CATION SPECIFICITY IN CELL VOLUME MAINTENANCE IN RECTAL GLAND CELLS OF THE DOGFISH (Squalus acanthias)

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Rectal gland cells swell massively when incubated in elasmobranch Ringer's in which Na^+ is replaced by K^+ or Rb^+ (Kleinzeller et al., J. Comp. Physiol. 155B: 145, 1985). Such swelling is a predicted consequence of a simple Donnan system in which no active cation pump acts to oppose the driving force for Cl^-, cation (and water) entry. On the other hand, cells swell but little when incubated in Li-substituted medium, although they lose Na^+ and K^+ and gain Li^+ (and some Cl^-). The ability of the cells to maintain their volume in high-Li^+-Ringer's does not require metabolic energy nor involve the Na,K-ATPase (Kleinzeller et al., Bull. 26: 163, 1986). The cation specificity of the swelling process, and the basis for the difference in the cell response to K^+ and Li^+ media were now explored. Details of experimental procedures were given previously (Kleinzeller et al., 1985).

Of seven cations now tested K^+, NH_4^+ and trimethylamine (Tri-MA) caused swelling 25% (Fig. 1). The swelling in high NH_4^+ at 2 h exceeded that in high-K^+ Ringer's by some 80%; this additional swelling reflects the contribution of the bicarbonate system (8 mM HCO_3^-; 1% CO_2 in air) [Feldman et al., this Bull.]; in high NH_4^+ media with a tris buffer the swelling was similar to that in high-K^+. Cations which share with K^+ sites on the Na-K-ATPase ans some channels (Rb^+, NH_4^+) cause massive swelling. The swelling produced by the rapidly permeant tri-MA relates to the lipid solubility of the non-dissociated base, and its subsequent intracellular dissociation (Ziyadeh et al., this Bull.). Li^+, guanidinium (Gua^+) and Cs^+ produce little swelling. Tetramethyl-(TMA) and tetraethyl-ammonium (TEA) caused a slight shrinkage. With all cations tested there was a rapid loss of tissue Na^+ to values around 35 mequiv./kg DW, corresponding to an intracellular Na^+ of 15 mM. With all cations (except K^+) there was also a large loss of tissue K^+ (from 320 mequiv./kg DW, control, to some 80 mequiv), the bulk occuring within 1 h. Judging from the changes in cell volume and the loss of K^+ all cations tested are permeant ($NH_4^+ > Tri\text{-}MA^+ > Cs^+ > Li^+ > Gua^+ > TMA^+ > TEA^+$).
The route by which Li^+ enters the cells is not know. Phloretin, (0.4 mM) DIDS (0.1 mM), ouabain (0.05 mM), amiloride (1 mM) and bumetanide (0.1 mM) had no effect on Li^+ uptake in high-Li^+ Ringer's.

Approximately 25% of K^+ remains in the tissue after 3 h incubation in high Li^+. The possibility was explored that the cells had not reached a steady state, and hence the swelling in Li^+ was less than in high K^+. After 12 h incubation, the cells showed only a 20% swelling in high-Li^+ medium, a value close to that found in Na^+ - medium containing 0.5 mM ouabain. Also, the Cl^- Donnan ratios for these two conditions showed identical values, with a steady state at 2-4 h.

The K^+ -induced swelling is reversible in the absence of Na^+ (high-Li^+-medium).

The observation that cells in Li^+-media are able to maintain a Donnan distribution of electrolytes for 12 h without the operation of the Na-pump, and with little swelling, requires a re-evaluation of the nature of the K^+ (Rb^+, NH^+)-induced swelling. It is suggested that a physical constraint, such as the cytoskeleton, may represent the physical force which prevents the cells from swelling; the actin filaments dissociate when intracellular K^+ is elevated, permitting an increased uptake of K^+, Cl^-, and H_2O. The finding that, as opposed to K^+, exposure of the cells to even 12 h in high-Li^+ medium did not produce major changes of the cells structure seen by light-microscopy, nor any changes in the cellular arrangement of actin, is consistent with the above view. The excessive swelling in NH_4^+ medium reflects the fact that NH_4^+ crosses the membrane in part as NH_3 with subsequent intracellular dissociation (Feldman et al., unpublished); the increased osmotic pressure then produces additional swelling.

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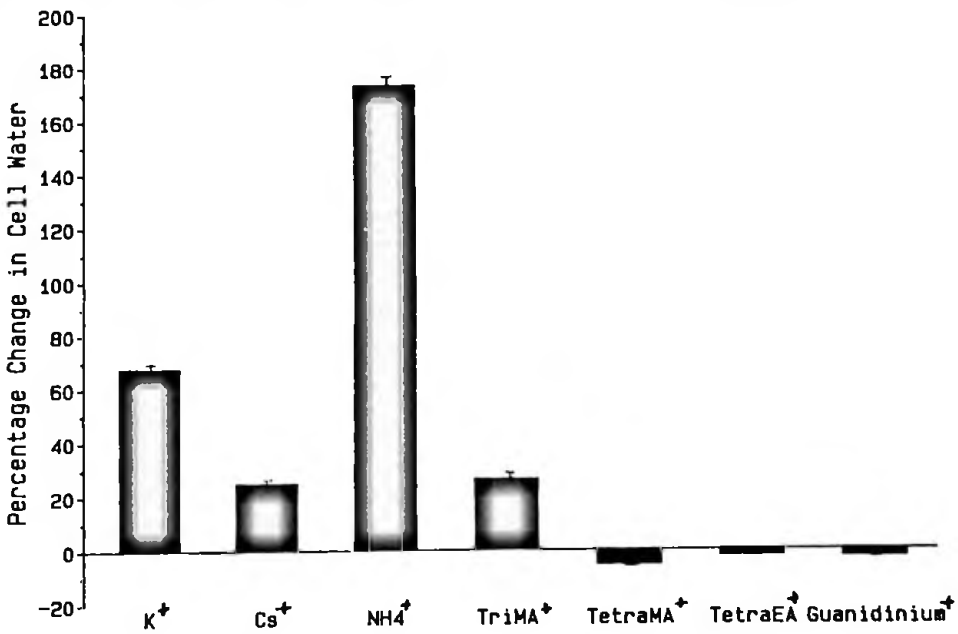

Fig. 1 Effect of cations on water content of rectal gland cells in % of control (Na^+-medium); 2 h incubation. Values $\pm$ SE (n = 4–5).