

# OCEANOGRAPHY

## CHAPTER I

### INTRODUCTORY

OCEANOGRAPHY has been aptly defined as the study of the world below the surface of the sea: it should include the contact zone between sea and atmosphere. According to present-day acceptance it has to do with all the characteristics of the bottom and margins of the sea, of the sea water, and of the inhabitants of the latter. Thus widely combining geophysics, geochemistry, and biology, it is inclusive, as is, of course, characteristic of any 'young' science: and modern oceanography is in its youth. But in this case it is not so much immaturity that is responsible for the fact that these several sub-sciences are still grouped together, but rather the realization that the physics, chemistry, and biology of the sea water are not only important *per se*, but that in most of the basic problems of the sea all three of these subdivisions have a part. And with every advance in our knowledge of the sea making this interdependence more and more apparent, it is not likely that we shall soon see any general abandon-

ment of this concept of oceanography as a mother science, the branches of which, though necessarily attacked by different disciplines, are intertwined too closely to be torn apart. Every oceanic biologist should, therefore, be grounded in the principles of geophysics and geochemistry; every chemical or physical oceanographer in some of the oceanic aspects of biology.

A feature equally inherent in sea science is that it is no less inclusive from the geographic standpoint, because the subjects with which it is concerned (the oceans) cover so large a part of the surface of our planet. And the vastness of the areas to be considered, whatever phase of the sea be under consideration, has (more than any other factor) determined the paths that the science of oceanography has followed in its advance from its early beginnings to its present state. Most oceanographers, too, would agree that the geographic factor has likewise been responsible for a failure to progress at a rate commensurate either with the relative importance of this field of knowledge in the general household of science, or with the amount of energy that has been devoted thereto during the past quarter-century.

In the nature of things, the oceanographer constantly meets a twofold obstacle of another sort, when he attempts to extend his investigations out from the shore-line to the high seas, no matter from

what headquarters he may work, in the necessity of studying the majority of oceanic phenomena and events *within* the sea, not merely upon it, or from its borders. Even if his investigation be of a sort that can be carried on in a laboratory on shore, the raw data must be gathered at sea. Therefore (as man is not an aquatic mammal) he must have a boat, a necessity that places him at a disadvantage as compared with the general biologist who turns to marine animals chiefly for convenience, and so can pick up many things of interest (and perhaps all that he needs in his particular work) on a stroll along tideline. If the student is to venture out more than a few miles from land, his craft must be large enough to contain living quarters and to navigate safely in all weathers, for oceanography is impossible unless some one does go out to sea, on short trips or on long. That is to say, for even one investigator, or one party, to gather information of any kind about the ocean in appreciable amount demands the labors of many, as reflected in the maintenance and operation of a sea-going craft, with crew to man her, with supplies for their subsistence; also (in these days) with fuel for her propulsion. And as any craft larger than a row-boat is an expensive means of conveyance for a small number of passengers, it follows that exploration into the economy of the high seas is essentially a costly undertaking.

The expense of extended voyages, combined with the necessity for such if large sea areas were to be studied more intensively than could be done from examination of vessels' log books, was no doubt the chief reason that systematic examination, even of the surface of the sea, was not seriously undertaken until the middle of the nineteenth century. But when, at about this period, science awoke to the whole new world for exploration that was offered by the oceans, it was soon learned that no very serious technical difficulties, apart from expense, were involved in extending investigations down into the abyss, whether it was a question of developing the contour of the sea floor, of gathering samples of the bottom, of sampling the living creatures, or of measuring the physical and chemical characteristics of the water.

It would, indeed, have been quite within the technical abilities of the Romans of Pliny's day to have plumbed the depths of the Mediterranean and to have explored its deep-water biota, though of course examination of the temperature and salinity of the sea must, in any case, have awaited the development of the sciences of physics and chemistry as we now know them.

Efficient gear was, in fact, so rapidly developed in the three years 1868-70, as soon as a serious start in that direction was made on the voyages of the

'Lightning' and of the 'Porcupine,' that when the 'Challenger' sailed two years later on the first ocean-wide exploration of the deeps (students of the history of science may well date the birth of modern oceanography from December 21, 1872, the date when she put to sea from Plymouth, England), the scientists on board were already in position efficiently to reap the rich harvest that stimulated many other subsequent expeditions in various parts of the world.

From that time forward, with every fresh venture below the surface of the sea, and with constant improvement in technical methods of operating gear of different kinds at great depths (we think especially of the introduction by Alexander Agassiz of wire rope for dredging and by Sir William Thomson of steel wire for sounding), a flood of new facts came pouring in so rapidly that more was learned about the sea and about the inhabitants of its deeps during the last thirty years of the nineteenth century than had been up till then. This was the heyday of the deep-sea exploring expedition, when one cruise after another was sent out by different maritime nations, when the broad relief of the ocean floors was mapped, when the general nature of the submarine sediments was determined, when the distribution of temperature and salinity was worked out in its essential outlines over the high seas, and

when the general characteristics of the deep-sea fauna were explored.

While this regional-descriptive era of oceanography will never definitely close so long as the science of the sea is pursued, there came a change, toward the end of the century just past, when persistence in the old discursive methods, determined by established habits of thought, no longer yielded new and wonderful discoveries at the rate that had been the order of the day when no one knew what was to be found at the bottom of the sea. Thenceforth, with increasing frequency, continued exploration along these preliminary lines yielded results more corroborative than novel. And a period of general oceanographic stagnation might then have succeeded to the preceding peak of activity (this did, in fact, happen in America), had there not arisen new schools, centering their attention on the biologic economy of the inhabitants of the ocean as related to their physical-chemical environment, on mathematical analysis of the internal dynamics of the sea water, and on the geologic bearing of submarine topography and sedimentation, rather than on areal surveys of one or another feature of the sea.

This conscious alteration of viewpoint, from the descriptive to the analytic, is one of two chief factors that gives to oceanography its present tone: the other is the growth of an economic demand that

oceanography afford practical assistance to the sea fisheries.

This demand developed first in northwestern Europe, where, as it chanced, the fisheries were so rapidly expanding, and increasing in intensity through the adoption of more effective methods of fishing, that dread of depletion began to loom in the offing, just when oceanography was approaching the end of its nineteenth-century boom; i.e., just when it needed a fresh stimulus.

The immediate, practical result was a concentration of attention on limited coastwise areas (sites of important fisheries) as contrasted with the broad oceans, and the development of an international and official organization — the Conseil International pour l'Exploration de la Mer — with power to co-ordinate the scientific efforts of the Fisheries Bureaus of the several nations fronting on these areas in northwestern Europe.

It is an interesting speculation whether, without this enforced direction of scientific attention to the North Sea region, we should have come to appreciate, as clearly as we do today, that application to the adjacent oceans of principles established by intensive investigation of such test cases (warranted by the uniformity of the sea over wide areas) offers the most promising lines of approach to many of the broad, underlying problems of oceanography. How-

ever this may be, we can hardly doubt that the advance of oceanography on the analytic-synthetic side would have continued slow and halting had not the Conseil and other coördinating institutions of more recent birth, but with similar aims, added their unifying influence to the attempts at synthetic investigation that would in any case have followed the alteration in viewpoint just mentioned. And it is certain that, today, the most rapid approaches toward an understanding of events in the sea are being made by orderly, intensive, and concerted attacks upon one or another phase, *via* definitely stated and apparently illustrative problems, rather than by haphazard accumulation of unrelated facts, gathered in the hope that somehow, sometime, these may be fitted together by some one. This is reflected in the fact that several broad-scale expeditions that have been sent out within the last few years — ‘Meteor,’ ‘Dana,’ ‘Carnegie,’ ‘Marion’ — have devoted their attention chiefly to extending to the high seas special lines of investigation the theoretical basis for which had already been developed from intensive studies falling in the general category just stated.

The foregoing remarks are introductory to the thesis that a discussion of certain of the underlying problems that seem most clearly to illustrate the general fields of research falling within the province

of the oceanographer, and that are now most to the fore, is integral in any rational exposition of the scope and present status of this inclusive branch of science. This, and no more, is attempted in the following chapters. To list all the problems that await the oceanographer will never be possible so long as science lives, for new ones will constantly unfold, as the boundaries of knowledge are rolled back.

In practice oceanography falls most conveniently into three chief divisions: (*a*) the geological; (*b*) the physical-chemical; (*c*) the biological.

To consider first the problems of the shape and composition of the basins that hold the oceans (i.e., submarine geology); next, those associated with the physical character and chemical composition of the waters that fill these basins (physics and chemistry of sea water); and third, those of the nature and activities of the animals and plants that inhabit the waters (life in the sea) is therefore a rational order of presentation. Subsequent chapters discuss the fundamental unity of these different divisions, and outline certain of the direct economic benefits that may be expected to accrue from the study of oceanography.

A word is perhaps due the reader to explain our omission of any references to authorities. Citations are an essential part of any presentation of the results of investigation, or of any textbook, but this is

## *Oceanography*

---

not necessarily true when the discussion is of things to be studied. In the present case to have mentioned authors would have necessitated a general bibliography of the subject; also roster of oceanographers, for each of the latter has by his published work helped to make this book possible. To cut this Gordian knot personal references are omitted.