LETTER TO THE EDITOR

The Effects of Double-Layer Polarization on the Conductance of Gramicidin Channels. A Reply to O. S. Andersen

Dear Sir:

O. S. Andersen (1983) has considered the currents carried by ions through gramicidin pores and has demonstrated that additions of indifferent electrolytes change the shape of the current-voltage relations at high potentials as expected from the Gouy-Chapman theory for double-layer polarization. Similar changes can be observed at low potentials and these are also consistent with double-layer polarization (Hladky, S. B., unpublished results). Andersen, however, goes on to conclude that this polarization distorts the conductance-concentration relation sufficiently that (p. 144) "the analysis of such data by fitting theoretical conductance expressions to the data . . . is subject to considerable uncertainties."

Three observations are pertinent. First, for pores that are at most singly occupied and in the absence of any indifferent electrolyte, the expected effects of polarization on the conductance-concentration relation disappear in the limit of zero potential. (This follows immediately from Andersen's Eqs. 34 and 39.) Second, the conductance-concentration relation at zero potential can be determined from the conductance-concentration relation at any finite potential and the current-voltage relations. In practice, for gramicidin the change in the ratio $g(0)/g(50\ \text{mV})$ is much smaller than the change in $g(50\ \text{mV})$, and the values of $g(50\ \text{mV})$ can be used directly with only small errors (see p. 366, Hladky, 1984). Third, the available experimental results for potentials below 100 mV strongly suggest that despite important effects above 100 mV the conductance-concentration relations below 50 mV have not been distorted. If such distortion were important, it would affect all permeant ions, although to differing extents, and the effects would be markedly altered by adding indifferent salt. Experimentally, there is no deviation from a simple Langmuir binding curve for sodium from 10 mM to 2 M (Hladky, 1974; Neher et al., 1978). Similarly, for thallium at 1 mM, where the effects are expected to be more pronounced, additions of magnesium sulphate had little effect (Neher et al., 1978). Furthermore, the data reported by Andersen for additions of tetraethylammonium chloride to 10 mM solutions of caesium, potassium, rubidium, or ammonium chloride also show little change in the currents at low potentials. Thus, at low concentrations, double-layer polarization must be considered in the analysis of all data obtained at high potentials and in any interpretation of the shape of current-voltage relations. However, the changes in the current that double-layer polarization produces at low potentials are sufficiently small that they do not cast serious doubt on the interpretation of conductance-concentration relations by Neher et al. (1978) and by Hladky and Haydon (1984).

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S. B. HLADKY,
Department of Pharmacology,
University of Cambridge,
Cambridge, CB2 2QD, United Kingdom

On the Effects of Interfacial Polarization. A Reply to S. B. Hladky

Dear Sir:

S. B. Hladky suggests that my data and calculations on interfacial polarization effects (Andersen, 1983) cast no serious doubt on the interpretation of conductance-activity relations measured at low potentials. The purpose of this reply is to show how Hladky's arguments support my conclusion: that there are considerable uncertainties involved in such interpretations. Hladky lists three points in support of his argument.

The first point was made on pages 142–143 in my article (Andersen 1983); see Eqs. 32–36 and Eqs. 37–41, and, in particular, Eqs. 32, 34, and 36, and Eqs. 37, 39, and 41.

In regard to the second point, the concentration-dependent changes in the conductance measured at any fixed potential will be larger than the changes in the ratio of the small-signal (zero-voltage) conductance, $g(0)$, and the measured conductance. It is likewise reasonable to assume that single-channel conductances measured at 50 mV, $g(50)$, should be valid estimators for $g(0)$. One may, however, run into difficulties at low salt concentrations if the data are used to distinguish among different models of ion permeation: With the parameters used to generate Fig. 7 in Andersen (1983), $g(50)$ is ~6% too large in 0.01 M monovalent salt, whereas $g(100)$ is ~17% greater than its value in the absence of interfacial polarization. (The corresponding distortions in 0.001 M monovalent salt are 16 and 51%, respectively. The impact of these small conductance changes must be evaluated in light of the potentially critical importance of accurate conductance data at low salt concentrations, to distinguish among qualitatively different kinetic descriptions of ion movement