laris E. Mey., 1849); **C. bidentata** (*Achyranthes bidentata* Blume, 1825); **C. breviflora** (*Achyranthes breviflora* Baker, 1897); **C. canescens** (*Achyranthes canescens* R. Br., 1810); **C. carsoni** (*Achyranthes carsoni* Baker, 1897); **C. conferta** (*Achyranthes conferta* Schinz, 1896); **C. elegantissima** (*Achyranthes elegantissima* Schinz, 1895); **C. fasciculata** (*Achyranthes fasciculata* Schweinf., 1867); **C. flabellifera** (*Achyranthes flabellifera* Boerl., 1891); **C. fruticosa** (*Achyranthes fruticosa* Lam., 1783); **C. grandifolia** (*Achyranthes grandifolia* Moq., 1849); **C. heudelotii** (*Achyranthes heudelotii* Moq., 1849); **C. involucrata** (*Achyranthes involucrata* Moq., 1849); **C. schinzii** Standley, nom. nov. (*Achyranthes lanuginosa* Schinz, 1895, not *A. lanuginosa* Nutt., 1820); **C. mauritiana** (*Achyranthes mauritiana* Moq., 1849); **C. moquini** Standley, nom. nov. (*Achyranthes javanica* Moq., 1849, not *A. javanica* Pers., 1805); **C. oblanceolata** (*Achyranthes oblanceolata* Schinz, 1895); **C. ovata** (*Achyranthes ovata* Ehrenb., 1867); **C. schweinfurthii** (*Achyranthes schweinfurthii* Schinz, 1896); **C. splendens** (*Achyranthes splendens* Mart., 1849); **C. velutina** (*Achyranthes velutina* Hook. & Arn., 1841); **C. welwitschii** (*Achyranthes welwitschii* Schinz, 1895).

ZOOLOGY.—*The bathymetrical distribution of the Arctic and Antarctic crinoids.*[1] AUSTIN H. CLARK, National Museum.

In their bathymetrical distribution the crinoids of the Arctic and Antarctic Oceans are most interesting. I have already[2] presented the reasons for considering the crinoids of the Atlantic, from the standpoint of their systematic interrelationships, and of their geographical distribution, as representing merely the fauna of an inland sea, derived from the fauna of the Indo-Pacific as a parent, the crinoids of the Arctic Ocean representing also an inland sea fauna derived in part from the Bay of Bengal direct, and in part from the adjacent portion of the Atlantic. The fauna of the Antarctic Ocean is merely the southerly extension of the deep water fauna of the Indo-Pacific Ocean.

Examining the diagram (fig. 1), we find that the line representing the Antarctic fauna, and that representing the Antarctic and the Arctic faunas combined, are strikingly similar to the line

[1] Published with the permission of the Secretary of the Smithsonian Institution.

[2] Internationale Revue der gesamten Hydrobiologie und Hydrographie, 1914.

representing the distribution according to depth of the genera confined to the Atlantic (fig. 2). This is the more remarkable when we remember that only one genus (*Hathrometra*) is common to the Atlantic and to the Antarctic, and to the Atlantic and the Arctic, while in the polar seas the temperature is comparatively uniform from the surface to the bottom in contrast to the Middle Atlantic where the surface temperature is very high.

It thus appears that essentially the same selective processes have operated both in the Atlantic and in the Antarctic in weed-

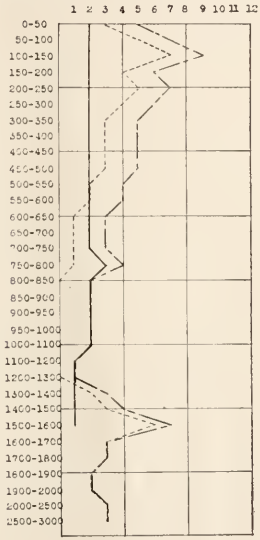

Fig. 1

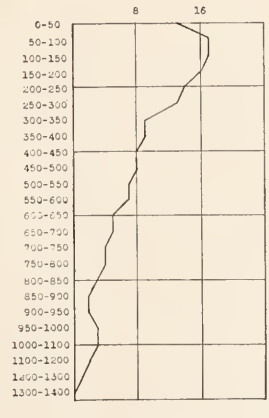

Fig. 2

Fig. 1. Bathymetrical distribution of the Artic (———) and Antartic (-----) crinoids, and of the two combined (— - —).

Fig. 2. The frequency at different depths of the crinoid genera confined to the Atlantic.

ing out the less adaptable of the primarily Indo-Pacific genera; but the results in each case are radically different, showing conclusively that the Atlantic could never have been populated by passage from the Indian Ocean south of Africa, between Africa and Antarctica.

An inland sea, biologically speaking, is a more or less enclosed body of water which, connected with an ocean, has received all

of its fauna from that ocean. Its fauna, therefore, is composed of the same types that occur in the ocean with which it is most intimately connected, with the less plastic and adaptable weeded out and the remainder modified in proportion to the difference between the physics and chemistry of the inland sea and that of the parent ocean.

All inland seas necessarily differ physically to a greater or lesser degree from the oceans with which they are connected. Their abyssal water cannot form a part of the general abyssal circulation of the oceans, moving slowly anticlockwise about the oceanic basins, and therefore tends to become more or less stagnant and, under certain conditions, either abnormally cold, as in the Arctic, or abnormally warm, as in the Mediterranean. Their surface water, no longer a part of the general superficial oceanic circulation, unless there be an outlet sufficiently large so that a continuous flow is maintained, increases in salinity through an excess of evaporation, as in the Mediterranean and in the Red Sea, or decreases in salinity through an excess of rainfall in the tributary drainage area as in the Baltic. Either of these changes is fatal to a certain percentage of the organisms which enter inland seas, so that necessarily their fauna is composed only of the more resistant and adaptable organisms of the parent oceans.

On account of the physical alteration of the waters of an inland sea, through which they become less favorable than oceanic waters for the support of marine organisms, inland seas never serve as the cradle for new organic types; their fauna is entirely derived from outside, though the component elements may be forced to undergo a certain amount of modification in order to meet the new conditions imposed.

An inland sea of the present epoch may be a derivative from a much greater sea of the past, as in the case of the Mediterranean.

The restriction in size of any large portion of an ocean immediately alters and restricts the circulation of the enclosed water, bringing it more and more under the influence of the local meteorological conditions; the effect upon the fauna is therefore exactly the same as though the sea arose through a sinking of the land

resulting in an inflow of oceanic water. The biological conditions in an inland sea are not in any way concerned with the question whether the sea originated by a sinking of the land, or whether it arose by a restriction of a previously much larger body of water. Both processes lead to a mean which is physically and oceanographically the same, and therefore biologically the same.

A number of curious types occur in enclosed seas which are quite different from any types inhabiting the oceans with which these enclosed seas were once connected. These types are mainly to be interpreted as relics of a once generally distributed fauna which, able to survive the changing conditions, have been preserved from extermination by the fact that none of the economically more efficient types of later origin, through competition with which they have been extirpated from the oceans, have been able to enter the enclosed basins, for the reason that these basins became cut off from the oceans before the appearance of these later types.

Such types are found in enclosed seas, but almost never in inland seas, for the reason that all types of later origin are excluded from the former; an animal type efficient and vigorous enough to overcome and to exterminate competing types in the oceans would, other things being equal, also be efficient enough to extirpate them from all the inland seas.

Among the crinoids two such types occur in the Caribbean Sea, *Isocrinus* and *Holopus*. These persist here not for the reason that they originated here, but because the disruption of the connection between the Caribbean region and the East Indies took place before the evolution of the more efficient and vigorous types now dominant in the Indo-Pacific littoral, through competition with which they have there been extirpated.

It is a curious fact that the sea about the Antarctic continent is more in agreement physically, chemically and biologically with an inland sea than with an ocean or broad embayment like the Arabian Sea or the Bay of Bengal. It might aptly be described as a combination of the Arctic Ocean and the Mediterranean, that is, a chilled Mediterranean; for the temperature is low,

varying little from the surface to the bottom, as in the more typical parts of the Arctic, or, farther from shore, with an intermediate warmer layer, also as in certain parts of the Arctic; while the salinity is high, varying but little from the surface to the bottom, as in the Mediterranean.

The Arctic and the Mediterranean are connected with the Atlantic through geographically and bathymetrically restricted channels. The Antarctic is connected with the oceans north of it by a bathymetrically narrowly restricted thermal zone; for the difference in temperature in the upper layers between the Antarctic and the South Pacific, Indian and South Atlantic Oceans is such as to preclude the entrance from any of the latter into the former of all organisms excepting only those of the cold abysses.

The Antarctic, therefore, is a great thermally isolated sea, directly connected with the oceans to the north only through the abysses, corresponding very closely in its physical, chemical and biological characters to a geographically isolated sea which is connected with the adjacent ocean only by a shallow strait.

As the necessary corollary of oceanographic changes, all tending toward oceanographic simplicity, the more restricted an inland, or an isolated, sea becomes, the more featureless and the more nearly vertical becomes the line representing the distribution of its crinoids in their relation to depth. Thus we are prepared to find the line representing the bathymetrical distribution of the Arctic crinoids nearly vertical and almost straight, although species of three quite different genera are involved. Practically the same featureless vertical line represents the bathymetrical distribution of the crinoids of the Mediterranean, and of the Okhotsk and Japanese Seas.

The crinoid fauna of the Arctic Ocean includes two species (*Heliometra glacialis* and *Ilycrinus carpenterii*) apparently derived from the crinoid fauna of the Bay of Bengal, and one (*Hathrometra prolixa*) derived from the Antarctic by way of the Atlantic.

The Arctic fauna of the western part of the Sea of Okhotsk and of the Sea of Japan includes one species (*Heliometra maxima*) derived from the Bay of Bengal, one species (*Thaumatometra tenuis*) derived from the Pacific to the southward of Japan, and

one species (*Psathyrometra erythrizon*) derived from the Pacific to the northeastward.

The oceanographic conditions in both of these divisions of the Arctic province are practically identical; but the faunal differences are such as to suggest that they never have been parts of the same fauna since the present distribution of land and sea became established.

Hathrometra prolixa is probably an intruder into the Arctic Ocean from the Atlantic under the present conditions, and the same is undoubtedly true of *Thaumatometra tenuis* and *Psathyrometra erythrizon* in the Okhotsk and Japanese Seas.

Judging from what we know of the fauna of the great Russian lakes, Aral, Balkash and Baikal, as well as of the lesser lakes between them, it appears not improbable that this region was the original home of *Heliometra*, which it reached from the southward, and from which, long ago, it spread both northward and eastward to the Arctic Ocean and to the Seas of Okhotsk and Japan; but there must always be kept in mind the very remote possibility that *Heliometra* reached the Okhotsk and Japanese Seas from the Arctic Ocean by way of the Bering Strait and the coast of Kamchatka, by some means divesting itself on the way of its inseparable Arctic companion, *Hathrometra prolixa*.

The bathymetric range of the three Arctic crinoids:

	fathoms		*fathoms*
Heliometra glacialis....	2–755	*Ilycrinus carpenterii*...	755–1563
Hathrometra prolixa...	10–1088		

The bathymetric range of the eighteen Antarctic crinoids:

	fathoms		*fathoms*
Thalassometra bispinosa	1600	*Trichometra remota*....	1600
Psathyrometra antarctica	1430	*Isometra angustipinna*.	56–600
Eumorphometra hirsuta.	140	*Thaumatometra abyssorum*.....	1600
Eumorphometra concinna.....	211–222	*Bathymetra carpenteri*..	2600
Promachocrinus kerguelensis.....	10–222	*Thaumatocrinus renovatus*.....	1347–1800
Solanometra antarctica.	75–150	*Ilycrinus australis*.....	1375–2575
Anthometra adriani....	124–500	*Ptilocrinus brucei*.....	2485
Florometra magellanica	17–782	*Ptilocrinus antarcticus*.	266
Hathrometra exigua....	50–140	*Hyocrinus bethellianus*.	1600–2575

The frequency of the Arctic and Antarctic crinoids at different depths:

Fathoms	*Artic*	*Ant-arctic*	*Total*	*Fathoms*	*Artic*	*Ant-arctic*	*Total*
0–50	2	3	5	800–850	2	0	2
50–100	2	5	7	850–900	2	0	2
100–150	2	7	9	900–950	2	0	2
150–200	2	4	6	950–1000	2	0	2
200–250	2	5	7	1000–1100	2	0	2
250–300	2	4	6	1100–1200	1	0	1
300–350	2	3	5	1200–1300	1	0	1
350–400	2	3	5	1300–1400	1	2	3
400–450	2	3	5	1400–1500	1	3	4
450–500	2	3	5	1500–1600	1	6	7
500–550	2	2	4	1600–1700	0	3	3
550–600	2	2	4	1700–1800	0	3	3
600–650	2	1	3	1800–1900	0	2	2
650–700	2	1	3	1900–2000	0	2	2
700–750	2	1	3	2000–2500	0	3	3
750–800	3	1	4	2500–3000	0	3	3