

CHAPTER VII

PHYSICAL, CHEMICAL, GEOLOGIC, AND BIOLOGIC UNITY IN THE SEA

IN the preceding pages we have, for the sake of clarity, discussed certain of the underlying problems of oceanography as though the sea, in its physical and chemical nature, were a stable thing, controlling the activities of life within it, though hardly affected by the latter; and as though these problems could profitably be attacked independently one of another. But oceanographers, as a group, have come to realize, during the past quarter-century, that this is far from the truth; and with this realization the science of the sea has entered a new intellectual phase.

The foundation for this alteration in viewpoint, from the descriptive to the explanatory, was a growing realization (this could have come only after multitudes of facts had been accumulated) that in the further development of sea science the keynote must be physical, chemical, and biological unity, not diversity, for everything that takes place in the sea within the realm of any one of these artificially divorced sciences impinges upon all the rest of them. In a word, until new vistas develop, our ventures in oceanography will be the most profitable if we regard the sea as dynamic, not as something static, and

if we focus our attention on the cycle of life and energy there as a whole, instead of confining our individual outlook to one or another restricted phase, whether it be biologic, physical, chemical, or geologic. Examples of this fundamental unity face the oceanographer at every turn, for while the nature of the sea water governs the lives of the animals and plants that inhabit it, at the same time the functions of the latter are as constantly altering the nature of their environment in a way to which we see nothing comparable on land.

Perhaps the most obvious example of this (one already mentioned) is the constant draft that so many animals and plants make on the water for the materials with which they build their skeletons, as a result of which vast quantities of lime and of silica are constantly being withdrawn. And while some of this goes back into solution when the organisms die, other vast quantities accumulate on the sea floor, in deposits of lime compounds, and of silicates.

On the whole, by this process, lime is accumulating toward the equator, and around the coastlines, silica toward the poles and in the ocean deeps. Why is it that lime accumulates more rapidly on the bottom in shoal water than in deep? Is the solvent power of deep water the greater, as has often been supposed, or have we to do with some bacterial action?

The mass production of plants in the sea withdraws temporarily from circulation the nutrients they need, and there is a certain permanent loss after their death, as of nitrates decomposing to the gaseous state, and of phosphates going into chemical union with bottom sediments. Just how are these losses made up so that the balance is on the whole maintained? How far is the pulse in the available supply of these nutrient substances in the sea responsible for the sudden outbursts of unicellular plants in such unbelievable numbers that they are the most spectacular events in marine economy, and is it their exhaustion of the water that destroys them, or are they self limited in some other mysterious way? In like manner, while the degree of alkalinity of the sea, like that of our own blood serum, is constant within narrow limits and any wide variation means death, the great drafts of carbon that plants make in their photosynthetic activities, added to various other biologic and chemical happenings, are as constantly tending to alter the ionic concentration of the various electrolytes in the solution, and thereby to raise or to lower the alkalinity. But while alterations so caused may actually progress to the fatal limit in enclosed pools, this never happens in the open sea. What rôle in maintaining this fundamental balance, against their own tendency to upset it, is played by living creatures, and how do they

affect the cognate matter of the CO_2 tension of the sea water relative to that of the air?

These illustrations, with those given in the preceding pages, are perhaps enough to show that, at bottom, the composition of the sea water is as much a biologic as a chemical problem, even though in many cases its solution can come only *via* the discipline of chemistry. On the other hand, as is stated repeatedly in the preceding pages, most of the basic problems of oceanic biology equally focus around the fact that the oceans are filled, not merely with water, but with water that is 'salt.'

We can quote no better example of the intimacy with which the disciplines of the biologist, of the geochemist, and of the geophysicist unite in concrete cases, than is afforded by the broad problem of the means by which the uniformity of sea water is maintained, for it is obvious that some of the processes that are constantly tending to disturb the balance fall in one, some in another scientific subdivision.

Thus the problems that center around the fact that the solutes contributed with river water are very different in their composition from sea salts; the withdrawals by animals and plants in the formation of their shells; around the withdrawals of food-stuffs by plants, balanced against the contributions to the water of other stuffs as carcasses decay; or around the alterations in ionic dissociation that result

from additions and withdrawals, are biochemical. But, the diluting effect of the rain that falls upon the surface of the sea or of the fresh water that is poured in by rivers, and the concentrating effect of evaporation, all offer problems in physics. Only in conjunction, therefore, can chemist, geologist, and biologist hope to learn how the sea water remains so constant that we must analyze to parts per million, even to parts per thousand million, before we can express the existing variations in the relative proportions of its different salts; or how it is that the alkalinity of the sea never varies outside the narrow range in which protoplasm can live — is in fact as delicately balanced as the alkalinity of our own blood serum.

Another obvious line of connection between the biological and the physical-chemical realms in the sea is *via* temperature; no creature can live, much less thrive, if the water be too hot or too cold. But even as seemingly simple a constant as temperature cannot be considered *per se*, or as an adjunct, in the sea, because water has no inherent temperature of its own, but is given the latter by a complex of constantly changing factors such as solar radiation, back-radiation to the air, evaporation, and the melting of ice. Consequently, in our examination of temperature, we are led without a break into the fields of astrophysics, of meteorology, and of polar geography. We are also led, and very abruptly, to a

consideration of the circulation of the sea, because the temperature there at any given time and locality is largely controlled by the currents, as the latter transfer cool or warm water masses from place to place. There is, too, a direct mechanical connection between ocean circulation and the lives of the marine inhabitants quite as important as that *via* temperature, for currents also carry plants and animals about, likewise other materials of all sorts. Currents, in fact, play much the same rôle in marine economy as do railroads, or any other transportation system on land.

We must realize that, wonderful medium though sea water be for the support of life, any animal or plant would soon exhaust the vital possibilities of the water in its immediate vicinity unless some transportation system were in operation, either to carry the creature elsewhere (whether voluntarily by its own activity, or involuntarily) or to bring to it new water holding in solution or in suspension the substances that the organism in question needs. For the latter sort of transport, the currents and drifts of the sea are wholly responsible; largely so also for the former, by effecting the involuntary migrations of creatures young and old, a kind of dispersal that is constantly going on, and on a scale much broader than is generally appreciated. If the life of the eel is perhaps the most spectacular instance of this type of

migration that has yet been followed through to its conclusion, thousands of other kinds of sea animals and plants equally owe their geographic distribution (presence here and absence there), and their dispersal from the regions where they were produced to other regions where they pass the greater part of their lives, directly and solely to mechanical transport by ocean currents. This category of travelers includes the majority of our important food fishes, for most of these, when young, drift at the mercy of tide and current for considerable periods.

Circulation is also solely responsible, for example, for the aeration of the deeps, without which all but the uppermost stratum would be a waste more desert than the Sahara. Currents, too, largely control the distribution of salinity over the oceans; they wear down some coastlines and build up others; they distribute sediments over the bottom of the sea; and they so largely determine the climates of the continents and the system of winds that there is no possible way to disentangle oceanography from climatology.

Reasons as cogent as these make even the biologist admit, no matter how strictly he may confine himself to his own narrow niche, that the currents of the sea offer today one of the most intriguing fields of study in sea science. And, as let us repeat, this is true not only from the descriptive side (for we still

have much to learn even about the characteristics of the larger and more impressive ocean currents as described above — Gulf Stream, for instance — let alone the obscure) but from the standpoint of the physical forces that keep the circulation of the sea in its closed and continuous operation. So the unfortunate biologist, even if mathematics are to him a closed book, as is the case with too many of us, must perforce take as keen an interest as do his physical confrères, in the modern applications of mathematics to oceanic dynamics, and hold as high an appreciation of them.

Studies in whatever division of oceanography also lead inevitably into the province of the geologist, if they proceed far enough, for in last analysis the shapes, often the structures of the basins that hold the oceans, must always be taken into account.

The contours of the coastlines and of the submarine slopes confront the student at every turn, no matter what his chosen field of research, because these are the factors that control the whole system of submarine circulation, however the latter be kept in motion. And as every oceanographer realizes but too well, circulation is, in the end, the lifeblood of all events that take place in the sea.

The problems of sedimentation in the ocean also bridge the gap between chemist, biologist, and geologist, because the oozes that accumulate on the

Unity in the Sea

floors of the deep basins so largely consist of the skeletons of animals and plants that sift down after death from the upper layers. Where, and in what numbers these skeletons commence to sink, is a problem as strictly biologic as any, for it depends in part on the geographic distribution of the species concerned, equally on their birth- and death-rate. But whether and in what quantities these skeletons do actually reach the bottom, also their effect upon the ocean water as they go back into solution (for given time enough, anything will dissolve in sea water) is a physical-chemical question. The ultimate fate of such of these skeletons as actually reach and accumulate on the bottom is a geologic question of the first rank, for reasons given in an earlier chapter. And the problems that center around the contributions that are made to the sea floor by reef-builders, and by other bottom-living animals, bridge the gap, no less directly, between the disciplines of biology and chemistry on the one hand, or geology on the other.

There is, we think, no need of further argument to prove that these several disciplines do inevitably interlock, or to point the intellectual necessity not only of recognizing, but of acting upon this unity, if we hope ever to gain any sound understanding of the sea, or of the lives of its inhabitants.

THE END