sisting of dead cells and detritus." Dissolved organic phosphorus has been reported from zooplankton excretions (*4*). The relative importance of phytoplankton, zooplankton, and detritus as sources of dissolved organic matter is not known.

Dissolved amino acids are present in sea water (*5*), but little is known of their sources. We report here that dissolved amino acids are released by living zooplankton. Samples of zooplankton were collected from waters of the continental shelf off Georgia and the continental shelf, Gulf Stream, and Sargasso Sea off the Carolinas. A coarse (No. 0) net was used in order to exclude phytoplankton and detritus. The mixed zooplankton samples were incubated at collection temperature (7.0° to 25.6°C) for periods of from 20 to 285 minutes. Animals were observed carefully during the tests. Movement was used as a criterion of vigor in all organisms but radiolarians. Samples were discarded if any doubt arose concerning the condition of the animals. Samples were filtered through a membrane filter that had a porosity of 0.45 $\mu$, preserved with a drop of chloroform, and frozen for subsequent analysis.

Total $\alpha$-amino nitrogen was estimated by a slight modification of the copper method of Pope and Stevens (*6*). This modified method resulted in recoveries in the range of 70 to 90 percent for typical amino acids added to sea water at concentrations comparable to those observed in the filtrates.

Release rates of dissolved amino acid based on 24 samples ranged from 2.4 to 30.5 mg of $\alpha$-amino nitrogen per gram dry weight of zooplankton per day, and were positively correlated with temperature, $r = 0.92$. The regression of dissolved amino acid release rate ($E$) on temperature ($T$) is estimated by the equation, $E = 1.0\ T\ (°C) - 5.9$. No significant correlation between release rates and duration of the test was observed.

There were no gross differences in release rates attributable to differences in taxonomic composition of the sample. However, chromatographic analyses of seven of the samples indicated that different zooplankton populations release different assemblages of individual amino acids, although arginine and taurine have been identified in all seven samples. Taurine is among the most abundant amino acids in the free amino-acid pools of marine invertebrates (*7*).

By using our data and the published data on primary production and density of net zooplankton in the Sargasso Sea and the Gulf Stream off the Carolinas (*8*), an estimate can be made of the amount of carbon in dissolved amino acids released by zooplankton as compared to the organic carbon produced by phytoplankton. This percentage approximates

$$\frac{4Z(T - 5.9)}{P} \times 100,$$

where $Z$ is total dry weight in the water column; $T$, the mean temperature of the water column; $P$, the mean daily primary production of the water column (grams of carbon per $m^2$); and 4 is the factor for converting $\alpha$-amino nitrogen to amino-acid carbon. Released amino-acid carbon is estimated to be 22 and 25 percent of primary organic production in the Sargasso Sea and Gulf Stream, respectively (*9*). These estimates indicate that dissolved-amino-acid release by zooplankton constitutes an important metabolic pathway in the plankton ecosystem.

R. E. JOHANNES
KENNETH L. WEBB*
*University of Georgia Marine Institute, Sapelo Island, Georgia*

### References and Notes

1. For reviews see G. E. Fogg, *New Biol.* **29**, 31 (1959); J. R. Vallentyne, *J. Fisheries Res. Board Can.* **14**, 33 (1957).
2. G. W. Saunders, *Bot. Rev.* **23**, 389 (1957); G. E. Fogg, *Rappt. Proces-Verbaux Reunions Conseil Perm. Intern. Exploration Mer* **144**, 56 (1958); R. R. L. Guillard and F. J. Wangersky, *Limnol. Oceanog.* **3**, 449 (1958); F. A. J. Armstrong and G. T. Boalch, *Nature* **185**, 761 (1960); J. A. Hellebust, *Limnol. Oceanog.* **10**, 192 (1965).
3. E. K. Duursma, *Neth. J. Sea Res.* **1**, 1 (1961); *ibid.* **2**, 85 (1963).
4. L. R. Pomeroy, H. M. Mathews, H. S. Min, *Limnol. Oceanog.* **8**, 50 (1963).
5. See review in D. W. Hood, *Oceanog. Marine Biol.* **1**, 129 (1963).
6. C. G. Pope and M. F. Stevens, *Biochem. J.* **33**, 1070 (1939).
7. J. W. Simpson, K. Allen, J. Awapara, *Biol. Bull.* **177**, 371 (1959); C. B. Cowey and E. D. S. Corner, *J. Marine Biol. Assoc. U.K.* **43**, 485 (1963).
8. G. A. Riley, H. Stommel, D. F. Bumpus, *Bull. Bingham Oceanog. Collection* **12** (No. 3), 1 (1949), tables 17, 18, 24. These data were derived from a study that was carried out at the same time of year and in the same areas of the Gulf Stream and Sargasso Sea in which our zooplankton studies were conducted.
9. These values are subject to at least two sources of error. (i) Crowding of zooplankton in experimental containers may result in increased metabolic rates (M. Satomi and L. R. Pomeroy, *Ecology*, in press) and measured release rates were probably higher than release rates of net zooplankton in nature. Experimental densities ranged from 0.6 to 9.2 g dry weight per liter. Over this range we found no significant increase in release rates associated with density when temperature was held constant in the statistical analysis. (ii) These experiments do not take into account zooplankton which are too small to be retained in plankton nets, but which constitute a metabolically important fraction of the zooplankton [R. E. Johannes, *Science* **146**, 923 (1964)]. These two sources of error tend to offset one another.
10. This research was performed in part during cruises of the Duke University Marine Laboratory research vessel, *Eastward*. We are grateful for the cooperation extended to us by the officers and crew and by various members of the Duke staff. We thank Dr. L. R. Pomeroy who read and criticized the manuscript. Supported by NSF grant GB-1040 and by grants from the Sapelo Island Research Foundation. Contribution No. 93 from the University of Georgia Marine Institute.

* Present address: Virginia Institute of Marine Science, Gloucester Point 23062.

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## Abnormal Corallites

In "Neoplasia in a coral?" [*Science* **148**, 503 (1965)] Donald F. Squires describes growths that are certainly neoplasms in the general sense of aberrant new growths. Some readers may infer that they are the special types of malignant neoplasms called "cancers." I should like to warn against this interpretation and at the same time offer an alternative.

Malignant neoplasms usually arise as discrete, unique events initially involving single cells. These altered single cells multiply to produce cancers. While reversion of such growth to normal is not unknown, it is certainly rare. Squires' Fig. 2 shows two *similar* "abnormal" corallites, separated by about 20 "normal" individuals. A third is described but not illustrated. In such colonies each corallite arises by the vegetative budding of a single previous individual. The colony is a clone. In this particular colony of 239 individuals the same type of abnormality has arisen three times and in each case has been followed by complete reversion to normal, without intergrades. That these three similar transformations represent separate events of the malignant type surpasses probability.

These growths, however, bear extraordinary resemblances, both in apparent structure and in distribution, to the "galls" which are common on many plants and which result from the continued presence of a great variety of sedentary predators. Such predations are not unknown in aquatic

organisms. An example is the intermittent galls on the green alga *Vaucheria*, caused by a rotifer [W. Rother, *Jahrb. Wiss. Botan.* **29**, 525 (1896)]. The abnormal growth of these galls is produced through the activity of "growth-hormones" secreted by the resident predator. These substances are related to if not identical with substances commonly secreted by fungus or bacterial invaders; the auxins and gibberellins are examples.

The abnormal corallites could well represent a hitherto unreported type of response to some sedentary predator—virus, bacterium, fungus, or invertebrate, which might have made three separate attacks on a single coral colony over a period of several years. I hope that Squires' article will alert others to be on the watch for similar phenomena, which may indeed have great importance in our understanding of the causes of neoplasia.

PHILIP R. WHITE

*Jackson Laboratory,*
*Bar Harbor, Maine*

1 June 1965

. . . From careful examination of Squires' Figs. 1 and 2, and the account in the text, it appears to me that what is described as a pathologic corallite on the specimens of *Madrepora kauaiensis* are actually colonies of the cyclostomata ectoproct belonging to the genus *Lichenopora* DeFrance 1823. Recently, I have found a few similar specimens of *Lichenopora* adherent to other bryozoans and coral in a collection, from Hawaiian waters, belonging to the Bernice P. Bishop Museum. The confusion is readily explained. Before DeFrance erected the genus *Lichenopora* in 1823, many members of this genus were referred to the *Madrepora*, a good indication of the superficial resemblance of the mineralized portions of these two animals.

JOHN D. SOULE

*Allan Hancock Foundation,*
*University of Southern California,*
*Los Angeles 90007*

3 June 1965

White and Soule have both raised the question of the possibility that the growths on the coral *Madrepora kauaiensis* resulted from growths about other organisms. Such a result is extremely probable among the corals, for they are hosts to large numbers of crustaceans and other organisms which cause the formation of "galls." The particular instance described was believed to arise from other stimuli because of the sequential development of the abnormal corallites, steps which also suggested that there was a certain similarity between the development and neoplasia.

Because of the unique nature of the specimen, extensive dissection and sectioning were not undertaken. Examination of the exterior and interior of the specimen shows no evidence of coral overgrowth of another organism as often found in other galls. Although not diagnostically definitive, x-ray diffraction patterns obtained from septal fragments of the abnormal growths show that they are aragonite and similar to diffraction patterns from other portions of the corallum. Bryozoans differ in the crystal form of calcium carbonate utilized in their skeletal structures, either aragonite or calcite being present. Corals, on the other hand, exclusively utilize aragonite. No undoubted *Lichenopora* has as yet been available to me for x-ray diffraction analysis to rule out conclusively the possibility that *Lichenopora* was the cause of the anomalous growths.

Growths resulting from activity of growth hormones as suggested by White are indeed a possibility, and the uncertainty of the neoplasia diagnosis is indicated by the query in the title of the note. Conclusive evidence of neoplasia can, of course, rest only with histological studies of the tissues of the specimen, unfortunately unpreserved in this instance.

DONALD F. SQUIRES

*Department of Invertebrate Zoology,*
*Smithsonian Institution,*
*Washington, D.C. 20560*

2 September 1965

## Quasi-Stellar Source 3C 273 B: Variability in Radio Emission

In a recent issue of *Science* Dent (*1*) has reported the very important discovery of variability in the 8000-Mc/sec radio emission of the quasi-stellar source 3C 273 B. The purpose of this note is to call attention to a numerical error in Dent's calculations which invalidates his conclusion that if the variable source emits by the synchrotron mechanism it must be much closer than the $1.5 \times 10^9$ light years assigned to it on the basis of its red shift (*2*).

Dent based his discussion on an article by Slish (*3*), who shows that below the frequency

$$\nu = [10^{33}\,\theta^{-2}\,S_\nu\,\nu^{\alpha}]^{2/(5+2\alpha)}\,B^{\,1/(5+2\alpha)} \quad (1)$$

self-absorption of synchrotron radiation will cause a rapid drop in flux. In this expression $\theta$ is the angular diameter of the source, $S_\nu$ its flux density in MKS units, $\alpha$ its spectral index at high frequencies ($S_\nu' \propto \nu^{-\alpha}$), and $B$ the magnetic field in gauss. For the case $\alpha = 0$ applicable to 3C 273 B and with $S_\nu = 3 \times 10^{-25}$ watt m$^{-2}$ cps$^{-1}$ (cps, cycles per second), Eq. 1 gives $\theta'' = 3 \times 10^9\,B^{1/4}\,\nu^{-5/4}$ arc seconds. If we take $B > 10^{-5}$ gauss and assume that the spectrum of the variable component extends down to 400 Mc/sec (following Dent), we find $\theta'' > 3 \times 10^{-3}$ sec. This is 1/30 of the value derived by Dent. The error must be Dent's, as I derived Eq. 1 independently as a check. At the cosmological distance of 3C 273, this corresponds to a lower limit of 23 light years for the diameter of the source, a value which is just marginally compatible with the observed variability. It should be noted that this argument is based on the assumption that the source is variable at 400 Mc/sec also. The lower limit on $\theta$ based on the 8000-Mc/sec data alone (with $\alpha = 0$) is $6 \times 10^{-5}$ sec, or 0.5 light years (whereas Dent found that the source would be optically thick at 8000 Mc/sec for $\theta < 2 \times 10^{-3}$ sec). We conclude that the 8000-Mc/sec data alone do not justify Dent's conclusion that the variable component cannot be due to a synchrotron source at great distance. Even the further assumption that the variable component is still strong at 400 Mc/sec is marginally compatible with such a source. Obviously any further information which can be obtained on the variability at lower frequencies will bracket the angular diameter better and permit conclusions as to the nature of the source.

A model which appears compatible with the present data consists of about 50 sources, each contributing to the flux and varying independently with periods of approximately 10 years. If each source is about 10 light years in radius, and has a magnetic field of $1.2 \times 10^{-2}$ gauss, the source can be