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CONTENTS



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## CORAL REEFS AS ZONATIONAL PLANT FORMATIONS[1]

IN choosing a meeting of the Botanical Society of America for the presentation of a paper concerning itself with coral reefs, I am acting deliberately and with serious intention of emphasizing a point, to me at least, seemingly fundamental to all coral reef discussion, and that is this: the coral reef, so called, is dominated and controlled by its plant symbionts even where there is a variety of organisms concerned. Furthermore, there are certain reefs, and these even of the complex atoll type, which are so overwhelmingly, even completely, made up of calcareous algae that they clearly merit the appellation of "nullipore" reefs rather than the time-hallowed, popular, but scientifically misleading designation of "coral" reefs.

Coral reefs have suffered from being early connected with a theory in such an intimate and intriguing fashion as to invite attack against the protagonists of theory rather than to stimulate unprejudiced study of reef history from the point of view of a symbiotic entity, such as, for example, its origin, its growth, its capacity for assuming and retaining definite morphologic form, as well as for morphologic change, its ability to regenerate and to reproduce itself. Any symbiotic aggregate, having unity in general habit, controlled by a certain dominant organism or certain dominant organisms, behaves as an ecologic unit and is designated as a formation. When a formation, because of the environmental factors controlling it, borders or encircles, even irregularly, the substratum of its habitat, it becomes a zonal or zonational formation, and it, as has been pointed out by various writers, but by Clements in particular, is an epitome of succession.

Zonal formations are well known in both animal and plant ecology. The "coral" reef, to use the general term in the abstract, but without prejudice, may be made up entirely of calcareous algae, as Rose Atoll or Onoatoa Atoll, or of both, as Funafuti Atoll, the barrier reef about Tahiti, Moorea, etc., or the exposed fringing reefs of Tahiti, Tutuila, etc. It seems impossible to imagine any "coral" reef, other than certain small "reef patches," being constructed absolutely of corals alone, since even the most important of

[1] Delivered before the Pacific section of the Botanical Society of America, at Pomona College, California, June 15, 1928.

"reef-forming corals" have little or no coherence (or adherence) with one another and no controlling influence as to reef-form production, but are passive symbionts, important at times and in certain types of reef as constructional material, but of equal importance as to whether they are incorporated into the growing structure as massive, resistant masses retaining their position of growth, or as rubble or sand, after partial or complete disintegration.

The "coral" reef symbionts, as classified in the decreasing order of importance by the Coral Reef Committee of the Royal Society in the studies of Funafuti Atoll, are (1) calcareous algae, (2) foraminifera, and (3) corals. What is the reason for placing the calcareous algae first? This was first brought forward by Stanley Gardiner (1903). It was emphasized and made more definite by Finckh (1904) and by others of the Funafuti Committee, and it was cast into definite form by Marshall A. Howe (1912). The dominance of certain types of calcareous algae in bringing about the zonal formations we call coral reefs is evident when we consider the living portions of any coral reef which is still actively growing. The crustaceous calcareous algae, or nullipores, are the binding or cementing agents, the active symbionts, in reef formation. The foraminifera and the corals contribute much less than the algae, even of the bulk of a "coral" reef and add little to its amalgamation into permanent form. They are passive symbionts, disintegrating and dispersed, unless overgrown and united to other aggregates by the nullipores. Were time allowed, this feature might be considered in detail, but Finckh, in particular, in the Funafuti report, has drawn a vivid picture of this interaction.

The active symbionts, the nullipores, are either surface or subsurface workers. The surface workers are sun-loving and surf-loving plants, heliazophytes and spumatophytes in ecological classification. The subsurface active symbionts of a coral reef are shade-loving, current-loving plants, skiarophytes and rheophytes in ecological classification. The cooperation of the first group with the similar heliazobionts and spumatobionts of other plant and animal groups for surface work and the cooperation of the second group with other skiarobionts and rheobionts of other plant and animal groups, bring about reef formation at various depths from the surface down to at least two thousand feet below the mean level of the ocean. Again, it would be desirable to proceed to detail, but time limits forbid. The various reports of the Funafuti Committee furnish much of the available data.

The growing region of an active reef is along its exposed outer edge and flank, since both light conditions and water in motion exist here in most favorable intensities for the growth of both active and passive symbionts. This fact has long been recognized. Even at considerable depths, currents exist, as has been shown by Bigelow for the Challenger Bank off Bermuda and by Stanley Gardiner off the Maldives in the Indian Ocean. The light conditions in clear tropical waters allow red algae of the Nullipore type to flourish down to two thousand feet or below. The temperature relations seem fairly definite and active "coral reef" formation seems to be confined to strictly tropical waters of 25° C. isocryme, or over, at the surface.

"Coral" reefs are formed, either around islands or island groups (usually volcanic) or project from submerged mountain tops. In all cases the formation is zonal. The division into fringing, barrier and atoll types is purely physiographic, the form being in all cases zonal. The interconvertibility of these zonal types, beginning with fringing, passing over into barrier, and thence into atoll has been postulated as a *necessary sequence* in the Darwinian theory of the origin of coral reefs, and as a result of the assumption that coral reefs, excepting only those of the fringing type, can not have been formed other than as a concomitant of *gradual and successive* subsidence of the substratum. Back of this assumption of gradual and successive subsidence, Darwin had two subsidiary ideas. The first, considered proven, dealt with depth limitation of reef-forming corals to about two hundred feet, while the second assumed as improbable the existence of substrata at such uniform depth below the surface and in such numbers as to account for the multitude and wide distribution of atolls. Since the study of typical reefs has relegated the reef coral to the subordinate position of passive symbiont and has indicated that reefs of the atoll type, the most difficult type to account for, are not necessarily dependent upon corals even as passive symbionts, the Darwinian factor of depth limitation ceases to have its extreme inhibition and obviates the *necessity,* at least, for assuming interconvertibility.

That reefs, even of large size, have carried on their development under still-stand conditions of ocean level not only for great lengths of time but also even from the beginning of their formation, seems to me to be clear in the case of those which are still living as reefs, and which show by their present level and the relation of this to the extent and position of their surface controlling nullipore. The barrier reef, and the protected fringing reefs within this, of Tahiti, show this conclusively. The details I have published in my phytogeographical notes on Tahiti (1926). In surface level, the protected fringing reef is the same as the barrier, although now dead as a reef. The barrier reef without it, separated from the fringing reef by a moat (or "lagoon") of varying width up to half a mile, and a depth averaging about twenty fathoms, still shows a broad outer belt of living pavement nullipore controlling its growth. This belt of pavement nullipore is about fifty meters wide and is extending slowly at not over a rate of one third to one fifth mm per year. The belt of living nullipore, covering at this time only about one third, if as much as that, of the surface of the barrier reef, indicates that the surface of the barrier has remained at the same level for many thousands of years. The dead surface of the barrier and the present dead surface of the now protected fringing reef within it indicate a continuation of this same level since the original fringing reef was extending outward until the rising barrier reef without it shut it off from the surge so necessary to the life of its pavement nullipore and killed it off, taking over the outward extension of the encircling reef structures of Tahiti. Earlier stages of the same process are seen on some sectors of the Tahiti coast where exposed fringing reefs are still provided with controlling pavement nullipores, while the future barrier reefs are still growing upward, but, even yet, are still several fathoms below the surface, thus allowing the waves to pass over them and to supply the vital surge to the fringing reefs within.

I realize the difficulty of making these matters clear and reenforcing them sufficiently in the time allowed, but I trust that I have justified my action in bringing before an assembly of botanists this aspect of the coral reef problem, *viz.*, that the so-called "coral" reef is a biological formation, controlled and moulded into zonal form by its plant symbionts; that the factors of light, aerated water and temperature control its dominant type of symbiont; and that depth limitation and interconvertibility, together with the assumption of the necessity for gradual and continuous subsidence, must be judged not from coral behavior, but from the relations of the controlling nullipores to their environmental factors. From such studies it seems fairly well indicated that reefs of all three physiographic types not only may, but do, develop to their full expression under still-stand conditions of ocean level.

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## SCIENCE AND THE PRESS

(*Continued from page 100*)

The chairman next called upon Mr. David Dietz, science editor of the Scripps-Howard newspapers, who gave the following address:

### Science, the Newspaper and Progress

I regard it a great privilege to be asked to take part in this symposium to-day upon the relationship which should exist between science and the press, for I regard the spirit which has motivated the organization of this symposium as one of the most important in the world to-day. It is a spirit which makes one hopeful for the future.

It is a new spirit and the very fact that it exists betokens the existence of a new point of view both in the field of science and in the field of journalism. I doubt very much if a symposium such as this would have been possible twenty years ago. In all probability, a majority of scientists would have felt at that time that the subject was neither fit nor proper for inclusion upon the agenda of a scientific convention. They would have regarded it as unethical in all probability. Certainly, they would have regarded it as undignified. Newspaper men for the most part would have had little interest in being invited to take part in such a symposium. Those were the days when science was synonymous with ten-syllable in-understandable words to be treated appropriately by the staff humorist and the cartoonist.

But the point of view has changed in both fields, not only to the mutual benefit of both science and journalism, but to the infinite benefit of the general public as well. The first newspaper publisher to see the necessity of this new point of view was that great far-sighted genius of the newspaper world, E. W. Scripps, the founder of the Scripps-Howard newspapers. After a number of conferences with the leading scientists of the nation, Mr. Scripps organized and endowed Science Service as an agency to gather and disseminate scientific news.

The thing which Mr. Scripps and those scientists who met with him saw was that progress would be immeasurably retarded without the quick and widespread dissemination of scientific thought.

There had been a tendency upon the part of the scientist to withdraw into the seclusion of his laboratory or his library not unlike a hermit in his cave. This action proceeded in every case from the highest and finest motives and is easy to understand. The scientist felt that in searching for the answer to his particular scientific problem he was devoting himself to the most important thing of which he knew. He felt, therefore, that nothing else mattered.

But gradually the feeling became stronger and stronger that something else did matter. This point of view that something else did matter was expressed in a clearer and more powerful way than I am capable of expressing it by Professor James Harvey Robinson in December. 1922, at a symposium at the