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This Week's Citation Classic™

Somero G N. Enzymic mechanisms of temperature compensation: immediate and evolutionary effects of temperature on enzymes of aquatic poikilotherms. *Amer. Naturalist* **103**:517-30, 1969.
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This study examined the kinetic properties of enzymes that are strongly conserved among all species regardless of their normal body temperatures. These properties were shown to include substrate binding ability and catalytic capacity. Rapid and long-term (evolutionary) effects of temperature on enzymes were compared. [The *SCI*® indicates that this paper has been cited in over 125 publications since 1969.]

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Even into the late 1960s, our ideas about enzyme structure and function were based almost exclusively on work done with animals and microbes adapted to temperatures near 37°C. During my PhD studies at Stanford University, I had studied Antarctic fishes, whose −1.86°C body temperatures make them the most cold-adapted vertebrates. Once, during a discussion of my work with a member of the Stanford biochemistry group, I was told that enzymes of animals really shouldn't be able to work at such temperatures and that these fish surely must have some way of keeping themselves warm so their enzymes could work in the time-honored ways noted for mammalian and *E. coli* enzymes.

These Antarctic fishes are, of course, strict thermal conformers to their freezing-seawater environment. Thus, their enzymes must maintain structural and functional integrity at sub-zero temperatures. When I began my postdoctoral studies with Peter Hochachka at the University of British Columbia, I was interested in discovering how this feat of enzyme adaptation was achieved.

We first sought to identify the enzymatic traits that are conserved in all homologs of an enzyme, regardless of an organism's adaptation temperature. To this end, we characterized kinetically homologs of several enzymes of intermediary metabolism that we had isolated from animals differing widely in normal body temperature. In the 1969 paper, these conservative trends were documented, and their physiological and evolutionary significance was discussed. We also examined the effects of rapid temperature changes on enzymes, showing that the response of an enzyme to temperature is strongly influenced by the substrate concentration available to the enzyme.

A summary of the initial work on this subject was submitted to the *American Naturalist*, a journal noted more for its papers on evolution and theoretical ecology than on biochemical topics. The major reason that this paper has received citations, I think, is that the readers of this paper were pleased to see an attempt being made to link protein biochemistry to questions relevant to ecology and evolution. Specifically, the paper had implications about biochemical determinants of species' distribution patterns and lethal limits, topics we have continued to study.[1-3] Also, the paper emphasized the importance of studying enzymes under *in vitro* conditions that are physiologically realistic. Thus, the messages of the paper were practical as well as theoretical.

I feel that the response to this paper has demonstrated that journals willing to accept interdisciplinary papers, ones that would probably be rejected as "too speculative" by the mainline journals of a special field, play a valuable role in facilitating cross-pollination among the diverse subdisciplines within biology. This is an achievement that grows tougher, yet more important, all the time.

1. **Graves J E & Somero G N.** Electrophoretic and functional enzymic evolution in four species of eastern Pacific barracudas from different thermal environments. *Evolution* 36:97-106, 1982.
2. **Somero G N.** Environmental adaptations of proteins: strategies for the conservation of critical functional and structural traits. *Comp. Biochem. Physiol. Pt. A* 76:621-33, 1983.
3. **Hochachka P W & Somero G N.** *Biochemical adaptation.* Princeton, NJ: Princeton University Press, 1984. 480 p.

