickelt als das rechte. Kalkkörper fehlen sowohl der Haut als allen inneren Organen.

Pelagothuria natatrix n. sp. Haut dünn, weich, etwas durchscheinend, violett bis purpurn gefärbt. Rumpf etwa dreimal so lang wie dick, nach hinten verjüngt und abgerundet. Länge des Körpers einschliesslich der Fühler bis 47 mm.; Dicke des Rumpfes bis 13 mm.; Durchmesser der Schwimmscheibe bis 35 mm.; Länge der Scheibenstrahlen bis 50 mm.

Im Mangel der Füsschen stimmt die neue Familie der Pelagothuriiden mit den Synaptiden und den Molpadiiden überein, unterscheidet sich aber von diesen durch das Fehlen der Kiemenbäume, von jenen durch den Besitz von Radialcanälen, den Ursprung der Fühlercanäle aus diesen Radialcanälen, die Unterbrechung der Quermusculatur der Körperwand, den Mangel der Wimperorgane. Das Fehlen der Kiemenbäume verweist die Pelagothuriiden unter den actinopoden Holothurien, zu denen sie zweifellos gehören, in die Nachbarschaft der Elasipoden, von denen sie aber wieder durch den Mangel aller Füsschen (und Ambulacralpapillen) geschieden sind. Ich glaube in ihnen Abkömmlinge von Elasipoden sehen zu müssen, die sich aus den Verhältnissen der Tiefsee zu Bewohnern der oberflächlichen Meeresschicht heraus- und emporgearbeitet und dem pelagischen Leben durch Ausbildung eines Schwimmapparates angepasst haben.

IV DENDROCHIROTAE.

Die Dendrochiroten sind durch neun Arten vertreten, die zu fünf Gattungen gehören; darunter befinden sich eine neue Gattung und sieben neue Arten. Eine Art *Phyllophorus aculeatus* n. sp. stammt nicht aus der Tiefe, sondern von der Küste von Panama. Die übrigen Arten sind Tiefenbewohner aus den Gattungen *Psolus* (vier Arten), *Psolidium* (zwei Arten), *Cucumaria* (eine Art) und *Sphaerothuria* n. g. (eine Art). Von den vier *Psolus*-Arten ist eine nur in einem jugendlichen, nicht sicher bestimmbaren Exemplare vorhanden. *Psolus pauper* n. sp. zeichnet sich durch völligen Mangel von Kalkkörperchen in der Haut der Sohle aus und steht im Übrigen den Arten *squamatus* und *fabricii* nahe. *Psolus digitatus* n. sp. hat ebenfalls den Habitus der beiden eben genannten Arten, unterscheidet sich aber durch die Gestalt der Fühler, welche einfach fingerförmige, unverästelte Schläuche darstellen; die Fühler haben demnach hier ihre jugendliche Form dauernd festgehalten — ein Fall, den wir bis jetzt nur bei den Molpadiiden-Gattungen *Eupyrgus* und *Hoplodactyla* kannten. *Psolus diomedeae* n. sp. schliesst sich durch die deutliche Ausbildung von je fünf interradialen Oral- und Analplatten an *Ps. antarcticus*, *tuberculosus* und *ephippifer* an, von denen er sich aber in anderen Merkmalen hinreichend unterscheidet.

Die beiden neuen *Psolidium*-Arten, *panamense* und *gracile*, geben Veranlassung die Diagnose der Gattung *Psolidium* einer Revision in dem Sinne zu unterwerfen, dass sie nunmehr lautet: "Zehn Fühler (die beiden ventralen kleiner als die übrigen); mittlerer Abschnitt des Triviums zu einer deutlich umgrenzten Sohle abgeflacht und hier mit gut entwickelten, auf die Ambulacren beschränkten Füsschen besetzt; auf der übrigen Körperoberfläche kleinere oder zu Papillen verkümmerte Füsschen, welche entweder überall zerstreut stehen oder sich an den Körperenden auf die Radien beschränken." Von der so gefassten Gattung *Psolidium* unterscheidet sich *Theelia* lediglich durch die Zahl (15) der Fühler. Zu *Psolidium* wird auch die Théel'sche Art *Psolus brasiliensis* gerechnet, so dass *Psolidium* nunmehr vier Arten: *dorsipes* Ludw., *brasiliense* Théel, *panamense* und *gracile* umfasst. Die *Psolidium*-Arten lassen sich als werdende, in Bildung begriffene *Psolus*-Arten ansehen. Die Formenreihe, welche sich von *Cucumaria* (und *Thyone*) beginnend durch *Colochirus* zu *Psolidium* und von hier zu *Theelia* und schliesslich zu *Psolus* verfolgen lässt, begründet die Ansicht, dass die Gattung *Psolus* keine alterthümliche und ursprüngliche, sondern eine verhältnismässig junge, vielleicht eine der jüngsten unter allen Dendrochiroten ist.

Die *Cucumaria abyssorum* Théel wurde in 64 Exemplaren aus Tiefen von 905—2232 Faden erbeutet, welche lehren, dass die var. *hyalina* Théel jugendliche, dagegen die var. *grandis* Théel alte erwachsene Thiere derselben Art darstellt.

Als die interessanteste aller bis jetzt ausgefundenen Tiefsee-Dendrochiroten erscheint die neue Gattung *Sphaerothuria* mit der einen Art: *Sph. bitentaculata* n. sp. Dieselbe hat eine fast kugelrunde Gestalt, und ist mit grossen Platten bepanzert, welche je einen kräftigen, frei hervorstehenden Stachel tragen. Die Fühler haben wie bei *Psolus digitatus* die einfach cylindrische, jugendliche Form bewahrt. Von den zehn Fühlern anderer Dendrochiroten sind die beiden ventralen, die bei jenen oft sehr viel kleiner sind als die übrigen, vollständig geschwunden. Von den acht übrig gebliebenen sind sechs (vier dorsale und zwei ventrale) verkümmert, dagegen nur zwei (ein rechter und ein linker) wohl entwickelt. Am Kalkring ist jederseits das ventrale Interradialstück mit dem seitlichen ventralen Radialstück zu einem anscheinend einheitlichen Stücke zusammengedrängt. Die ungemein kleinen Füsschen sind auf die Radien beschränkt; ihre Füsschencanäle durchbohren die Platten des Hautpanzers. Aus einem Vergleiche mit *Cucumaria* (*Echinocucumis*) *typica* (Sars) geht hervor, dass die *Sphaerothuria* aus der *Echinocucumis*-Gruppe der Gattung *Cucumaria* abzuleiten ist.

V. MOLPADIIDAE.

In der Sammlung sind sechs Arten vertreten, von denen nicht weniger als vier neu sind. Eine Art: *californica* n. sp. gehört zur Gattung *Caudina*, drei Arten: *violaceum* (Stud.), *granulatum* n. sp. und *intermedium* n. sp. gehören zur Gattung *Trochostoma*, zwei Arten: *danielsseni* Théel und *spinosum* n. sp. zur gattung *Ankyroderma*. Die *Caudina californica* ist durch ihre Kalkkörper scharf unterschieden von den bisher bekannten *Caudina*-Arten. *Trochostoma violaceum* (Stud.) und *Ankyroderma danielsseni* Théel konnten bis jetzt als rein antarktische Formen angesehen werden, während sich nunmehr herausstellt, dass sie in tiefem kalten Wasser nordwärts den Äquator überschreiten. Dass dieses Vordringen in tropische Meeresgebiete Hand in Hand geht mit dem Herabsteigen in grössere, kalte Tiefen lässt sich besonders bei *Trochostoma violaceum* nachweisen. Die neue Art *Trochostoma granulatum* ist durch ihre Kalkkörper characterisiert und entbehrt wenigstens in den vorliegenden Exemplaren der "weinrothen Körperchen." Auch die andere neue *Trochostoma*-Art: *intermedium* ist durch ihre Kalkkörper gekennzeichnet, welche ihr eine vermittelnde Stellung zwischen den arktischen Arten: *Tr. arcticum, boreale, thomsonii* und dem antarktischen *Tr. antarcticum* anweisen; an einem Exemplare konnte die innere Organisation genauer untersucht werden. Von dem bis jetzt nur nach einem einzigen Exemplare aus der Ausbeute des *Challenger* bekannten *Ankyroderma danielsseni* sind im Ganzen 29 Exemplare vorhanden, welche eine Bestätigung und Ergänzung der Théel'schen Angaben ermöglichten. In ihrer geographischen Verbreitung bietet diese antarktisch-pacifische Art ein Gegenstück zu der arktisch-atlantischen *A. jeffreysii*, ohne indessen, wie Théel vermuthete, nur eine Varietät der letzteren zu sein. Die neue Art *Ankyroderma spinosum* unterscheidet sich von der übrigens nahe verwandten *A. danielsseni* vorzugsweise durch die Kalkkörper der Rumpfhaut und die verhältnismässig grössere Länge des Schwanzes.

VI. SYNAPTIDAE.

Nur eine Art *Synapta abyssicola* Théel liegt in Bruchstücken aus 1672 und 1772 Faden Tiefe vor, welche in ihren Kalkkörpern nur insofern eine Abweichung von den typischen Exemplaren zeigen als die Ankerarme keine Zähnchen besitzen. Wegen dieses Unterschiedes geben die vorliegenden Bruchstücke einstweilen zur Aufstellung einer besonderen Varietät: *pacifica* Veranlassung. Sie gestatten ferner nähere Mittheilungen über den anatomischen Bau dieser Art, von der bis jetzt einzig und allein die Kalkkörper bekannt waren.

Bonn, den 6. April, 1893.

No. 5. — *The Development of the Scales of Lepidosteus.* By W. S. Nickerson.[1]

The scales of Lepidosteus have been studied by several investigators. Their most prominent peculiarity is the possession of a hard, smooth, nearly homogeneous outer layer, which in the adult condition lies free to the exterior not covered by other tissue. The question of most immediate interest concerning the scales is the one in regard to the source and nature of this outer layer. The view which has been generally held concerning it is that recently maintained by Oscar Hertwig ('79), who believes that it is a true enamel layer derived from the overlying epidermal tissue.

The more recent studies of Klaatsch ('90) seem to contradict this conclusion by showing that it has a dermal origin. Closely connected with the question concerning this layer, and in part dependent upon the answer found for it, is that of the relationship existing between the Ganoid scale and the scales of Selachians, Teleosts, and Dipnoi. Additional interest is also given to this inquiry by the fact that it has a bearing upon the question of the relation of scales to teeth.

The writers who up to this time have investigated the scales of Lepidosteus have, with one exception, had only adult material for study, and therefore their conclusions regarding the outer layer were necessarily drawn chiefly from the physical properties of the finished scale. Since in the adult the tissue has disappeared from the outer surface of the scales, it is evident that the source of the problematical outer layer can be determined only by the study of young fishes in which the scales are in process of formation, and still covered by the tissue which produces them.

Klaatsch ('90) in his study of material from a single young gar-pike made some very interesting and important observations, which, if confirmed by subsequent investigations, must overthrow the idea of Hertwig, that the outer layers of the ganoid scale are directly homologous with the enamel of the teeth of higher vertebrates.

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

By the study of abundant material from several (ten) different fishes of various ages and sizes, I have endeavored to trace the course of development with sufficient thoroughness to settle the origin of the layer now in dispute, and if possible to throw some light upon the homologies of the scales of the Ganoids. For the most part my observations lead me to conclusions in agreement with those of Klaatsch, although in regard to some points I am unable to coincide with his views.

For the greater part of the material used I am indebted to Dr. Edward L. Mark, who very kindly placed at my service his own supply. These fishes had been reared by him in aquaria from eggs collected at Black Lake, N. Y., in the spring of 1882. They had been killed at intervals by various fixing reagents, as indicated in the table following, and carefully preserved in alcohol. The histological conditions were very faithfully preserved in all except one specimen. This, the largest and oldest fish of the lot, had died in the aquarium after attaining an age of fifty-two months and a length of thirty centimeters. When found it could have been dead but a few hours at most, and was at once preserved in alcohol. On studying this fish I found the scales in a most interesting stage of development, but unfortunately the epidermis had so far degenerated that it was impossible to make out anything of importance concerning its relation to the scale. I was moreover somewhat apprehensive lest the confinement in which these fishes had been reared, together with the handling and other unnatural treatment to which they had been subjected, might have rendered the conditions of the scales found in this and the other larger fishes abnormal to some extent.

I was unable to obtain at once healthy material of the proper age to show the later stages of growth, and to this fact is due a considerable delay in the completion and publication of the results of my work. The missing later stages were supplied by material from two young gar-pikes which Mr. S. P. Bartlett of the Illinois State Fish Commission obtained and very kindly sent me. They were killed according to my direction by immersion in strong alcohol, a method that is very satisfactory for epidermal and dermal tissues, and which has the advantage over acid killing-fluids of leaving calcareous structures quite unaffected. For other material which I have studied I am indebted to Prof. E. A. Birge of the University of Wisconsin, and through Dr. Mark to Prof. Jacob Reighard of the University of Michigan. The material from both of these sources had been killed in alcohol.

To all of these gentlemen I wish to express my gratitude, and especially to Dr. Mark, not only for his liberal supply of material which it had cost him much time and labor to obtain, but also for his direction and many valuable suggestions.

Tabulated List of Fishes studied.

Length. mm.	Age. Months.	Killing Reagent.	Condition.	Received from
145	18+	Merkel's fluid.	Local aggregations of spongy connective tissue.	Dr. Mark.
115	18	$HgCl_2$ (hot).	Bony scale beginning to be formed.	" "
150	18+	Merkel's fluid.	Spines being formed.	" "
160	19	90 per cent alcohol.	Few spines.	" "
175	24	Picro-sulphuric acid.	Edges of scale beginning to overlap.	" "
190	35	2 per cent chromic + acetic (few drops).	Mature spines all over scales.	" "
287	?	Alcohol.	Spines all over scale; no ganoin layer.	Prof. Birge.
300	52	Died, 90 per cent alc.	Epidermis degenerated; thin ganoin layer.	Dr Mark.
300	?	Alcohol.	Spines on edges; thin ganoin layer.	Mr S. P Bartlett.
460	?	Alcohol.	Few spines on edges; thicker ganoin layer	Prof Reighard.

The method used has been chiefly the preparation and study of series of sections. In all except very young stages it was necessary to decalcify the material before it could be sectioned, and even after decalcification sections in most cases could not be cut thinner than 15 μ, and often in the later stages it was necessary to make them between 20 and 30 μ thick. For decalcifying I used 90% alcohol to which was added a small quantity of 10% hydrochloric acid (in the ratio of about 3 to 1). The tissue was usually left in this acid alcohol twenty-four hours or more, and then soaked in several changes of fresh alcohol to remove all traces of the acid before staining. Sections prepared by grinding down scales have also been studied, as well as scales freed from the soft tissues by treatment with caustic potash. Only by the use of the latter reagent was I able to get a satisfactory knowledge of the spines which cover the scale in its immature state.

The stains which have given the best results are Boehmer's alum hæmatoxylin and Kleinenberg's hæmatoxylin. As a nuclear stain the former is much the better; the latter is especially useful in the study of the glands of the epidermis and in bringing cell membranes into prominence.

The young Lepidosteus in which I found the earliest indication of the formation of scales was about 145 mm. long and a little over eighteen months old. Klaatsch has stated that the scales appear upon the dorsal side of the body earlier than upon the ventral, and as the material studied was taken in this specimen (as in most cases) from near the ventral line, it is probable that the scales begin to form upon the dorsal portion of the body at a somewhat earlier age.

Before the beginning of the formation of the scales the integument is about 225 μ thick. The epidermis is nearly twice as thick as the dermis and is made up of numerous layers of spheroidal or cuboidal cells (Fig. 1). The cells of the deepest layer are somewhat elongated in a direction perpendicular to the surface, and consequently have the appearance of indistinctly columnar epithelium.

There are two kinds of glandular structures present in the epidermis. Those of one kind have a spherical, or more often ovoid or oblong form, with the greater axis perpendicular to the surface of the body, and appear in sections as spaces of corresponding shape. The long diameter in the larger of these spaces is not infrequently (Fig. 1) from one half to two thirds the thickness of the epidermis (75–100 μ).

The glands are quite irregularly distributed, some areas being only very meagrely provided with them, while in others they are so crowded as to leave little more than thin filmy partitions between them. Sections parallel to the surface in such areas present a net-like appearance, the empty gland cells corresponding to the meshes. To each space there belongs a flattened nucleus, which is closely applied to the wall near its deep end. The whole structure is doubtless to be considered as a single cell which has taken on a secretive function, — a unicellular gland.

These glandular spaces sometimes appear empty, but are more often found partly filled by an indistinctly granular colorless substance (coagulum), probably precipitated by reagents from the fluid or semi-fluid secretion which they held during life (Plate I. Fig. 1, Plate II. Fig. 16). I do not find that these spaces have any means of communication with one another, and only very rarely do I find one having an opening to the exterior. Klaatsch has described these as mucous glands. I have no doubt that they are concerned in the production of the slime by which the young "gars" are thickly covered. They are not, however, the only agents concerned in its production.

The epidermal glands of the second kind are considerably smaller than those already described; they are nearly spherical, and have an average diameter of from 18 to 25 μ. They do not appear to have been recognized by previous observers. Some of these lie in the deeper part of the epidermis, but much the greater number and the larger ones occur near the surface, where many of them open.

They stain deeply with Kleinenberg's and with Delafield's hæmatoxylin, but in all other stains used, even in other hæmatoxylin dyes, the nuclei alone are colored, and in this condition they can be distinguished from small glands of the first kind only by very careful observation. This probably accounts for their having been overlooked heretofore. In Kleinenberg's hæmatoxylin the whole gland takes a blue tint, while the wall presents a reticulated appearance due to an irregular network of lines of a much deeper blue color. This appearance is shown in Figure 2, *a–e*. The glands lying in the deeper part of the epidermis (*d*) take less color than those situated just below the surface (*c*); those which open at the surface vary much in the intensity of their coloring, the differences doubtless being due to the varying amounts of mucin contained in them. The distribution and peculiar staining qualities of these glands show that they originate in the deeper part of the epidermis and migrate to the surface, where their secretion is discharged.

Hæmatoxylin has long been known to stain mucus deeply. Hoyer ('90) found that basic stains are those which chiefly affect mucin, and that hæmatoxylin stains which contain alum act like basic stains. Of the four hæmatoxylin dyes which I have used, Kleinenberg's (basic) and Delafield's (alum) gave characteristic deep blue stains to these glands; Boehmer's (alum) and Ehrlich's (acid), on the other hand, gave pure nuclear stains. Hoyer imputed certain failures of hæmatoxylin stains to act in their normal manner to lack of "ripeness," and it is possible that this may be the reason for Boehmer's alum hæmatoxylin not coloring the mucin in this case.

At all events, I believe that the stains which I have obtained afford sufficient ground for declaring that these cells act as glands, and secrete the mucin element of the slime by which the young gar-pikes are thickly covered. The other and larger glands first described, which take only a nuclear stain with Kleinenberg's hæmatoxylin, must be considered to have the function of secreting some component of slime other than mucin.

The distribution of these mucous glands, like that of the kind first described, is somewhat irregular, and the two kinds are about equally numerous; those of the larger kind are, however, much more conspicuous by reason of their size. Both kinds of glands are found in the epidermis as long as it persists over the surface of the scales.

Chromatophores are abundant in the epidermis. They vary greatly in size and shape, and are found in all parts of the layer.

The boundary between epidermis and dermis is marked by the presence of a distinct basement membrane.

The dermis (Fig. 1), before it has begun to undergo modifications preparatory to the formation of the scales, is only about half as thick ($75\ \mu$) as the epidermis, and is composed of bundles of connective-tissue fibres which may be divided into three sets according to the directions in which they run. Two sets are parallel to the surface and diagonal to the axis of the body, the third is perpendicular to the directions of the other two. Of the first two sets, the fibres of one have a direction backward and ventrad parallel to the direction which the rows of scales will have later. The fibres of the other diagonal set cross these in such a way as to make the dorsal and ventral included angles a few degrees less than right angles, the anterior and posterior included angles being consequently a little greater than right angles. The fibres of the third set are much less numerous than those of either of the other two, and, as they extend perpendicularly through the dermis, serve to bind together the different layers. Nuclei are irregularly distributed among the fibres, as in ordinary connective tissue. Blood-vessels are numerous, and ramify chiefly in the outer part of the layer just beneath the basement membrane. Chromatophores are present, as in the epidermis, and are found mostly upon the two surfaces of the layer, being especially numerous at the deeper one (Fig. 1). Upon the outer surface they lie at nearly uniform distances apart (Fig. 4). Beside these color cells there is associated with them at the deeper surface of the dermis, between it and the musculature, quite a thick but very irregular sheet of finely granular white pigment. Concerning the origin of this pigment I have been able to learn nothing.

The first indication of the formation of scales is a change in the outer part of the dermis. There appear local thickenings of spongy tissue, which are made up of many nucleated cells and a small number of fibres lying among them without definite arrangement. These regions of modified dermis are abundantly supplied with blood-vessels. At first these thickenings are quite distinct from one another, being separated by tracts of unmodified tissue; thus each one resembles a very much flattened papilla.

A similar condition found in the early stages of the formation of the scales of Teleosts is described by Klaatsch ('90, p. 159) and by Hofer ('90, p. 111). Both of these authors regard these dermal thickenings in Teleosts as homologous with the dermal scale papillæ of the Selachians. This view receives a certain amount of support from the fact that in Selachians, Ganoids, and Teleosts the first indication of the formation of scales is the appearance of local elevations of the dermis in the form of papillæ. On the other hand, it is difficult to imagine any change due to increased local activity of the tissue taking place in the dermis without producing modifications resembling to some extent papillæ. That the scales of all the groups of fishes owe their origin primarily to the dermis seems therefore a sufficient explanation of the early appearance of these papilla-like local modifications of this layer, and not to require the assumption of any direct homology between the resulting structures. The fact that in Selachians the scale is formed over the surface of the papilla, while in Ganoids (Lepidosteus) and in Teleosts it arises in the midst of the mass of cells forming the elevation, is a fundamental difference not to be overlooked. Furthermore, at a later period in the formation of the scales of Lepidosteus there arise dermal papillæ just beneath the basement membrane, over the surface of which calcareous material is laid down to form spines. These receive an ectodermal enamel secretion over their tips, and later pierce the epidermis, and thus exactly resemble in all important features the spines of the placoid scales of Selachians. The formation of the spines in Lepidosteus has been described already by Klaatsch ('90, p. 130), and will be treated of more fully further on in this paper.

The condition found in Lepidosteus is intermediate between that presented by Selachians and that described in Teleosts. The presence of the spines enables us to say that the papillæ by which they are secreted, not the broader, earlier formed dermal thickenings, are the homologues of the papillæ formed in Selachians. As the early conditions found in Teleosts so closely resemble those in Lepidosteus, there can be no choice but to interpret these dermal thickenings as homologous with those of Lepidosteus. They cannot therefore be considered the homologues of the scale papillæ of Selachians, as maintained by Klaatsch and Hofer.

Hofer claims that in the trout the basal layer of cells of the epidermis becomes modified over the scale papillæ to form an enamel membrane, though this never becomes functional and the cells soon lose their specialized character. Klaatsch studied the same form, and very positively denies that any such modification takes place. He says (p. 159): "Speciell die basale Epithelschicht lässt auch nicht die geringste Veränderung wahrnehmen." In view of this conflict of testimony, it seems more probable that the differences in the condition of the basal cells of the epidermis observed by Hofer were due to variations in different individuals than to changes normally taking place in the same individual.

At a little later period these areas of dermal thickening have extended laterally until their edges have become confluent, and the dermis may then be described as made up of two layers, an outer spongy layer and an inner fibrous layer, though no definite line of demarcation separates the two. This is the earliest stage described by Klaatsch. At the time when the formation of the scale begins, the spongy layer in its thickest parts is about equal in thickness to the deeper fibrous layer. The places in which scale formation is to take place are indicated by a somewhat greater thickness of the spongy layer.

The scale first appears (Fig. 3) as a thin sheet of calcareous secreted matter in the midst of the outer layer of the dermis. It is surrounded on all sides by the dermal cells, which lie thickly accumulated around it and cover it on its outer surface from two to four cells deep, completely separating it from the epidermis. Around its margin the cells lie closely packed, and at the posterior edge are particularly numerous. To these dermal secreting cells Klaatsch has given the name "Scleroblasten," a term which I shall adopt in referring to them.

The scale plate is not quite parallel with the surface of the body; its posterior margin is very slightly inclined outward, and with the scleroblasts around it forms a low elevation against the base of the epidermis (Fig. 3).

Secreted matter is not deposited where blood-vessels from below pierce the outer or scleroblastic dermal layer, and consequently openings through the scale result at such places. These persist to form the canals which pierce the middle area of the adult scale (Haversian canals of authors). The vessels which traverse them ramify upon the outer surface of the scale to supply nourishment to the overlying scleroblasts. No difference in character could be detected between the cells on the upper and those on the under side of the scale.

Almost as soon as the calcareous material of the scale begins to be laid down some of the surrounding scleroblasts become enclosed by it (Fig. 3). This process goes on hand in hand with the increase in the size of the scale, and as a result the scleroblasts are distributed through all parts of it. That the distribution is a fairly regular one may be seen from Figure 15 (Plate II.) and Figure 21 (Plate III.). In a scale from which the soft parts have been removed by treatment with caustic potash, the cavities occupied by these cells may be very distinctly seen. Each one has leading from it a small number of canals (canaliculi) which branch and traverse the scale to unite with similar canaliculi from the neighboring cavities. Thus the whole scale is traversed by a network of fine ramifying tubules connecting the osteoblastic cavities. As may be seen in section, however, all the canaliculi from a given cavity show a tendency to spread out in a plane parallel to that surface of the scale within which it has been buried, so that the cavities in most intimate connection are those which lie at the same distance below the surface. Thus the material of the scale is divided into more or less regular lamellæ of calcareous matter alternating with successive layers of cell cavities and their connecting canaliculi. These cavities are in communication with the exterior by means of canals which penetrate the scale and break up at their inner ends into fine tubules to join the canaliculi. They penetrate from both the upper and the lower surface, though much more abundantly from the lower (Plate II. Fig. 15, and Plate III. Fig. 21). At the opening of each of these canals at the surface of the scale there is a large cell (Plate I. Figs. 8 and 9, Plate III. Fig. 22, Plate IV. Fig. 23), from which a process extends into the lumen. These cells were called by Hertwig "Odontoblasten," and the canals occupied by their processes "Dentinröhrchen." I must, however, agree with Klaatsch that the names are poorly chosen, for the reasons set forth by him. The constant character of dentine, as the term has been used, is the absence of enclosed cells, and as the substance penetrated by the processes of these cells contains such elements (osteoblasts), it seems undesirable to call it dentine or the cells odontoblasts. Hertwig's nomenclature rests on an assumption of homology which has not been proved true. However, as these terms have been adopted in the literature, it is perhaps inadvisable to introduce new ones at this time. Besides the odontoblasts with their processes extending into the dentinal tubules which Hertwig describes and figures ('79, p. 5, Taf. III. Fig. 4), he mentions the presence of a granular substance partially filling the lumen of the canals. Klaatsch asserts that cells are present in the dentinal tubules (p. 138). I have found by diligent searching a few cases in which, as stated by the latter author, cells seemed to be present in the lumen of the tubes. I have, however, observed other cases in which a flattened cell lay just at the side of the tube, but separated from its lumen by a thin layer of secreted material. I am therefore led by this and by the infrequency of the cases to believe that the cells apparently occupying the tube have a similar position, but that since they lie in radii of the tube perpendicular to the plane of the section they have the appearance of being in the lumen of the tube. Figure 8 will make this clear. At the opening of the tube is seen a cell which is apparently about to be enclosed between the secretion of the large odontoblast cell and the present wall of the canal. At a little later stage this, if seen in a plane at right angles to the present, would appear to lie in the lumen.

Each of these tubes is lined by a very thin secretion from the cell which extends into it, — a secretion of the same character as the material of the scale. In later stages, after the ganoin layer has begun to be formed, this sheath persists even after decalcification, when the ganoin is entirely destroyed (Plate IV. Fig. 23).

The scale increases both in thickness and in lateral extent by the deposition of new layers of material secreted by the surrounding scleroblasts. Thus the edges of adjacent scales come together, and finally overlap one another. Owing to the slight elevation of the posterior margin of the scale, previously mentioned, this edge of each scale overlaps the anterior edges of the adjacent posterior scales; for the same reason, each scale is in turn overlapped on its anterior edge by the posterior edges of the scales in front of it (Plate IV. Fig. 31).

Increase in thickness takes place upon both the outer and the inner surfaces, though much more rapidly upon the inner one. As the scale thickens inwardly, fibres which lay irregularly disposed beneath it in the spongy dermis are enclosed by the secretion. As the calcification extends deeper, the felted regularly arranged bundles of connective-tissue fibres of the deeper dermis are also enclosed, and help to make up the deeper part of the scale. These fibres extend across from one scale to another and so form a strong but flexible connection between adjacent scales. They are the "Schuppenligamente" of Hertwig. The ratio of outward to inward growth is shown by the arrangement of the layers of the scale (Plate II. Figs. 15, 16, and Plate III. Fig. 21). The oldest part of the scale is that in which the dentinal tubules from the opposite surfaces meet and break up into minute branches (Plate III. Fig. 21).

In their immature state, and before the outer layer has begun to be formed, the scales bear upon their outer surface numerous slender conical spines or teeth. These were first described by Reissner ('59, p. 260). They stand up from the surface not quite perpendicularly, but have a slight inclination toward the tail (Plate I. Fig. 7, and Plate IV. Figs. 26, 28). They are transient structures, which frequently leave no trace of their existence in the adult scale. They begin to be formed when the scale is still comparatively thin (75–100 μ), and like it they owe their origin to the cells of the outer or scleroblastic layer of the dermis from which they are principally formed.

The first step in the formation of a spine is an increase in the number of the cells lying upon the upper surface of the scale just under the basement membrane. A thickening is thus formed which rises up against the base of the epidermis in the form of a papilla (Plate I. Fig. 5). The basal layer of epidermal cells becomes arched over it, and the columnar character of the cells much more pronounced. The papilla increases in height rapidly, pushing forward into the epidermis, with its point directed slightly caudad, but remaining at its base little if any larger than at first. The cells of which it is composed are the same in character as those overlying the scale; in the axis of the papilla they are crowded together without any definite arrangement, but at its periphery, where they adjoin the basement membrane which separates them from the epidermis, there is perceptible a certain degree of regularity in the arrangement of the nuclei; they lie rather closely appressed, being elongated radially to the axis of the cone.

After the papilla has attained a considerable height there appears upon its tip a thin crust of calcareous matter secreted by its cells; this gradually extends down over the sides, forming a conical cap (Plate II. Fig. 10), which is pushed forward by growth from below as the papilla increases in height. In the early stages of its formation, the papilla merely indents the lower surface of the epidermis, but as the point of the spine is pushed forward it causes a swelling upon the outer surface of that layer (Plate I. Figs. 5, 6). At the same time that this is taking place the thickness of the spine cap is being increased by the addition of new material from within. By the continuation of these processes the point of the spine is made to pierce the epidermis and so lie free to the exterior, while the basal end joins the scale already formed below. There is no joint or hinge of any kind at the place where the two unite, but the material of the spine is directly continuous with that of the outer part of the scale. The cells of the papilla are thus entirely shut off from the other scleroblastic cells which lie over the outer surface of the scale except at one point, where a small opening persists through the side of the base of the spine at its junction with the scale (Plate I. Fig. 7, and Plate IV. Fig. 26).

I have as yet said nothing concerning an enamel layer upon the spines, because it could not be observed in any material of the stages described. Both Hertwig and Klaatsch assert that the points of the spines are covered by a cap of enamel. Reissner says (p. 260): "Die ganzen Stacheln scheinen übrigens auch einen dünnen Ueberzug von Schmelz zu besitzen." In scales which have reached the condition in which spines are present the thickness and hardness are such as to make section cutting impracticable, unless the tissue is first decalcified. In sections of decalcified scales no trace of an enamel cap is to be seen, nor is any space left between the point of the spine and the base of the overlying epidermis to indicate that anything has been lost. I was for some time inclined to believe that both Hertwig and Klaatsch were mistaken in asserting the presence of an enamel cap. In spines, too, which were broken off from scales which had been treated with caustic potash to remove the fleshy matter, there was evidently no enamel present. Such a spine is shown in Plate II. Fig. 11. Its cavity is seen to be continued up into the tip as a dendritic system of fine tubules (Dentinröhrchen of Hertwig), whose finest branches can be traced quite to the surface, and so preclude the possibility of an enamel cap being present.

I succeeded in learning the true condition only when, by the aid of a low power of the microscope, I watched the caustic potash slowly eat away the tissue from the surface of the spine-bearing scale. As the epidermal tissue became clear and began to be dissolved, there could be seen supported in it minute scattered caps unconnected with the scale or the spines. With a little search, however, these caps were found in some cases resting directly over the points of spines, but raised slightly from them (Plate IV. Fig. 27). Similar conical caps were also found in the bottom of the watch-glass after the soft tissues had been entirely destroyed. Several of these loose caps were picked up and transferred to glass slides. On treating them with weak acid (2% HCl) their points quickly dissolved away, leaving the cap truncate (Plate II. Fig. 12, *a*, *b*). The rest not only was not dissolved, but it showed no change when stronger acid (10% HCl) was added. From this it would seem that the only part of the spine which can be considered to be enamel is the small apex which is dissolved away by the acid, or else that the basal cells of the epidermis first secrete a substance which is largely animal (not mineral) matter, a substance which closely resembles the matrix of the scale itself. But I know of no case of true enamel in which the secretion is of such a mixed nature.

Whether the bony material of the spine or the enamel tip begins to be formed first I have no means of determining. I believe that the two formations begin nearly simultaneously, although there is some reason for thinking that the enamel is not secreted until a part of the bony spine has been formed, for in a few cases I find peculiar abnormally shaped tips (Plate I. Fig. 6, Plate III. Fig. 18, and Plate IV. Fig. 26) which are more readily explained upon the former assumption. These all occur on individuals raised in aquaria, and I believe them to be due entirely to artificial influences, — perhaps to handling. If the enamel were already present over the tip of the spine, I cannot believe that its point could be so distorted, whereas the matrix of the bony part of the spine is probably somewhat plastic when first secreted. It is also conceivable that, before the commencement of secretion, some distortion of the papilla permanently altered its form and caused the abnormal shape of the spine. This seems to me less probable, however, in view of the particular forms which the points of the spines have taken.

The material of the spine is in lamellæ, though these are not as distinct as in the scales. The insoluble part of the point (Plate II. Fig. 12, *b*) is doubtless made up of the first formed lamellæ of the spine which have separated from the rest of the cone on treating with caustic potash. In Figure 25 (Plate IV.) is shown the splitting between lamellæ caused by an oblique cut through the basal part of a spine. No scleroblastic cells, however, are enclosed between the layers, and the material of the spine therefore differs from that of the scale at its base in that particular. But the absence of enclosed cells is not surprising, in view of the thinness of the walls of the spine. In reaction toward acids there is no difference between spine and scale.

The number of spines upon a scale is wholly indefinite, and their arrangement for the most part not subject to any precise law. They are more numerous near the free (i. e. posterior) margins, and here show a tendency toward an arrangement in lines parallel with the edges of the scale (Plate IV. Fig. 31). I have counted over thirty spines on the posterior margins of a scale whose central area was nearly destitute of them. Though some spines are formed near the centre of the scale, by far the greater number arise near the posterior edges. With the growth of the scale, however, the margin advances, leaving them farther and farther from the edge.

The scleroblasts overlying the scale about the bases of the spines do not cease their secretive activity when the spines are completed, but their secretion continues to be employed gradually to thicken the scale by additions to its upper surface. The amount of material so added is very little in the central part of the scale, but toward the margins, where growth is still taking place, and where the greater number of spines are formed, it is considerable (Plate II. Fig. 13). This results in the basal ends of the spines being surrounded and incorporated in the outer layers of the scale (Plate IV. Figs. 24, 25). These outer layers also contain enclosed cells, and are composed of exactly the same material as the layers immediately underlying them.

It is this outer part of the scale which Klaatsch believes to be the enamel layer of Hertwig and other authors, and which he calls *ganoin*. He says (p. 141): "Sie [die Ganoinschicht] entsteht im Anschluss an die Zahnbildung auf der Schuppe; sie ist eine direct Fortsetzung des Zahnbeins der kleinen Schuppenzähne." He also says (p. 132): "Die Substanz der Ganoinschicht stimmt in ihrer homogenen Beschaffenheit mit dem Dentin der Zähnchen überein."

In this I believe that Klaatsch is in error. It is inconceivable to me that any one who had seen ground sections of the ganoin under the microscope could for a moment confound with it the dentine of the spines. Moreover the figure of ganoin given by Klaatsch (Tafel VII. Fig. 6) represents a condition quite different in appearance from that presented by the true ganoin. Furthermore, as shown by the table already given (page 117), I found no trace of the ganoin layer on the scales of a fish 289 mm. long while the fish from which Klaatsch's material came was only 180 mm. long. Reissner ('59, p. 260) says concerning the spines "ihre Insertionsstellen unmittelbar unter dem Schmelz liegen." The presence in this outer layer of enclosed osteoblasts, which are absent from the layer described by Reissner and Hertwig, the fact that it is not destroyed by acid, and its optical properties, all give convincing proof that the material secreted "im Anschluss an die Zahnbildung auf der Schuppe" is not the layer described by Hertwig and others as enamel. If then, as I believe, Klaatsch did not see the layer in question, his claim in regard to its origin can have no weight, and the question of its source remains where Hertwig left it.[1]

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[1] It is only fair to state, however, that both the 17.5 cm. and the 19 cm. garpikes which I studied were killed in acids, so that I have no undecalcified material of the same size as that which Klaatsch studied, for a perfect control of his statement about the ganoin layer.

I have frequently found in sections of scales of different ages, killed by various reagents, a narrow marginal zone appearing somewhat different from the rest of the section (Plate I. Fig. 3, and Plate III. Figs. 17, 20). This often appears strikingly like a different layer of material, and is sharply bounded from the deeper-lying layers. I believe that this appearance is due to the action of reagents used in killing or staining (*in toto*), or both, and not to any natural difference between the parts of the scale. No such difference is found in material killed in alcohol. Klaatsch refrains from stating anything concerning the methods he used or the manner in which his fish had been killed. The impression produced by the study of his paper is that he was misled by some artificial condition such as I have just mentioned and figured.

I have already stated that the spines frequently leave no trace of their existence in the adult scale. To what their disappearance is due I am unable to state positively. Before the outer layer begins to be formed they have almost completely disappeared from all the central part of the scale, but usually a few still remain close to the posterior edges. Hertwig ('79, p. 7, Taf. II. Figg. 1, 2, 3, 10) has described and figured certain little knob-like elevations projecting up into the ganoin layer, and he believes them to be remnants of spines which have been lost. In this conclusion he agrees with that already expressed by Reissner ('59, p. 260). I have carefully looked through series of sections from two different adult "gars" for such structures, but without finding them. Hence it would appear that their occurrence cannot be considered a constant feature. In scales from one young fish 46 cm. long, however, I found some peculiar structures similar to those figured by Hertwig. One of these is shown in Plate II. Figure 14 and is without doubt, as Hertwig maintained, the base of a lost spine. It had been entirely buried in the ganoin. There were also present a number of other much smaller bodies lying between the top of the scale and the overlying tissue in the space from which the ganoin had been dissolved. These were widely scattered, and many were little larger than an odontoblast cell; they were of an ovoidal or spheroidal form, and appear to be the same in composition as the one figured (Plate II. Fig. 14), and I am led to the conclusion that they are also remnants of the bases of lost spines, which were probably in process of absorption when the secretion of the ganoin began and buried them. Hence I believe that the obliteration of spines is in general due to absorption, though it is hardly conceivable that the distal part of the spine disappears in this way. That the disappearance of the spines is due to resorption was suggested by Hertwig ('79, p. 8).

The ganoin layer begins to be formed first over the central area of the scale, and covers all but a very narrow marginal zone, as a regular coating of uniform thickness. At this time the spines have mostly disappeared from all except the posterior margin. The ganoin is separated from the bony part of the scale by a distinct, regular line, and shows markedly different optical properties. It is more highly refractive than the part below, and appears entirely homogeneous except for a very delicate striation parallel to the surface, which probably corresponds to irregularities in the rate of deposition. It cannot be seen in cut sections, since it is entirely destroyed by decalcification, without which section cutting is impossible in scales of this age. In sections prepared by grinding it presents the appearance seen in Plate II. Figure 15. As seen from the surface, too, the appearance is quite unlike that of the bony part of the scale, which is not covered by it (Plate IV. Fig. 27). A knowledge of this layer can be obtained only by combining the results of study both of sections from decalcified tissue and of preparations made by grinding undecalcified scales of the same stage of development.

I find the ganoin layer first present in a fish 52 months old (30 cm. long) reared in confinement; it is also present, and a very little thicker, in a fish of the same length from Quincy, Ill. (Plate II. Fig. 15). In the former case the relation of the scale to the epidermis could not be made out, but in the latter all the tissues were well preserved in a perfectly healthy condition, and the epidermis was distinctly separated from the scale by a thin layer of dermal scleroblasts seldom over two or three cells thick (Plate II. Fig. 16, and Plate IV. Fig. 23). The former of the two figures cited shows about an average condition, and the latter a place near the opening of one of the canals which pierce the central part of the scale where the blood-vessels and surrounding tissue make an unusually thick sub-epidermal sheet. Small blood-vessels are abundant in this layer.

On the scales of a young Lepidosteus 44 cm. long, in which the layer of ganoin had a thickness approaching that found in the adult, the sub-epidermal layer still persisted over the scales of both the ventral and the dorsal regions, though in the latter the epidermis showed a perceptible decrease in thickness.

I am therefore led to the conclusion that, as maintained by Klaatsch, the outer scale layer, called enamel by L. Agassiz, Reissner, and Hertwig, is secreted, not by the epidermis, but by cells of dermal origin. Hence it is not enamel in the modern sense of the term, but may better be known by the name of ganoin, the term introduced by Williamson and recently revived by Klaatsch.

The great difference in physical properties between this ganoin and the underlying layers of the scale, and the striking resemblance which it bears to the enamel of the scales of Selachians and of the teeth of lower vertebrates, have suggested that the secretion of the epidermal cells may have made its way through the very thin layer of dermal tissue separating the epidermis from the scale. If this were so, the thin layer of sub-epidermal tissue with its rich blood supply would have to be regarded merely as a device for providing an adequate supply of nourishment to the epidermis during its work of secretion, — a device not necessary in the case of the selachian spines by reason of the small size of the secreting area, nor in the mammalian tooth, because of the sunken position of the enamel organ in the gum. This theory would also account for the absence of prismatic structure in the layer.

The condition of the cells of the basal layer of the epidermis, however, makes this hypothesis untenable. There is nothing in their form or appearance to give any ground for comparing them with the cells active in secreting the enamel cap upon the points of the spines in Lepidosteus, or with the cells which in the Selachians secrete the enamel which coats the scales. They are not more elongated than in early stages when the scale is just beginning to form; their nuclei are not larger, nor do they show any difference in staining quality; in short, it is impossible to look upon them as an enamel organ. (Compare Figure 10 with Figures 16, 22, and 23.)

We are thus compelled to admit that the dermal scleroblasts give rise to three different products: (1) calcareous scale material with animal matrix and included scleroblasts; (2) ganoin; and (3) a membrane which Hertwig has called enamel membrane, but which may better be known henceforth as ganoin membrane.

This membrane is clearly visible in all sections of tissue from which the ganoin has been dissolved away (Plate II. Fig. 16). It is a structure which is entirely distinct from the basement membrane with which it was confounded by Hertwig, and in sections appears thicker and more prominent than the basement membrane (Figs. 16, 22, and 23).

It appears that we have to do here not with a differentiation of the cells of one layer, but rather with a modification of the function of the same cells at different periods in their history. The only case at all comparable to it with which I am acquainted is that of cartilage cells, which in the formation of endochondral bone become transformed into osteoblasts; i. e. the character of the secretion of the same cells is different in the different periods of their activity, and hence to that extent the two cases are similar.

In young scales in which the ganoin layer is still thin it forms an even coat, and the striation visible in it is parallel to the surface. In sections of older scales there are, near the edges, a series of notches in the lower surface of the ganoin which conform to inequalities of the upper surface of the underlying bony layers (Plate II. Fig. 16). Similar conditions have already been described and figured by Williamson and others. Figures 15 and 16 (Plate II.) show that each notch marks the point which was once the edge of the ganoin layer, and that the formation of ganoin on one side of this point (right, Fig. 16) and of bony material on the other must have gone on for some time without any lateral extension of the ganoin taking place. It is also evident that extensions of this layer equivalent in amount to the distance between successive notches must have taken place periodically, not by continuous growth. The cause of such periodicity I have no means for determining.

The fine striations (lamellation) in the ganoin which have already been mentioned have directions in this part of the layer slightly different from those in the region farther from the margin of the scale. Instead of being parallel with the upper surface, they are conformable to the earlier surfaces of the layer, and so have a dip downward toward the underlying bony material as they approach the edge of the scale. They also gradually diminish in thickness toward the central area of the scale, showing that the process of secretion went on less rapidly there than it did nearer the margin of the scale.

The "tubes lepidines" of Williamson are clearly visible in ground sections, though not present in cut sections of decalcified scales. They are due to the presence of uncalcified connective-tissue fibres, as has been stated by Klaatsch. These fibres in drying shrink, and so leave minute spaces about them which the balsam does not enter (*tbl. lpd.*, Plate II. Fig. 15, and Plate III. Fig. 21). The course of these "tubes" is very characteristic, and is shown in Figure 15. They are absent in the part of the scale immediately beneath the ganoin layer; they begin in that part which was first formed, and from here they radiate, — the directions being downward in the middle of the scale and diagonally downward and outward near either end of the section.

Klaatsch says concerning them (p. 129): "Untersucht man eine Schuppe des jungen Lepidosteus in getrocknetem Zustande, nach Isolation mit verdünnter Kalilauge, so findet man in ihr sehr zahlreiche zu ihrer Oberfläche parallel verlaufende Röhrchen. Dasselbe gilt von den senkrecht aufsteigenden Faserbündeln. Die Röhrchen, welche sie in getrochnetem Zustande hinterlassen, sind von Williamson bei der erwachsenen Schuppe als 'tubes lepidines' bezeichnet worden."

As may be seen in Figure 15 (Plate II.), the greater number of these "tubes" have an oblique direction; none are exactly parallel to the surface, though the ones near the ends of the section are nearly so, and only a small part are vertical. Thus it is evident that their courses are not the same as those of the fibres of dermis which has not undergone calcification, neither do they agree with Klaatsch's statement concerning them. It is also noticeable that they do not have the same direction as the dentinal tubules among which they lie, but that the two often cross at considerable angles. Klaatsch does not account for this, neither am I confident that I can explain the causes of the differences in direction to which I have called attention; but it would seem to be due to the odontoblast cells — in common with a part of the other scleroblasts — migrating before the advancing line of calcification in a direction perpendicular to the surface of the scale adjacent to them, such migration being however independent of the course of the fibres among which they lie.

I find that the small scales from the under side of the lower jaw agree with the description and figures of Hertwig ('79, pp. 2, 3, Taf. I. Figg. 1–5). They closely resemble the larger scales in all essential respects, differing from them chiefly in size and in having the form unmodified by the proximity of adjacent scales. They are composed of a basal bony plate, which is not destroyed by acid, of which the central part is covered by a layer of ganoin, soluble in acid, about which there remains a narrow marginal area not covered by the ganoin, but bearing one or a few spines. The number of the spines, upon which Hertwig laid emphasis, is, however, as has been stated concerning the larger scales, entirely indefinite, and can be of no morphological importance. The scales described by Hertwig as having one spine owe this condition doubtless to the others having been lost, not to the scale having been developed as the basal plate of that single spine, as is the case in the placoid scale. Such scales cannot therefore be considered as the complete homologues of the placoid scales of Selachians.

Mark ('90, p. 11) has described the act of swallowing in the young gar-pike; this process gives a satisfactory explanation for the feebly developed condition of the scales upon the under side of the lower jaw. He observed that in the act of deglutition the floor of the mouth became very much distended, so much so as to lead him to compare it to the pouch of a feeding pelican. The frequent distention to which this part of the skin is subjected by the greedy habits of the young fish furnishes a sufficient reason why continuous plates of hard bony material are not formed in this part of the dermis. The small size of the scales described by Hertwig ('79, p. 9) as lying at the bases of the fins is doubtless to be explained in a similar manner. Instead of being atavistic conditions, as maintained by him, they would appear to be due entirely to the action of purely mechanical influences.

I have already spoken of the canals which pierce the central part of the scale, and which have been called Haversian canals by Hertwig and Klaatsch. Their usual course is from below directly through the scale to the upper surface, where the vessels which traverse them spread out in all directions through the sub-epidermal layer. There are sometimes one or two vessels of considerable size which at the upper surface break up into small branches, but quite as often the canal is filled by a large number of minute vessels apparently distinct from one another. The course of these canals is not, however, by any means constant. I have found that sometimes, instead of running directly through, they extend for some distance inside the scale parallel with the surface. Indeed, in the scales of one fish (287 mm. long) the rule seemed to be for quite a number of canals to run horizontally through the scales for considerable distances. This condition seems to me to give an additional reason for regarding these canals as Haversian, or perhaps better — since the osteoblasts are not arranged in concentric lamellæ about them — as Volkmann's canals. Figures 28 and 29 (Plate IV.) are from sections of such scales. In the former figure the canal extends the greater part of the length of the scale and opens to the surface at five points, near those marked *for.*, as can be seen in other sections not figured.

The surface contour shows some quite marked peculiarities in several instances. Figure 30 (Plate IV.) represents a portion of a scale from the same fish as the one last mentioned (287 mm. long). The upper surface bears numerous rounded elevations or hillocks, upon which for the most part the spines are borne. The variations in shape and height are indicated in the figure. Frequently the canals pierce the scale just beneath these elevations and open to the upper surface at one side, as indicated by dotted lines. These slightly abnormal conditions seem to me to show that not only in histological structure, but also in surface contour and in the degree to which Haversian (or Volkmann's) canals are developed, Lepidosteus scales stand somewhat more nearly related to those of Polypterus than has been held to be the case.

The relation of the Ganoid scale as seen in Lepidosteus to those of other groups of fishes remains to be considered. If my conclusions with regard to this case be true, the idea that any Ganoids have enamel-covered scales will have to be discarded, for Polypterus scales are so nearly like those of Lepidosteus as to make a difference of origin extremely improbable, and no other fishes of this group have scales so closely resembling enamel in physical characters. What relation do the scales of Lepidosteus bear to those of Selachians? In the scales of these two forms there is much that is unlike. In the former the basal plate begins to be formed first, in the latter the spine is the part first to appear; in the former the spines are many upon each scale, and they are small and transient, in the latter there is only one to a scale and they are large and persistent. In the former the scale plate contains osteoblasts, Haversian canals, dentinal tubules, and three crossing systems of incorporated fibres; in the latter only dentinal tubules (not in all respects homologous with those of Lepidosteus) and in most cases a few ends of the vertical set of fibres, though in the more highly developed cases three sets of fibres are found.

There is however one respect in which the two agree quite closely. The spines are in all essential characteristics alike. Both have the tip covered by enamel secreted by the basal epidermis cells; both have the main part composed of calcareous secretion (dentine) of dermal cells lying within and occupying a central cavity. Both have a system of dendritic tubules extending from the cavity into the region of the tip, and both arise by the calcification of the outside of a dermal papilla. These must, then, be taken as the fundamentally homologous parts, and must serve as the basis for comparison.

In the Selachians the simple spine has remained as the typical structure, and only in the more highly developed cases (Mustelus lævis) has the basal plate been developed to the extent of incorporating in itself the fibrous dermis.

In the Ganoid scale two changes have taken place in the passage from the condition in Selachians: —

1. The basal plate has increased in size and in complexity of organization until it has become the essential structure; not only has it incorporated in itself the dermal fibres, but with them it has also taken

in the scleroblastic dermal cells to become osteoblasts, and in connection with this process it has developed a system of tubules for supplying them with nourishment. Moreover, instead of being formed simply as a continuation of the process by which the spine is produced, it has come to develop independently of the spine, for it is only in a late stage of its growth that the two become united. Thus the Ganoid scale plate seems to have arisen from the placoid basal plate by increase in size and with important modifications.

2. The spine, on the other hand, has become reduced in size and in complexity of structure, and is in Ganoids (Lepidosteus) only a rudimentary organ arising late and disappearing early, as is frequently the case with degenerate structures, the "wisdom teeth" of man being a familiar illustration of this.

Hertwig's view is that the scales of Lepidosteus have arisen by the fusion of numerous smaller basal plates of scales of the Selachian (placoid) type. Each spine upon a scale of Lepidosteus therefore represents a primitive placoid scale, and the whole Ganoid basal plate has arisen by the fusion of as many simple scales as the total number of spines formed upon its surface. Klaatsch objects to this interpretation, since the number of spines is so large and wholly indefinite, and because the spines lack such an orderly arrangement as that which the scales have in selachians.

My own view in regard to this matter is essentially the same as that expressed by the latter author. Though the Ganoid scale must be regarded as a more highly developed basal plate than that found in the Selachians, its origin is not due to the fusion of many small ones, but rather to the calcification which in Selachians originated in connection with the formation of placoid spines, having become in Lepidosteus an independent process no longer dependent upon the impulse given by the growth of the spine. The hereditary tendency toward the growth and calcification of papillæ still shows itself, however, in the formation of the small spines, though these are retarded in time and but feebly developed.

As long as each spine had a basal plate, as in Selachians, the spatial requirement of this plate exercised a controlling influence upon the number and the arrangement of the scales (= spines). When now, as in Lepidosteus, the spines have come to arise independently of the underlying plate, such restraint is removed, and we consequently find an increase in the number of the spines and a lack of regularity in their arrangement.

Upon the development of the scales of Teleosts I have made no observations, but employ for comparison with the process in Lepidosteus the accounts given by Klaatsch and Hofer.

In the earliest stages of development a similar modification of the dermis takes place in both cases, giving rise to local thickenings of this layer within which the scale begins to be formed as previously described. These I hold to be homologous structures, but not the homologues of the dermal spine papillæ of Selachians.

The resulting bony plates formed in the two cases are homologous but that of Lepidosteus attains to a much higher degree of development than the one formed in Teleosts. The part to be formed first in the Teleost scale is, as in Lepidosteus, the outer more homogeneous part, but in many cases it differs from the corresponding part of the scale of Lepidosteus in the absence of enclosed osteoblasts. That these are present in some species and absent in others which are very near relatives shows that this difference cannot be of any great morphological importance. Whether they have been secondarily acquired in one case or secondarily lost in the other need not concern us here. Their absence in some cases cannot prevent the layer being considered the homologue of the corresponding layer in Lepidosteus.

The deeper fibrous part of the Teleost scale is the later formation, and in this respect, as well as in general structure and method of development, agrees with the deeper part of the scale of Lepidosteus.

The outer layer of the Lepidosteus scale, the ganoin, which is the part latest formed, is absent in the scales of Teleosts. It is a layer which has been developed within the order of Ganoids, and is not found in any other group of vertebrates.

Throughout the series of scale structures beginning with the Selachian type there has been a constant tendency toward reduction of superficial parts (spines) and increase of the deeper parts which are independent of the epidermis. In Selachians the process of scale formation begins at the surface of the dermis just beneath the basement membrane. In Ganoids there is the same process repeated at the base of the epidermis, but in a much less vigorous manner, while the principal activity is deeper-seated, in the midst of the dermis. In the higher Teleosts the whole scale growth is within the dermis, and the more superficial process is entirely lost.

Thus I believe that the basal plate of the scale of Lepidosteus and the Teleost scale have both been derived from the basal plate of the placoid scale, and have for the most part been modified along the same lines.

That the general course has been the same in both cases is shown by the fact that a broad flat bony plate composed of two layers, an outer more homogeneous and a deeper fibrous one, has resulted in both cases, that these have developed ontogenetically in a very similar manner, and have come to overlap one another in similar diagonal rows. This has, in both cases, involved the reduction of the spines, which in some of the lower Teleosts (e. g. Siluroids) and in Lepidosteus are present in a degenerate condition, but are absent in the greater part of the Teleosts. That in some of the lower Teleosts (e. g. Hypostoma) they do not fuse with the basal plate, but are joined to it by connective-tissue fibres only, may be considered an evidence that degeneration has here gone a step farther than in Lepidosteus.

Klaatsch's idea that the upper layer (Hyalodentin) of the Teleost scale is homologous with the ganoin layer cannot be true, for the two develop quite differently and their physical and chemical properties are very unlike. If, as I believe, Klaatsch did not see the true ganoin in Lepidosteus, but mistook for it the outer part of the bony scale below, his conclusion in regard to the homology of this layer is in perfect accord with that which I have expressed.

If my conclusions concerning the origin and nature of the outer layer (ganoin) of the scales of Lepidosteus is correct, it will follow that no very close and direct relationship can exist between these scales and teeth. Their only relationship is such as arises from the fact that they are both derived from an ancestral condition similar to that found in the scales of Selachians. This primitive condition has been modified by changes leading in opposite directions. In the mouth, the spines have been developed to form the teeth ; on the surface of the body, the basal plate has given rise to the scales. Thus each represents at present only a highly modified part of the early ancestral prototype.

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EXPLANATION OF PLATES.

All figures were drawn with the aid of an Abbé camera lucida, from specimens of Lepidosteus osseus, L.

ABBREVIATIONS.

ba. spi.	Base of spine.
can	Canal.
chr'ph.	Chromatophore.
drm f'br.	Fibrous portion of dermis.
drm. spng.	Spongy " "
fac.	Surface.
fac. e'drm.	Surface of ectoderm.
for.	Foramen.
gan.	Ganoin.
gln.[1]	Gland, first kind.
gln.[2]	Gland, second kind.
mb. ba.	Basement membrane.
mb. gan.	Ganoin membrane.
nl.	Nucleus.
od'bl.	Odontoblast.
pap. spi.	Spine papilla.
pig.	Pigment.
sc.	Scale.
scl'bl.	Scleroblast.
spi.	Spine.
tbl. de.	Dentinal tubule.
tbl. lpd.	" Lepidine tubule."
vs. sng.	Blood-vessel.

PLATE I.

Fig. 1 Longitudinal section of skin of young gar-pike, 145 mm. long × 140.

" 2. Mucin gland cells of ectoderm ; *a–d*, stained with Kleinenberg's hæmatoxylin ; *e*, stained with Boehmer's alum hæmatoxylin , *a–d* represent successively younger stages. × 500.

" 3. Longitudinal section through posterior end of very young scale from fish 150 mm. long. × 262.

" 4 Optical section of ectoderm, parallel with surface ; from tissue stripped off from surface of scales of fish 300 mm. long, after decalcifying the chromatophores lie at a deeper level than the gland spaces, and therefore appear at different focus × 110.

" 5 Section from fish 150 mm. long, showing two stages in the formation of spine papillæ; the section is not quite parallel to axis of larger papilla. × 370.

" 6. A part of the section next to that represented in Figure 5, showing summit of larger spine papilla and its peculiar shaped secreted tip *x* is line in which the farther plane of the section cuts the basement membrane. × 370.

" 7. A longitudinal section through a spine to show the canal connecting its central cavity with the exterior. × 100.

" 8. Odontoblast with its process extending into dentinal tubule. From lower surface of scale of fish 460 mm. long. × 500.

" 9. Another odontoblast, having two nuclei. Conditions as in Figure 8.

NICKERSON — SCALE OF LEPIDOSTEUS. PL. I.

W. B. N. del. B. Meisel lith. Boston

PLATE II.

Fig. 10. Section through the axis of a spine papilla in which secretion has begun. From fish 150 mm. long. × 387.

" 11. Optical section of spine broken off from scale of a young Lepidosteus 300 mm. long. × 387.

" 12. Tip of spine loosened by use of caustic potash, *a*, before treating with hydrochloric acid; *b*, after applying acid. × 137.

" 13. Section through posterior edge of a scale from a fish 300 mm. long (52 months old), showing portions of imbedded bases of four spines. × 200.

" 14. Base of a lost (resorbed ?) spine, which had been surrounded by ganoin before the latter was destroyed by decalcification. From fish 460 mm. long. × 198.

" 15. Section (prepared by grinding) through scale of fish 300 mm. long, from S P Bartlett. × 31

" 16. Section through posterior margin of decalcified scale from fish 300 mm. long. × 198.

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16.

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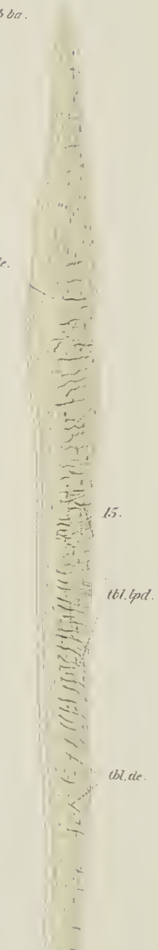

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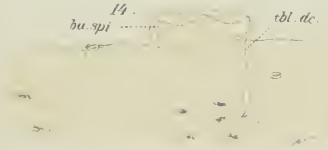

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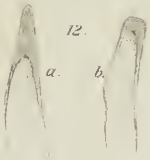

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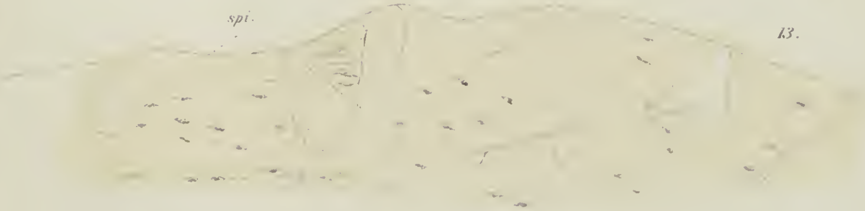

W S N del
B Meisel lith Boston

PLATE III.

Fig. 17. Section through axis of a spine showing the difference in appearance between the superficial bony layers of the scale and those lying deeper. From fish 190 mm. long. × 370.

" 18. An abnormally shaped spine tip. × 370.

" 19. Fibrillar appearance of the under surface of a scale from a fish 287 mm. long, after treatment with caustic potash. × 275.

" 20. Section through anterior edge of a scale from a fish 190 mm. long; showing fibres of connective tissue in the scale. × 275.

" 21. Portion of ground section of scale of fish 300 mm. long. × 152.

" 22. Portion of section of scale and overlying tissue from a fish 460 mm. long. × 198. In a ground section of an immediately adjacent scale the ganoin layer on the corresponding part was 12–15 μ thick. Both in this and the succeeding figure (Plate IV. Fig. 23) an odontoblast is shown lying upon the upper surface of the scale and sending its process down through the ganoin layer in a dentinal tubule.

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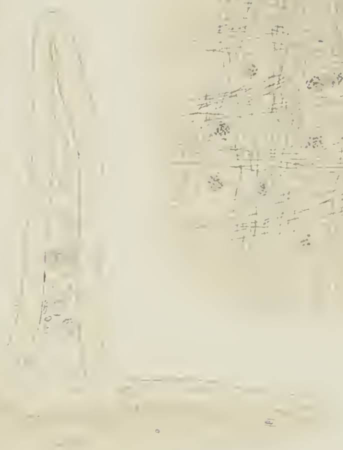

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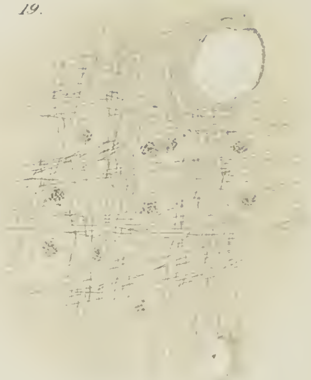

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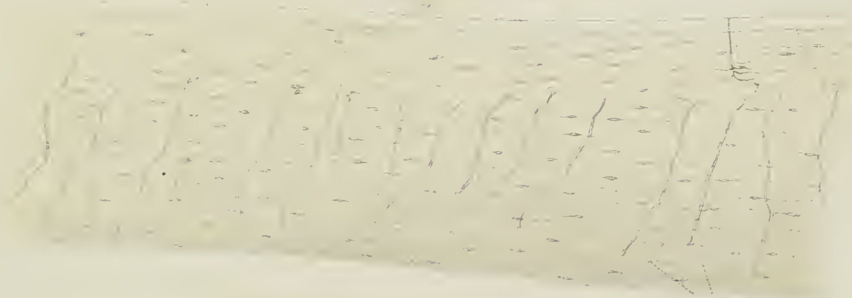

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PLATE IV.

Fig. 23. Portion of section of scale and overlying tissue from a fish 460 mm. long. × 362. See description of Figure 22, Plate III.

" 24. Base of spine beginning to be imbedded in the outer layers of the scale. From fish 190 mm. long. × 370.

" 25. An oblique section through the base of a spine partly imbedded in the scale. From a fish 300 mm. long. × 387.

" 26. Section through a spine having an abnormally shaped tip. × 105.

" 27. Surface view of posterior extremity of a scale freed from soft tissues by treatment with caustic potash, showing loosened cap on point of spine. × 75.

" 28. Longitudinal section through a scale of a fish 190 mm. long. × 44.

" 29. Longitudinal section through a scale of a fish 287 mm. long. × 25.

" 30. A representation of a portion of the surface of a scale of a fish 287 mm. long. The dotted lines show the positions of Haversian (or Volkmann's) canals beneath the surface. × 31.

" 31. Outlines of several scales of a fish 300 mm. long. The dots indicate the positions of the spines on four scales. × 6½.

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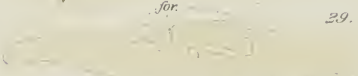

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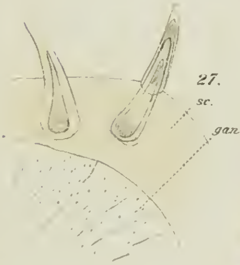

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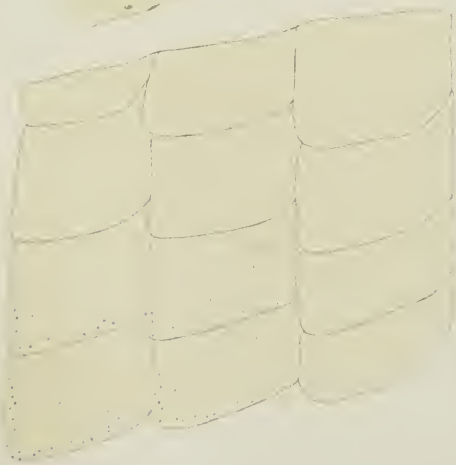

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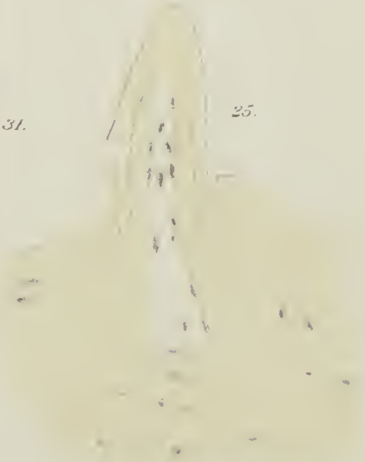

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No. 6. — *Studies in Morphogenesis.* — I. *On the Development of the Cerata in Æolis.* By C. B. Davenport.[1]

While at Mr. Agassiz's Newport Laboratory last summer, I collected, early in August, some specimens of Æolis[2] which occurred abundantly on the Hydroids. The individuals varied greatly in size, and, since Nudibranch eggs had been abundant on the same Hydroids earlier in the season, I regarded most of them as immature.

I was particularly struck by the regularity with which the cerata, or dorsal papillæ, were distributed over the surface of the body, and the constancy in position of young cerata in relation to the older ones.

Figures 1 and 2 are drawings of two individuals showing the arrangement of the cerata. They are placed in transverse rows, which are not equidistant, however, but grouped in twos or threes. In each transverse row the largest ceras lies dorsalmost, the smaller more ventral, the youngest of all being often indicated by only a slight protuberance at the base of and ventral to the next older. The regularity of the process of budding of new cerata induced me to make sections to determine its details.

The cerata of Æolis contain, as is well known, processes of the alimentary tract, — the so called hepatic cœca (Plate II. Fig. 12). They are covered externally by the ectodermal epithelium. Between ectoderm and hepatic cœcum are mesodermal cells, which lie (1) in a thin layer at the inner surface of the ectoderm, (2) in a thin layer over the cœcum, and (3) between these two layers, surrounding blood spaces or loosely distributed.

The cœcum of each ceras connects at the base with a lateral diverticulum of the alimentary tract, — gastric diverticulum, — with which also the cœca of all of the other cerata of the same transverse row unite (Plate I. Fig. 3, *ga. dv.*). There are as many of these gastric diverticula as there are transverse rows of cerata (Fig. 4, *ga. dv.*).

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

[2] Owing to the immaturity of the individuals, I was unable to determine the species accurately. Figures 1 and 2, however, show the external form of the species (one or two) employed.

Distal to the cœcum, at the apex of the ceras, lies a sac which in the adult opens to the exterior and is connected at its proximal end with the cœcum in such a manner that the walls of the two organs are continuous, and their cavities confluent through a communicating canal. The existence of this communicating canal, although in past times called in doubt, has recently been correctly reaffirmed by Herdman ('90, p. 52). The walls of the sac are composed of almost completely vacuolated cells, which contain nettling organs or nematocysts. Since the cells of such sacs contain nematocysts, the sacs are called nematophores or cnidophores. Cnidophores are characteristic of the Æolidæ. Figure 13 represents a cross section through a cnidophore, showing the vacuolated cells and the nematocysts therein (*nt'cy.*).

The first indication of the formation of a new ceras is a thickening of the mesenchyme at the base of a young ceras and upon its ventral aspect (Plate I. Fig. 5, *ms'chy.*'). At a slightly later stage (Fig. 6) the mesenchyme has become greatly thickened, and a protuberance of the ectoderm has occurred. Karyokinetic figures indicate that the mesenchymatous mass is growing by cell proliferation. The growing mesenchymatous cells, as well as the adjacent cells of the gastric diverticulum, stain more deeply than those of other regions.

At a slightly later stage (Fig. 7, III.) the wall of the gastric diverticulum (*ga. dv.*) has begun to protrude into the thickened mesenchyme, and the ectoderm is sharply evaginated. Still later (Fig. 8, IV.) these features become more pronounced. The mesenchymatous cells become arranged into three or four layers, of which one is closely applied to the ectoderm, and another to the hepatic cœcum.

It is important to note, (1) that the ectoderm of the new ceras lies, at at an early stage, in the angle made by the body wall with the ventral wall of the next older ceras; (2) that the mesenchyme is directly continuous with that of the ceras, and is in fact transitional from the mesoderm of the trunk to that of the ceras; and (3) that the budding entoderm lies at the distal extremity of the gastric diverticulum, that is to say, at the angle made by the gastric diverticulum, and the last ceras arisen therefrom (Fig. 3, *cer.* 3). The mother cells of each of the three layers of the incipient ceras thus lie in the outer margin of the region whence the corresponding layer of the last formed ceras has arisen. With the development of the ceras it gradually becomes farther removed from the next older one (Fig. 3).

The next stage figured (Plate II. Fig. 9) shows a ceras whose length is slightly greater than its diameter at the base. The mesoderm is greatly flattened, and the entodermic wall of the cœcum is composed of cuboidal deeply stainable cells. At a stage at which the length of the ceras is less than twice its greatest diameter (Fig. 10), a circular fold occurs in the distal third of the cœcum, constricting the lumen. The cells of the distal compartment stain deeply, like those of the hepatic cœcum of the preceding stage. They do not at all resemble the unstained cells of the ectoderm.

At a stage only very slightly older than the preceding (Fig. 11), one finds the cells of the distal sac partly vacuolated and containing nematocysts. This distal sac can be traced forward into the oldest stages, and it becomes the cnidophore. Its lumen constantly retains its connection with that of the hepatic cœcum through the communicating canal. A communication with the outside world at the apex of the ceras is established only at a later stage by a close approximation of the cnidophore to the apex of the ceras and a disintegration of the apical ectodermal cells.

Herdman asserts in two or three places ('90, p. 52, and Herdman and Clubb, '89, p. 233, '92, p. 552), that the cnidophores arise by an invagination of the ectoderm on the apex of the ceras; but although in his last paper he says he has "shown" it in the earlier ones, I fail to find that he has offered the slightest evidence for his statement. It seemed indeed *a priori* more probable — from what we know of the origin of protective organs, and especially of the origin of nematocysts in the Cnidaria — that the cells of the cnidophore had an ectodermal origin. But they have not. This is the conclusion to which I am forced by the following considerations. (1.) The development just outlined, which has been traced in a series so complete as to leave little chance for misinterpretation. (2.) The absence of an external opening until quite a late stage. Since the axis of the cnidophore does not in later stages coincide with that of the ceras, and since it is not easy to obtain sections which pass through the entire axis of the ceras, especial care must be exercised in determining the absence or presence of an apical opening. Figure 12 is a strictly axial section. The apical ectodermal cell shows signs of degeneration, and its outer surface is sunken in. (3.) The presence of nematocysts in those cells also which lie in the hepatic cœcum *proximal* to the constriction, and for which no one has maintained a derivation from an invagination of the apical ectoderm.

The cells of the hepatic cœcum, especially at a late stage, show large numbers of nematocysts of the two kinds mentioned by Herdman ('90). Cf. Figures 14 and 15. That these nematocysts have been developed *in situ*, and have not migrated from the cnidophore through the communicating canal and become incorporated into the "hepatic" cells, is indicated by the fact that they are found in different stages of development (Fig. 14, *nt'cy.'*). One finds first of all small ovoid areas, which stain deeply; later, one finds an elongated deeply staining central streak, while the rest of the vesicle remains colorless. This central streak is the proximal part of the thread. In some cases I have seen in the "hepatic" cells the larger kind of nematocyst mentioned by Alder and Hancock ('55, Expl. Fam. 3, Plates 7 and 8, Fig. 16); in fact, they seem to occur quite as abundantly here as in the cnidophore.

Comparing the origin of nematocysts in the Æolidæ and Hydra, — for a knowledge of which in the latter group we are indebted among others to K. C. Schneider ('90, pp. 332, 345), — the most striking difference is that the nettle capsules in Hydra arise in the ectoderm only (so it is maintained), and that those which do occur in the entoderm have not been formed there, but have been devoured. In Æolis, similar capsules arise in diverticula of the alimentary tract, and therefore from entoderm. Secondly, the nettling capsules of Hydra are formed in indifferent cells lying at the base of the ectoderm; in Æolis they are produced in the large "hepatic" cells. Finally, in Hydra only one nematocyst is formed in a single cell, and this comes to occupy nearly the whole of it; in Æolis several nematocysts (Figs. 13, 14) are produced in a single cell.

This comparison raises the question whether the so called hepatic cœcum is properly named, — whether its cells have either the function of storing up reserve stuff or of secreting digestive fluids. To this question I can give no final answer, but it is worthy of note that the "hepatic" cells of Æolis do contain numerous small granules which stain deeply in hæmatoxylin. This is true even for the cells which produce nematocysts (Figs. 14, 15). A comparison with sections of the hepatic cœca of Doto coronata treated in the same way shows, however, that the "hepatic" cells of Æolis are smaller and contain smaller granules than do those of Doto, in which genus, of course, no nettling organs are formed. From their smaller size, and the smaller size of the contained granules (whether these are stored food stuff or katabolic product), I am inclined to regard the hepatic function of the cells forming the wall of the cœcum of Æolis as less important than in Doto.

The sum total of the nematocysts in the hepatic cœcum of any ceras is much greater than in the cnidophore. On physiological grounds the latter term is in Æolis applicable to the entire cœcum, and not merely to its distal part.

After having found that the cerata arose in close connection with preceding ones of the same transverse rows, and therefore ultimately in close connection with the first or dorsalmost ceras of each row, it seemed desirable to determine the origin of the dorsalmost longitudinal series of cerata, and of the origin of new transverse rows. Sagittal, or slightly inclined longitudinal, and also frontal sections of young specimens gave the desired information. Figure 16 represents a longitudinal section which is not strictly sagittal, the upper edge of the section plane having been tilted about 30° towards the right so as to pass at the same time through the alimentary tract and the dorsal series of cerata, — the only series as yet developed on that side. From the drawing it is clear that the alimentary tract sends off diverticula, which pass directly into the first cerata of each transverse row. Behind the most posterior ceras the mesenchyme is thickened over the alimentary tract, which runs to the posterior end of the body. In a section a little removed from this (Fig. 17, II.), one sees the beginning of another papilla behind number III. of the series represented, — the foundation of another transverse row. The ectoderm has already begun to fold upwards, and the alimentary tract sends out a prominent pocket.

Of very great importance is the fact that just behind the Anlage of the ceras the testis is arising, so that the mesenchyme which seems to take the initiative in the formation of the ceras gives rise also to the sexual cells. Moreover, the two cell masses arise close together, and indeed in a definite relation to each other. As is clear from an inspection of Figure 16, the sexual glands — ovary and testis — lie between the transverse planes occupied by the cerata, and in each mass the ovary lies in front of the testis, so that successive transverse sections cut from the head backwards pass in order through a transverse row of cerata, through an ovarian mass, and through a testicular mass. This succession is, however, not that in which the Anlagen of the three organs have been established out of the mesenchyme of the tail end; for, as Figure 17 indicates, new sexual cells arise before the ceras which lies in front of them begins to appear.

The oblique (nearly frontal) section, Figure 18, shows the same relation of the sexual glands and the cerata. A reconstruction of the series shows that diverticula arise from the parts of the alimentary tract indicated by the designations *cer.* I., II., III., and IV. These diverticula correspond in position to transverse rows of cerata. The same reconstruction shows that between these diverticula ovary and testis follow in the way just described. At the extreme tail end the section passes obliquely through the glands of the foot, then through the mass of indifferent mesenchyme which lies under the dorsal ectoderm at *. Just in front (IV. ♂) sexual cells are being cut off from the mesenchyme as a paired mass whose two lobes are united in the median plane.

I have above assumed, somewhat gratuitously, that the mesenchyme takes the initiative in ceras production. The evidence for this lies in two facts. (1.) The first indication of the formation of the new ceras is seen in the thickening of the mesenchyme at the base of the next older ceras (Fig. 5). It is not until after a solid mass of mesenchymatous cells is produced that the ectoderm begins to evaginate, almost as though pressed outwards (Fig. 6). The alimentary diverticulum is produced still later (Fig. 7). (2.) That the cœcum does not take the initiative is indicated by the fact that I have found young cerata composed only of ectoderm and a thickened mesenchymatous core, the entoderm not having yet penetrated into it.

The capacity possessed by Nudibranchs of regenerating the cerata is well known. I have not experimented with them, and have no sections of stages in the process. The known phenomena of regeneration in other cases makes it probable that the capacity for regeneration depends upon the existence of embryonic tissue. We should therefore expect to find thickened, embryonic mesenchyme lying at the base of the dorsal papillæ. As a matter of fact we do find it, as is shown in Figure 16 at the base of cerata II. and III. (*). The mesenchyme at the base and in front of ceras I. was torn away in sectioning; in adjacent sections the basal mesenchyme appears thickened here also.

The foregoing study of the development of the cerata of Æolis points emphatically to one conclusion, namely, the embryonic or growth tissue of Æolis is in its origin identical with that producing sexual cells. Like the latter, it is germ tissue; it differs from the sexual cells chiefly in this, that it gives rise to growths constituting part of the body of the present individual, — growths which are as mortal as any other part of the present individual; whereas the sexual cells play no part in the production of the present individual, but eventually give rise to a new individual and its germ tissue. It differs, secondly, from the sexual cells in this, that it gives rise to one kind of organ only, — the mesenchyme to the mesenchyme of the buds, the entodermal diverticulum to the entoderm of the buds.

The mesenchymatous growth tissue of Æolis resembles the sexual cells, however, in this, that while it goes to produce the mesenchyme of any ceras, *a*, not all of it is used up in forming the mesenchyme of ceras *a*, but some of it remains behind to form a new ceras, *b*, and the Anlagen of other new cerata. Thus, as in any young individual we may distinguish between the differentiated tissue and the germ tissue from which new individuals will arise, so in any ceras we may distinguish between the differentiated tissue and the embryonic tissue from which new cerata will arise.

While, however, the sexual cells have the capacity of reproducing new individuals indefinitely, the mesenchyme at the base of the cerata does, as a matter of fact, produce only a limited number of cerata. Of this limitation there are, however, all degrees. In some cases, as in Doto, only one ceras is produced in a transverse row; in some species of Æolis, on the other hand, young cerata are produced, even in adult individuals, at the ventral end of the long transverse rows, so that here the growth is apparently limited only by the duration of life of the individual. In all cases the limitation in the reproduction of cerata must be considered as resulting, not from the limited capacity of reproduction of the embryonic tissue, but from the needs of the species.

CAMBRIDGE, December 20, 1892.

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PLATE I.

ABBREVIATIONS.

an.	Anus.	*ga.*	Stomach.
can. comn.	Communicating canal.	*ga.′*	Prolongation of stomach backwards.
cer. 1, 2, *etc.*	Cerata of the same transverse series.	*ga dv.*	Gastric diverticulum at base of transverse rows of cerata.
cn'ph.	Cnidophore.	*ms'chy.′*	Mesenchyme of developing ceras.
cœ.	Hepatic cœcum.	*œ.*	Œsophagus.
cœ.′	Forming hepatic cœcum.	*pd.*	Foot
epl.	Capillary vessel.	*rt.*	Rectum.
ec'drm.	Ectoderm.		
ec'drm.′	Ectoderm of young ceras.		
en'drm.′	Entoderm of young ceras.		

Figs. 1, 2. Two figures of young individuals of Æolis sp., showing arrangement of cerata in transverse rows, which are numbered with Roman numerals. × 5.

“ 3. Transverse section of a young Æolis showing the stomach, the gastric diverticulum, and hepatic cœca of a transverse row of cerata. × 45.

“ 4 Outline of alimentary tract of Æolis, copied from Alder and Hancock, showing gastric diverticula and points of connection of hepatic cœca.

“ 5–8. Four vertical sections through different stages in the development of the cerata.

“ 5. First stage in formation of ceras. Mesenchyme thickened at *ms'chy.* Right side. × 405.

“ 6. Second stage in formation of ceras. Mesenchyme thickened still further. Ectoderm beginning to evaginate in the axis. Left side. × 405.

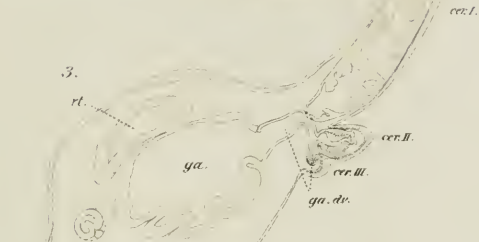
“ 7. Third stage in formation of ceras. Gastric diverticulum beginning to outfold to form hepatic cœcum of new ceras. Left side. × 228.

“ 8 Fourth stage in formation of ceras. Right side. × 228.

1.

2.

3.



4.

5.

6.

7.

8.

C. B. D. del.

PLATE II.

ABBREVIATIONS.

can. comm.	Communicating canal.
cer. I., II., *etc.*	Cerata of I., II., etc. transverse rows.
cn'ph.	Cnidophore.
cœ.	Cœcum.
ec'drm.	Ectoderm.
ga.	Stomach.
ga.'	Posterior prolongation of stomach.
ga. dv.	Gastric diverticulum.
gl. nid.	Nidamental gland.
gl. pd.	Foot gland.
gn.	Ganglion (cerebral).
mo. buc.	Buccal mass.
ms'drm.	Mesoderm.
ms'drm.'	Mesoderm lining body wall.
ms'drm.''	Mesoderm lining hepatic cœcum.
nt'cy.	Nematocyst, smaller kind.
nt'cy.'	Developing nematocyst.
nt'cy.''	Nematocyst, larger kind.
pd.	Foot.
pe. ves	Penis sac.
rad.	Radula.
rhn.	Rhinophore.
rt.	Rectum.
te.	Testis.
ur.	Ureter.
I., II., III., ♀, ♂.	Lobes of ovary and testis.

Figs. 9–11. Three stages in the development of the cerata. Vertical sections × 120.

" 12. Longitudinal section of ceras just before formation of external opening of cnidophore. × 120.

" 13. Transverse section of adult cnidophore, showing nematocysts. × 405.

" 14. Bit of transverse section of hepatic cœcum, showing fully formed and developing nematocysts in hepatic cells. × 405.

" 15. Bit of transverse section of hepatic cœcum, showing large nematophore. × 405.

" 16. Longitudinal section of young Æolis, inclined about 30° from vertical, passing through axis of alimentary tract and first ceras of three transverse rows. × 76.

" 17. Enlarged view of the posterior of the two regions marked by asterisks in Figure 16, but from a section adjacent to Figure 16, showing parietal mesoderm, some of which is about to form that of the youngest transverse row, and some to give rise to sexual cells, *te.* × 318

" 18. Longitudinal section of young Æolis. Oblique in front, nearly frontal behind. Showing repetition of sexual organs and their relation to transverse rows of cerata. × 76.

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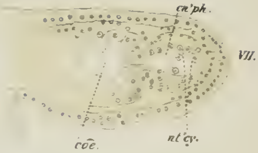
10.

11.



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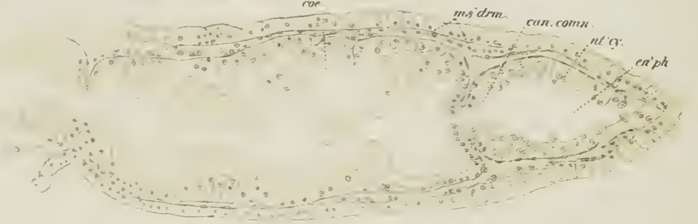

14.

18.

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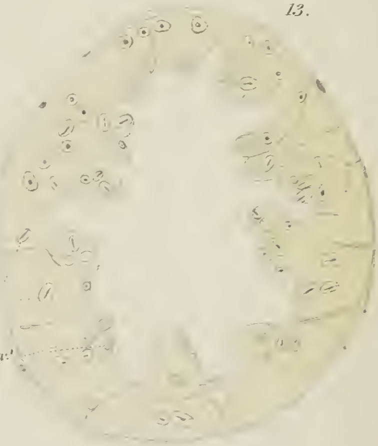

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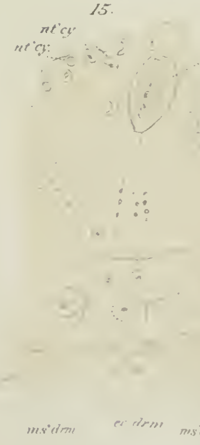
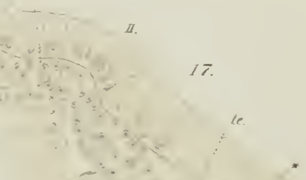
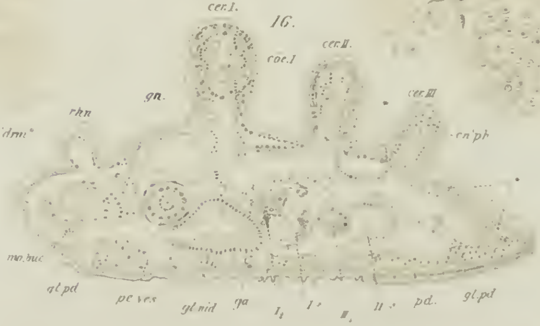


17.



16.



No. 7. — *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.

[Published by permission of Marshall McDonald, U. S. Fish Commissioner.]

VI.

Preliminary Descriptions of New Species of Crustacea.[1] By WALTER FAXON.

ORDER PODOPHTHALMIA.

SUBORDER DECAPODA.

Family MAIIDÆ.

Euprognatha granulata, sp. nov.

Carapace coarsely granulate ; two erect blunt spines in median line of carapace, one on the gastric, the other on the cardiac area ; a transverse row of four or five small tubercles in front of the gastric spine ; a spine near the middle of each branchial area, with a smaller lateral spine below and a little in advance of it ; the hepatic area bears a short blunt spine on its most prominent part ; there are, besides, three or four prominent tubercles on the angle which divides the hepatic and pterygostomian regions. The antennary spine is very long, reaching beyond the rostral horns ; the three horns of the rostrum (interantennulary and lateral) are about equal in length ; the supra-orbital spines are well developed, and, like the antennary and three rostral spines, are conspicu-

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[1] Figures of all the species described in this paper will appear in the final report, whose publication is deferred pending the preparation of the lithographic plates. A record of the stations occupied by the "Albatross" during her cruise of 1891 will be found in Bull. Mus. Comp. Zoöl., Vol. XXIII. No. 1, pp. 4–8.

ously granulated. The post-orbital spines are even more coarsely tuberculated. When viewed from above their margins appear laciniated. Surface of abdomen thickly set with bead-like tubercles; the first segment bears a prominent granulated spine, and there is a rudimentary spine on each of the three following segments. Chela slender, covered with small tubercles; the remaining segments of the cheliped and the ambulatory appendages are furnished with small spines, tubercles, and scattered curled setæ.

Length of carapace, 7 mm.; breadth, 6 mm.

Station 3369. 52 fathoms. 2 females.

Anamathia occidentalis, sp. nov.

Carapace pyriform, furnished with spines and tubercles which are arranged as follows: four on the gastric region (two in the median line, two lateral); the posterior median has the form of a tubercle, from which a low blunt keel runs back to the cardiac region; one on the cardiac region, one (tubercle) on the intestinal region, one on each hepatic region, five on each branchial region. Of the branchial spines the one near the middle projects upward and forward, the longest spine of the carapace, one half as long as the rostral horns. In addition to these spines and tubercles there are four or five small tubercles on the outer border of the pterygostomian region. Rostrum produced into two divergent awl-shaped horns, which are more than one fourth the length of the carapace. Pre-orbital spines acute, post-orbital processes obtuse. Chelipeds twice as long as the carapace, not much more robust than the ambulatory limbs; chela little longer than the merus, the basal part cylindrical, distal part gradually widening to the base of the fingers; fingers smooth, slightly curved, less than one half as long as the basal portion; prehensile edges regularly dentate, closing throughout their length. The merus of all the legs has a small tubercular projection at the distal end above, most prominent on the anterior pair. The carpus of the chelipeds has two low ridges on the outer face. Abdomen seven-jointed.

Length of carapace without the rostral horns, 45 mm.; length of rostral horns, 12 mm.; breadth of carapace, 38 mm.

Station 3404. 385 fathoms. 1 male.

MAIOPSIS, gen. nov.

Carapace subtriangular, as broad as long, spinose; rostrum produced anteriorly into two divergent horns with an accessory spine upon their outer margins; interorbital space broad. Eyes small, eyestalks slender, retractile within the orbits. Orbits large, with a forward aspect, incomplete below, the upper margin prominent, with two deep fissures, and supra-ocular spines. Epistome short. Basal segment of antennæ very broad, with three prominent spines upon its anterior margin; flagellum of the antennæ widely separated from the cavity of the orbit by a broad process of the basal segment. Merus of outer maxillipeds notched at the antero-internal angle. Legs of moderate length; carpus of chelipeds elongated, not carinated; chela elongated and slender, fingers canaliculate within, but not spoon-shaped at their tips, their prehensile edges meeting throughout most of their length, not distinctly toothed; ambulatory legs spinose. Abdomen (male) seven-jointed, terminal joint short and broad.

This genus is proposed for the reception of an interesting Maioid dredged in 182 fathoms on the west coast of the Isthmus of Panama. It combines in one form characters of the genera *Maia*, *Cyclomaia*, *Paramithrax* (subg. *Leptomithrax*), and *Schizophrys*. In its general aspect it bears a close resemblance to *Maia*, and the likeness is enhanced by the small eyes and slender eyestalks, the elongated wrist and hand, and the short epistome. It differs from *Maia* in having a much broader carapace, a less deeply cloven rostrum, spinose legs, supra-ocular spines, and trenchantly in the exclusion of the antennal flagellum from the orbit by a process of the basal segment of the antenna. In the latter regard it agrees with the genus *Cyclomaia*, the basal segment of the antenna being very broad, three-spined on its distal border, and giving off a process which separates the flagellum from the orbit by a wide interval; it also agrees with *Cyclomaia* in having a short epistome, a short and broad terminal abdominal segment, and supra-ocular spines. It differs from *Cyclomaia* by having a subtriangular carapace, longer rostral spines, and a less abruptly declivous front. It is like *Paramithrax* and *Schizophrys* in the exclusion of the basal antennal segment from the orbit, but this segment is much broader than in these genera, and three-spined; moreover, *Maiopsis* differs from *Paramithrax* and *Schizophrys* in having a more broadly triangular carapace, supra-ocular spines, slenderer wrist and hand, less deeply cleft rostrum, and spinose ambulatory legs. Like *Schizophrys*, it has an accessory spine on each rostral horn. In the shape of the carapace *Maiopsis* is intermediate between *Maia* and *Cyclomaia*. In the form of the fingers it stands between *Maia* and *Paramithrax* on the one side, and *Schizophrys* and *Cyclomaia* on the other, as the fingers, though canaliculate within, are but slightly excavated at the tips. The synthetic character of the species upon which this genus is based suggests the propriety of ultimately extending the scope of the old genus *Paramithrax* so that it may embrace this form, together with *Cyclomaia* and *Schizophrys*.

Maiopsis panamensis, sp. nov.

Dorsal surface of carapace thickly set with spines of various sizes and scattered hooked setæ. The largest spines are distributed as follows: five on the gastric region, one on the genital, one on the cardiac, four on the intestinal, and about seven on each branchial region. Margin of carapace armed with twelve prominent spines, three of which are on the hepatic region. The sternum is ornamented with small tubercles along each side of the abdomen. The first abdominal segment is furnished with a bidentate tubercle. Legs covered with numerous spiny tubercles; the meri armed with three or more prominent spines at the distal end. Chela long and slender, the tubercles of the hand smaller than on the other parts of the legs; fingers nearly smooth. A deep pit at base of movable finger.

Length from base of rostrum to posterior margin of carapace, 112 mm.; breadth, 113.5 mm; length of rostrum, 22 mm.; length of rostral horns, 11 mm.; breadth between eyebrows, 38 mm.; length of cheliped, 156 mm.

Station 3355. 182 fathoms. 1 male.

Family PARTHENOPIDÆ.

Lambrus hassleri, sp. nov.

This is the Pacific coast representative of *Lambrus pourtalesii* Stimps. (*L. verrillii* Smith) of the east coast of North America. It differs from the latter species as follows: the carapace is broader in proportion to its length; the branchial regions are more expanded and inflated, the inflation extending farther in toward the cardiac area so as to involve the oblique row of small tubercles; that is to say, this row of tubercles, which in *L. pourtalesii* lies low down in the fossa between the branchial and cardiac regions, is raised up, in *L. hassleri*, on the swell of the branchial region. The spines on the edges of the chelipeds, moreover, are not laciniated to such a degree as in *L. pourtalesii*.

Length of a female specimen, 27 mm.; breadth, including lateral teeth, 38 mm.

Station 3368. 66 fathoms. 1 female.
" 3427. 80 " 1 male, 1 female.

This species was previously obtained during the voyage of the "Hassler" at Magdalena Bay, Lower California, August 14, 1872. The specimens then obtained were apparently picked up dead on the shore.

Family CANCRIDÆ.

Xanthodes sulcatus, sp. nov.

Carapace granulated, granulation heaviest on the lower surface, and near the borders of the upper surface. Deeply impressed grooves separate the gastric from the branchial regions, and the mesogastric from the lateral gastric lobes. The groove which continues in the median line to the front, anteriorly to the mesogastric lobe, is crossed a short distance behind the frontal margin by a transverse groove, which meets on each side another groove running parallel to the upper margin of the orbit. In this way there are marked off a pair of frontal and a pair of orbital areolets. The frontal margin is nearly straight, finely denticulate, and separated from the orbital areolets by a groove. Antero-lateral border of the carapace armed with four spines or teeth, E, N, T, S, of Dana's nomenclature, there being no tooth at the external orbital angle; of these teeth the first is the smallest, the third the largest, and the second and fourth are of about equal size; the margins of all the teeth are denticulate. The chelipeds are short and unsymmetrical; the merus is granulated on its outer face, spinulose on the upper edge, and grooved near the articulation with the carpus. The carpus is granulated on its outer side, and furnished with a median internal tooth. The meri of the ambulatory appendages are spinulose along their upper edges.

Length of carapace, 8 mm.; breadth, 11 mm.

Station 3355. 182 fathoms. 1 male, 1 female.
" 3391. 153 " 1 male, 3 females.

Panopeus latus, sp. nov.

Carapace broad, convex in antero-posterior direction, granulated, especially on the hepatic, branchial, and cardiac regions; areolations well marked and protuberant. Front divided by a small median incision into two slightly convex lobes, whose edges are simple and not produced into teeth at the lateral angles. Antero-lateral margin cut into five teeth; post-orbital tooth small, separated from the second tooth by a shallow granulated sinus; the third tooth is the broadest, and rounded off at the apex; the fourth is the most salient, and acute; the fifth is very small, and acute; all the teeth have crenate or else spinulose margins. The margin of the orbit is minutely crenulate; its upper part is marked by two closed fissures; the external hiatus of the orbit has the form of a triangular notch; the lower margin is produced to form an obtuse tooth at the inner angle. The subhepatic region is granulous, but not provided with a tubercle. The merus of the third pair of maxillipeds is also granulated. The carpus of the chelipeds is rough with small tubercles, grooved along the distal margin of the outer side, and armed internally with a small blunt tooth; the hands are robust, inflated, smooth except near their articulation with the carpus where scattering granules appear; upper and lower margins rounded; fingers long, down-curved, smooth, canaliculate, their cutting edges irregularly armed with small and rather sharp teeth, without any prominent basal tooth; when closed the fingers are separated by a slight gape, and their tips cross one another; the color of the fingers in alcoholic specimens is very light brown. The chelæ of the right and left sides are unequal in size, but similar in shape. The ambulatory appendages are setose, their merus joints furnished with small teeth along their upper edges. The seventh segment of the sternum in the male is entirely concealed by the base of the abdomen. The coxæ of the fifth pair of legs are in contact with the third abdominal segment. The penultimate segment of the abdomen has concave sides, the terminal segment is broad and rounded.

Length of carapace, 6.5 mm.; breadth, 10.25 mm.

Station 3397. 85 fathoms. 1 male.

In this species the carapace is short, the posterior margin wider than usual in the genus. In its general aspect it recalls *P. xanthiformis* A. M. Edw.; the meri of the ambulatory legs are denticulated on their upper margins as in *xanthiformis*, but in *latus* the carapace is much broader and more convex in an antero-posterior sense, the front is less prominent and destitute of lobes at the lateral angles, the carpal tooth is blunt, etc.

Panopeus tanneri, sp. nov.

Carapace moderately convex both lengthwise and transversely, smooth and polished in the central and posterior part, coarsely granular on the anterior gastric and hepatic regions. The gastric and hepatic areas are well marked off by depressions. Front nearly straight, divided by a median triangular fissure, and projecting as a blunt tooth at each lateral angle; a double edge is formed by a groove which runs along the front, the lower edge projecting farther forward than the upper edge; both upper and lower edges are finely granulate. The antero-lateral margins of the carapace are cut into triangular teeth; the first and second of these teeth are small, coalesced, connected by a shallow sinus; the third and fourth are of about an equal size; the fifth is much smaller; all the teeth are granulous on their anterior border, smooth on posterior border; the depressions between the third and fourth and the fourth and fifth teeth are continued in as furrows for some distance on the carapace, finally uniting and meeting the cervical furrow. The upper margin of the orbit forms a tooth at the inner angle above and outside of the external marginal tooth of the front; there is a closed fissure near the middle of the superior orbital border; the external fissure is a triangular notch; a blunt tooth at the inner angle of the lower margin. There is no subhepatic tubercle. A transverse row of tubercles on the front of the eyestalk (when viewed retracted within the orbit) just inside the eye. Chelipeds unsymmetrical; carpus squamoso-rugose, with a slight transverse groove, and armed with a prominent but not very sharp internal tooth; propodus robust, superior border rounded and squamoso-tuberculate, outer surface smooth, fingers of larger chela gaping, movable finger armed with a blunt tooth at base; fingers of smaller chela slenderer, without prominent teeth; fingers of both hands black, hooked at extremities, tips crossing. Base of abdomen entirely covers the sternal segments; penultimate segment of abdomen short, posterior angles prolonged backward; last segment short, pentagonal. In young specimens the granules of the carpus and propodus are more numerous and sharper pointed.

Length of carapace, 6.25 mm.; breadth, 10 mm.

Station 3405. 53 fathoms. 5 male (3 adult, 2 young).

" 3368. 66 " 1 male.

Family PORTUNIDÆ.

Achelous affinis, sp. nov.

Carapace moderately convex both longitudinally and transversely, the frontal region depressed, horizontal; surface rugose, granular, and pubescent. Front not prominent, composed of four blunt teeth, not counting the internal angle of the orbit; the two teeth near the median line are equilaterally triangular, separated from one another by a triangular notch; the next teeth on the outer side are separated from those within by a shallow sinus, and fall off abruptly on the outer side into a deep notch which separates the front from the inner orbital angle. The two middle teeth of the front are a trifle longer than the lateral teeth. The tooth formed by the projecting inner orbital angle does not attain the level of the frontal teeth; it is double, the orbital margin just outside of it being slightly folded, raised, and projected forward so as to form a secondary tooth similar to that in *A. spinimanus*, but not so well marked. The antero-lateral margin of the carapace is nine-toothed, including the tooth at the outer orbital angle; the posterior tooth is hardly larger than those in front of it; the posterior margin of these teeth is convex. The anterior edge of the merus of the chelipeds is armed with five spines. The carpus has an internal and a smaller external spine. There is a spine on the propodus at the base at the point of articulation with the carpus, and another on the upper margin a little distance back of the articulation with the dactylus. The distal edge of the merus of the fifth pair of legs is spinulose.

Length, 25 mm.; breadth, 39 mm.; length of merus of chelipeds, 24 mm.; length of propodus, including digit, 33 mm.; length of internal carpal spine, measured from distal margin of carpus, 3.3 mm.

Station	3379.	52 fathoms.	5 males, 4 females.
"	3390.	56 "	1 male.

A large number were also taken in the tow-net at the surface at the following stations: Off Mala Point; Hydr. 2627; Nos. 3355, 3371, 3382, 3386, 3398; 50 miles south of Guaymas.

The specimens taken at the surface are small, and much darker in color than those that came up in the trawl, but show no structural differences. I take them to be the same species in the pelagic stage of its existence.

This species is very closely related to *Achelous depressifrons* Stimps., from the Atlantic side of the continent. Compared with *A. depressifrons* it is broader, and the curve formed by the front and the antero-lateral margin of the carapace forms an arc with a longer radius; the lateral lobe of the front is broader; the tooth of the inner orbital angle is double, as above described; the teeth of the antero-lateral margin have broader bases, and the anterior one at the outer orbital angle is not so prominent; the protuberances on the cardiac and branchial areas are less prominent; the internal carpal spine is shorter, and the distal margin of the merus of the fifth pair of legs is denticulate behind the articulation of the carpus.

Family CORYSTIDÆ.

TRACHYCARCINUS, gen. nov.

Carapace pentagonal, moderately convex, lateral margins long, nearly straight toothed. Front narrow, produced, three-toothed. Orbits large, with forward aspect, imperfect, with two hiatuses above, one below, and one at the inner angle; lower wall formed chiefly by the carapace. Anterior margin of buccal cavity not distinctly defined, epistome short, ridges of the endostome developed. Sternum long and rather narrow. Abdomen of male narrow and five-jointed, the third, fourth, and fifth segments consolidated. Eyestalks very small, retractile within the orbits. Antennules longitudinally folded. The antennæ lie in the inner hiatus of the orbit; their basal segment is but slightly enlarged, not filling the hiatus at the inner angle of the orbit, nor attaining to the front, subcylindrical, unarmed, imperfectly fused with the carapace; the second segment is longer and slenderer than the first, the third segment about equal to the second in length, but slenderer; all these segments are furnished with long and coarse setæ; the whole antenna is less than one half as long as the carapace. The ischium of the outer maxillipeds is produced at its antero-internal angle; the merus of the same appendages is rounded at the antero-external angle, obliquely truncated but not emarginated at the antero-internal angle, where it articulates with the following segment. Legs of moderate length. Right and left chelipeds very unequally developed in the male. Dactyli of ambulatory legs styliform, straight, slender, longer than the penultimate segments.

The pentagonal shape of the carapace recalls the genus *Telmessus* White. But in *Telmessus* the front is divided by a median notch, the orbit is much more complete, the basal segment of the antenna sending off an external process that completely fills the hiatus at the inner angle of the orbit. In the structure of the orbit and antennæ, and in the shape of the merus of the outer maxillipeds, *Trachycarcinus* is much like *Hypopeltarium* Miers (*Peltarion* Jacq.).

Trachycarcinus corallinus, sp. nov.

Carapace irregularly pentagonal, clothed with a dark brown pubescence, and bearing flattened tubercules of ivory whiteness arranged in groups, as follows: two anterior lateral and one posterior median, on the gastric region; four, disposed in two pairs, on the cardiac region; five or six on each branchial region; and one, of a crescentic shape, on each hepatic region. Each group of tubercles resembles the crown of a complex molar tooth whose cusps have been worn down to a common level. Front tridentate, the median tooth twice as long as the lateral. Walls of the orbit furnished with four teeth separated by deep hiatuses; these teeth are a pre-ocular, median superior, post-ocular, and subocular. Antero-lateral border of carapace armed with three prominent teeth; another minute tooth just back of the largest posterior lateral tooth. Eyestalks slender; eyes small, unpigmented, with imperfectly faceted cornea. Chelipeds asymmetrical in the male; in adults the larger claw is naked, smooth, and ivory-white, like the tubercles on the carapace; the merus has a few small teeth along its upper margin, most of them near the two ends of the segment; the upper margin of the carpus is armed with one strong tooth, and is denticulated along its whole length; the propodus is short, the immovable finger bent down at an obtuse angle with the lower border of the palm; the dactylus is furnished with small tubercles on its upper border; both fingers are armed with large blunt teeth on their opposed edges. The smaller claw is slenderer than the large claw, and its fingers are proportionally longer. In the female both chelipeds are of approximately equal size, and resemble both in size and shape the smaller cheliped of the male. The ambulatory limbs are unarmed, but clad with coarse setæ.

Length of carapace, 26 mm.; breadth, 27 mm.

Station	3353.	695	fathoms.	1 female.
"	3356.	546	"	5 males, 4 females.
"	3418.	660	"	1 male.

Family GECARCINIDÆ.

Gecarcinus malpilensis, sp. nov.

Carapace very broad and convex anteriorly, flattened and narrowed posteriorly; surface microscopically granulated; antero-lateral margin rounded, not denticulated; the median gastric furrow is well marked; the furrow separating the gastric from the branchial regions does not extend forward far enough to separate the gastric from the hepatic area; the so called genital area is separated by a pronounced groove from the branchial and cardiac regions, but not from the gastric; there is a deep indentation at the anterior extremity of the lateral genital furrows; the furrows bounding the cardiac region on either side are moderately developed. Front deflexed at right angles to the axis of the body, deep, concave above the margin, margin not reflexed, granulated. The merus of the outer maxillipeds is five-sided, outer side convex, distal slightly notched, antero-internal straight and parallel to the long axis of the body, forming an obtuse angle with the postero-internal margin, which is slightly concave. Merus and carpus of chelipeds devoid of spines or teeth. Dactylus of the ambulatory legs furnished with six rows of spines.

Length, 55 mm.; breadth, 76 mm.; width of hind border of carapace, 19 mm.; width of front, 11 mm.; depth of front, 7 mm.

Malpelo Island, March 5. 1 male.

This species is very distinct from any previously described. Compared with the previously known species from the Pacific coast, it is nearest to *G. quadratus*

De Saussure, but the outline of its carapace is very different; in this regard it is similar to *G. ruricola* from the eastern coast. Moreover, the front is narrower, deeper, and bent down at a sharper angle than in *G. quadratus*, and the merus of the outer maxillipeds is very different in shape from that of *G. quadratus* or any other known species.

Family PINNOTHERIDÆ.

Pinnixa panamensis, sp. nov.

Male. — Carapace short and very broad, smooth and punctate for the most part, granulated at the sides. The lateral angles form a prominent shoulder, back of which the carapace diminishes rapidly in width. A transverse depression involves the hinder part of the gastric and the fore part of the cardiac regions. This depression is bounded behind by a ridge which extends across the carapace between the bases of the last pair of thoracic appendages. Back of this ridge the carapace is deflected at an angle of about forty-five degrees. Front depressed, divided by a median notch into two not prominent lobes; margin setose. The chelipeds are small, with very robust carpus and hand, destitute of spines, but furnished with some setæ along their edges; carpus squamose on the anterior and superior parts of the outer side; propodus not broader than the carpus, compressed laterally; a row of tubercles along the superior border forms a sort of crest; a longitudinal row of setiferous squamous tubercles runs lengthwise of the hand from the proximal end, stopping short of the base of the immobile finger; the surface between this and the dorsal crest is thickly beset with tubercles, but below it the surface is almost smooth down to a row of tubercles which runs along the inferior margin; immovable finger straight, the dactylus closing against it throughout its length; dactylus furnished with long setæ on the upper margin; no prominent teeth or tubercles on the cutting edge of either finger. First and second ambulatory limbs of moderate length, nearly naked, with slender and straight dactyli; last three segments tuberculate on superior margin. Third pair very much enlarged; the merus has a convex anterior border, and is pubescent on the anterior third of the upper surface; posterior margin double, spinulose. Fourth ambulatory legs very small, not reaching beyond the distal end of the merus of the third pair; upper surface smooth. Dactyli of penultimate and last pairs of legs short, acute, set at an angle with the propodi so as to form prehensile hooks. End joint of abdomen broader than the preceding joint, semicircular. The dactylus of the outer maxillipeds articulates with the propodus near the distal end of the latter. The carapace is 5 mm. long by 10 mm. broad.

The female is larger than the male, the carapace is more highly polished, the transverse depression not so pronounced, and the appendages are more thickly clothed with setæ. Length of carapace, 6.3 mm.; breadth, 13 mm.

Panama, March 12. 4 males, 6 females ovig.

Family MATUTIDÆ.

Osachila lata, sp. nov.

Carapace laterally expanded; three low obtuse protuberances on the gastric region, one on the cardiac, three or four on the branchial. Front prominent, bilobed, the lobes separated by a completely closed fissure. Antero-lateral margin of carapace sharp; behind the point where the subhepatic ridge joins the margin, the margin is divided into five obscure lobes, each of which is denticulate. Merus of chelipeds tuberculous along the upper edge and outside of it; carpus tuberculate externally, distal and superior margins produced to a cristiform tooth which continues back upon the carpus the crest on the superior border of the propodus; propodus tuberculate on the outer face, superior border denticulate and cristate. Edges of ambulatory limbs slightly cristate, dactyli pubescent on distal portion.

Length, 24.5 mm.; breadth, 32 mm.

Station 3427. 80 fathoms. 1 male.

Family DORIPPIDÆ.

Æthusa ciliatifrons, sp. nov.

Carapace broader than long, branchial regions much inflated; surface granulated on the branchial and cardiac regions, pubescent on the gastric region. Front and anterior part of the lateral border ornamented with long upturned cilia. Front between the orbits divided by a triangular median sinus and two slightly shallower lateral sinuses into four triangular teeth of equal length. Branchio-cardiac lines deeply impressed, meeting together in the median line in front of the heart. Eyes small, mounted on very short peduncles, just reaching, when extended, to the angles of the orbital sinuses. Chelipeds equal, small and slender; chela smooth, not more robust than the carpus; fingers longer than the palm, laterally compressed, curved inward, longitudinally grooved, thin prehensile edges straight and regularly denticulated. Ambulatory appendages very long (the second longer than the first), naked and minutely granulated; propodus slightly shorter than the merus, compressed, grooved longitudinally on both the upper and lower faces; dactylus one half longer than the propodus, flattened, curved, grooved and ribbed longitudinally, its upper edge very sharp. Last two pairs of thoracic limbs densely clothed with setæ. Sternum rather coarsely granulated. Conspicuous red transverse bands adorn the chelipeds and first two pairs of ambulatory appendages.

Length of a male (carapace), 26.5 mm.; breadth, 29.5 mm.

Station 3387. 210 fathoms.
" 3389. 153 "
" 3391. 259 "
" 3396. 127 "

Æthusa pubescens, sp. nov.

Carapace a little broader than long, densely pubescent; frontal margin ciliated; cardiac area open in front, the branchio-cardiac lines not meeting one another in the median line; front four-toothed, the median teeth more widely, but less deeply, separated from each other than from the lateral; the antero-lateral angles reach the level of the frontal teeth. Eyes as in the last described species (*Æ. ciliatifrons*). Chelipeds equal, small, with pubescent merus and naked carpus and hand; fingers longer than palm, compressed, curved, gaping at base. Ambulatory appendages similar to those of *Æ. ciliatifrons*, but free from granulation. Abdomen (of female) very broad, pubescent.

Length, 26 mm.; breadth, 29 mm.

Station 3367. 100 fathoms. 1 female.

This species resembles *Æ. ciliatifrons*, but the median notch of the front forms a more open angle in *Æ. pubescens*, and the sinus separating the front from the external orbital angle is not so deep. The branchio-cardiac lines do not meet in front of the cardiac area, and the cardiac area is not so much sunken below the level of the branchial regions; the branchial areas, moreover, are not so convex, nor is the cardiac region so uneven. The whole surface is densely pubescent, and the abdomen of the female is much broader. The fingers too are different, inasmuch as they are separated by quite an interval at base. The first and second pairs of ambulatory limbs are imperfect in the only specimen at hand, but they are very similar, as far as they go, to the corresponding appendages of *Æ. ciliatifrons*.

Æ. pubescens may prove to be the full-grown state of *Æ. lata* Rathbun, the description of which has just appeared in Proc. U. S. Nat. Mus., Vol. XVI. p. 258, 1893.

Æthusina smithiana, sp. nov.

In this species the carapace is longer than broad, and is not much narrowed anteriorly. The front is four-toothed, the middle pair of teeth large, triangular, separated from one another by a wide triangular sinus which is broader than the antennular sinus; between these teeth the margin is bent down till it meets the epistoma below; the lateral teeth of the front are spiniform and shorter than the middle teeth. The surface of the carapace is clothed with a short pubescence, and is lightly granulous; the branchio-cardiac grooves are well marked. The post-orbital teeth are spiniform, and they project far beyond the extremity of the small eyestalks. The eyes are smaller than the extremity of their peduncles. The chelipeds are equal, smooth, naked, unarmed; the merus cylindrical, the carpus short and rounded: the fingers about equal in length to the body of the chela, compressed, prehensile edges sharp and not provided with distinct teeth or tubercles. The ambulatory legs are nearly naked, the second pair more than twice the length of the carapace, the dactylus longer than the propodus. The last two pairs of legs terminate in short recurved claws, which are setose on the posterior edge. The sexes do not seem to differ in any marked degree.

Length of carapace (male), 9.3 mm.; breadth, 8 mm.

Station 3370. 134 fathoms. 3 females.
" 3380. 899 " 2 males.

This species is nearly related to *Æ. abyssicola* Smith, but its carapace does not diminish so much in width anteriorly, the external frontal spines are less developed, the external orbital spine is much longer and brought forward so that the orbits face more to the front. From *Æ. challengeri* Miers it differs in the greater development of the frontal and external orbital spines.

Cymopolia tuberculata, sp. nov.

Carapace very broad, subpentagonal, branchial regions swollen. Front four-toothed, the teeth blunt, separated from each other by narrow sinuses which are rounded at the bottom; the two middle teeth are longer than the lateral ones, and the median sinus is deeper than the two lateral. The antero-lateral margin of the carapace is four-toothed, counting the prominent tooth at the external angle of the orbit; the posterior tooth of the series is the smallest. The upper margin of the orbit has three deep fissures defining two triangular teeth; the lower margin of the orbit has two fissures enclosing a broad truncate tooth or lobe; there is also a broad and prominent lobe just below the inner orbital angle; above this lobe is a single tooth at the inner angle. The surface of the carapace is ornamented with granulated tubercles; the parts between the tubercles are more finely granulated, and when viewed under a lens are found to be furnished with fine hairs. The chief tubercles are disposed as follows: one pair on the frontal region behind the margin; four in a transverse row on the anterior part of the gastric area, and five on the posterior part of the same area arranged thus :˙:; of these the posterior pair is the smallest; four in a transverse line on the cardiac region and one median behind the transverse series; about six on each branchial area; six just anterior to the straight posterior margin of the carapace (three on each side). There are three small tubercles on each eye-stalk near the margin of the cornea. The chelipeds are small, slender, equal; the carpus tuberculose, the fingers as long as the hand proper, curved downward and inward, crossing at the tip, their prehensile edges finely denticulate in small specimens, nearly entire in larger ones. The second and third ambulatory limbs are very long, the second slightly longer than the third; their merus joints are granulated and costate above, and armed with a prominent spine at the antero-distal angle and a smaller one each side at the point of articulation with the carpus; this holds good of all three pairs of ambulatory appendages; the carpi are carinate on their anterior margin, with a vestige of a tooth at each end of the carina; the anterior edge of the propodus is also carinate. The ambulatory legs are ornamented with transverse bands of red, three of which cross the merus. The abdomen and sternum are granulated.

Length, 13 mm.; breadth, 18 mm.; length of ambulatory leg of second pair, 34 mm.; merus of do., 9.3 mm.; carpus, 5.6 mm.; propodus, 9 mm.; dactylus, 7.5 mm.

Station 3355. 182 fathoms. 4 males, 1 female.

Cymopolia zonata Rathbun (Proc. U. S. Nat. Mus., XVI. 259, 1893), lately described from the Gulf of California, 40 fathoms, differs from *C. tuberculata* as follows. The carapace is narrower and more quadrangular. The median lobes of the front are small and inconspicuous, while the lateral lobes are very broad and are separated from the median lobes by a slight, shallow notch. In *C. tuberculata* the four frontal lobes take on the form of prominent triangular teeth, clearly separated from each other by deep triangular sinuses. The antero-lateral margin of the carapace is three-toothed in *C. zonata*, four-toothed in *C. tuberculata*. The tubercles near the posterior margin of the carapace are more elongated in the former species than in the latter. The hand of the former is much broader, and is armed with prominent spiny tubercles. Finally the meri of the ambulatory legs are much shorter in *C. zonata*, and are armed at the distal end with a blunt triangular tooth, while in *C. tuberculata* this tooth is transformed into a long sharp spine, and a pair of smaller spines is present, one on each side of the proximal end of the carpus.

Family RANINIDÆ.

Raninops fornicata, sp. nov.

Carapace very convex from side to side, naked, smooth or nearly so, punctate. Rostrum acute, lightly carinate, the carina extending backward for a short distance on the carapace. Superior margin of orbit armed with three acute teeth, the second of which is curved forward; the anterior tooth is separated from the rostrum by a deep rounded sinus, from the second tooth by an angular notch; the second tooth is separated from the third by a nearly straight interval; the third tooth lies some distance in front of the posterior end of the orbit. Back of the orbit there is a strong procurved spine on the margin of the carapace. Eyestalks compressed, equal in length to one half the width of the carapace. Second segment of the third maxilliped equal to the third joint, crossed by a piliferous line; third segment notched at the antero-internal angle. Cheliped: merus unarmed, microscopically spinose above, setose below; carpus minutely rugoso-spinulose, the superior distal angle projecting as a sharp tooth; propodus lightly rugose, upper and lower borders margined, unarmed, palmar edge irregularly and inconspicuously toothed; dactylus without any prominent tooth. The dactylus of the fourth pair of legs has a very convex internal border, the dactylus of the fifth is long, narrow, and spatulate. Abdomen setose; telson obtuse at the end.

Length of carapace, 12 mm.; breadth, 8.6 mm.

Station 3369. 52 fathoms. 1 specimen.

Family LITHODIDÆ.

Rhinolithodes cristatipes, sp. nov.

The carapace is subtriangular in outline, its surface devoid of setæ, but covered with low squamiform tubercles; the whole gastric area is raised into a conical prominence; there is also a prominent crescentic rounded ridge on each branchial region, enclosing the cardiac area in a deep fossa open only behind. The rostrum is straight and conical, with a vertical plate projecting below from the proximal half down between the eyestalks; this plate is toothed anteriorly but does not reach forward nearly to the tip of the rostrum. The antero-lateral margin of the carapace is five-toothed; the second, third, and fourth of these teeth give rise to long thread-like cilia. There is another tooth at the angle between the postero-lateral and posterior margins; posterior margin straight. The upper surface of the eyestalk is covered with small tubercles and a blunt spine projects over the cornea. The movable scale of the antenna is spiniform and bears two blunt spinules on the outer side and two smaller ones on the inner. The chelipeds are unequal (the right being the larger); coxa granulated, setose on the lower inside margin; lower margin of the merus armed with three or four blunt teeth, superior margin toothed, internal distal border setose, external distal border forming a bilobed crest; outer face of carpus squamous, margins cristate, the internal crest expanded and cut into setiferous lobes; propodus tuberculated without, smooth within, toothed and setose on superior margin; immobile finger, as well as the dactylus, excavated within, setose; the larger claw has blunt teeth on the fingers, while the fingers of the smaller claw have nearly straight cutting edges. The ambulatory appendages have cristiform anterior margins from the merus to the propodus inclusive; the crest of the carpus is entire, but that of the merus is bilobed, of the propodus trilobed; the posterior margins of these appendages are dentate and more or less setose, the dactyli are provided with curved acute black tips, and with pencils of hair especially on anterior margins. The abdomen is indurated, with three rows of tuberculated plates.

Length of carapace, 16.5 mm.; breadth, 16.5 mm.

Station 3354. 322 fathoms. 1 male.

I have seen neither specimen nor figure of the type of this genus, *Rhinolithodes wossnesenskii* Brandt, from the coast of Alaska, and the specimen above described possibly does not belong to the same genus. Brandt's generic diagnosis (Bull. Phys.-Math. Acad. Sci. St. Pétersbourg, VII. 174, 1849) appears to include specific as well as generic characters. The specimen above described conforms to Stimpson's diagnosis of the genus (Proc. Acad. Nat. Sci. Phila., 1858, p. 231): "Abdomen scutis triseriatis obsessum. Antennarum aciculum margine spinosum. Pedes mediocres."

Echinocerus diomedeæ, sp. nov.

Carapace subpentagonal, gastric and branchial regions inflated, the whole surface beset with tubercles which give rise to minute setæ. There is one rather more prominent tubercle in the depression on each side of the gastric area. Rostrum short, three-spined; one of the spines is median and inferior, two are paired near the base above; in one of the two specimens obtained the median spine is toothed below. The antero-lateral margin of the carapace is irregularly toothed. Eyestalks spinulose above, with one prominent spine projecting forward over the cornea. The movable scale or spine of the antenna is spinulose on each side (four or five spines on each margin). The merus of the cheliped bears a spine on the inner side at the distal end; the carpus is smooth outside, the inner border expanded into a seven-toothed crest setose within, the outer border straight, naked, and keeled; the chelæ are of unequal size (the right being the larger), setose, spiny on the upper edge; fingers spoon-shaped within, setose and somewhat gaping. Ambulatory appendages: the meri are spinose on their edges; the anterior border of the carpus of the first pair is furnished with a crest whose edge is even and entire; the propodus of the first pair is crested along the proximal half of its anterior border, while the distal half is armed with two or three teeth; the carpus and propodus of the second and third pairs are toothed on the anterior margin, the propodus of the third pair is also toothed on the posterior margin; all the segments are hirsute, especially the dactyli. When the legs are closely folded against the sides of the carapace a wide interval is left between the carpi of the cheliped and first pair of ambulatory appendages, bounded by the opposite crests of these segments, and forming a passage for the admission of water to the gills. This orifice is similar to that seen in *E. foraminatus* Stimps., but it is not so perfectly formed The apex of the abdomen (in the female) is turned to the right (most strongly in the larger specimen); the marginal plates are wanting on the left side; all the abdominal appendages excepting the first are aborted on the right side.

Length, 64 mm.; breadth, 71 mm.

Station 3384. 458 fathoms. 1 female.

Station 3394. 511 fathoms. 1 female ovig.

In this species the aicle of the antenna is spinous on the margins only, as in *E. foraminatus* Stimps.

Paralomis aspera, sp. nov.

Carapace pentagonal, as broad as long; gastric, cardiac, and branchial regions well defined and prominent; whole surface of carapace and abdomen thickly beset with papillæ or tubercles, each one of which is encircled with a crown of stiff setæ. Rostrum short, indistinctly tripartite, multispinose. A sharp dark-tipped spine at the external orbital angle, another at the antero-lateral angle of the carapace, and four or five, irregularly arranged, on the margin of the branchial region.

The dorsal face of the second abdominal segment consists of a single plate, undivided by longitudinal sutures, with a deep depression on each side of the middle. The following segments are unsymmetrical on the two sides of the unique type specimen (female), the abdomen being twisted to the right. The lateral margins of these segments are laciniated.

Eyestalks spinulose above; eyes very black, with downward aspect. Distal segment of antennule much longer than the antecedent segment, tuberculous above. Antennæ of moderate length; outer margin of first segment spinulose; second segment spinulose, and produced on the outer side to a long spine; movable acicle reaching to the distal end of the peduncle, spinose, the longer spines marginal, one spinule on the lower side and another on the upper side near the base; penultimate and ultimate segments of peduncle bear small setiferous tubercles. Right cheliped more robust than its fellow, thickly beset with strong spines. Ambulatory legs long, robust, spinose like the chelipeds; their basal segments are wellnigh covered by the overlapping margin of the abdomen (in the female).

Length of carapace, 113 mm.; length of rostrum, 9 mm.; breadth of carapace, 113 mm.; length of posterior ambulatory legs, 255 mm.; merus, 68 mm.; carpus, 39 mm.; propodus, 72 mm.; dactylus, 56.5 mm.

Station 3353. 695 fathoms. 1 female.

This species, like the one next described, is much longer legged than *P. granulosa* (Jacquinot), the type of the genus. In this regard it is more like the two "Challenger" species described by Henderson. The specimen above described was infested with a huge *Peltogaster* 36 mm. in breadth.

Paralomis longipes, sp. nov.

Male. — Carapace triangular; gastric, cardiac, and branchial regions well defined, protuberant; the most prominent part of the cardiac area reaches a higher level than the branchial areas; whole surface of carapace thickly covered with blunt papillæ; viewed under a lens each tubercle is seen to be encircled with a ring of short, stiff setæ; one of the tubercles, situate in front of the centre of the gastric region, assumes a spiny form. Rostrum furnished with three prominent spines, one median and inferior, two lateral and superior; the latter are not so long as the inferior spine; there is, too, a spinule on the lower side of the inferior spine, and a still smaller one above, between the roots of the superior pair There are two pairs of long spines on the anterior margin of the carapace, one at the external orbital angles, the other at the antero-lateral angles of the carapace. There are also three or four prominent spines on the side of each branchial area. Eyestalks spinulose above. Basal segment of the antenna armed with an external spine, the second segment with several spines, the most prominent of which is on the outer side; acicle furnished with five prongs or spines, the largest median, the others lateral; flagellum much longer than the carapace. Cheliped of moderate size (the right one has been lost from the only male specimen obtained), coxa tuberculate on the lower face, the following segments armed with strong spines, fingers excavated within, slightly gaping, penicillate, cutting edges entire. Ambulatory appendages very long, second and third pairs of about equal length and longer than the first pair; all of them armed, like the chelipeds, with spines; the spines tend toward a regular arrangement in longitudinal rows, and the spaces between the spines are smooth and naked, i. e. nearly free from spinules, tubercles, or setæ. Second segment of abdomen composed of a single calcified plate, marked by a deep hollow on each side of the middle ; the other segments of the abdomen are of a leathery, semi-membranaceous consistency, and are made up of five longitudinal rows of plates, viz. one median row, flanked by a row on each side, the latter in turn bounded externally by a marginal series; whole surface of abdomen verrucose.

Length of carapace, including rostrum, 84 mm.; breadth, 78 mm.; breadth between the antero-lateral angles of carapace, 34 mm.; length of last ambulatory appendages, 242 mm.; merus, 76 mm.; carpus, 36 mm.; propodus, 64 mm.; dactylus, 47 mm.

In the female the right chela is larger than the left, and the prehensile edges of the fingers are furnished with blunt teeth. The abdomen is asymmetrical, the apex turned to the right, the marginal plates absent from the left side; the right side bears but one ovigerous appendage (the first). The abdomen nearly conceals the basal segments of the thoracic legs, which in the male are almost entirely exposed.

Station 3371. 770 fathoms. 1 male, 1 female ovig.

The egg measures 2 mm. in diameter.

Lithodes panamensis, sp. nov.

Carapace subpyriform, of about equal length and breadth; gastric and branchial regions very convex ; a deep depression on each side at the anterior limit of the branchial areas, and another between the gastric and cardiac areas. Rostrum cylindrical, terminating in three spines or teeth, one of which is median, the other two lateral; a long horn, slightly upcurved, is given off from the lower side of the proximal end of the rostrum. The whole surface of the carapace is rough with low warty protuberances ; the gastric region bears two pairs of spines, the anterior pair separated by a greater interval than the posterior pair. Two small spines on each branchial area, and two on the intestinal region. The orbit is bounded externally by a prominent spine, and there are five more spines on the lateral border of the carapace, viz. one at the antero-lateral angle, one on the hepatic region, and three on the branchial. Besides these there is a rudimentary lateral spine near the anterior limit of the branchial region. The posterior margin of the carapace is tuberculated, not spinose. The third segment of the antennular peduncle is equal to the first segment in length, and considerably longer than the second segment. The antennæ are about equal in length to the carapace without the rostrum; the second segment is armed with a long and sharp external spine; there is, moreover, on the antenna of the right side a movable thorn-like acicle equal in length to the last two segments of the peduncle together; the acicle is armed with a small tooth on the external margin midway between the base and the tip. There is no trace of an acicle on the left antenna. As the type specimen is the only one obtained, it is impossible to tell whether the acicle is normally present or absent. The last segment of the peduncle is nearly twice as long as the penultimate segment. The chelipeds are furnished with scattered tubercles, a few of which assume a spiny form. The left cheliped is rather slenderer than its fellow. The ambulatory legs are long and rather slender, their meri sparsely furnished above with tubercles, which tend to a spiny form on the anterior and posterior margins; at the distal end of the anterior margin of the meri there is a prominent spine-like tooth; the carpi and propodi are armed with teeth, chiefly on the anterior margins; the dactyli are equipped with four short spines (two superior and two lateral) near the proximal end. The abdominal segments (of the female) are roughened by low tubercles, and dentate on their margins. The lateral teeth of the marginal plates of the right side are drawn out into long spines. The tergal plate of the second abdominal segment is completely fused with the epimera, showing no trace of an intervening suture. The marginal (episternal?) plates of this segment are bounded within by a distinct suture.

Length of carapace, excluding rostrum, 79 mm.; rostrum, 14 mm.; breadth of carapace, 79.5 mm.; length of posterior pair of ambulatory legs, 193 mm.; merus, 58.5 mm.; carpus, 31 mm.; propodus, 54 mm.; dactylus, 33 mm.

Station 3384. 458 fathoms. 1 female.

This species finds its nearest relative in *L. murrayi* Henderson (Rep. Challenger Anomura, p. 43, Plate IV.), from the distant Prince Edward Island in the Southern Ocean. The latter species differs from *L. panamensis* in having a much longer rostrum, which is forked at the end, a more oval and spiny carapace, shorter external antennal spine, more spinose legs, etc.

Family PAGURIDÆ.

Cancellus tanneri, sp. nov.

Differs from *C. canaliculatus* (Herbst) in having a much shorter and broader abdomen, in the lobate character of the marginal crests of the first and second pairs of legs, in the pubescence of the thorax and abdomen, and in the shortness of the antennæ. From *C. typus* M. Edw., it is distinguished by having the anterior border of the carapace less deeply incised on either side of the rostrum, and the telson squarely truncated posteriorly, not notched in the middle; the coxæ of the last pair of legs, too, present a very different shape, since they lack the prominent anterior lobe observable in *C. typus*. *C. parfaiti* A. M. Edw.

et Bouv., compared with *C. tanneri*, displays longer eyestalks, while the thorax and abdomen are less pubescent, and the coxal segments of the posterior legs are much more protuberant.

Length of carapace, 7 mm.; breadth, 5 mm.; length of eyestalk, 3 mm.

Station 3368. 66 fathoms. 1 male.

Found in a cavity in a piece of dead coral rock.

The abdomen in the unique type specimen is not quite symmetrical, but this may be an individual peculiarity resulting from the shape of the cavity in which the animal lived.

Pylopagurus longimanus, sp. nov.

Carapace smooth, naked, polished; rostrum short, triangular, subacute, advanced farther than the rounded lateral angles. Abdomen longer than cephalothorax. Eyestalks equal in length to the first two segments of the antennulary peduncle. Ophthalmic segment uncovered. Ophthalmic scales separated by a considerable interval, triangular, their tips split in a horizontal plane so that they end in two acute teeth, one above the other, the lower tooth the longer. Last segment of antennulary peduncle very long and slender (much longer than the eye-stalk). Right cheliped of enormous size, much exceeding the whole body in length ; the outer face of the merus is nearly smooth, the lower and inner faces granulated ; carpus very large, equalling in length all the preceding segments combined, its surface granular, the granules assuming the form of small spinulose tubercles on the dorsal face, which is limited within by a row of larger teeth. Chela irregularly oval, the external side flattened to form an opercular facet, which is thickly set with granules and surrounded with a margin of denticles. Left cheliped very small, its segments more hairy than those of the right ; basal part of propodus short and swollen, the fingers long, gaping at the base; the outer or upper faces of the propodus and dactylus are granulated, and definitely bounded by a line of regularly arranged granules on the outer margin of the dactylus and the inferior margin of the propodus ; the inner or lower face of the chela is pretty free from granules, but is furnished with numerous setæ, those on the dactylus being grouped in conspicuous tufts or pencils. Penultimate pair of thoracic appendages almost perfectly chelate, its rasp restricted to the distal part of the claw, broad, and composed of many rows of scales.

The legs are yellowish, banded and mottled with red.

Length of carapace, 10 mm.; eyestalk, 4 mm.; right cheliped, 34.5 mm. (merus, 8 mm.; carpus, 11 mm.; propodus, 14.8 mm. ; dactylus, 10 mm.).

In younger, smaller specimens the chelipeds are shorter in proportion to the length of the body, and the major claw is shorter, broader, and of a more regular oval form. A specimen, whose carapace is 6.5 mm. long, gives the following dimensions for the right cheliped : total length, 16.5 mm.; merus, 4.5 mm.; carpus, 5.5 mm.; propodus, 7.5 mm. ; dactylus, 4.5 mm.

Station 3368. 66 fathoms. 5 males.

Resembles *P. ungulatus* (Studer), but readily distinguished from that species by the great size of the right cheliped, the irregularly oval outline of the right chela, the great length of the distal segment of the antennulary peduncle, etc.

Pylopagurus affinis, sp. nov.

This species is nearly related to *P. ungulatus*, from which it differs in the following respects. the eyestalks are longer, and narrower at the distal end; the external prolongation of the second segment of the antenna is longer and slenderer; the upper margin of the carpus of the right cheliped is armed with two or three spines, the largest of which is close to the anterior border; the outer face of the carpus is smooth save where a light tubercular ridge runs along the middle. In *P. ungulatus* this face of the carpus is thickly covered with spinulose granules which assume larger proportions and a uniserial arrangement on the superior and inferior margins. On extending the comparison to the large chela, further differences between the two species become apparent. In both species the external face is flat, covered with minute spinulose granules, and surrounded by a border of sharp spines; but in *P. affinis* the marginal spines are larger and more irregular, and the flat opercular facet is not sharply defined at the proximal end by the regular arrangement of the marginal spines as in *P. ungulatus;* instead, one finds the marginal series of spines broken down at this point, thus effacing any distinct limit between the opercular face of the chela and the articular surface which connects the propodus with the carpus. The inner or lower surface of the large chela is smooth in *P. affinis*, granulated in *P. ungulatus*. The left cheliped is quite different in the two species: in *P. affinis* the several segments of which it is composed give rise to long setæ, which give the appendage a very hairy appearance when contrasted with *P. ungulatus;* the inferior border of the chela is conspicuously toothed, while in *P. ungulatus* it is entire. The ambulatory legs are more hairy in the Pacific species than in *P. ungulatus*, and their carpal joints are not so distinctly dentate on the superior border. The rasps of the fourth pair of legs are multiserial in both species. The telson is symmetrical, subcircular in outline, its posterior border convex and entire; in *P. ungulatus*, the telson has a deep and wide posterior median notch.

Length, about 12 mm.; length of carapace, 4.5 mm.

Station 3397. 85 fathoms. 1 male.

There are three simple unpaired abdominal appendages on the left side, in the type specimen. The vasa deferentia are extruded from the base of the fifth legs on each side. They appear as slender threads, the one on the right side much longer than its fellow, and twisted into a small bunch.

Pylopagurus hirtimanus, sp. nov.

This species closely resembles *P. rosaceus* A. M. Edw. et Bouv.,[1] from the West Indian seas. Compared with the type of *P. rosaceus* it presents the following differences. The eyestalks are a little slenderer, and together with the ophthalmic scales are separated by a wide interval in which the antennules lie, exposed from above. In *P. rosaceus*, on the contrary, the ophthalmic stalks and scales are closely approximated, concealing the antennules beneath. The outer face of the right chela is ornamented with conical tubercles, whose bases are expanded into circular plates; these plates are closely packed over the surface of the chela, so that no interstices are left between them; their borders are cut into a large number of minute radiating processes; on the basal half of the propodus the tubercles give rise to long setæ, which render that part of the claw conspicuously hirsute, in contrast with the distal part which is naked; furthermore, on the distal half of the propodus, especially on the concave surface of the immovable finger, the tubercular processes tend to become obsolete, leaving only the basal circular radiate plate; the bases of the conical teeth along the outer margin of the hand and the movable finger are expanded at the base into flattened roundish surfaces with radiate margins; these surfaces form a conspicuous outer border to the hand; the inner face of the hand is tuberculated. In *P. rosaceus* the tubercles of the outer face of the chela are encircled by rounded granules much less numerous than the radiating points in *P. hirtimanus;* the tubercles are so loosely arranged that numerous interstices are apparent between them; the hairs on the basal half of the hand are not so well developed as in the Pacific species; the whole outer face of the immovable finger is strongly tuberculated, the teeth of the lower margin are not expanded into conspicuous plates, and the inner face of the chela is nearly smooth. The carpus in *P. hirtimanus* is armed with larger spines on the internal margin, is more hairy, and more coarsely granulated on its inner, inferior, and outer surfaces than it is in *P. rosaceus.* The left chela is comparatively smaller than in *P. rosaceus*, is more strongly toothed along the internal margin of the propodus and dactylus, and exhibits, besides, most of the above specified peculiarities of the right claw. The primary branch of the unpaired abdominal appendages is shorter and broader than in *P. rosaceus.* The rasp on the propodus of the fourth pair of legs is uniserial, as in *P. rosaceus.*

Length of carapace of largest male, 12 mm.; length of carapace in front of cervical groove, 7 mm.; breadth across the branchial regions, 9.5 mm.; length of large claw, 11 mm.; breadth of large claw, 7 mm.

Station 3367. 100 fathoms. 2 males, 1 female.
" 3368. 66 " 5 males, 5 females.

A good deal of the color is still preserved in alcohol. The lower surface of the eyestalk is quite a deep red, while the upper surface is a pale yellow. The

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[1] Mem. Mus. Comp Zoöl., XIV. No. 3, p. 97, Plate VII. Figs. 10-17, 1893.

merus and carpus of the chelipeds and all the segments of the ambulatory legs from the ischium to the dactylus inclusive are banded transversely with bright red on a yellowish ground.

Catapagurus diomedeæ, sp. nov.

The carapace is smooth and naked, and divided into an anterior and posterior section by the cervical groove. The anterior margin projects slightly between the eyestalks, forming a blunt rudimentary rostrum. The gastric region is sharply defined, and presents an indistinct longitudinal furrow on each side of the median line; it is lightly convex in both directions. The branchial regions of the right and left sides are strongly inflated and sharply separated from each other by a re-entrant angle formed by the curving forward of the posterior border of the carapace on each side of the median line.

The eyestalks are rather long and slender, being about equal in length to the anterior section of the carapace. The ophthalmic scales are very small and minutely bifid at the tip. The third segment of the antennulary peduncle is about two thirds the length of the eyestalk, and increases in diameter from the base to the distal end; the superior flagellum is rather longer than the distal segment of the peduncle, and its enlarged ciliated basal portion forms rather more than one third of its whole length. The inferior flagellum is about one half as long as the superior, and is composed of about eleven segments. The peduncle of the antenna surpasses the eyestalk by one half the length of its distal segment; the acicle is long and slender, tipped with a few setæ; it reaches forward a little beyond the eye; the flagellum reaches beyond the tips of the ambulatory legs. The chelipeds are nearly alike in shape and size; their segments are clothed with long setæ, which assume a tomentose appearance on the chelæ; the carpus is about equal in length to the chela, its inner face is perpendicular, the inner margin of the upper side is armed with seven small spines; there is also a spine at the distal end of the superior margin of the carpus; the chela is short and thick, the fingers about the same length as the basal portion of the propodus, slightly down-curved, meeting throughout their length, working horizontally. The ambulatory legs are of nearly equal length, surpassing the chelipeds, setose, the carpus armed with a sharp tooth at the distal end of its upper side; the propodus is twice as long as the carpus, the dactylus is considerably longer than the propodus, and, like that segment, is distinctly curved; it is tipped by a small horny nail. The fourth pair of legs is but slightly subcheliform; the rasp is formed of a single row of scales. There are three small rudimentary appendages on the left side of the abdomen; the first and second of these are two-branched, the secondary branch being exceedingly minute.

The sexual tube, which issues from the coxal segment of the last thoracic appendage of the right side, is very long in this species.

Length of carapace, 5.5 mm.; abdomen, 8 mm.; cheliped, 12.5 mm.; last ambulatory leg, 17.5 mm.; ocular peduncle, 2.5 mm.

Station 3355. 182 fathoms. 1 male.

This species differs much from the more typical species of *Catapagurus*, *C. sharreri* A. M. Edw. and *C. gracilis* Smith, in the shortness of its chelipeds and ambulatory limbs, the symmetry of its chelipeds, and the length of the protruded vas deferens. It is more nearly related to *C. australis* Henderson (Challenger Anomura, p. 76, Plate VIII. Fig. 1). It would seem to have a close general likeness to *Pagurodes piliferus* Henderson, but the gills in *C. diomedeæ* are of the phyllobranchiate type.

Spiropagurus occidentalis, sp. nov.

The carapace is smooth and naked except on the sides of the branchial regions, where a few hairs arise; the branchial regions are swollen, membranaceous, and covered with a network of white lines; the cardiac region is long and narrow; the portion of the carapace in front of the cervical groove is calcified, produced in the median line anteriorly to form a short, broad, and obtuse rostrum, which does not conceal the ophthalmic segment; the lateral teeth are acute, and project as far as the rostrum does; they form a sharp demarkation between the front and the oblique antero-lateral border of the carapace.

The ophthalmic scales are triangular, with simple tips. The ocular peduncles are enlarged at the distal end, hardly overreaching the distal end of the second segment of the antennulary flagellum and the third segment of the antennary flagellum. The last segment of the antennulary peduncle is more than twice as long as the penultimate segment. The second segment of the antennal peduncle is produced externally into a long, sharp tooth; the antero-internal angle is likewise armed with a small spine; the acicle is long, sharp, curved, and furnished with setæ, as are also the several joints of the peduncle.

The chelipeds are subequal, the right chela being appreciably larger than the left; the ischium is armed with about five denticles along the internal margin; the inner margin of the merus is armed with the same number of rather larger teeth; the inner margin of both of these segments is furnished with long and slender setæ; the surface of the carpus is rough with setiferous rugæ, and is armed with scattered spinules upon its upper face and with a row of larger spines along the internal margin of the upper face. The external face of the propodus is armed with spines which are regularly arranged in five longitudinal rows; only at the distal end of the propodus, at the base of the fingers, do these spines lose their regular serial arrangement; from the bases of these spines spring long setæ; the fingers are acute, tuberculo-spinose and setose, like the hand. The fingers of the left hand are longer in proportion to the palm than those of the right hand. The ambulatory legs are rather robust, and longer than the chelipeds; their lateral surfaces are smooth; the upper margins of the carpi are armed with a row of little spines, and the corresponding margins of the propodi are denticulated; the dactyli are longer than the propodi, but not so long as the propodus and carpus combined; the anterior pair of ambulatory legs differs from the posterior pair in having the dactylus and propodus a little shorter, and the lower edge of the merus more hairy and minutely spinulose. The telson is deeply cut by a broad median notch in its hind margin into two lobes, the left of which is the larger. The margins of both lobes are spinose.

There is (in the alcoholic specimens) a narrow red ring around both fingers near their tips, a broader band of the same color around the base of the fingers, and a red patch on the inner side of the anterior face of the hand.

Length of carapace, 6.5 mm.; greatest breadth of carapace, 6 mm.; length of ocular peduncles, 2.3 mm.

Station 3368. 66 fathoms. 1 male.
" 3379. 52 " 1 male.

This species, like *S. iris* A. M. Edw., is characterized by the spiny armature of the chelipeds. It differs from *S. iris* by having a smaller number of spines upon the anterior face of the chela, and in their arrangement in a few definite longitudinal rows, the surface between the rows being spineless and reticulated. The chela does not display the lively iridescence so striking in Milne Edwards's species, nor are the ophthalmic scales bidentate at the end. The merus of the third maxilliped is not armed with a distal spine, as in *S. iris*.

Paguristes fecundus, sp. nov.

The anterior or gastric section of the carapace is smooth in the central and hinder parts, rugose near the front, and tuberculose in the antero-lateral region, where a few of the tubercles assume a spiny form; from the tubercular surface spring long slender setæ. The anterior margin of the carapace is produced in the median line so as to form an acute triangular rostrum, which projects beyond the subacute lateral processes; between the rostrum and the lateral processes the anterior border is concave and thickened so as to form a rim. The anterior gastric lobes are clearly defined anteriorly.

The ocular peduncles are long and cylindrical, reaching considerably beyond the antennal peduncle, but not quite so far as the antennulary peduncle. The ophthalmic scales are of moderate size and bidentate at the tip, the external tooth very minute. The antennal acicle reaches almost to the end of the peduncle; it is setose, and armed with six spines, two of which form a terminal fork, the others being marginal. The external prolongation of the second antennal segment is narrow, setose, and minutely spinulose; there is, moreover, a spinule on the upper face of this segment behind the base of the acicle; the antennal flagellum is very short (about equal in length to the anterior section of the carapace). The third pair of maxillipeds are closely approximated at the base; their merus joints are armed with three or four denticles on the lower margin, and one at the distal end of the upper margin.

The chelipeds are short and of like size and shape; the merus is smooth within, rugose without; the two inferior margins are armed with minute black-tipped spinules. The carpus is tomentose and spinulose, the largest spines occurring along the superior border; the hand is both spinulose and pubescent, but the hair is less dense upon the fingers than upon the basal portion of the hand, which is short and swollen below; the fingers are short, excavated within, and terminate bluntly in a dark corneous nail. The ambulatory limbs are pubescent, particularly on the upper and lower margins; the distal end of the merus, and also the carpus, propodus, and dactylus, are armed with numerous spines; the most prominent of these spines are arranged in a row along the upper border of the carpus and propodus; the dactylus is about equal in length to the propodus and carpus together. The legs of the fourth pair are furnished with long hairs on their upper margin, and there are a few spines on the upper margin of the carpus; the propodus is rather longer than the dactylus, and the rasping surface on its lower margin occupies two thirds of its length. The last pair of legs is much less hairy than the preceding pair; the rasping surface, which is truncate posteriorly, falls a little short of reaching the middle of the hand. The telson is divided by a pair of lateral incisions and a median one into four lobes, those on the left side the larger; the pair of terminal lobes are obscurely toothed on their margins.

Length of carapace, 9.5 mm.; breadth, 7 mm.; length of ocular peduncle, 4 mm.

Station 3368. 66 fathoms. 2 females ovig.

This species is nearly related to *P. lymani* A. M. Edw. et Bouv.,[1] of the West Indian region, and to *P. subpilosus* Hend.,[2] of New Zealand. From the former it is distinguished by the more prominent and acute rostrum which overhangs the ocular segment, by the smaller number of spines on the antennal acicle, and by the armature of the telson, the margin of which is ornamented with obscure teeth, while in *P. lymani* it is furnished with numerous spines whose tips are horny and dark colored. From *P. subpilosus* it differs in having shorter eyestalks and antennal acicle, fewer spines on the antennal acicle, a longer and narrower external prolongation of the second joint of the antenna, and a differently shaped telson.

The ovisacs of both specimens are large and filled with eggs.

Family PORCELLANIDÆ.

Petrolisthes agassizii, sp. nov.

In the shape of the carapace and the front this species bears a close resemblance to *Petrolisthes sexspinosus* (Gibbes) and *P. occidentalis* Stimps., but the transverse ridges are more broken anteriorly, while posteriorly they extend without interruption across the whole width of the carapace, being here more perfectly developed than in the two species above named. The carpus and claw,

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[1] Mem. Mus. Comp. Zoöl., XIV. No. 3, p 49, Plate IV. Figs. 13–22, 1893.

[2] Challenger Anomura, p. 77, Plate VIII. Figs. 2, 2 *a*, 1888.

moreover, are longer and narrower; the anterior margin of the carpus is three-toothed instead of five-toothed. The squames of the carpus and claw do not tend to widen out into ridges or folds either on the upper or lower face, but preserve the form of close-set imbricated scales over the whole surface, including the space between the longitudinal depressions of the carpus and along the depressed line of the propodus. The form of the carpus approaches nearer to that of *P. armatus* (Gibbes), but the present species may be readily distinguished from *P. armatus* by the prominent rugæ of the carapace and the squames of the chelipeds. From *P. edwardsii* (Sauss.) it is distinguished by its longer chelipeds, by the ridges of the hinder part of the carapace extending clear across the carapace without interruption, etc. The ridges of the frontal lobes are much more strongly developed in *P. agassizii* than in any of the allied species.

Carapace 5 × 5 mm.; cheliped, 34 mm.

One male, taken with *Petrolisthes occidentalis* Stimps. on the reef at Panama, at low tide, March 12.

Pachycheles panamensis, sp. nov.

Carapace subcircular, of equal length and breadth; upper surface flattened, granulate, and setose, especially on the gastric and anterior part of the branchial regions; posterior portions of the branchial regions lightly rugose. Front broad, produced to a rounded median lobe, lateral portions straight, inner orbital angle rounded, not produced; outer orbital angle projecting as a triangular tooth between the eye and the base of the antenna. Lateral border of the carapace with a concavity behind the antenna; the margin is slightly raised as a rim which is lost in one of the branchial rugæ before reaching the hind border of the carapace; hind border slightly concave. Chelipeds: unequal, the right being the larger; upper surface of the merus rugose and setose, under surface smooth, internal distal angle produced as a denticulated tooth; carpus short and broad, upper surface tuberculous and setose, internal border armed with a large tooth at the base, followed by one or two smaller teeth, lower surface smooth and naked; upper surface of the propodus furnished with small tubercles which bear stiff bristles, inner margin rounded, not toothed, outer margin granulated, lower surface convex, naked and polished near the centre (where the surface is reticulated in the larger claw), squamoso-granular and setose near the edges; fingers gaping, crossing at tips, toothless on both the inner and outer margins (or at most slightly denticulated on the outer margin). Ambulatory appendages setose.

Length of carapace, 6.5 mm.; breadth, 7 mm.; breadth of frontal margin, 2 mm.

Panama, March 12. 1 female ovig.

Pachycheles rudis Stimps. is a larger species, with the posterior margin of the carapace more concave (the concavity having almost the shape of a triangular notch); the carapace and chelipeds are less setose than in *P. panamensis*, the anterior margin of the carpus not prominently toothed, and there is a strong protuberance near the middle of the upper surface of the propodus. In *P. tuberculipes* Lockington, the central part of the front is triangular and deeply furrowed along the median line, the chelipeds and ambulatory legs are knobbed so as to present "a mass of tubercles above." *P. panamensis* appears to be near *P. barbatus* A. Milne Edwards, from the Azores, but in the latter species the front is broader and the carpus more denticulated.

Family GALATEIDÆ.

Pleuroncodes monodon (M. Edw.)?

Compared with Milne Edwards's figure of *P. monodon* (Ann. Sci. Nat., 3ᵉ sér. Zool., XVI. Plate XI. Figs. 6–9), the "Albatross" specimens present a more obese appearance; their greatest width is across the cardiac region, while in the figure of *P. monodon* it is near the posterior end of the carapace; the cardiac area, too, in the examples before me, is sunk below the level of the rest of the carapace, and the transverse piliferous lines are more broken at this point, as well as on the gastric region, than appears to be the case in *P. monodon*, to judge from the figure referred to. Unless these discrepancies are due to the inaccuracy of Milne Edwards's draughtsman, the "Albatross" specimens belong to a new species.

Station	3385.	286	fathoms.	16 males, 7 females.
"	3386.	242	"	9 males, 14 females.
"	3396.	259	"	2 males, 2 females.
"	3423.	94	"	18 males, 11 females.

Munida obesa, sp. nov.

In this species we see an approach to the genus *Pleuroncodes*, as the sides or latero-inferior walls of the carapace are somewhat swollen, so that they show a little when the animal is viewed from above. The basal joint of the antennæ, too, is more exposed from above than it is in the typical species of *Munida*. The lateral rostral spines, or supra-ocular spines, are curved upward more than the median rostral spine, and the three are nearly parallel, the lateral spines reaching about half way to the tip of the median; all three are microscopically spinulose on their upper edge. There are two pairs of spines on the anterior part of the gastric region in line with the lateral rostral spines. Of these two pairs the anterior is the larger. There is also a longitudinal line of spinules in the median line between the two pairs just spoken of. There are, in addition to these, several small spines irregularly arranged on each side of the gastric region. The cardiac area is somewhat sunk below the level of the surrounding parts; its anterior margin is denticulated, with a larger spine on each side. The lateral margins of the carapace are armed with ten or eleven spines, the one on the antero-lateral angle being the longest. The second abdominal segment is ornamented with a transverse row of eight small spines. The other abdominal segments are normally destitute of spines, but in a few of the many specimens before me there are two or four small spinules on the third segment. The pleuræ of the third, fourth, and sixth abdominal segments are acute, the rest blunt. The eyes are large, and are provided with rather long cilia on the edge of the cornea. The basal joint of the antenna is armed with a long and sharp spine which reaches forward beyond the eyes; the second joint also has a long spine on each side. The chelipeds are long and hairy; the merus, carpus, and basal part of the propodus are spiny, the fingers long, slender, the cutting edges straight and finely spinulose. The ambulatory appendages are setose, the upper and lower edges of the merus are spinulose and there is, moreover, a row of spinules on the outer surface, this external line of spinules being best developed on the proximal end of the segment. The carpus is armed with small spines on the upper margin, and one spine on the distal end of the lower margin; the penultimate and terminal joints are unarmed.

Length, 65 mm.; length of carapace, 34.5 mm.; breadth of carapace between epimeral sutures, 21 mm.; length of rostrum, 11 mm., length of cheliped, 84 mm., merus, 26 mm., carpus, 10 mm., basal portion of chela, 18 mm., dactylus, 21 mm.

Station 3389.	210 fathoms.	2 males, 7 females.
" 3355.	182 "	5 young.

Munida refulgens, sp. nov.

In this species the setæ on the ridges of the thorax and abdomen and on the legs are resplendent with iridescent hues. The rostrum is long, triangular in cross section, the upper surface scabrous, the lateral margins armed with two to four spines which are generally placed unsymmetrically on the two sides. The supra-ocular spines are short. There is a transverse line of spinules back of the base of the rostrum, the two which lie on either side of the median line being larger than the others. Seven marginal spines on each side of the carapace, the ones at the antero-lateral angles the largest. There are no spines on the abdominal segments. The abdominal pleuræ are acute. The basal joint of the antenna has a plate-like expansion, but is not spinose; the second joint is furnished with an external spine. Chelipeds very long, squamose, and clothed with silky setæ; the merus has a row of spines on the upper margin, another on the inner side, and a row of smaller ones on the outer side; the carpus is provided with three or four spinules at the distal end; the chela is slender, the outer finger flattened, ribbed above, the outer edge rather convex and expanded toward the base; cutting edges of fingers finely denticulated. The anterior border of the merus and carpus of the ambulatory appendages is spinose. The general color in life is red. In the alcoholic specimens the color is retained in the chelæ and particularly in the rostrum.

Dimensions of largest specimen (male). Length, 91 mm.; length of carapace, including rostrum, 43 mm.; breadth of carapace, 34 mm.; length of cheliped, 211 mm., merus, 90 mm., carpus, 15 mm., basal part of chela, 56 mm., dactylus, 42 mm.

Station	3367.	100 fathoms.	13 males, 18 females (7 ovig.).
"	3378.	112 "	15 males, 19 females (14 ovig.).
"	3379.	52 "	1 young.
"	3427.	80 "	1 young.

In *M. iris* A. M. Edw., the setæ are iridescent, as in this species, but the rostrum lacks the lateral spines and the supra-ocular spines are much longer, reaching beyond the eyes; from *M. irrasa* A. M. Edw., our species differs in the shape of the hand, in the relatively shorter median rostral spine provided with lateral spines, etc.

Munida propinqua, sp. nov.

The carapace of this species is rather flat; the rostral spines are scabrous, the lateral reaching to a point beyond the eyes; there is a prominent spine on the gastric area behind each lateral rostral spine, another on each side behind and external to these, and a pair of very small ones on the median line at the base of the rostrum; besides these there are about four small spines on the anterior half of the carapace. The anterior lateral angle of the carapace is truncated, the lateral border seven-spined. The pleuræ of the abdomen are rounded, short, and broad; the second abdominal segment is furnished with a transverse row of about eight spines, the rest of the segments being destitute of spines; the terga of the second to the fourth segments are very smooth behind the central transverse fossæ. The first joint of the antenna is armed with a long spine, the second joint with one on each side. There is a minute spine at the antero-inferior angle of the carapace. The chelipeds are robust, setose, and spiny; merus spiny on upper and inner parts; carpus spiny on all sides; The hand is furnished with two rows of spines on the lower side, another along the middle of the outer face, and three irregular series along the upper side; both the fingers are spinulose. Ambulatory limbs setose, spinose along the superior and inferior edges. In small specimens the lateral spines of the rostrum may be shorter than the eyestalks.

Length, 84 mm.; carapace (including the rostrum), 45.5 mm.; breadth, 26 mm.; length of cheliped, 96 mm.

Station	3384.	458 fathoms.	11 males, 6 females (1 ovig.).
"	3394.	511 "	1 male.
"	3404.	385 "	1 male juv.

This species resembles *M. miles* A. M. Edw., but the carapace of *M. propinqua* is flatter, the cardiac area is more distinctly circumscribed by a furrow, the abdomen bears spines only on the second segment, and the abdominal segments are not so much sculptured.

Munida gracilipes, sp. nov.

Carapace rather flat and quadrangular. Lateral spines of rostrum less than one half the length of the rostrum, shorter than the ocular peduncle. Four spinules on the gastric area arranged in the form of a square, — two behind each lateral rostral spine ; a longitudinal row of obsolescent spinules in the median line from base of rostrum to the cardiac area ; one spine on the cardiac region, a pair on the intestinal region, and one on each side of the cardiac region just back of the cervical suture. The lateral margins of the carapace are armed with about seven spines, the first of which is the largest. The second abdominal segment is armed with a transverse row of six spines, the third with a row of four, the fourth with a row of four and one median spine behind the transverse row. This is the normal arrangement, but in one specimen out of the four there is an additional pair of spines on the second and third segments back of the transverse row. The pleuræ of the third, fourth, and fifth abdominal segments are acute. Eyes very large, reniform. The chelipeds are very long and slender, the merus spinose (the chief of the spines being on the inner side of the joint) ; the carpus also is spinose. The hand has about eight spines on the upper margin and one on the lower ; there are several acute spines on the outer border of the movable finger, the cutting edges of the fingers are straight, finely denticulated or spinulose.

Length, 24 mm.; breadth, 8 mm.; length of cheliped, 34 mm.

Station 3391. 153 fathoms. 4 specimens.

This species is very near to *M. stimpsoni* A. M. Edw., but the carapace is flatter, less granulated, more quadrangular in outline, with more evident transverse rugæ ; the lateral rostral horns are shorter, the eye larger, the transverse ridges on the abdominal somites fewer in number; the lateral spines of the carapace and the abdominal spines are better developed, the cardiac area narrower and bounded by more distinct furrows.

Munida microphthalma A. M. Edw.?

Bull. Mus. Comp. Zoöl., VIII. 51, 1880.

Station 3370. 134 fathoms. 1 female ovig. Length, 20 mm.

Only one specimen of *M. microphthalma* has been returned to this Museum from Paris. It is a very small specimen, without chelipeds. The "Albatross" specimen differs from this one in having the rostral median spine less upturned. The chela, compared with that of *M. microphthalma*, as figured by Henderson (Rep. Challenger Anomura, Plate III. Fig. 4), has no spine on the outer margin of the dactylus, and the row of spines on the outer face of the hand is obsolete.

M. microphthalma was taken by the "Blake" among the West Indies in 573–1030 fathoms, and by the "Challenger" in the same region in 390 fathoms, north of the Kermadec Islands in 600 fathoms, and near Ascension Island in 425 fathoms.

Galacantha rostrata A. M. Edw.

Galacantha rostrata A. M. Edw., Bull. Mus. Comp. Zoöl., VIII. 52, 1880.
Galacantha bellis Hend., Ann. Mag. Nat. Hist., 5th Ser., XVI. 418, 1885; Rep. Challenger Anomura, p. 167, Plate XIX. Fig. 6, 1888.

Station 3362.	1175 fathoms.	1 male.
" 3400.	1322 "	3 males, 2 females (1 ovig.).
" 3413.	1360 "	1 female.

The "Albatross" specimens differ from the typical West Indian form in the greater divergence of the lateral spines, the anterior being more nearly parallel with the axis of the body; the abdomen is smoother toward the central part of the segments; the dorsal spine of the fourth abdominal segment is smaller. There is considerable variation among different individuals, and the characters pointed out by Henderson to distinguish *G. bellis* can hardly be deemed of specific value. The color in life is red, paler and yellowish toward the middle of the carapace. *G. rostrata* has been collected in the West Indian seas in from 1098 to 1591 fathoms, and off Juan Fernandez in 1375 fathoms (*G. bellis* Hend.).

Galacantha diomedeæ, sp. nov.

Rostrum without lateral spines; distal part turned upward at an angle of less than 95° in most specimens, but in some cases the inclination is greater; basal part marginate, the margin running for some distance along the anterior edge of the carapace; a slight keel runs back from the rostrum to the median gastric spine. Gastric spine smaller than in *G. rostrata;* anterior lateral spine much longer than the posterior; there is an additional small spine on the side of the carapace, just behind the cervical suture. Anterior half of the carapace ornamented with setiferous squamous tubercles; on the posterior half of the carapace the tubercles assume the form of interrupted transverse ridges. The median spines of the abdomen are small, diminishing successively in size from the first to the third, which is obsolete in some examples. Upper surface of abdomen rather hairy, the pleuræ tuberculose, angles rounded. The legs are rough with granular setose tubercles. There are two prominent spines at the distal end of the carpus of the chelipeds, and one at the distal end of the carpus and merus of the ambulatory limbs. The antennæ are twice and a half as long as the body.

Dimensions of a female specimen. Length of body, 79 mm.; length of carapace, 39 mm.; breadth of carapace, not including the lateral spines, 25 mm.

This species runs into a well marked variety, in which the anterior lateral spines, as well as the median gastric spine, are very much smaller than in the typical form. This variety may be called *Galacantha diomedeæ parvispina*. At one station (3429) both forms were obtained at the same haul.

This species differs from *G. rostrata*, *areolata*, *spinosa*, and *talismanii* in the rugose nature of the sculpture of the hinder half of the carapace. In the relative proportion of the anterior and posterior lateral spines it agrees with *G. spinosa*.

Station 3357.	782	fathoms.	1 female juv.
" 3363.	978	"	3 males, 3 females ovig.
" 3364.	902	"	1 female.
" 3366.	1067	"	3 males, 1 female ovig.
" 3371.	770	"	5 males, 2 females (1 ovig.).
" 3373.	1877	"	1 male.
" 3393.	1020	"	3 males.
" 3407.	885	"	2 males, 1 female.
" 3429.	919	"	1 male.

Var. *parvispina.*

Station 3418.	660	fathoms.	1 male.
" 3419.	772	"	1 female ovig.
" 3424.	676	"	1 male.
" 3429.	919	"	1 male.
" 3435.	859	"	18 males, 17 females (6 ovig.).
" 3436.	905	"	6 males, 4 females (3 ovig.).

In both *G. rostrata* and *G. diomedeæ* there is a curious sexual difference. In the male the proximal half of the telson is furnished on each side with long amber-colored setæ, which are entirely wanting in the female. The same difference between the sexes is found in some species of *Munidopsis*.

G. diomedeæ is often infested with parasites. One of the males from Station 3371 bears a *Peltogaster*, while seven specimens (5 males, 2 females) of var. *parvispina* house a *Bopyrus* in the left branchial chamber.

The eggs of this species measure 3 × 2.5 mm.

Munidopsis[1] vicina, sp. nov.

Near *M. ciliata* Wood-Mason, from which it differs as follows. It is a very much smaller species, the adult ovigerous female being only twenty-nine millimeters long; the anterior margin of the propodus of the ambulatory appendages bears two very prominent spines. The telson lacks the pair of long and narrow plates which lie on each side of the small central plate in *M. ciliata*. As in *M. ciliata*, the carapace is covered with squamous tubercles, the rostrum is curved slightly upward, and the chela is short.

Length, 29 mm.; breadth, 9.5 mm.

Station 3360.	1672	fathoms.	1 female.
" 3382.	1793	"	1 female ovig.

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[1] The genus *Munidopsis*, as here understood, includes *Galatodes*, *Orophorrhynchus*, and *Elasmonotus* of A. Milne Edwards, and *Anoplonotus* of Smith.

Munidopsis agassizii, sp. nov.

The carapace of this species is moderately convex, with a deep transverse depression across the anterior part of the cardiac area. The rostrum is long, slightly upturned, and armed near the middle with a pair of lateral spines. The gastric area has four pairs of spines, the anterior pair the largest. The cardiac area bears two or three pairs of spines. The lateral margins of the carapace carry from six to eight spines each, and there is a longitudinal series of small spines within the margin on the branchial area. A small spine is situated on the anterior margin between the eye and the antenna. The posterior border of the carapace is ornamented with six (in one specimen seven) spines. There are also several spines on the sides of the carapace below the epimeral suture. There is a very small spine over each eye. The antennæ are shorter than the body, the first joint bears a long external spine, the second joint two lateral spines, the third joint two lateral spines and one superior. The chelipeds are long and slender, the merus and carpus have no long spines, the propodus carries four spines on the upper edge and several rudimentary spinules, the fingers are spinulose, their cutting edges straight and denticulated. The ambulatory appendages have spiny meri and carpi, the longest spines being one at the distal superior border of each of these joints. The second, third, and fourth abdominal segments bear four spines each. The abdominal pleuræ are rounded.

Length, 23 mm.; length of carapace, 12.4 mm.; breadth of carapace, 8 mm.; length of rostrum, 4.5 mm.

Station 3389. 210 fathoms. 1 male, 1 female.

This species bears a general resemblance to *M. erinacea* (A. M. Edw.) and *M. spinifera* (A. M. Edw.). It differs from both these in having a flatter carapace marked by a deeper transverse depression across the cardiac area, in having a larger number of spines on the sides of the carapace, and in the presence of spines on the pterygostomian regions and a small but distinct spine over the eye. It also has strong spines on the superior edge of the hand which are wanting in *M. erinacea* and *M. spinifera*. In the possession of three pairs of gastric spines it agrees with *M. spinifera*, but differs from *M. erinacea*.

Munidopsis villosa, sp. nov.

The whole surface of the body and limbs is beset with setæ, which arise from low squamous tubercles and transverse rugæ on the carapace, and from the transverse ridges of the abdominal segments. The rostrum is triangular, the distal half upturned, cylindrical, and pointed, the proximal half naked below and slightly carinated in the median line. A pair of short, stout, blunt spines on the gastric region. One spine at antero-lateral angle of the carapace, one on margin of the hepatic area, and a rudimentary one on the side of the branchial region. There is a medium spine on the second, third, and fifth abdominal segments, and a rudiment of one on the fourth. The abdominal pleuræ have rounded external angles. The eyes are freely movable and destitute of spines. The second antennal segment is armed with a prominent external spine. The chelipeds are robust, setose, and granulate ; the merus has a short superior spine and two lateral spines at the distal end; the carpus is similarly equipped, though on one side the superior spine is obsolescent ; the chela is broad and strong, the fingers excavated, denticulated on their cutting edges and at their tips. The merus of the first pair of ambulatory appendages has an external distal spine ; the carpus of all the ambulatory limbs has two longitudinal ridges, and that of the first and second pair has a spine on the upper border at the distal end of the joint.

Length, 55 mm.; breadth, 18 mm.; length of carapace, 31 mm. ; rostrum, 8 mm.

Station, 3394. 511 fathoms. 1 male.

Munidopsis hystrix, sp. nov.

Carapace setose and thickly covered with small spiny tubercles; three spines of special prominence on the gastric area disposed in the form of a triangle with apex directed backward; one on the cardiac area; two (rarely six) on the hind margin of the carapace; one on each branchial area. There is a spine at the external angle of the orbit, and the lateral margin of the carapace is spinose. The rostrum is long, lightly curved upward from the base to the tip, and armed with from two to five spines on each side ; these spines are unsymmetrically arranged on the two sides. The second, third, and fourth abdominal segments are conspicuously two-ridged; the second segment has a pair of small spines on the anterior ridge, and another pair nearer the median line on the posterior ridge; the third segment also has a pair of spines on the anterior ridge, and in some specimens a third spine in the median line on the posterior ridge. The abdominal pleuræ are truncate. The chelipeds are long, very spiny from the proximal end of the merus to the base of the fingers; the chief spines of the propodus are on the upper margin of the segment ; there are two spines near the base of the dactylus. The ambulatory appendages are long, setose, and spinose except the dactylus joint. A spine over the eye. Antennæ shorter than the body ; a spine on the outer side of the first segment, one on each side of the second and third segments, and one on the upper side of the third segment.

Length of ovigerous female, 47 mm. ; length of carapace, 25 mm. ; breadth, 15 mm. ; rostrum, 8 mm.

Station	3417.	493 fathoms.	1 male, 2 females ovig.
"	3424.	676 "	4 females (2 ovig.).
"	3425.	680 "	7 males, 5 females (2 ovig.).

Munidopsis sericea, sp. nov.

The whole surface of the body and limbs is covered with a silky pubescence. The rostrum is long, curved gently upward, convex above, but not carinated, armed with a prominent spine on each side near the middle, and with three more minute spinules near the base. Gastric region swollen, armed with two conical spines and ten or twelve small spinuloid tubercles. The cardiac region has a prominent transverse ridge near the centre, in front of which is a deep depression separating it from the gastric region; the ridge is armed with a pair of short spinules. There is a small spine on the anterior border between the eye and the antenna, a large one at the antero-external angle, three on the border of each hepatic region (the middle of one of these is the largest), and one small one on the border of each branchial region just behind the cervical suture; there are besides about ten sharp tubercles on each branchial area, and five or six pairs of spinules on the posterior margin of the carapace. Pterygostomian regions granulated. There is a pair of spines on the second, third, and fourth abdominal segments; besides these there are several small spinules on the terga and pleuræ of these segments; the pleuræ are rather narrow, with rounded lateral angles. The chelipeds are wanting in the unique specimen. The ambulatory appendages are spinulose, the spinules of the dactyli restricted to the hind margin. The eye is provided with a very minute spine. The antennæ are rather longer than the body, the basal joint has a short external spine, a longer one at the lower internal angle, and a small one at a higher level on the inner side. The latter spine shows, when the animal is viewed from above, between the eyestalk and the antenna. The subsequent segments of the antenna are armed as usual in this genus.

Length, 39 mm.; length of carapace, 12 mm.; length of rostrum, 8 mm.; breadth of carapace, 12 mm.

Station 3394. 511 fathoms. 1 male.

Munidopsis margarita, sp. nov.

In this species the rostrum has a gentle upward curve near the tip; it is carinate above, and minutely spinulous on the margins. The surface of the carapace is rough with squamous tubercles and forward-pointed spines. The gastric and cardiac regions are prominent, and separated from one another by a deep depression; a pair of spines on the gastric, and one spine on the cardiac region, attain a special prominence. A long sharp spine outside the eye forms the outer wall of a well marked orbit. There are eight spines on each lateral margin, six on the posterior (including those at the postero-lateral angles). The branchial areas are iridescent. Second abdominal segment: the anterior transverse ridge, which is broken down in the centre, bears on each side a prominent hooked spine, which is enlarged at the base and denticulated on the outer margin; the posterior ridge is furnished with three hooked spines; the pleuræ of this segment bear each a broad, flattened, forward-pointing tooth with denticulated edges; when the animal is viewed from above, this tooth appears to form the lateral extremity of the pleura, which really lies below it, and is rounded. Third abdominal segment: both ridges are spiny and denticulate, three spines being specially prominent on each ridge. Fourth abdominal segment: armed with but one small median spinule. The sides of the carapace below the epimeral sutures are covered with spiny tubercles, and display an iridescent lustre. The eye has two spines projecting over the cornea from the inner side; the posterior of these spines is very minute. The antennæ are very slender and about as long as the carapace; the first and second joints are provided with a prominent external spine, the third joint with three spines, viz. one external, one internal, and one superior. The chelipeds are absent in both the specimens. The ambulatory appendages are spinulose on all the segments except the dactyli, which are finely serrate on the hind margin. The legs, and more especially the sternum, are iridescent, like mother of pearl. This iridescence is seen in a less degree in several other species of this genus.

Length, 20 mm.; length of carapace, 11 mm.; breadth, 7 mm.; length of rostrum, 3.5 mm.

Station 3404. 385 fathoms. 1 male, 1 female.

Munidopsis crinita, sp. nov.

The whole surface is clothed with long setæ, which are longest and densest on the chelipeds and ambulatory appendages. The rostrum is very broad at the base and ends in three points, the middle of which is the longest; the rostrum is slightly carinate in the median line. The carapace is roughened by low setiferous ridges. The antero-lateral angles are obliquely truncate; a spine over the antennæ, and four on the lateral margin, the last one just behind the cervical suture, the third one obsolescent; hind margin unarmed. A pair of spines on the gastric region, behind the base of the rostrum. The abdomen is devoid of spines, and there is no spine over the eye. The antennæ are slender, shorter than the body; the basal joint is provided with a long spine on the external side, and another on the internal side; the second joint has an external spine, the third an internal one. Chelipeds: merus five-spined; carpus with one prominent spine; hand unarmed, broadest at base of fingers, cutting edges of fingers toothed. Ambulatory limbs setose, hind border of dactyli spinulose.

Length, 19.5 mm.; carapace, 11.5 mm.; rostrum, 2.6 mm.; breadth of carapace, 7.5 mm.

Station 3384. 458 fathoms. 1 female.

This species resembles *M. rosacea* (A. M. Edw.), *M. latifrons* (A. M. Edw.), and *M. tridens* (A. M. Edw.). From the first (*Comptes Rendus*, XCIII. 934, figured in *Recueil de Figures de Crustacés nouv. ou peu connus*, 1^re^ livr.) it differs in having a much shorter rostrum, in the presence of a pair of spines on the gastric region, in the different shape of the hand, the absence of prominent spines on the meri of the ambulatory legs, and its greater pilosity. From the second (judging from Milne Edwards's short description of that species) it is distinguished by the long setæ, gastric spines, and broader carapace. From the last it differs in being very hairy, etc. *M. rosacea* comes from the north coast of Spain, *M. latifrons* from the Barbadoes, *M. tridens* from St. Kitts.

Munidopsis ornata, sp. nov.

Carapace convex, the whole upper surface, including the rostrum, thickly covered with low squamous tubercles; seen under a magnifying power the surface of each tubercle is seen to be made up of a number of secondary scale-like prominences; the tubercles are not lengthened out transversely to form ridges on any part of the surface; two of the tubercles on the gastric region take on a spiny character. The rostrum is nearly horizontal, triangular in cross-section, the margins serrate; the anterior border of the carapace is convex between the eyes and the antennæ, but has no spine at this point; lateral border four-toothed, one of the teeth lying at the antero-lateral angle, two on the hepatic region, and one on the edge of the branchial region behind the cervical suture; the posterior border is delicately festooned, but not armed with spines. The abdomen is spineless, its surface punctate, anterior half of the pleuræ of the second segment tuberculate, all the pleuræ rounded. The eye has a transverse granulated tubercle running over the cornea from the inner side. The antennæ are very slender, and do not exceed the carapace in length. The chelipeds are moderately robust; the merus tuberculate and armed with a row of short spines along the upper edge; the carpus spino-tuberculate, with two longitudinal furrows on the outer side; the hand almost smooth on the inner side, outer side and superior surface roughened with low tubercles; fingers a little curved upward, spoon-shaped at the denticulate and setose tips. Ambulatory appendages: meri flattened, tuberculate, upper edge produced to a spinose carina; the carpi have three denticulate ridges; propodi scabrous, with an irregular row of spines on under side; the dactyli have black tips, and are finely spinulose on their posterior edges.

Length, 23 mm.; length of carapace, 12 mm.· breadth, 8 mm.; length of rostrum, 3 mm.

Station 3404. 385 fathoms. 1 male.

Munidopsis scabra, sp. nov.

The rostrum is triangular, slightly curved upward, carinated above, the lateral edges and the carina lightly denticulated. The carapace is covered with squamous setiferous tubercles which end in spiny points. There is a transverse row of six more prominent spiny tubercles on the gastric region. The posterior border of the carapace is ornamented with a denticulated rim (about eight denticles). There is a spine between the eye and the antenna below the anterior margin of the carapace. The abdomen is devoid of spines, the pleuræ have truncated lateral angles. A spine projects over the cornea of the eye. The antennæ are shorter than the body; a spine on the outer side of the basal joint, one on each side of the second joint, and one on each side and one on superior margin of third joint. The chelipeds are long, spinose, except the fingers; hand long, the basal part longer than the fingers. All the joints of the ambulatory appendages are spiny except the dactyli.

Length (ovigerous female), 40 mm.; length of carapace, 13.5 mm.; breadth, 14 mm.; rostrum, 5 mm.

Station	3424.	676 fathoms.	2 males, 1 female ovig.
"	3425.	680 "	1 male, 1 female ovig.

Munidopsis tanneri, sp. nov.

Carapace flat, quadrangular, covered with squamous setiferous tubercles which have a tendency to develop spiny points on the gastric region. This is especially true of a transverse row of six on the anterior part of that region. The rostrum is triangular and horizontal. There is a prominent spine on each side of the anterior margin of the carapace between the eye and the antenna, another at the antero-lateral angle, and two or three on the side of the hepatic area; the hind border of the carapace is denticulated. A small spine over the eye. Antennæ shorter than the body; one spine on the outer side of the first joint, two lateral and one superior on the second and third joints. Cheliped (present in only one specimen) long, slender; merus and carpus many-spined; propodus spiny along the upper and lower margins; tips of fingers enlarged and denticulated. Ambulatory limbs: a prominent row of spines on the upper edge of the merus and carpus, propodus and dactylus devoid of spines. Abdomen without spines; pleuræ narrow, angles rounded.

Length, 41 mm.; length of carapace, 23.5 mm.; breadth, 15.5 mm.; rostrum, 6 mm.

Station	3396.	259 fathoms.	2 males, 1 female (1 male with *Bopyrus*).
"	3397.	85 "	1 male.

This species is nearly related to *M. scabrosa*, but differs from the latter species in having the carapace broader and flatter, with squamous tubercles which are not produced into points except a few on the gastric area. The spine between the eye and the antenna is longer; the propodi of the ambulatory legs are smoother, with no well-developed spines.

Munidopsis hamata, sp. nov.

Body and limbs clothed with short, scattered setæ. Rostrum long, curved slightly upward, basal half furrowed longitudinally, with a row of short spines on each side of the furrow; infero-lateral edges of rostrum also furnished with small spines. Carapace quadrangular, anterior border forming a right angle with lateral border, both borders spinulose; lateral border with an indentation at anterior boundary of hepatic area; a deep depression back of each hepatic area and another across the anterior part of the cardiac region; the upper surface of the carapace is adorned with spinulose tubercles, and a median longitudinal row of more prominent spines runs along the gastric and cardiac regions; the anterior spine of the cardiac region overhangs the transverse depression, the posterior spine of the row springs from the hinder rim of the carapace. There is a median hooked spine on the tergum of the second, third, fourth, and fifth abdominal segments and many spiny tubercles irregularly disposed on these segments; the pleuræ of the third to the sixth abdominal segments are narrow but blunt, those of the second to the fifth are costate. The ocular peduncle is movable and devoid of a spine. The antennæ are about as long as the body; the basal joint has an inferior and a small external spine; the second joint also bears an external spine. The chelipeds are long and slender; all the joints from the ischium to the propodus are equipped with longitudinal rows of small spines; the chela is not broader than the basal part of the propodus, the fingers are straight, their prehensile edges denticulate. The ambulatory appendages are spinulose.

Length of male, 49 mm.; length of carapace, 25 mm.; breadth of carapace, 14 mm.; length of rostrum, 9 mm.; length of cheliped, 47.5 mm.; merus, 15 mm.; carpus, 5.5 mm.; chela, 19 mm.

Station	3394.	511	fathoms.	13 males, 16 females ovig.
"	3395.	730	"	3 males.

Munidopsis aspera (Hend.).

Elasmonotus asper Hend., Ann. Mag. Nat. Hist., 5th ser., XVI. 416, 1885; Rep. Challenger Anomura, p. 163, Plate XIX. Fig. 4, 1888.

Station	3357.	782	fathoms.	1 female ovig.
"	3358.	555	"	1 male.
"	3370.	134	"	1 female.
"	3402.	421	"	2 males, 5 females (3 ovig.).
"	3403.	384	"	1 male.
"	3406.	551	"	2 males.

This species is subject to considerable variation. In the specimens from Stations 3402, 3403, and 3406 the tubercles of the carapace are more numerous and less spiny than in those secured at the other stations. The ambulatory appendages of all the "Albatross" examples are apparently more spiny than in the types from the "Challenger." The latter came from the Straits of Magellan, 245 fathoms.

Munidopsis quadrata, sp. nov.

Carapace quadrangular, the anterior and lateral margins forming a right angle; upper surface flat, spineless, but furnished with low squamiform tubercles.

Rostrum curved upward, broad at base, narrowing anteriorly to form a long, sharp acumen. Central part of gastric region prominent above the hepatic region, from which it is separated by a deep pit. A prominent transverse ridge on cardiac region, forming the posterior wall of a deep fossa. Antero-lateral angles rounded. Second segment of abdomen armed with a median spine which is curved forward; third and fourth segments with a very prominent ridge which bears an acute median tooth; pleuræ of second segment faintly tuberculate, the others narrow with the external angles rounded but not truncate. Eye spineless, almost concealed by the base of the rostrum. Antennæ about as long as the carapace; a conspicuous spine on the upper side of the third segment. Cheliped long, tuberculate with the exception of the fingers; chela slender, fingers not gaping. Ambulatory legs tuberculate with the exception of the dactyli, which are furnished with small teeth on the posterior margin.

Length of body, 29 mm.; length of carapace, 15.5 mm.; breadth of carapace, 9 mm.; length of rostrum, 6 mm.; length of cheliped, 30 mm.

There is some variation in the length and upward curvature of the rostrum among the different specimens. A female, from station 3424, differs markedly from the males in having the tubercles on the carapace and appendages much more strongly developed.

Station 3424.	676 fathoms.	2 males, 1 female ovig.
" 3425.	680 "	1 male.

Munidopsis depressa, sp. nov.

Closely allied to *M. hamata*, but differs as follows. The cephalothorax is more swollen, so that the sides of the carapace are visible below the epimeral sutures when the animal is viewed from above. The median row of spines on the carapace consists of a smaller number of spines (two on the gastric region, one on the cardiac region, and one on the posterior margin). The spinules of the lateral margin of the carapace are less developed. The depression on the carapace involves the gastric region to a greater degree. The anterior margin of the carapace is not so straight, and it is not spinuliferous. The antero-lateral spine is more prominent, the eyes smaller, and the antennæ shorter (shorter than the carapace). There is, moreover, no spine on the fifth abdominal segment.

Length, 32 mm.; carapace, 19 mm.; rostrum, 5 mm.; breadth of carapace, 12.5 mm.

Station 3425. 680 fathoms. 1 male.

Munidopsis carinipes, sp. nov.

Carapace quadrangular, flat, marked by a median tuberculated ridge on the gastric and cardiac regions; sides converging a little from front backward; the antero-lateral angles form a rounded shoulder. Rostrum broad at base, nearly horizontal, sides converging near tip, which is blunt; upper surface nearly flat, lightly granulated. The rest of the upper surface of the carapace has a coarser granulation. There is a conspicuous hooked tooth on the third and the fourth abdominal segment, and in some specimens there is a rudimentary one on the second and the fifth segment; the teeth on the third and fourth segments have denticulated margins in adult specimens; abdominal pleuræ long and narrow. Chelipeds very long, lightly tuberculate; chela long, slender, fingers rather short, smooth, with straight denticulated prehensile margins. The meri of the ambulatory legs granulated, superior border produced to a keel, the edge of which is entire; the lower margin of the meri is also entire; the carpi have three tuberculated ridges, one superior, two external; the propodi are lightly tuberculated; dactyli smooth, their hind margin armed with about five teeth. Eye spineless, nearly hidden under the rostrum. Antennæ shorter than the carapace, first, third, and fourth joints armed with an external spine.

Length, 30 mm.; carapace, 16 mm.; breadth, 9.5 mm.; rostrum, 5 mm.; cheliped, 40 mm.; merus, 13 mm.; carpus, 4.5 mm.; propodus, 17 mm.; dactylus, 7 mm.

Station 3353. 695 fathoms. 2 males, 1 female ovig.

Near *M. longimana* (*Elasmonotus longimanus* A. M. Edw.), from which it differs in having the rostrum more nearly plane, the merus of the cheliped much less strongly tuberculated, the meri of the ambulatory limbs more strongly carinated, with lower margin entire instead of denticulate; the spine on antennal peduncle is more prominent, while the tooth on the second segment of the abdomen is absent or at best rudimentary.

Two specimens (male) of *Elasmonotus longimanus* A. M. Edw., and one (female) *E. brevimanus* A. M. Edw., have been returned to Cambridge from Paris. I suspect that these may prove to be the male and female of one species. The chelipeds of the female specimen of *M. cristatipes* are lost.

Munidopsis hendersoniana, sp. nov.

In this species, as in *M. armata* (*Elasmonotus armatus* A. M. Edw.) and *M. marginata* (*Elasmonotus marginatus* Hend.), the lateral margins of the carapace are extended as sharp crests overhanging the sides of the body. The upper surface of the carapace is rather flat, and is clothed with a close short pubescence; the sides are nearly parallel. The rostrum is long, acute, nearly horizontal, the upper surface roof-shaped. There is an acute tooth on the anterior margin of the carapace external to the eyestalk and another at the antero-lateral angle; otherwise the carapace is unarmed. The eyestalks are immovable and prolonged into a long horn one half as long as the rostrum; seen from above, the eyestalks appear like lateral spines of the rostrum. The eye is rudimentary, occupying the basal part of the lower side of the peduncle. The antennæ are shorter than the body, the basal joint armed with a well developed inferior spine. The chelipeds are short robust and tomentose; there is a spine at the distal superior angle of the ischium and another near the distal end of the lower internal edge; five spines along the superior margin of the merus and two inferior distal spines; the carpus bears a superior proximal tooth together with three teeth on the distal margin; the chela is short and stout, the hand without teeth or spines; the fingers are very thick and short, meeting one another only at their spoon-shaped denticulated tips; there is a rounded tubercle at the base of the inner margin of the immovable finger; the outer margin of this finger is denticulated. Ambulatory limbs: five to seven spines on the superior and external inferior margins of the meri (those on the superior margin the largest); upper edge of carpus three- to four-spined; propodi and dactyli unarmed. Abdomen without spines.

Length, 37 mm.; carapace, 20 mm.; rostrum, 6.5 mm.; breadth of carapace, 12 mm.; length of cheliped, 28 mm.

Station 3393. 1020 fathoms. 3 males, 1 female (with *Peltogaster*).

Nearly related to *M. edwardsii* (*Elasmonotus edwardsii* Wood-Mason, Ann. Mag. Nat. Hist., 6th series, VII. 201, 1891) of the Bay of Bengal, but easily distinguished from that species by the lateral margins of the carapace, which in Wood-Mason's species are divided into two lobes, but in *M. hendersoniana* are entire.

Munidopsis inermis, sp. nov.

In this species the whole surface of the body and appendages is naked and free from spines and tubercles. The carapace is rather flat above, with subparallel sides; the gastric region is protuberant and separated from the hepatic and cardiac areas by conspicuous furrows. The surface of the carapace is punctate and lightly granulate and rugose on the branchial regions. The rostrum is triangular, blunt at the apex, bent strongly downward, and slightly carinate above. The antero-lateral angle is rounded, and a rounded lobe projects from the anterior margin above the base of the antenna. The abdomen is smooth, naked, devoid of spines and ridges; the abdominal pleuræ are rounded. Ocular peduncle free, spineless. The peduncle of the antenna is also destitute of spines; the flagellum is wanting in the only specimen obtained. The chelipeds are also missing. The ambulatory appendages are smooth, unarmed; the dactyli long (equal to the propodi in length), slightly curved, acute at the tips. The appendages of the third, fourth, and fifth abdominal segments are simple and rudimentary. The merus of the third maxilliped is short, its antero-internal margin three-toothed; the palpus of this appendage is nearly as long as the merus and ischium combined.

Length, 12 mm.; carapace, 6 mm.; breadth, 4 mm.

Station 3354. 322 fathoms. 1 male.

This species nearly resembles *M. polita* (*Anoplonotus politus* Smith), but the carapace of the former is longer and narrower, the rostrum is curved more strongly downward, and the propodi of the ambulatory limbs are much shorter in proportion to the dactyli.

Uroptychus nitidus occidentalis, subsp. nov.

Differs from the typical *Uroptychus nitidus* (A. M. Edw.)[1] as follows: the branchial regions are more swollen, giving to the posterior half of the carapace a more convex lateral outline; the rostrum is shorter, the chelipeds shorter and more robust, the fingers shorter in proportion to the length of the basal part of the propodus; the branchial regions are more distinctly margined. It approaches in some respects *U. uncifer* (A. M. Edw.), in which the rostrum and chelipeds are still shorter. In some specimens of *occidentalis* there are a few low tubercles on the inner side of the proximal end of the merus and ischium of the chelipeds, — a condition similar to that in *U. australis* Hend. which may be considered a variety of *U. nitidus*. *U. politus* Hend., another closely related form, is distinguished by its short antennal acicle.

Length of body of a female, 29 mm.; length of carapace, 15 mm.; length of rostrum, 4 mm.; breadth of carapace between antero-lateral spines, 5 mm.; breadth across the branchial region, 10 mm.; length of cheliped, 44.5 mm.; merus, 11 mm.; carpus, 12.5 mm.; chela, 17.5 mm.; dactylus, 6 mm.

Station 3384. 458 fathoms. 2 males, 2 females ovig.

Uroptychus pubescens, sp. nov.

Carapace, without including rostrum, broader than long, pubescent; a transverse row of spines across the gastric region from one side of the carapace to the other; lateral border of carapace spinulose; the anterior margin has a deep concavity above the eye, outer angle of the concavity armed with a spine. Rostrum one half as long as the rest of the carapace, bent downward a little, acute, with entire setiferous margins. Eye small, not broader than the eye-stalk, with brown pigment. Abdomen naked, smooth, pleuræ subacute. Antennæ equal in length to the carapace with the rostrum; acicle shorter than the peduncle. Chelipeds long, all the joints as far as the fingers spinulose, the spinules with broad bases; propodus not broader than the carpus; carpus equal in length to the basal portion of the propodus; fingers straight, a slight tooth near the base of the dactylus; the tips of the fingers cross. Meri of ambulatory legs minutely spinulose on the superior margin, distal end of propodus spiniform on the hind margin, whole hind margin of dactylus armed with spines; all the joints of the ambulatory limbs are furnished with long setæ.

Length (female), 44 mm.; breadth, 17.5 mm.; length of carapace, 21 mm.; length of rostrum, 7.5 mm.; length of cheliped, 57 mm.; merus, 12 mm.; carpus, 15 mm.; chela, 24 mm.; dactylus, 9.3 mm.

Station 3354. 322 fathoms. 2 females ovig.
" 3355. 182 " 1 female ovig.

This species is more nearly related to *U. insignis* Hend. than to any other described species.

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[1] Bull. Mus. Comp. Zoöl., VIII. 62, 1880.

Uroptychus bellus, sp. nov.

Carapace broad, branchial regions inflated, upper surface naked, smooth, and polished; the branchio-cardiac lines meet in the median line of the carapace; the anterior margin has a concavity above the eye, forming an orbit with a spinule at its external angle. There is one spine at the antero-lateral angle, one on the margin of the hepatic area, and eight on the margin of the branchial region; the branchial spines decrease in size posteriorly. The rostrum is long, tapering, acute at the apex, and concave at the base above. The abdomen is smooth, the pleuræ subacute. The eyestalks are short and stout, the eye not wider than the peduncle, black. The antennæ are very slender, shorter than the carapace, the acicle considerably shorter than the peduncle. Chelipeds very long, naked except for a few setæ on the fingers, polished; the ischium bears a spine on the superior margin and several others on the lower side; the merus and carpus are armed with spines arranged in longitudinal rows; there is a row of spines on the upper margin of the propodus (the row is double at the proximal end), another series on the outer face reaching from the proximal end about half-way to the distal end, and another still shorter row of more rudimentary spines just outside the latter series; the fingers are separated by a gap; their prehensile edges are denticulate, with one or more prominent teeth near the base of the dactylus. Ambulatory appendages: meri and carpi of the first and second pairs spinulose along the upper edge, these joints being spineless on the third pair. All of the ambulatory appendages are subchelate, the distal end of the propodus being enlarged and furnished with spines against which the spined dactylus closes.

Length (male), 17 mm.; carapace, 10.5 mm.; rostrum, 4.5 mm.; breadth of carapace, 7.7 mm.; cheliped, 31 mm.; merus, 7 mm.; carpus, 9 mm.; chela, 14 mm.; dactylus, 5 mm.

Station	3354.	322	fathoms.	1 female ovig.
"	3355.	182	"	1 male.

Family AXIIDÆ.

Axius crista-galli, sp. nov.

Near *Axius acutifrons* (*Eiconaxius acutifrons* Bate), but differs in the following regards. The margin of the rostrum is armed with prominent teeth. The median carina of the rostrum, entire or at most but slightly serrate in the former species, is here cut into about seven prominent teeth. The larger claw differs from the corresponding organ in *A. acutifrons* in lacking the serration on the superior margin of the propodus, in the presence of a strong tubercle on the anterior border of the hand between the bases of the fingers, and in the absence of prominent teeth on the prehensile edges of the fingers.

Length, 24.5 mm.; length of carapace, 10 mm.

Station 3359. 465 fathoms. 3 males, 1 female.

The female carries eighteen eggs of large size (2 × 1.5 mm.).

Family CALOCARIDÆ.

CALASTACUS, gen. nov.

Abdomen long, enlarged in the middle, narrowed at each extremity, pleuræ broad and rounded. Cephalothorax laterally compressed, rostrum long, acute; eyes rudimentary, subglobose, unpigmented, unfaceted. Second antenna on a horizontal line with the first antenna; the second segment armed with a long external spine (stylocerite) and a still longer articulated style-shaped scale (scaphocerite). Third maxilliped pediform. First and second pairs of legs chelate. First abdominal appendages of male modified to serve as sexual organs (gonopods). Outer branch of swimmerets divided near the posterior margin by a diagonal suture. Telson long, quadrangular. Gills composed of a central stem which bears two rows of filaments. Branchial formula:

Somite	VIII.	IX.	X.	XI.	XII.	XIII.	XIV.	
Epipods	1	1	1	1	1	1	0	= 6
Podobranchiæ . .	0	1	1	1	1	0	0	= 4
Arthrobranchiæ .	0	2	2	2	2	2	0	= 10
Pleurobranchiæ .	0	0	0	0	0	0	0	= 0

Differs from *Calocaris* in having a long styloid scaphocerite appended to the peduncle of the external antennæ.

Calastacus stilirostris, sp. nov.

Carapace naked, punctate; apex of rostrum turned a little upward; two strong spines turned upward and forward at base of rostrum; a light median carina runs along the back from the base of the rostrum, fading out before reaching the hind border of the carapace. Chelipeds long, symmetrical on the two sides; coxa furnished with a small spine on the anterior border of the distal end; ischium armed with from one to four spines on the lower margin; merus laterally compressed, armed with a spine on the upper edge near the distal end and a variable number (four to eight) of spines on the lower edge. Carpus triangular, unarmed. Chela: upper and lower margins sharp, the upper armed with five to seven spines, inner and outer faces with a few scattered spinules; fingers with denticulate prehensile edges and curved crossed extremities. Second pair of legs furnished with small chelæ.

Length of carapace, 22.2 mm.; rostrum, 5.5 mm.; abdomen, 30 mm.; cheliped, 39 mm.; chela, 17 mm.

Station 3418. 660 fathoms. 9 males.

Family ASTACIDÆ.

Nephropsis occidentalis, sp. nov.

Pubescent. Carapace cylindrical, the branchial regions convex. Rostrum densely ciliated on the margins, armed with a pair of lateral teeth near the middle; a double row of prominent granulations on the dorsal surface, diverging posteriorly and continued backward for some distance on the gastric region. A small, blunt papilla in the median line of the gastric area, a pair of acute teeth near the anterior margin at the base of the rostrum, and another pair just above the insertion of the second pair of antennæ; a small papilla in the median line on the intestinal region. Abdominal pleuræ rather longer-pointed than in *N. stewarti*, but not so much so as in *N. agassizii* and *N. atlantica;* their anterior borders are finely denticulated, but are destitute of spinous processes. Telson armed with a sharp spine in the median dorsal line, near the proximal end.

Length, 119 mm.; carapace, 51 mm.; rostrum, 14 mm.; second antenna, 225 mm.

Station	3418.	660 fathoms.	23 males, 32 females.
"	3424.	676 "	2 males.

Family ERYONTIDÆ.

Willemoesia inornata, sp. nov.

Similar to *W. leptodactyla*, but readily distinguished from it by the small number of spines on the margin and dorsal ridges of the carapace. The armature may be formulated thus: —

Marginal . . . . 5 to 8 — 2 to 3 — 0 to 6
Median ridge . . . . 1 to 5 — 0

The marginal spines which lie behind the cervical groove, if found at all, are but rudimentary, while there are no spines on the submarginal carina or along the lateral boundaries of the cardiac area, where they are present in *W. leptodactyla*. The third maxilliped bears only a slender epipod; the membrane that connects this limb with the body carries a small, but perfectly formed gill (arthrobranchia). According to Spence Bate, this gill is absent in *W. leptodactyla.*

Station	3374.	1823 fathoms.	8 males, 6 females.
"	3381.	1772 "	1 male, 1 female ovig.
"	3382.	1793 "	2 males, 4 females (1 ovig.).
"	3399.	1740 "	2 males, 1 female.
"	3400.	1322 "	1 female.

Polycheles[1] tanneri, sp. nov.

Orbital sinus rounded at the bottom, outer margin spinulose. Median carina of carapace furnished with two anterior rostral spines, followed by five (or six) spines in front of the cervical groove, the fourth (or fifth) of which is double. The arrangement of these spines may be thus formulated: 2. 1. 1. 1. 1. 2. 1 (or, 2. 1. 1. 1. 2. 1). Back of the cervical groove the spines of the median carina are 2. 2. 2. Marginal spines of carapace arranged as follows: 5—3—13 or 14). A longitudinal row of four small spinules on the anterior division of the carapace midway between the median and marginal rows, and a row of twelve or fifteen on the branchial regions inside the margin of the carapace. There are, besides, two or three spines on each side of the hind margin of the carapace, and a few along the cervical groove.

Resembles *P. nanus* (Smith), but differs in the number of spines on the median and sublateral carinæ of the carapace, in the existence of a spine on the antero-external angle of the first and second abdominal pleuræ, and in the greater number of spines on the merus, carpus, and propodus of the chelipeds. *P. nanus*, moreover, is described as having the posterior pair of thoracic appendages chelate in the male, while in the males of *P. tanneri* that I have examined these appendages are simple. Compared with the types of *P. agassizii* (A. M. Edw.), the carapace of the present species is broader and fewer-spined on the margins; the first and second abdominal pleuræ are armed with an anterior lateral spine; the rostral spine is double; and the orbital sinus is broad and rounded at the bottom. *P. agassizii*, like *P. tanneri*, has non-chelate posterior legs in the male.

Station 3354.	322 fathoms.		1 male.
" 3402.	421	"	2 males, 1 female.
" 3403.	384	"	12 males, 14 females.
" 3409.	327	"	1 female.

Polycheles sculptus pacificus, subsp. nov.

Differs from the Atlantic *P. sculptus* Smith as follows. The carapace is broader in proportion to the breadth of the abdomen, the lateral margins converging strongly at the posterior end, where, in *P. sculptus*, they continue nearly parallel to one another; there is a small spine on each branchial region inside of and on a level with the second spine of the submarginal carina, which spine is entirely wanting in *P. sculptus;* the spine on the anterior border of the ophthalmic lobe is larger and blunter; the pleuræ of the second abdominal somite have a different shape, their anterior margins being in line with the anterior margin of the tergum, whereas in *P. sculptus* they form a strong obtuse angle with that margin.

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[1] The genus *Polycheles,* as here defined, comprehends *Polycheles, Pentacheles,* and *Stereomastis* of Bate.

These differences, although slight, are constant, and should be recognized in our nomenclature, if any significance is attached to geographical variation.

The last thoracic appendages are chelate in the adult female, while they are but imperfectly so in breeding males; that is, in the male the "thumb" is very much shorter than the index.

Station 3353.	695	fathoms.	1 male.
" 3392.	1270	"	1 female.
" 3393.	1020	"	3 males, 3 females.
" 3394.	511	"	12 males, 20 females.
" 3418.	660	"	1 male, 1 female.
" 3419.	772	"	1 female.
" 3424.	676	"	1 female ovig.

Polycheles granulatus, sp. nov.

Carapace long oval, broadest across the anterior branchial region; dorsal surface granulated, but nearly devoid of spines; there are two small rostral spines, and back of these, on the low granulated median carina, lies another pair followed by one or two spinules on the gastric area. The submarginal ridge is incurved and composed of minute spinulose granules. Orbital notch narrow, armed with a spine at its internal angle and with another at its external angle. Marginal spines thus disposed : 9 (or 10) — 3 — 15. The anterior abdominal pleuræ are rounded, gradually becoming acute as one passes backward to the sixth. The posterior thoracic legs in the sole specimen seen (a female) end in a small but perfect chela.

Length, 99.5 mm.; length of carapace, 45 mm. ; greatest width of carapace, 37 mm. ; length of cheliped, 118 mm. ; ischium, 19 mm. ; merus, 33 mm.; carpus, 22 mm. ; basal part of propodus, 14.5 mm. ; dactylus, 22 mm.

Station 3380. 899 fathoms. 1 female.

Eryonicus cæcus Bate?

Station 3375.	1201	fathoms.	1 male, 62.5 mm. long.
" 3377.	764	"	1 female, 40 mm. long.
" 3383.	1832	"	1 juv., 37 mm. long.
" 3388.	Surface to 400 fathoms, submarine tow-net.		4 juv., 19–29 mm. long.

Bate's description of *E. cæcus* was drawn up from a single immature specimen, 13 mm. long, in which the first abdominal appendages were undeveloped. The largest of the "Albatross" specimens is a sexually mature male with well developed gonopods. It differs from Bate's specimen in having much shorter spines upon the carapace and abdomen ; the spines of the lowest series on the branchial region decrease in length posteriorly, while in the type spceimen the posterior spines in this row are the longest. Whether these discrepancies are due to difference in age, or whether they denote specific diversity, cannot be determined until more mature specimens are obtained from the Atlantic. In the smallest of the "Albatross" specimens (which have attained a length of 19 mm.) the spines, especially those of the abdomen, are relatively longer than in the adult, though not so long as in the type described by Bate.

As regards the ophthalmic sinuses and lobes, the genus *Eryonicus* is like *Polycheles* (*Pentacheles*).

Eryonicus spinulosus, sp. nov.

In this species the spines of the carapace, instead of being wellnigh limited to nine longitudinal ridges, as in *E. cæcus*, are thickly strewn over the whole surface. The intervals between the spines give rise to slender hair-like setæ. This is the arrangement of the spines of the median carina of the carapace :

2. 1. 1. 1. 2. 1. 1. — 2. 2. 1. 2.

The sublateral carina bears fourteen small spines, the lateral,

5 — 2 — 13 or 14.

The uppermost of the two carinæ below the lateral is denticulated anteriorly and armed with a spine at the front end behind the second antenna. The lowest ridge carries twelve spines, which increase slightly in length posteriorly. The rostral spines are very small, but on each side of the rostrum the front margin of the carapace is produced so as to form a pair of horns over the base of the first pair of antennæ. The abdomen is ornamented with seven longitudinal rows of spines, one dorsal and median, the others paired and lateral. The lowest of the lateral rows is on the upper part of the pleuræ.

Length, 37 mm. ; carapace, 21 × 17 mm. ; abdomen, 17 mm.

Station 3403. 384 fathoms. 1 specimen.

Family GNATHOPHYLLIDÆ.

Gnathophyllum panamense, sp. nov.

Closely related to *G. elegans* of the Mediterranean Sea, but distinguished by a prominent conical protuberance, pigmented with black, on the upper part of the cornea. In *G. elegans* this tubercle is wanting or reduced to the merest vestige, discernible only by aid of a lens. The rostrum of *G. panamense* is furnished with seven teeth above, and one below. Color entirely different from that of *G. elegans*. The ground tint is dark brown, ornamented with a multitude of light blue spots, amongst which are sixteen red spots. Rostrum, eyes, and antennæ whitish, flagellum of second antenna orange. The fifth and sixth abdominal segments, the telson, and the swimmerets are also white. Basal joints of second pair of chelipeds violet, the merus, carpus, and fingers whitish, basal part of propodus orange. Third, fourth, and fifth pairs of legs violet.

Panama, March 12. 1 female ovig.

G. fasciolatum Stimps., from Australia and Amboyna, agrees closely in form with *G. elegans,* but differs wholly in the pattern of its color marks from both *G. elegans* and *G. panamense.* *G. zebra* Richters, from Mauritius, is without much doubt the same as *G. fasciolatum.* Ortmann has lately recorded a *Gnathophyllum* from Tahiti as a new species, *G. pallidum.* It differs from *G. fasciolatum* only in the absence of color marks, — a difference due possibly to the action of alcohol.

Family CRANGONIDÆ.

Sclerocrangon atrox, sp. nov.

Of the described species of *Sclerocrangon, S. ferox* G. O. Sars comes nearest to this species. These are some of the chief points of difference. In *S. ferox* the upturned rostrum is simple, while in *S. atrox* a long acute tooth is given off from its ventral side, a tooth which reaches as far forward as the tip of the rostrum. In the former species the dorsal carinæ of the sixth abdominal segment bear two pairs of well developed spines, while in the latter species one finds but one pair of very small spines at the posterior end of the carinæ. The pleural spines of the abdomen are much longer in the former than in the latter, and on the fifth somite there are four to five spines on each pleura against two in *S. atrox.* The eyes are much smaller in *S. ferox,* and lack the spine above the cornea seen in *S. atrox.*

Length of the largest specimen (a female), 162 mm.

Station 3418. 660 fathoms. 3 males, 2 females (1 ovig.).
" 3424. 676 " 4 females.

Sclerocrangon procax, sp. nov.

Nearly related to *S. agassizii* Smith, from the Atlantic side of the continent. The rostrum of *S. procax* is longer than in *S. agassizii,* and inclined upward at a much sharper angle; the same is true of the antero-lateral spines of the carapace. The most conspicuous difference is found in the anterior spine of the median carina of the carapace, which is much longer and nearly erect in *S. procax.* The two flagella of the first antenna in the male, *S. procax,* are subequal, while in the male *S. agassizii* the outer flagellum is much longer than the inner; the scale of the second antenna, moreover, is narrower in the former species than in the latter, and the terminal segment of the inner branch of the second abdominal appendage in the male bears on its inner margin a short blunt stylamblys, which is wanting in *S. agassizii.* In neither of these species is this segment produced into a lobe at the base of its outer margin, as it is in the more typical species of *Sclerocrangon,* e. g. *S. ferox* and *S. atrox.*

Length, 49 mm.

Station 3380. 899 fathoms. 1 male juv.
" 3418. 660 " 2 males, 3 females.
" 3435. 859 " 2 females ovig.
" 3436. 905 " 1 female.

Pontophilus occidentalis, sp. nov.

Allied to *P. abyssi* Smith and *P. batei.*[1] From the former it differs in having a shorter rostrum, larger eyes, and more strongly developed carinæ on the carapace. From the latter it also differs in its shorter rostrum armed with two pairs of lateral teeth; in the presence of a sharp spine on the sternum between the second pair of legs; in the length of the antennal scale, which in *P. occidentalis* is equal to the distance from the tip of the rostrum to the cardiac spine; in the shortness of the second pair of legs, which reach only half way to the distal end of the merus of the first pair; and in the absence of the spine on the outer margin of the merus of the first pair of legs.

The eyes are as large as in *P. gracilis* Smith(much exceeding the rostrum), but they are nearly colorless, and unfaceted, as in *P. abyssi* and *P. batei.*

Length, 73 mm.; carapace, 21 mm.

Station	3361.	1471	fathoms.	2	specimens.
"	3363.	978	"	2	"
"	3366.	1067	"	1	"
"	3381.	1772	"	4	"
"	3382.	1793	"	5	"
"	3392.	1270	"	1	"
"	3398.	1573	"	2	"
"	3413.	1360	"	4	"
"	3414.	2232	"	1	"
"	3415.	1772	"	2	"

Paracrangon areolata, sp. nov.

Rostrum long, acute, upturned, inferior margin armed with two spines. A prominent carina extends the length of the carapace in the median dorsal line; it is armed with four spines, three on the gastric, one (obsolescent) on the cardiac region. Orbit incomplete, bounded externally by a slender spine. Just below the base of the second antenna the antero-lateral angle of the carapace is drawn out into another rather stronger spine. Just behind this, and from a little higher level, a strong, sharp horn is directed outward and forward; this horn is in continuity with a rounded ridge which runs inward to the external orbital spine. A longitudinal carina on each side of the gastric region, armed with a small spine a little way behind the middle; from this spine another ridge runs upward and inward, meeting the median carina at the base of the third spine. The branchial regions are traversed by a series of ridges which

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[1] *Pontophilus gracilis* Bate, Rep. Challenger Macrura, p. 487, 1888. This name having been previously employed for another species by Smith (Bull. Mus. Comp. Zoöl., X. 36, 1882), I have substituted the name *Pontophilus batei* for *P. gracilis* of Bate.

anastomose in such a way as to divide these regions into cells of different sizes; they are armed with three small spines, the anterior of which is the spina hepatica.

The thoracic sterna are armed with two median spines, one of which is situated on the somite which normally bears the second pair of legs (absent in this genus), the other on the somite behind this. Abdominal pleuræ acute.

Chelipeds of moderate length, with a spine on each side of the distal end of the carpus, and another long and acute one at the antero-internal angle of the propodus.

Length, 85 mm.

Station 3424. 676 fathoms. 2 males, 3 females (1 ovig.).
" 3425. 680 " 1 male.

Family GLYPHOCRANGONIDÆ.

Glyphocrangon alata, sp. nov.

Rostrum armed with a pair of lateral spines on a level with the anterior end of the eye; posterior to this pair of spines follows a variable number of smaller marginal spines (three to five on each side). The anterior half of the rostrum is unarmed, although ciliated on the margin. A light spinulose carina runs along the median line of the rostrum from the base to the anterior third (in some specimens this carina is obsolete). On each side of the median line there are, on the basal part of the rostrum, four or five small spinules.

Carapace and abdomen thickly tuberculated. On the antero-lateral regions of the carapace, and on the abdominal pleuræ, the tubercles assume a spiny character. For the rest, the tubercles are mostly compressed, their tops truncate and more or less eroded. It is further to be noted that these tubercles are arranged in longitudinal rows, and that six of these rows on each side of the carapace form, by their prominence, imperfect carinæ, corresponding in position to those commonly found in species of this genus. Between the external orbital spine and the spine at the antero-lateral angle of the carapace lies a strong spinous tooth, acute at the end and vertically compressed, its base broadening out in such a fashion that the whole tooth forms an acute, wing-like expansion. This is, in fact, the greatly developed anterior part of the fourth carina (counting from the median dorsal line). Behind it the carina continues as a low toothed ridge. A median interrupted dorsal carina runs along the abdomen, broken up into two teeth on the base of the telson.

Length, 116 mm.

Station ? 12+ specimens.
" 3395. 730 fathoms. 1 "
" 3418. 660 " 2 "

Glyphocrangon spinulosa, sp. nov.

Rostrum long, acute, margins armed with vertically flattened spinous teeth from base to the level of the anterior extremity of the eyes, beyond which point the margins are unarmed; the anterior pair of the lateral spines are the largest. A median longitudinal row of smaller spines extends from the anterior boundary of the gastric area to the anterior fourth of the rostrum; anteriorly, these spines are confluent at their bases, forming a carina which is continued forward beyond the spines to the tip of the rostrum. Just inside the marginal spines is an irregular longitudinal row of very small spinules on each side of the rostrum.

The carapace is thickly covered with spinules which are laterally compressed. Along six longitudinal lines on each side of the carapace the spines are larger, more flattened, forming interrupted carinæ. The third carina (reckoning from the dorsal line) ends anteriorly at the deep branchio-hepatic sulcus. The fourth carina is especially prominent on the hepatic region, where it is broken up into two or three prominent teeth. The two lowermost carinæ are obsolescent. The anterior margin of the carapace is produced into a large external orbital spine, directed obliquely upward and outward. The hind margin of this spine is furnished with a variable number of spinules.

The abdomen, like the carapace, is spinulose on the dorsum and pleuræ. An interrupted carina extends the length of the median dorsal line. On the sixth segment this carina is toothed along its edge. The second to the fourth abdominal pleuræ are armed with two spines curved outward and backward, the anterior one being the larger. The fifth pleura is likewise armed with two spines, but in this case the posterior spine is the larger. The sixth pleura ends posteriorly in a single spine directed outward at a greater angle than those of the more anterior somites. The median dorsal abdominal carina is continued along the basal part of the telson as a line of four or five teeth, which decrease in size from before backward.

Length, 105 mm.

Station	3353.	695	fathoms.	11	specimens.
“	3418.	660	“	91	“
“	3419.	772	“	1	“
“	3424.	676	“	19	“
“	3425.	680	“	1	“
“	3435.	859	“	2	“

Glyphocrangon sicarius, sp. nov.

Rostrum as long as the rest of the carapace, armed with a pair of short, blunt, lateral teeth, a little in advance of the front of the eyes, and with another pair of obsolescent ones at the root. Between these two pairs of teeth the margins of the rostrum are concave and slightly raised. From the anterior teeth the rostrum tapers regularly to the point. The upper surface is plane and smooth. A slight median carina, most obvious near the tip, runs through the whole length of the rostrum from the anterior end of the gastric area to the tip ; the lateral margins are slightly rimmed. The lower surface of the rostrum is longitudinally grooved, and wholly devoid of a median keel.

Orbital spine rather short and thick, directed a little outward and upward. The spine at the antero-external angle of the carapace is also short and thick, slightly exceeding in length the orbital spine. From its base a low keel extends backward over the hepatic area, — a keel unarmed with spines, but broken into two tubercles, the hinder of which is the more prominent. In the small triangular area between this keel and the gastro-hepatic sulcus are several tubercles disposed for the most part in a single row. The gastric region is free from tubercles in the median line save one minute one at the anterior boundary near the base of the rostrum; but on either side, this region is ornamented with tubercles ; these are not spiny, nor do they tend to form very well marked carinæ. On the branchial regions there are three carinæ on each side; the uppermost of these is broken up into five or six tubercles ; the top of these tubercles, as well as those of the other carinæ on the branchial and hepatic areas, exhibit a corroded surface, and a similar appearance is manifest on the whole lower surface of the carapace where it is bent beneath the thorax. The abdomen is irregularly bestrewn with low tubercles. The telson is straight and much shorter than the rostrum ; it is furnished with a small, laterally compressed tooth in the median dorsal line at base; both the dorsal carinæ and the lateral margins are obsoletely dentate along their basal half.

Length, 124 mm.; length of rostrum from tip to anterior gastric groove, 30.5 mm.; length of carapace, including rostrum, 58 mm.

Station 3382. 1793 fathoms. 2 specimens.

Family PANDALIDÆ.

Heterocarpus vicarius, sp. nov.

This is the Western representative of *H. gibbosus* Bate, from the Philippine Islands. It differs from that species as follows. The carapace is very much longer both in proportion to its height and to the length of the rostrum, and its dorsal margin is not so convex. The teeth on the upper edge of the rostrum are more numerous and closely set. The lateral carinæ of the carapace are more prominent. The third abdominal somite forms a sharper angle or knee. Finally, the antennulary flagella are longer and subequal in length.

Length, 110 mm.; rostrum, 26 mm.; carapace, including rostrum, 55 mm.

Station 3385.	286 fathoms.	49 specimens.
" 3386.	242 "	91 "
" 3389.	210 "	7 "
" 3396.	259 "	68 "

Heterocarpus hostilis, sp. nov.

Similar to *H. alphonsi* Bate, from off the Philippine Islands and Japan, but readily distinguished from that species by the stronger upward curve of the rostrum, by the presence of but one tooth in the median dorsal line of the carapace back of the base of the rostrum, and by the *two* spines on the third abdominal segment.

Length, 197 mm.; rostrum, 70 mm.; carapace, including rostrum, 108 mm.

Station	3353.	695	fathoms.	22	specimens.
"	3363.	978	"	24	"
"	3364.	902	"	3	"
"	3371.	770	"	20+	"
"	3380.	899	"	6	"
"	3393.	1020	"	8	"
"	3395.	730	"	2	"

Heterocarpus affinis, sp. nov.

Very similar to *H. hostilis*, from which it differs in the following particulars. The rostrum is much shorter; measured from the tip to the posterior limit of the orbit, it about equals the rest of the carapace in length. There are fewer teeth on its dorsal margin (five or six); the number of teeth on its lower margin varies from six to ten. The median dorsal line of the carapace is more convex, and it is armed, back of the base of the rostrum, with two acute teeth, where there is but one tooth in *H. hostilis.*

It bears a resemblance, further, to *H. dorsalis* Bate, collected by the "Challenger" in the Banda Sea, but it may be at once distinguished from the Oriental species by its shorter rostrum and the presence of two median teeth on the third abdominal segment.

H. affinis and *H. hostilis* belong to different geographical areas. *H. affinis* is the more northern form, found off Acapulco and Cape Corrientes, while *H. hostilis* was obtained in the Gulf of Panama.

Station	3418.	660	fathoms.	13	specimens.
"	3424.	676	"	5	"
"	3425.	680	"	9	"

Family NEMATOCARCINIDÆ.

Nematocarcinus agassizii, sp. nov.

The rostrum is one fifth longer than the rest of the carapace (in some small specimens only equal to the rest of the carapace), slender, nearly horizontal for the basal two fifths of its length, the remaining portion gently upturned and ending in a very acute point; its upper margin is continued backward in the form of a carina, which becomes obsolete on the hinder part of the gastric region; this carina is pectinate, or armed with close-set, forward-pointing teeth on the anterior part of the gastric region; the teeth are continued on the upper margin of the rostrum through one third or two fifths of its length, the distal third or three fifths of the rostrum being entirely free from teeth above; the lower edge of the rostrum is ciliated above the eyes and armed with three (rarely four) teeth, separated by wide intervals, on the distal half.

The third abdominal segment is somewhat prolonged posteriorly over the next segment, but the hind margin is rounded off and does not form a prominent tooth. The telson is tipped with three pairs of spines, the intermediate pair the longest; there are, besides, about six pairs of small spines on the dorsal side of the telson.

The flagella of both the antennules and antennæ are prodigiously developed, the antennule being nearly twice, the antenna more than twice, the length of the whole body including the rostrum; excepting the proximal part of the organ, the annuli of the antennary flagellum are enlarged at the distal end, giving a beaded appearance to the flagellum. The antennal scale reaches rather more than half-way to the end of the rostrum; it is truncate at the distal end and armed externally with an apical spine.

The legs have the characteristic shape and proportions of the genus. The dactyli of the third and fourth pair are slender, acute, somewhat curved, and invested by a pencil of long hairs. The dactyli of the fifth pair are stouter but very short, and hidden in the tuft of hairs which arises from the distal end of the propodus.

The outer blade of the swimmeret slightly surpasses the telson. It is fringed with long hairs along the internal and distal margin, and furnished with a minute tooth and a movably articulated spine on the external border near the distal end. The inner blade is a trifle shorter than the telson; it is also fringed along its whole margin with long hairs.

Dimensions of a female specimen. Length of body, rostrum included, 139 mm.; length of rostrum, 35 mm.; length of carapace, rostrum included, 61 mm.; length of telson, 20 mm.; length of antennule, 267 mm.; length of antenna, 315 mm.; length of antennal scale, 19 mm.

This species, like all the *Nematocarcini*, is very fragile. The long and slender rostrum is often broken off during life, and the attempt to restore it sometimes results in an abnormally small and otherwise monstrous rostrum, which might easily be mistaken for a specific character if ample material were not at hand.

Station	3353.	695	fathoms.	2	specimens.
"	3354.	322	"	4	"
"	3358.	555	"	90	"
"	3359.	465	"	2	"
"	3364.	902	"	4	"
"	3370.	134	"	8	"
"	3380.	899	"	7	"
"	3384.	458	"	1	"

Station	3393.	1020	fathoms.	8	specimens.	
“	3395.	730	“	3	“	
“	3406.	551	“	1	“	
“	3407.	885	“	14	“	(1 bopyrized).
“	3418.	660	“	4	“	
“	?	?		24	“	

Family MIERSIIDÆ.

Acanthephyra cristata, sp. nov.

Differs from *A. debilis* A. M. Edw. (= *A. gracilis* Smith) in having a much shorter and fewer-spined rostrum, two pairs of longitudinal lateral carinæ on the carapace, a dorsal carina on the fourth abdominal segment, and by the absence of a series of denticles on the posterior margin of the dorsum of the fourth and fifth abdominal segments.

From *A. lanceolata* (*Systellaspis lanceolata* Bate) it also differs by having the rostrum shorter, the lateral and dorsal carinæ of the carapace more prominent, and by the absence of a prominent tooth on the anterior margin of the first abdominal segment.

This species, like *A. debilis* and *A. lanceolata*, has no carina on the dorsal surface of the fifth and sixth abdominal segments.

Length, 78 mm.; rostrum, 13 mm.; carapace, including rostrum, 27.5 mm.

Station	3361.	1471	fathoms.	1	specimen.
“	3381.	1772	“	1	“

Acanthephyra cucullata, sp. nov.

The integument is soft, membranaceous, and transparent in alcohol. The carapace is carinated in the median dorsal line anteriorly; this carina is furnished with seven minute teeth, and is continued forward to a very small acicular rostrum, which hardly reaches forward to the end of the eyes; the infero-lateral margins of the orbit are continued downward for some distance nearly parallel with one another in a nearly vertical direction, and then suddenly diverge and trend backward, forming the upper wall of the orbit; a sort of hood is thus formed of the anterior part of the carapace, overhanging the facial region. The infra-orbital angle is rounded, not spiniferous. The antennal spine is acute, and advanced forward of the infra-orbital angle. The branchiostegian spine is small and continuous with a longitudinal carina that runs along the branchial region of the carapace. A low fold or ridge marks the upper boundary of the branchial region.

The abdomen is carinated in the median dorsal line on the second to the sixth segment inclusive; the carina is most prominent on the third segment, where it is produced into a strong posterior tooth which overhangs the anterior part of the fourth segment; the three following segments are furnished with minute posterior teeth. The posterior half of the telson in the unique specimen at hand is missing; there is one pair of minute marginal spines at the hind end of the remaining proximal half. The eyes and eyestalks are well developed, the stalks broadening toward the distal end, and projecting a slender blunt process on the inner side close to the cornea; the eye itself is as broad as the distal end of the peduncle.

The basal segment of the antenna is armed with an acute external spine; the antennal scale is long, gradually narrowing distally to the apex, which is furnished with a small spine.

The thoracic appendages have the form characteristic of the genus *Acanthephyra*, and appear to offer no important specific characters.

Length, 87 mm.; carapace, 27 mm.; antennal scale, 16 mm.

Station 3381. 1772 fathoms. 1 male.

Notostomus fragilis, sp. nov.

Dorsal line of carapace convex and keeled from anterior to posterior margin, anteriorly produced into a short, acute rostrum, which does not exceed the eyestalks in length; the dorsal carina is armed with seven or eight minute teeth on the anterior gastric region and the basal portion of the rostrum; lower margin of rostrum unarmed. A longitudinal carina on each side of the carapace begins near the orbit, above the infra-orbital spine, and runs back to the posterior margin; another carina runs obliquely downward and backward, dividing the branchial from the hepatic regions. The inferior lateral carina is obsolete except for a short distance behind the spine which lies near the anterior margin of the carapace behind the base of the second antenna.

The abdomen is strongly compressed, the third, fourth, fifth, and sixth segments dorsally carinated; the carina terminates in a small tooth at the hind end of the fourth, fifth, and sixth segments; on the fourth segment the carina is divided into two parts by a deep notch about two thirds of the distance from the anterior to the posterior margin of the segment. The telson is channelled on the dorsal side, and is tipped with two long spinous setæ.

The eyestalks taper from the base to the tip; their outer and upper margins are nearly straight, but their inner and lower surfaces are swollen; on the inner side of each stalk, a little way behind the eye, there is a blunt tubercle. The eye itself is small and black. The integument of the eyestalk is transparent, and when held to the light discloses the optic ganglion within, giving off a nerve to the retina and another to the tubercle on the inner side of the stalk.

The basal segment of the antennule is armed with a very small but sharp external spine. The outer side of the second antenna, on the contrary, is unarmed. The antennal scale is very broad, oval, and furnished with a small spine on the external border, near the distal end. The third maxillipeds are robust; they reach forward far beyond the end of the antennal scales; their terminal segment is triangular in cross section. The first pair of legs are also robust, about equal in length to the third maxillipeds, and their chela is strong, with fingers about equal to the hand in length. The second pair of legs are longer but much weaker than the first pair, the carpus and propodus much elongated, and the fingers not more than a third as long as the hand. The ischium and merus of both the first and the second pair are flattened, and the same compression is seen in the three following pairs of legs, which have the form and proportions characteristic of the genus. The inner branches of the swimmerets are about the length of the telson, while the outer branches are rather longer.

Length, 70 mm.; carapace, 30 mm.; telson, 14 mm.; antennal scale, 11 mm.

Station 3371. 770 fathoms. 1 specimen.

In this specimen the integument is soft and membranaceous, and the carapace is so collapsed that it is difficult to restore its true outline. In several respects this species shows an approach to the genus *Hymenodora,* e. g. the soft integument, small eye, and the reduction of the rostrum.

Notostomus westergreni, sp. nov.

Similar to *N. patentissimus* Bate, with which it agrees in nearly all the details of carinæ, etc., but it differs much from Bate's species in its general form and proportions, the carapace being longer in proportion to its height, and less convex along the dorsal line than it is in *N. patentissimus.* The rostrum, besides, is armed with many more spines (at least twelve) on its inferior margin. Bate says that in *N. patentissimus* the antennal carina terminates in the posterior margin of the carapace, where it is confluent with the lowermost, submarginal carina. This is not the case in *N. westergreni.*

Length, 127 mm.; length of carapace, including rostrum, 61 mm.; height of carapace, 31 mm.

Station 3399. 1740 fathoms. 1 male.

Family PASIPHAEIIDÆ.

Pasiphaeia cristata americana, subsp. nov.

This form is closely allied to *P. cristata* Bate, dredged by the "Challenger" in 315 fathoms, near the Fiji Islands. The "Albatross" specimens differ in some respects from the Fiji specimen. They may be considered a geographical race of the same species.

On comparing the two forms it appears that the carapace of the "Albatross" specimens is considerably longer in proportion to the length of the whole body than it is in the Fiji form, and that the dorsal crest is smaller and somewhat differently shaped. The fifth and sixth abdominal segments are much shorter in proportion to the length of the telson in the former. The antennulary peduncle is only one third as long as the carapace, while in the typical *P. cristata* it is about one half as long as the carapace. Furthermore, the flagellum of the antenna in the former is longer than the body, whereas in the latter it is described as being only one half as long.

Length 65 mm.; carapace, 22 mm.; telson, 7.5 mm.

Station	3385.	286	fathoms.	4	specimens.
"	3396.	259	"	2	"
"	3403.	384	"	2	"
"	3406.	551	"	3	"

Pasiphaeia magna, sp. nov.

This species is second only to *P. princeps* Smith in dimensions. It is most similar to *P. tarda* Kröyer, from the North Atlantic. Differs from the latter species by having the dorsal line of the carapace more convex, the posterior part of the carapace higher in proportion to the anterior part, the dorsal keel of the carapace rounded except on the anterior gastric region, and the anterior rostrum-like tooth longer and differently shaped. The proportional length of the segments of the third pair of legs appears to be quite different in the two species : in *P. tarda*, according to Kröyer, the propodus and dactylus are of equal length and four times as long as the carpus, while in *P. magna* the dactylus is even shorter than the carpus, which is itself only one sixth as long as the propodus. In *P. tarda*, following Kröyer, the lower margin of the second segment of the second pair of legs is furnished with three spines ; in *P. magna* this margin is unarmed but for the tooth at its distal end.

Length, 145 mm. ; carapace, including the anterior dorsal tooth, 55 mm.

Station 3384. 458 fathoms. 1 specimen.

Family PENEIDÆ.

Sicyonia affinis, sp. nov.

This species is the Pacific coast representative of *Sicyonia edwardsii*[1] of the Atlantic coast of America. It agrees with *S. edwardsii* in the form and dentition of the carapace, but differs in the form and sculpture of the abdominal segments. In *S. edwardsii* the first four abdominal segments are rugose, and ornamented on the sides with two deeply impressed transverse lines, followed by another less deeply incised near the hind margin of each segment ; moreover the pleuræ of these segments are angulated below. In *S. affinis* these

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[1] *Sicyonia edwardsii* Miers, Ann. Mag. Nat. Hist., 5th series, VIII. 367, 1881 ; *Sicyonia carinata* (Olivier) Milne Edwards, Ann. Sci. Nat., XIX. 344–346, Plate IX. Fig. 9, 1830 ; nec *Sicyonia carinata* (Olivi).

segments are smooth, the impressed lines are absent with the exception of the hinder one of the deeply cut pair, and the pleuræ are broadly rounded below; the peduncle of the second antenna is not much over one half the length of the antennal scale, and the whole appendage is but little longer than the carapace.

Length, 62 mm.; carapace, 20 mm.

Station	3367.	100	fathoms.	1 male, 1 female.
“	3369.	52	“	1 male.
“	3378.	112	“	2 females.
“	3379.	52	“	1 female.

The color in life, as shown in a sketch made by Mr. Westergren, is light greenish yellow, banded with vermilion on the branchial regions and abdomen. Appendages red, antennary flagellum transversely banded with light and dark. The coloration is quite different from that of *S. edwardsii* as given by Dana (Crust. U. S. Explor. Exped., p. 602).

Sicyonia picta, sp. nov.

Rostrum a little shorter than the eyestalks, laterally compressed, elevated, armed with six teeth, three superior, three terminal; inferior margin ciliated. Carapace carinate in the median dorsal line; the carina is furnished with two teeth, one minute, on the anterior part of the gastric region at the base of the rostrum, the other larger, over the cardiac region. An infra-orbital and an hepatic spine are present. General surface of carapace punctate and sparsely clothed with setæ. Abdominal segments smooth, with a median dorsal carina which rises into a strong tooth on the first segment directed upward and forward; on the fifth and sixth segments the carina is drawn out into an acute tooth which is directed horizontally backward. The pleuræ of the abdominal segments are margined and armed with a tooth on the lower border; on the second, third, and fourth segments the tooth is hamate, being directed outward and backward. The general surface of the abdomen is smooth, with a transverse groove on each side of the segments. The telson is channelled above, acute at the tip, and armed with a pair of small lateral spines near the distal end. The eyes are very large, horizontally flattened. Basal segment of antennule armed with two spines on its exterior border; flagella shorter than the peduncle. The peduncle of the second antenna reaches about two thirds of the way to the end of the scale; the flagellum is about equal to the abdomen in length; the basal segment of the peduncle is furnished with a long and acute external spine. The sternum is armed with a long spine between the bases of the second, third, and fourth pairs of legs, as is usual in species of this genus. The last pair of abdominal appendages are a little shorter than the telson.

Length, 70 mm.; carapace, 24 mm.

Station	3355.	182	fathoms.	1 male.
“	3387.	127	“	6 males, 4 females.

On the hinder part of each branchial region there is a dark (in alcohol) ring of pigment. *S. ocellata* Stimpson and *S. penicillata* Lockington are similarly ornamented. The flagellum of the antenna is banded alternately with light and dark color, and there are traces of color on the margins of the rostrum, the dorsal carinæ, and appendages.

Peneus balboæ, sp. nov.

Integument thin and membranaceous, its surface thickly beset with minute squamiform tubercles. The rostrum of the sole specimen procured is broken off a little short of the anterior end of the eye; on the upper margin of the part remaining, and on the median line of the gastric region there is a series of eight slender acute teeth, three of which lie behind the orbit. Rostrum continuous posteriorly with a sharp, non-sulcated carina which becomes obsolete before reaching the posterior margin. Suborbital angle prominent, but not armed with a spine; a small branchiostegian spine projects from the margin on a level with the second antenna. Neither the cervical nor any other grooves are apparent on the carapace. A faint longitudinal ridge runs along the side of the carapace on a level with the orbit; this carina is most conspicuous on the gastric region. Another longitudinal ridge runs from the suborbital angle, dividing into two branches near the middle of the carapace. A third ridge extends from the branchiostegian spine to the lower branch of the ridge last noted. Fourth, fifth, and sixth abdominal segments dorsally carinated, the sixth armed with a small horizontal spine. The fourth, fifth, and sixth segments are also ornamented with a lateral ridge. Eyestalks short; eyes large, globular, black.

Length, 93 mm.; carapace, exclusive of rostrum, 29.5 mm.

Station 3371. 770 fathoms. 1 female.

Solenocera agassizii, sp. nov.

Similar to *S. siphonocera* (Philippi), but different from that species in having the two antennulary flagella much shorter and subequal, and a larger number of teeth on the upper margin of the rostrum and gastric region. Comparison of a specimen fifty-seven millimeters long with *S. siphonocera* of equal size from the Bay of Naples shows that in the former the antennulary flagella are but four fifths the length of the carapace, and that there are eight teeth on the rostrum and gastric region, while in the Neapolitan specimen the antennulary flagella are as long as the distance from the tip of the rostrum to the middle of the third abdominal segment (two fifths longer than the carapace), and there are but six teeth on the rostrum and gastric region. Moreover, not only is the upper flagellum broader (1 m.) and blunter in *S. agassizii* than in *S. siphonocera* (where it is only $\frac{1}{3}$ m. in breadth), but is also subequal in breadth to the lower flagellum, while in the Mediterranean species the upper flagellum is conspicuously narrower than the lower one.

In full-grown specimens of *S. agassizii*, which attain a length of 150 mm., the antennulary flagella are only one half as long as the carapace, or even less. The flagellum of the second antenna is very slender and enormously long, — more than two and two thirds times the length of the whole body. The number of teeth on the rostrum and gastric region is nine.

Length of an adult female, 149 mm.; carapace with rostrum, 54 mm.; rostrum, 13.5 mm.; second antenna, 410 mm.

Station 3389. 210 fathoms. 2 males, 8 females.
" 3391. 153 " 5 males, 6 females.

A *Solenocera* has been recently recorded from the Bay of Bengal by Mr. J. Wood-Mason.[1] In this species the antennulary flagella are described as being shorter and broader than in any previously described species. As no other characters are mentioned, it is impossible to tell whether it is the same as the "Albatross" species. When the remoteness of the localities is considered, it seems hardly warrantable to assume the identity of the East Indian and American species of a comparatively shallow-water genus.

Peneopsis diomedeæ, sp. nov.

Integument hard, firm, and smooth. Rostrum long, nearly horizontal, except near the tip, where it is bent up slightly, acute, armed with four teeth above. A dorsal carina, armed with one tooth on the posterior part of the gastric region, runs the length of the carapace. Cervical groove very deep, but not cutting the dorsal carina. Another deep groove runs backward, and then diagonally upward from the cervical groove toward the posterior border of the carapace, stopping just short of the posterior margin. Antennal region well defined by the cervical groove below and a gastro-antennal groove above. A strong antennal tooth on the margin of carapace, below the orbit, another at the infero-lateral angle, a third just behind the groove that marks the posterior limit of the antennal region, and a fourth on the hinder edge of the cervical groove. Above and behind the last mentioned tooth the cervical groove is indented, and the upper angle of this indentation tends to assume the form of a small tooth or spine.

Fourth, fifth, and sixth abdominal segments carinate on the median dorsal line, and produced to teeth posteriorly. Telson deeply grooved on dorsal side, and armed with a pair of spiniform lateral teeth near the tip. The antennules with their long flagella surpass the whole body in length; the prosartema is oval, foliaceous, reaching forward as far as the posterior border of the upper face of the cornea. The exopods of the second maxillipeds are very small, not longer than the short ischial segment of the limb. Upon the appendages back of these, the exopods are reduced to the merest rudiments, discernible only by the use of a lens. In some individuals, indeed, the exopods of the posterior appendages are altogether wanting.

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[1] *Solenocera hextii* Wood-Mason, Ann. Mag. Nat. Hist., 6th ser., VII. 188, 1891.

Length, 215 mm.; carapace, 101 mm.; rostrum, 42 mm.; antennal scale, 33 mm.; telson, 33 mm.

Station	3353.	695 fathoms.	2 females.
"	3358.	555 "	1 male.
"	3384.	458 "	3 females.
"	3393.	1020 "	3 females.
"	3394.	511 "	3 males, 1 female.
"	3395.	730 "	1 male, 1 female.

Haliporus nereus, sp. nov.

Integument membranaceous. Carapace lightly granulated. Rostrum about one third the length of the rest of the carapace, horizontal, armed with six teeth above, ciliated below. Median dorsal line of carapace carinate, with two teeth on the posterior half of the gastric region. The antennal, branchiostegian, and hepatic spines are present, besides one behind the branchiostegian, and another still farther back on the hind border of the cervical groove. Orbital region definitively bounded by an hepatic and a gastro-hepatic sulcus. The hindmost of the lateral spines of the carapace lies in the anterior angle of a triangular field enclosed by branches of the cervical groove; from the infero-posterior angle of this triangle two carinæ run backward along the branchial area; the upper one ends at the postero-lateral margin of the carapace, the lower one meets the inferior submarginal carina of the branchial area before attaining the posterior border. These two carinæ, with the submarginal ridge of the carapace, enclose a long oval area on each branchial region. Third to sixth abdominal segments carinated; on the sixth segment the carina ends in a small tooth. Eyestalks about one half the length of the rostrum; eyes large, black, much broader than their stalks.

In the female there is a large process, covered with stiff hairs, and flattened on the inner side, developed from the base of the third pair of legs. Behind this process lies a pair of flat, setiferous sternal processes. Between the legs of the fourth pair there hangs in the median line a nearly vertical curtain-like partition, notched on the free lower margin, and flanked by two lower blunt setiferous tubercles. The sternum of the posterior thoracic segment has a slightly elevated median longitudinal ridge, and a low transverse ridge at the posterior boundary of the segment.

Length, 81 mm.; carapace, 31 mm.; rostrum, 8 mm.

Station	3353.	695 fathoms.	1 female.
"	3366.	1067 "	1 female.
"	3382.	1793 "	2 females.
"	3398.	1573 "	2 females.
"	3399.	1740 "	1 male.
"	3400.	1322 "	2 females.
"	3407.	885 "	1 female.
"	3413.	1360 "	1 male, 2 females.

Haliporus doris, sp. nov.

A larger and more robust species than *H. nereus*, with a stronger upward curve to the rostrum. The tubercular processes of the third pair of legs, together with the sternal tubercles immediately behind them, are very like the corresponding structures in *H. nereus*. But here the likeness between the sexual parts of the females of the two species ends. Betwixt the legs of the fourth pair there is a transverse diaphragm consisting of a median tongue, concave on its front face, its lower edge entire, supported on each side by a strong blunt triangular process, of equal height with the median tongue-like plate. Between the bases of the fifth pair of legs, in place of the low longitudinal ridge seen in *H. nereus*, there is, in this species, a large setiferous trigonal tooth, acute at the tip, equalling in height the transverse partition on the sternum of the antecedent segment. The posterior median angle of this tooth abuts against the low transverse ridge that forms the posterior limit of the last thoracic sternum.

Length, 104 mm.; rostrum, 10 mm.; whole carapace, 42 mm.

Station	3414.	2232 fathoms.	4 females.
"	3415.	1879 "	1 female.

Haliporus thetis, sp. nov.

Integument membranaceous. Rostrum rather less than one third as long as the rest of the carapace, curved strongly upward, upper margin convex, armed with five teeth. A distinct carina, bearing three teeth, runs the length of the median line of the gastric area, from the base of the rostrum to the cervical groove. Back of the cervical groove this carina continues on as a low blunt ridge to the posterior border of the carapace. Posteriorly, this ridge gives off two pairs of lateral branches, which course diagonally backward to the posterior margin of the carapace, marking off two triangular fields on the cardiac region, one enclosed within the other. The spinous armature of the carapace consists of an antennal, a very small branchiostegal, an hepatic, and a lateral spine on the posterior edge of the cervical groove. The spine which lies a little way behind the branchiostegian spine in *H. nereus* and *H. doris* is lacking in this species. Antennal and orbital regions well defined. All the segments of the abdomen are carinate along their median dorsal line. The pleuræ are shallow and rounded. A longitudinal furrow on each side of the abdominal segments. Eyestalks one half the length of the rostrum; eyes large, black, broader than their stalks.

Length, 94 mm.; rostrum, 9 mm.; carapace, including rostrum, 33 mm.

Station 3413. 1360 fathoms. 1 female.

Aristæus occidentalis, sp. nov.

Similar to *A. antennatus* (Risso) of the Mediterranean Sea. By comparison with Duvernoy's figures of *A. antennatus* it appears that the Pacific species has a longer, more strongly upturned rostrum, and that it differs furthermore in having the sixth abdominal segment carinated and toothed, and in having much longer abdominal appendages. As in *A. antennatus*, there is no epipod on either the last or the next to the last pair of legs.

Length, 158 mm.; rostrum, 49 mm. carapace, including rostrum, 85 mm.

Station	3403.	384 fathoms.	1 male.
"	3410.	331 "	2 females.

Hemipeneus triton, sp. nov

This species, like *H. spinidorsalis* Bate, is remarkable for the long, curved thorn on the dorsal side of the third abdominal segment. It differs from *H. spinidorsalis* in having a much shorter rostrum, and longer, more flattened outer antennulary flagella. The rostrum is shorter than in any previously described species, being much shorter than the eyestalks; it is furnished with from two to four teeth above. The sixth abdominal somite is longer than in *H. spinidorsalis*. Another difference between the two species affects the inner branch of the second abdominal appendages of the male; in both species this branch is triple; in *H. spinidorsalis* the anterior piece is a horny plate, concave within and furnished with setæ on its distal border; the middle piece has the form of a long triangular tooth, shorter than the anterior plate; the posterior piece is a longer multiarticulate flagellum, homologous with the inner branch of the following pairs of appendages. In *H. triton*, the middle tooth-like process is developed into a broad plate which exceeds in length the anterior plate.

Length, 127 mm.; carapace, 44.5 mm.; rostrum, 6 mm.

Station	3360.	1672 fathoms.	1 female.
"	3374.	1823 "	1 male, 5 females.
"	3381.	1772 "	3 males, 1 female.

Benthesicymus tanneri, sp. nov.

In this species the carina on the fifth and sixth abdominal segments terminates posteriorly in a small acute tooth, whereas in *B. altus* Bate these segments are devoid of teeth, the posterior margin rising to form a peculiar transverse ridge. *B. brasiliensis* Bate differs from *B. tanneri* in having the carapace higher, with more convex infero-lateral borders, the third, fourth, and fifth abdominal segments toothed, the sixth toothless, and in the absence of the tooth or tubercle on the sternum between the abdominal appendages of the first pair. *B. bartletti* Smith, from the Atlantic side of the continent, resembles *B. tanneri* in many respects, but is distinguishable at a glance by the long spine on the dorsum of the fifth abdominal segment. *B. moratus* Smith, another allied species, differs in having a distinct hepatic spine, a much broader merus joint to the second maxilliped, in the presence of small exopods at the bases of all the thoracic appendages, etc.

Color in life, deep red, with a large patch of bright blue on the back of the second, third, and fourth abdominal segments; eyes black.

Length, 112 mm.; carapace 44.5 mm.; rostrum, 8 mm.

Station	3358.	555	fathoms.	3 males, 2 females.
“	3362.	1175	“	1 male, 1 female.
“	3363.	978	“	3 males, 5 females.
“	3364.	902	“	2 males.
“	3365.	1010	“	1 female.
“	3366.	1067	“	1 male, 1 female.
“	3376.	1132	“	2 females.
“	3377.	764	“	1 male.
“	3380.	899	“	1 male.
“	3384.	458	“	27 males, 36 females.
“	3393.	1020	“	2 males, 3 females.
“	3400.	1322	“	1 female.
“	3403.	384	“	1 male, 1 female.
“	3404.	385	“	1 female.
“	3407.	885	“	5 females.
“	3410.	331	“	2 males, 3 females.
“	3411.	1189	“	1 male, 1 female.
“	3418.	660	“	7 males, 8 females.
“	3424.	676	“	1 male.
“	3425.	680	“	1 male.
“	3435.	859	“	3 males, 2 females.
“	3436.	905	“	5 females.

Family SERGESTIDÆ.

Sergestes inous, sp. nov.

Near *S. mollis* Smith. Besides differences of minor importance, the following structural difference is apparent: in *S. mollis* the posterior pleurobranchia of the antepenultimate thoracic segment is replaced by a small simple lamella, which is concealed beneath the following gill, while in *S. inous* the said pleurobranchia is well developed and unconcealed.

Length 113 mm.; carapace, 34.5 mm.

Station 3380. 899 fathoms. 1 female.

Sergestes phorcus, sp. nov.

Carapace devoid of spines; rostrum cristiform, short, subquadrate, the anterior margin produced to a short point in the middle. Second, third, and fourth abdominal segments lightly sulcate in the median dorsal line; sixth somite armed with a minute posterior dorsal spine. Eyestalk shorter than proximal segment of the antennulary peduncle; eye subspherical, much wider than its stalk. First and second segments of the antennulary peduncle of equal length, the third considerably shorter. Thoracic appendages much like those of *S. robustus* Smith.

Length, 65 mm.; carapace, 21 mm.

Station	3382.	1793	fathoms.	1 male.
"	3386.	242	"	1 female.
"	3388.	1168	"	2 females.
"	3401.	395	"	1 female.
"	3437.	628	"	1 female.

Sergestes halia, sp. nov.

A small species, in which the cervical groove is nearly obliterated on the dorsal part of the carapace, and the posterior transverse furrow, which in some species of *Sergestes* forms the front boundary of the cardiac area, is obsolete. A sharp spine near the antero-lateral margin of the carapace, and another on the hepatic area. Rostrum cristiform, tapering to a slender, acute point, which overreaches the eye. A longitudinal ridge runs from the base of the antenna backwards, dividing at the hepatic spine into a superior and an inferior branch; the former forms the upper boundary of the branchial area, the latter courses along the middle of the branchial area and fades out before reaching the posterior border of the carapace. Abdominal segments unarmed.

Length, 29 mm.; carapace, 9.3 mm.

Station 3388. Surface to 400 fathoms (submarine tow-net). 3 males.

Suborder SCHIZOPODA.

Family LOPHOGASTRIDÆ.

Gnathophausia dentata, sp. nov.

In this species a thin triangular crest, produced at the apex to a spine, is found at the base of the rostrum, over the anterior part of the gastric region; a minute denticle near the anterior, and another near the posterior end of the crest. The lower spine of the infero-posterior angle of the carapace is reduced to a mere tooth, obsolete in some specimens. Antennal scale very broad (breadth equal to one half the length.)

Distinguished from *G. gracilis* W.-Suhm by the prominent dentate gastric crest, the small size, or even absence, of the lower spine of the infero-posterior angle of the carapace, the greater breadth of the antennal scale, etc.

Gnathophausia gracilis, var. *brevispinis* Wood-Mason, agrees with *G. dentata* in the obsolescence of the lower posterior spine, but I infer from Wood-Mason's short description that this variety conforms to the type of *G. gracilis* as regards the gastric teeth, antennal scale, etc.

Length, 60 mm.; carapace, including rostrum and dorsal spine, 33 mm.; rostrum, 14 mm.; dorsal spine, 4 mm.

Station	3361.	1471	fathoms.	1	specimen.
"	3375.	1201	"	1	"
"	3400.	1322	"	1	"
"	3406.	551	"	1	"
"	3411.	1189	"	1	"

Family EUCOPIIDÆ.

Eucopia sculpticauda, sp. nov.

Frontal margin very prominent, forming a three-sided blunt rostrum, which projects between the eyestalks and wholly conceals the subjacent ocular segment. Anterior part of the telson deeply furrowed for a little less than one half its length, the furrow bounded on each side by an elevated, rounded ridge; a low median keel, beginning in the anterior furrow, runs back to the hind end of the telson ; a constriction near the hind end divides off a terminal plate, which is broadly rounded at the end, its lateral margin concave ; the whole dorsal face of the telson, from the posterior end of the anterior ridges to the terminal plate, is beautifully ornamented with a network of ridges like honeycomb.

Length, 66 mm.; carapace, measured from lower angle of orbit to posterior end of the lateral wings, 23 mm.

Station	2619 Hydr.	1000	fathoms.	1 female juv.
"	3407.	885	"	1 female.
"	3413.	1360	"	1 male.

Family MYSIDÆ.

Petalophthalmus pacificus, sp. nov.

Similar to *P. armiger* W.-Suhm,[1] but different in some particulars. The rostrum is more prominent and triangular; there is a median tooth on the

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[1] Amongst the material dredged by the "Blake" in the Atlantic in 1877–78, I find the female of *P. armiger*. It agrees closely with the male, barring the usual sexual differences, viz. the presence of an incubatory pouch, and the simple structure of the caudal limbs; the mandibular palp, carapace, telson, etc., are as in the male. The brood-pouch consists of six pairs of incubatory lamellæ. The Schizopod described by Suhm as the female of *P. armiger* is apparently a *Boreomysis*. It may be called *Boreomysis suhmi*.

carapace behind the base of the rostrum ; the caudal limbs are simple in the male.

Length, 31 mm.

Station 2637 Hydr. 700 fathoms. 1 male.

SCOLOPHTHALMUS, gen. nov

Carapace rostrate, small, covering only the anterior part of the thorax, leaving the last two thoracic segments exposed. Abdomen slender, cylindrical, sixth segment the longest. Eyestalks transformed to sharp spines, visual elements wanting. Antennular peduncle rather long and robust. Antennal scale elongate, oval ; proximal fourth of outer edge smooth, naked, terminating in an angle which bears a strong seta ; the rest of the outer edge fringed with hairs like the inner edge. Mandibular palpi reaching to about the middle of the antennulary flagellum, terminal segment narrowly oblong. Second maxillæ with inner basal part expanded, three-lobed, terminal segment expanded at distal end, triangular. First maxillipeds without an exopod, but furnished with a well developed epipod. Second maxillipeds of moderate length, subpediform. Legs long and slender, antepenultimate pair reaching forward beyond the base of the antennal scale. Marsupial pouch of the female composed of seven pairs of incubatory lamellæ. Telson large, apex truncate, not incised. Outer plates of the swimmerets (uropods) not divided by a transverse suture.

Scolophthalmus lucifugus, sp. nov.

Frontal margin of carapace produced so as to form an acute rostrum ; anterolateral margins oblique, armed with two spines, one behind the external margin of the antennule, the other at the anterior inferior angle. Cervical sulcus well marked, with a distinct linguiform dorsal area behind it. Posterior lateral wings short and rounded. Abdominal segments smooth and cylindrical, sixth segment nearly as long as the two antecedent segments combined. Telson broad, truncate. Eyes atrophied, their peduncles assuming the form of spines. Antennal peduncles one half as long as the carapace, second and third segments about equal in length, a little longer than the first, the third slenderer than the first and second ; the flagella are equal to or rather longer than the peduncle, and present a uniform structure of small articulations, the basal part of the outer flagellum not being expanded. The antennal scale and mandibular palpi are described in the generic diagnosis ; the antennal scale is equal in length to the antennular flagellum. Abdominal limbs (of the female) simple, increasing in length posteriorly, the fifth pair distinctly two-jointed. Inner branch of uropods slender, lanceolate, surpassing the telson and the outer branch, the latter of which is oval and divided by transverse suture.

Length, 42 mm.

Station 3400. 1322 fathoms. 1 female.

CERATOMYSIS, gen. nov.

Cephalothorax robust. Carapace short (leaving the last two segments of the thorax exposed), spinose; frontal margin truncate, not forming a rostrum, armed at the external angles with a pair of long horn-like spines; a conspicuous notch at the anterior end of the lateral margin serving as an excurrent orifice from the respiratory chamber. Abdomen slender, cylindrical, spinose; sixth segment not much longer than the fifth. Eyes absent, their stalks taking the form of slender styles, whose tips are soft and delicate, perhaps serving as tactile organs. Antennular peduncle rather short; flagella much longer than the peduncle, flattened and fringed with long setæ on their margins. Antennal scale linear, ciliated on both margins. Mandibular palpi reaching beyond the antennular peduncle; terminal segment long oval, margins fringed with long setæ. First maxillipeds devoid of an exopod. Distal segment of second maxillipeds oval, ciliate. Legs long and slender, propodi not segmented. Seven pairs of incubatory lamellæ in the female. Fifth and sixth abdominal limbs elongated in the female. Telson linear, setose on the margin. Both branches of the uropods linear, setose on each margin, subequal, shorter than the telson; outer branch not divided by a transverse suture.

Ceratomysis spinosa, sp. nov.

In front of the cervical groove are three long erect spines in the median line, the foremost of which is on the frontal margin; there is, besides, a spine on each side of the carapace in a transverse line with the middle one of the median row; behind the cervical groove there is one spine in the median line near the posterior margin of the carapace, two on each side of the tongue-shaped dorsal area, and a long row of six on each side, in line with the lateral spines of the gastric area. Abdomen armed with five longitudinal rows of spines (one median, four paired and lateral). Telson very long and narrow, nearly equalling the length of the remaining portion of the abdomen.

Color in life, milk-white.

Length, 36 mm.; carapace, 9 mm.

Station 3357. 782 fathoms. 1 female.