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This Week's Citation Classic™

Stephens G C & Schinske R A. Uptake of amino acids by marine invertebrates. *Limnol. Oceanogr.* 6:175-81, 1961.
[Dept. Zoology, Univ. Minnesota, Minneapolis, MN and Marine Biological Lab., Woods Hole, MA]

This paper showed that 29 genera representing 10 phyla of marine invertebrates were capable of removing dissolved free amino acids from dilute solution. [The *SCI*® indicates that this paper has been cited in over 110 publications since 1961.]

Grover C. Stephens
Department of Developmental and Cell Biology
University of California
Irvine, CA 92717

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This paper is a textbook case of serendipity. The work was originally undertaken to investigate the possibility that ciliary-mucoid filter-feeding animals could remove proteins from solution. This protein filtration had been reported in the literature as occurring in the common edible mussel and was interpreted as a physical retention of protein molecules in the interstices of the net-like mucous sheet secreted by these organisms in feeding.[1] This mechanism seemed improbable to me in view of the large volume of water known to pass through the mantle cavity at low pressure. A filter of such retention properties did not seem possible. I therefore felt that the protein might be adsorbed to the mucous sheet and set out to investigate this possibility. Amino acids were selected because a convenient analytical procedure was available (ninhydrin reaction), selection of different amino acids would modify the net charge of the molecules at the pH of seawater, and they were sufficiently small molecules so that physical restraint was not a reasonable explanation for their removal.

We found that amino acids were indeed removed from solution by mussels. However, we examined animals that did not feed by a ciliary-mucoid filter mechanism and found they also were capable of removing free amino acids from seawater at our test concentrations of 2.0 mM. These control observations led to reassessment of our observations with mussels and the further experiments and observations reported in the paper. The initial misconception responsible for initiating the work is still perceptible in the discussion, although, by that time, I had recognized the broader implications of the work. Fortunately, I also recognized some of the major concerns still to be addressed before it would be possible to conclude that components of the naturally occurring dissolved organic material in the ocean could be acquired by marine invertebrates at rates that might be nutritionally significant.

I look back on the paper with great pleasure. At that time, I wanted to locate an area of research that would lead in a direction different from the one I was pursuing. Although circadian rhythms were and remain a fascinating subject, I was dissatisfied with my recent efforts in that field as well as my forays into crustacean endocrinology. Thus, the paper represents for me the first step in a new direction and a major change in my research that I feel has been both rewarding and fascinating.

I suppose that the paper has been cited as frequently as it has because the major thrust of its tentative conclusions has been borne out and validated as more sophisticated analytical procedures have become available and have been used to study the phenomenon.[2-4] The possibility of the utilization of dissolved resources by marine invertebrates has far-reaching implications. A great deal remains to be done to determine the importance of this food source in the nutrition of marine organisms, its impact on energy flow in marine ecosystems, and the physiology of the transport systems responsible for net uptake. For these reasons, workers in other laboratories have been attracted to the field and some of my own former students and associates have continued such work.

1. **MacGinitie G E.** The size of the mesh openings in mucous feeding nets of marine animals. *Biol. Bull.* 88:107-11, 1945.
2. **Stephens G C.** Recent progress in the study of "Die Ernährung der Wassertiere und der Stoffhaushalt der Gewässer." *Amer. Zool.* 22:611-19, 1982.
3. **Manahan D T, Davis J P & Stephens G C.** Bacteria-free sea urchin larvae: selective uptake of neutral amino acids from seawater. *Science* 220:204-6, 1983.
4. **Manahan D T, Wright S H & Stephens G C.** Simultaneous determination of net uptake of 16 amino acids by a marine bivalve. *Amer. J. Physiol.* 244:R832-8, 1983.

