Ionic Permeabilities of an *Aplysia* Giant Neuron

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Received 3 September 1974; revised 9 January 1975

**Summary.** In a giant neuron of *Aplysia californica*, permeabilities and conductances obtained by measuring net fluxes of Na\(^+\), K\(^+\) and Cl\(^-\) with ion-specific microelectrodes were compared with those obtained by measuring transmembrane current and potential changes when the three ions were varied in the external solution. Net fluxes were measured with ion-specific microelectrodes, after blocking metabolic processes, thus allowing movement of ions down their electrochemical gradients. Permeabilities and conductances obtained from the “chemical” measurements (i.e., ion-specific electrodes) were generally comparable to the values obtained from “electrical” measurements. Where discrepancies occurred, they could be explained by showing that some of the assumptions necessary to use the “electrical” method were not quantitatively true in this system. The absolute magnitudes of the permeabilities are significantly less than those found in many axonal preparations. There is also a relatively high $P_{Na}/P_{K}$ ratio. The selectivity of the membrane against ions such as Tris\(^+\) and MeSO\(_3^-\) is not good, Tris\(^+\) being nearly as permeable as Na\(^+\) and MeSO\(_3^-\) about one-half as permeable as Cl\(^-\). These properties may be characteristic of somal membranes.

A systematic study of the individual ionic permeabilities of a nerve cell body has not yet been reported. However, it has been shown that the somal membrane has a greater resistivity than the axonal membrane (Gorman & Mirolli, 1972; Carpenter, 1973) and that the ionic selectivities of the somal and axonal membranes may be different (Wald, 1972).

In general, two different methods have been used to measure ionic permeabilities and/or conductances in excitable tissues. The first of these methods might be called the chemical method and involves measuring ionic fluxes or changes in internal ion concentrations by means of isotopic tracers or spectrophotometry. The second or electrical method involves monitoring electrical changes across cell membranes when the concentrations of the permeable ions in the external solution are varied by replacement with impermeant ions. These methods have been most successfully applied to large axon and large muscle fibers.
Ion-specific microelectrodes similar to those described by Thomas (1969), Brown, Walker and Sutton (1970), and Brown and Brown (1973) present a unique opportunity to monitor ionic activities and measure net chemical fluxes in an *Aplysia* nerve cell body; and such fluxes have been reported for the potassium and chloride ions (Russell & Brown, 1972a, b). The technique, however, is somewhat tedious but very few assumptions need be made to obtain the flux information. This contrasts sharply with the electrical method which, when applied to *Aplysia* cells, is relatively simple but requires several basic assumptions concerning the permeability of the replacement ions used in the experiments.

Consequently, by comparing the results of both methods, we can not only obtain the permeabilities of Na⁺, K⁺ and Cl⁻ in this preparation but also test to see if the assumptions inherent in the electrical method are reasonable.

If the assumptions prove acceptable, then the simpler method may be used in the future to obtain permeability data in this and other similar preparations. However, if they are incorrect, either great care must be taken in the application of the electrical method or another method should be used.

The basic approach in this paper will consist of obtaining the chemically derived permeabilities and then determining the permeabilities by the electrical method with assumptions similar to those previously reported in the literature (Gorman & Marmor, 1970; Hagiwara, Toyama & Hayashi, 1971; Brodwick & Junge, 1972). We will then examine any differences between the two methods, keeping the possibility in mind that the assumptions made to use the electrical method may not have been totally correct.

**Materials and Methods**

Specimens of *Aplysia californica* were either obtained from Pacific Biomarine Supply Company or collected by one of the authors from the Pacific coast between Los Angeles and San Diego. They were maintained at 14 °C in a sea water aquarium. The abdominal ganglion was excised and pinned to Sylgard® resin in the bottom of an acrylic plastic chamber having a volume of 2.0–2.5 ml. The connective tissue capsule of the ganglion above the giant cell (R2) (Frazier *et al.*, 1967) was removed before microelectrode impalement. In some experiments the nerve cell body was isolated from its axon by a ligature (Russell & Brown, 1972a).

In the cooling experiments, the chamber was maintained between 3 and 6 °C either by means of a circulating coolant or by regulating a feedback controlled peltier device. The extremely sluggish response of the Na⁺-sensitive electrodes at low temperatures required that experiments in which these electrodes were used be carried out at room temperature.

Membrane potential ($V_m$) was measured with conventional glass microelectrodes having tip diameters of less than 1 μ and resistances of 5–12 MΩ when filled with 3 M