took place. The experimental results can be very briefly stated, and are quite at variance with the displacement theory. Liming with burnt lime and high calcic limestone appreciably increased the calcium outgo and depressed the magnesium outgo. In a similar manner applications of magnesium, either as oxide or as carbonate, increased the magnesium outgo and very markedly depressed the calcium outgo. The result from liming with dolomite—a double carbonate of calcium and magnesium—is of special interest. It was found that in spite of calcium enrichment supplied by this material there followed a decreased outgo of calcium and an increased outgo of magnesium. It should be borne in mind that the sum of the enhanced outgo of calcium and magnesium was found to be nearly constant. These findings have an especial interest in explaining the detrimental effect that high-calcic limes may exert upon such a magnesia-loving crop as tobacco. They throw a new light upon many of the interpretations given to the older studies of lime-magnesia ratios.

Study of the accumulated data for calcium and magnesium outgo from economic liming in the lysimeter experiments shows that the loss of lime is too small to account for the decreasing benefit to legumes of high lime requirement. A need for reliming is therefore apparently due to changes in the form or state of the large residual fraction of added lime rather than to extensive outgo in those soils that possess good fixing capacity. It has been demonstrated to our satisfaction that after added lime is absorbed by the soil the absorption product undergoes a progressive decrease in availability. This phenomenon may be a simple "aging," using the term in the chemical sense, for which there are many analogies in the formation of precipitates that in time become increasingly less soluble.

Much has been said relative to base-interchange—a phenomenon that is of great importance in the genesis and subsequent make-up of dyke-reclaimed soils and those of arid regions. Under humid conditions Tennessee soils do not show base-interchange reactions in the zone of incorporation of calcic and magnesic materials, even in the presence of high concentrations of a neutral calcium or magnesium salt; but on the contrary they show a repressive action. On the other hand, the percolates from lime- or magnesia-treated surface soil do exert a base-interchange effect in the subsoil where the action of sulphates, nitrates and chlorides comes into play beyond the zone of contact between the soil and additions.

The writer has reserved for the close of this paper a brief discussion of a most interesting and important soil reaction which explains certain soil phenomena and also has other and unexpected applications as an important analytical procedure both in the soils laboratory and in industry. That is the formation of the ternary systems, $CaO–Fe_2O_3–CaSO_4$ and $CaO–Al_2O_3–CaSO_4$. These compounds and the reactions involved were new to soil chemistry, and their discovery is one of the more interesting achievements of the station's researches.

In connection with certain lysimeter experiments it was observed that very heavy liming—100 tons of CaO per acre—practically inhibited the outgo of sulphates for a year or two, but that this effect was not permanent. The phenomenon was studied from various angles, and finally by means of a synthetic study with pure gels, the formation of compounds of both iron and aluminum united with CaO and $CaSO_4$ was found to be the explanation. These compounds are of low solubility as long as the system is alkaline, but are readily soluble in either neutral or acid media. Further investigation showed that aqueous solution of calcium hydroxide and calcium sulphate readily attacked aluminum complexes in the soil, with the formation of the ternary compound. Afterward the reaction was utilized as the basis of a chemical method of determining the amount of reactive alumina and silica and promises much as a useful yardstick in the measurement of the colloidal properties of a soil. Industrially the discovery is valuable because an explanation is given for the disintegration of concrete under certain conditions, which had previously not been understood, and furnishes the necessary information for the avoidance of such trouble in the future.

In conclusion, the fact may well be emphasized that the soil solution is the source of all the nutrients taken up by the roots of plants. As Brazeale has said, "The plant deals with the soil solution and with the soil solution only." It is this solution that is obtained by means of lysimeters. Lysimeter findings may therefore be studied to advantage by plant physiologists and others who are interested in learning what effects manurial treatments may be expected to exert upon crop-nutrient assimilation and plant-ash content.

# A DEVELOPING VIEW-POINT IN OCEANOGRAPHY

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AT the Princeton meeting of the National Academy of Sciences on November 18 last, its committee on oceanography, consisting of W. Bowie, E. G. Conklin, B. M. Duggar, J. C. Merriam, T. W. Vaughan and F. R. Lillie (*chairman*), with H. B. Bigelow, *secretary*, submitted a report on its study of the scope, economic importance and present status of oceanography, with recommendations as to how this science may more effectively be encouraged in America. To the general scientific public the most significant feature of the report is perhaps the general conclusion, reached by the committee, that the establishment on our Atlantic coast of a new organization dedicated to the encouragement and prosecution of oceanographic investigation is "the greatest need at the present time, both from the point of view of American oceanography and also for adequate participation of this country in a study necessarily international." The committee concludes further that "the establishment and endowment of an Atlantic Oceanographic Institute should be realized at the earliest possible moment."

The report is too long to be summarized here.[1] We, therefore, think it pertinent to set forth something of the view-point developed in the report that led to the recommendation of this particular kind of support for oceanography, rather than to the more conventional suggestion that our knowledge of the sea would be most rapidly increased by more deep-sea expeditions, and greater.

This commitment implies, as is indeed the fact, that oceanography has of late entered a new intellectual phase, to explain which a word of retrospect is necessary. While in one sense this is among the oldest of natural sciences, in another it is one of the youngest. To date its absolute birth is an impossibility, for this took place when first some fact about the sea was not only observed but recorded: certainly this happened many centuries before the Christian era. And with the passage of the centuries recorded knowledge continued to accumulate about one phase or another of what we now call oceanography. But this could hardly have been dignified with the rank of a separate science down to the early years of the century just passed, because it had not yet passed the stage of collecting and recording isolated facts, whether about the surface of the sea, about its inhabitants in shallow waters or about its margins. In fact all that lay below the surface of the open sea, or more than a few fathoms down from tide-line around its shores, continued, down to the late seventeen hundreds, as much a mystery as it had been to the Phenicians, except when some deep-sea fish was cast up upon the strand. Indeed, it was not until about the middle of the nineteenth century that systematic examination even of the surface of the sea was seriously undertaken, or that scientists awoke to the fact that the underlying waters offered a whole new world for exploration, that offered no unsurmountable difficulty.

Evidently this descent into the abyss could not be made without the development of suitable instruments, whether to plumb the depth, to sample the living creatures there or to measure the physical and chemical characteristics of the water. And philosophically it is interesting that it was the birth of this new view-point, reached from gleanings with very primitive gear during the preceding fifty years or so, which led to the development of efficient instruments—not the reverse.

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

Students of the history of science may well date the birth of modern oceanography from December 21, 1872, the day when the *Challenger* set sail from Portsmouth, England, on her memorable voyage. And thenceforth, with every fresh venture below the surface of the sea, such a flood of new facts came pouring in that it seemed for a time as though this fact-catching could never lose its novelty. One great deep-sea expedition led to another, and more was learned about the sea during the last thirty years of the nineteenth century than had been during the preceding three thousand. But after a time, as so often happens when some scientific discipline takes a sudden spurt, this fact-catching began to lose something of its freshness.

At first, when no one knew what lived on the bottom of the sea, every new fish that was drawn up was a marvel. But now we have come to have a more sophisticated outlook upon such things. Students began, in short, to feel that the mere accumulation of facts from the sea, when there is an inexhaustible supply, may actually become a bit sterile, just as catching fish is to a sportsman where fish are too plentiful. To maintain interest under such circumstances, one must need the fact—or the fish, as the case may be. So it was natural that when persistence in the old methods no longer yielded startling discoveries, signs could be seen of the approach of a period of stagnation, following the peak of fevered activity. And oceanography would probably be in a moribund state in America to-day, just as the art of sailing a square-rigger is, but for the birth of the new idea that what is really interesting in sea science is the fitting of these facts together, and that enough facts had accumulated to make the time ripe for an attempt to lift the veil that had obscured (and still obscures) any real understanding of the marvelously complex and equally marvelously regulated cycle of events that takes place within the sea.

The foundation for this conscious alteration in

[1] It is now available in mimeographic form.

view-point, 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, we believe that our ventures in oceanography will be 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 as a whole in the sea, instead of confining our individual outlook to one or another restricted phase, whether it be biologic, physical, chemical or geologic. This applies to every oceanographer: every one of us, if he is to draw the veil backward at all, must think and work in several disciplines. He must be either something of a Jack of all trades or so closely in tune with colleagues working in other disciplines that all can pull together.

We see here a case where economic pressure was largely responsible for lifting a field of knowledge, willy-nilly, to a higher and more rarefied atmosphere of what we flatter ourselves by calling "pure science"—in this instance the plight of the commercial sea-fisheries of northern Europe. The countries bordering on the North Sea had exploited the resources of the fisheries for centuries. And it chanced that just when oceanography was enjoying its nineteenth century boom, the fisheries were also so rapidly expanding in intensity, through the development of more effective fishing methods, that the dread of overfishing became imminent. What more natural than for the maritime nations to turn for advice to the sea scientists who had for the past fifty years been so busily carrying on explorations of the sea, naming and classifying the fishes—especially when the deep-sea expeditions had been so largely supported by taxpayers' money?

But sound advice as to the wise management of the fisheries science could not give, for while volumes of facts had been garnered about the individual species of food-fishes, and as many more about the medium in which these live, there had as yet been no general and concerted attempt to fit these two categories of facts together, or in other words, to unravel the skein of factors that controls the lives of fishes in the sea. It was, however, clear enough, once attention was directed thereto, that if the exploitation of the deep-sea fisheries was to be based on sound, rather than on hit-or-miss, principles of conservation, it demanded just this understanding of the lives of its victims; it was equally clear that such an understanding could be gained only through a synthesis of studies in many fields, and that no mere piling up of data, however extensive, could yield it.

All this was so obvious, once pointed out, and the economic urge was so pressing that a vast amount of attention (and a vast amount of money) has been expended on fisheries-biology during the past quarter century, and an appreciation of the need of unity has come to permeate the whole edifice of oceanography. But even with this new view-point and new impetus, science has given assistance much more slowly to the suppliant fisheries than had been hoped, because the requisite synthesis of knowledge has proved a task immensely difficult intellectually as well as technically, and because we are only now beginning to appreciate the appalling complexity of every marine problem—a complexity which if discouraging in one way offers in another way a most alluring stimulus. Speaking as a biologist, the proverbial "way of a maid with a man" is glass-clear as compared with the way of a fish in the sea, for in the sea there is no such thing as a hermit fish—or fact: every sea animal depends on an endless chain of other animals or plants and equally on an endless chain of facts and events in its inanimate surroundings.

Though we have been studying cod, mackerel, lobsters and the rest, with men and ships at sea, in libraries and laboratories ashore, with hopes and with discouragements, for all these years, we do not yet know all the links in the life chain of any single species, or even which links are apt to be the most important, or even where to seek more than a few of these links. But oceanographers do now very thoroughly appreciate that the geophysical and chemical links are quite as vital—perhaps even more so—than those of the sort more usually named biologic.

When one picks up a fish, one may be said, allegorically, to hold one of the knots in an endless web of netting of which the countless other knots represent other facts, whether of marine chemistry, physics or geology, or other animals or plants. And just as one can not make a fish-net until one has tied all the knots in their proper positions, so one can not hope to comprehend this web until one can see its internodes in their true relationship. This is to-day the conscious aim of oceanographers.

To look more closely at some of the lines of knots in the web will perhaps help to bring this conception home.

On the whole, the simplest of these to follow, and certainly among the most important, are the food lines, *via* which one species is interdependent upon another. Thus a shark may eat a pollock, a pollock may eat a smelt, a smelt eat an amphipod, an amphipod eat a copepod and a copepod eat a diatom, and each must find its food-species at hand or perish. Or followed in the reverse description, we see here, as clearly, an enemy-prey line, for amphipods, if plentiful enough, may locally exterminate copepods, or fish locally decimate amphipods. And big fish may so prey upon little ones (even of their own species) that this last factor must seriously be taken into consideration in studying the maintenance of stocks of fishes on certain of our most productive fishing banks, for there is no prejudice against cannibalism in the sea; that is a purely terrestrial invention.

Nor can the biologist focus narrowly upon the biologic lines in this allegoric web, the chemist on the chemical, for when any animal is hatched into the sea and throughout its life, its survival depends quite as much upon whether its physical and chemical surroundings are favorable as upon the immediate food supply, or presence of enemies; while in life and in death marine organisms profoundly affect their aqueous environment. This interdependence, by and large, is much more intimate in sea than on land, for reasons that there is not space to enter upon here. Marine animals and plants being, as a class, much less effectively protected against their environment (because the marine aquatic environment is a favorable one, not an unfavorable, as is the air), the balance in this respect is often a very delicate one indeed. For examples of this, one need only turn to the tremendous fluctuations that are known to take place from year to year and over periods of years in the numerical abundance of various fishes in the sea, from purely natural causes with which the hand of man has had nothing whatever to do. It will be enough here to refer to the proverbial ups and downs shown by the mackerel. In the eighties of the past century American waters swarmed with mackerel: the sea was full of them. They then dwindled in abundance (though with ups and downs) until, at their low point, in about 1910, the mackerel might almost be called a scarce fish. But then the stock began to build up again, in spite of the fishery, until to-day it seems that we may look forward to another period of tremendous plenty in the near future. Annual fluctuations, almost equally spectacular, are well known to have taken place among the herring and among many other species.

We now realize that these periods of plenty and of scarcity in essence reflect good and poor years of production; that for many fishes a year of good production is decidedly an unusual event, so that a given year-class may dominate the stock over a considerable term of years, whereas other species may maintain a more nearly even population. And we begin to be able to predict, from the number of young fish produced and surviving in a given year, the probable productivity of the fishery in years to come. But we are still totally in the dark as to the exact causes of such fluctuations, except that they certainly are not inherent in the vital nature of the species concerned but have to do with external circumstances, or events, in the end physical-chemical.

The most 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 can not be considered *per se,* or as an adjunct, in the sea, because water has no inherent temperature, but is given the latter by a complex of such factors 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, 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. We think here not only of thousand-mile migrations such as those of the young eel but also of shorter travels such as those of the codfish, by which the little fry are dispersed from the inshore grounds of their nativity to offshore banks, where they grow and fatten for the nets or hooks of the fishermen, and of similar events in the lives of the haddock, of the herring, of the mackerel, of the plaice and of a host of others.

In our allegorical web of the sea, the current-lines also lead in many other directions. Currents of a sort not so familiar (*i.e.,* vertical) are 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 coast lines and build up others; they distribute sediments over the bottom of the sea; they affect indirectly and directly the comings and goings of every seaman who sails 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 to-day one of the most intriguing fields of study in sea science. And 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—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, and hold as high an appreciation of the modern applications of mathematics to oceanic dynamics.

The interrelations between the chemical and the biological phases of oceanography are quite as close as those just mentioned, again, perhaps most easily illustrated *via* the food-line. Even the tiniest animal in the sea must have organic stuff on which to feed. And we have been in the habit of thinking that sea-animals, like land, must depend in the long run on green plants for their pastures. Perhaps this is not an invariable rule, for it is possible that the autotrophic bacteria may prove to short-circuit this line more generally than now seems likely. But in the main, animal life in the sea does depend for its existence on the ordinary marine plants, chiefly on the planktonic plants. The problem of the food supply of these plants falls directly within the province of the chemist, for the only sources for plant food in the sea are the substances dissolved in the surrounding water. Consequently the biologist is as intimately concerned with the sea water itself as is the geochemist. Whether for the one or for the other, most of the basic problems of oceanography focus around the fact that the oceans are filled not merely with water, but with water that is "salt."

Though sea water may be named the most complex of all common substances if judged by the number of its constituents (for doubtless it contains, in solution, all the known elements), it is on the other hand the most uniform of all common substances, next to air, as measured by chemical analyses of ordinary delicacy: Sea water is sea water from whatever ocean we may draw it. And one of our most interesting oceanic problems of to-day is how this uniformity is maintained against the great variety of processes that are constantly working to destroy it. Here, again, the disciplines of the biologist, of the geochemist and of the geophysicist unavoidably unite, for some of these processes belong in one, some in another of these scientific subdivisions.

This is self-evident; for example, 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. Consider, again, the chemical problems that center around the fact that the solutes contributed with river water are very different in their compositions from sea salts; around the withdrawals of lime, of silica, even of strontium by animals and plants in the formation of their shells; equally 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 such additions and withdrawals. Only in conjunction can chemist, geologist or biologist hope to learn how the sea remains so constant through it all 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. It is only by a synthesis far more thorough than has ever yet been accomplished that we can ever hope to understand the working of the marvelous and self-operating regulatory system that maintains this balance now and that we may be sure has maintained it through past geologic ages.

From whatever point in our allegorical web we may choose to commence, whether geophysical, chemical or biologic, if we proceed far enough in our exploration we are inevitably led into the province of the geologist (and *vice versa*), for the oceanographer, if he is to be anything of an architect (not a mere bricklayer) must equally concern himself with the shapes and with the structure of the basins that hold the oceans.

As truly as the character of the bottom of the sea largely determines what kinds of animals live thereon (which every fisherman knows to be the case), biological processes going on within the water as largely determine what sorts of sediments shall accumulate in any given place to make up this bottom, except around the coasts, where these processes are masked by silt washed down from the land. Consequently the problems of sedimentation in the ocean fall as much within the province of the biologist as of the geologist. Thus the oozes that accumulate over the greater part of the sea floor consist of the skeletons of animals and plants that sift down after death from the upper layers.

Where, when and in what quantity these skeletons start to sift down is a problem as strictly biologic as any, for it depends in part on the geographic distribution, equally on the birth and death rate of the particular plants and animals concerned. But whether and in what quantities these skeletons do actually reach the bottom is a physical-chemical question, as is the ultimate fate of such of them as do arrive there. So, too, is their effect upon the bottom water of the ocean when they go back into solution, for given time enough anything will dissolve in normal sea water. But at the same time, the alterations caused in the sediments by the entrapped water offer very important and far-reaching geological problems, for while we know that the limestone and shale rocks were originally laid down under the water under conditions comparable to those of to-day, they differ greatly in their present state from the muds and oozes that are now accumulating under the seas. Two of the most pressing problems in this field concern the method of formation of petroleum and of iron ores. In fact, no one will dispute that the study of the modern sea bottom is a geologic necessity, for only by this means can geologists hope to understand how the different classes of sediments now solidified into rock were originally accumulated and subsequently metamorphosed.

The shapes of the oceans, too, confront the oceanographer at every step, whatever be his particular chosen field of research, because it is the contours of the coast lines and of the submarine slopes that confine and control the whole system of submarine circulation, however it may be kept in motion. And as every oceanographer realizes, this circulation is in the end the life blood of all the events that take place in the sea.

There is, I think, no need to quote more examples to show that the different disciplines of oceanography inevitably interlock, or to prove the intellectual necessity of not only recognizing but indeed acting upon this unity, if we hope ever to gain a thorough understanding of the sea and its inhabitants. Any attempt (conscious or unconscious) to hold them apart can result only in frustrating this high aim and in setting us backward to the stage of simply gathering and accumulating facts in unrelated categories.

# OBITUARY

## WILLIAM A. ORTON

DR. WILLIAM A. ORTON, scientific director and general manager of the Tropical Plant Research Foundation for the past five years, and formerly senior pathologist in charge of the office of cotton, truck and forage crop disease investigations at the Bureau of Plant Industry, U. S. Department of Agriculture, died at his home in Takoma Park, D. C., on January 7. He was in his fifty-third year, having served slightly more than twenty-five years in the department at the time he resigned to take up the tropical research work. Funeral services were conducted at the Takoma Park Presbyterian Church on January 9, and interment was in Rock Creek Cemetery, D. C.

The death of Dr. Orton closed a brilliant career, one marked during its later years by a courageous struggle against ill health which was a marvel to his associates. In spite of these limitations, he was a leader in the field of plant pathology and tropical agriculture, and has accomplished results of outstanding importance in the thirty years since he entered the Department of Agriculture.

Dr. Orton was born on February 28, 1877, at North Fairfax, Vermont, and was graduated from the University of Vermont with the B.S. degree in 1897. After a year of graduate work in the University of Vermont, specializing in botany and plant pathology, he received his M.S. degree in 1898. In 1915 the degree of D.Sc. was conferred upon him by the University of Vermont. He entered the Department of Agriculture on June 1, 1899, two years before the establishment of the Bureau of Plant Industry, and