Further Studies on Sodium Movement in Mammalian Muscle

by

H. McLennan

With 3 Figures in the text

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Previous work has suggested the possibility that there exists in mammalian muscle a mechanism whereby sodium and potassium transfer across the cell membrane is linked; and further, that some adsorption process of Na probably precedes uptake of this ion into the cells (McLennan 1957).

It was considered (Harris 1950, McLennan 1957) that the time course of loss of radioactivity from a muscle previously loaded with labelled Na could be described by three rate constants, one governing desorption from the surface to the extracellular fluid, and the others respectively the movements inward and outward from the surface across the cell membrane. This situation is shown schematically in Fig. 1. It was earlier suggested that (a) under normal conditions 'n1' and 'n2' are greater than 'n', and the efflux of Na from the muscle follows a simple exponential time course; (b) [Na_s] is approximately the same as [Na_c]; and (c) under the condition of a high extracellular K concentration the desorption is no longer the slowest step, and Na efflux is described by equations which involve two time constants. Harris (1950) has shown that the slower of these will be 'n2'.

In the present work these conclusions have been supported and extended. It has been possible to estimate the concentrations of Na in the surface and cellular phases ([Na_s] and [Na_c]), and to measure the time constants 'n' and 'n2' under various conditions.
Methods

All measurements were carried out with excised m. extensor digitorum longus of the rat, at 20°C. The procedures involved in estimating ionic fluxes in these muscles using radioactive tracers have been described in detail in earlier papers (e.g. McLENNAN 1957). In brief, the excised tissue is incubated for four or more hours in a Ringer-type medium containing a proportion of $^{22}$Na. This period is sufficient to allow complete exchange of the tissue Na with that of the medium. Thereafter the tissue is transferred to a non-radioactive medium of any desired composition, and the decline in the muscle radioactivity measured from time to time.

The Ringer-type medium used was buffered with bicarbonate, and bubbled with 95% O$_2$ - 5% CO$_2$ to give a pH of 7.4. The medium contained, in m.mol./l., Na$^+$ 144, K$^+$ 5.5, Ca$^{2+}$ 2, Mg$^{2+}$ 1, Cl$^-$ 110.5, HCO$_3^-$ 43, SO$_4^{2-}$ 1, glucose 10. Potassium phosphate solution (pH 7.1, 154 m.mol./l.) with respect to K$^+$ or 5% glucose solutions were bubbled with O$_2$ gas. In one or two experiments KCl solution (0.154 M.) was used in place of the mixed K phosphate. Substantially similar results were obtained when due allowance was made for the swelling of the muscle cells which occurs in KCl.

The strophanthin used was of the 'g' variety, otherwise known as ouabaine. The final concentration used in the medium was 5 μg./ml., and the solution was freshly prepared before each experiment.

Results

The time course of the efflux of labelled Na (hereinafter designated Na*) from a muscle which has been previously loaded with the tracer is a simple exponential process after loss of the extracellular Na has been completed. This condition is observed when a muscle is incubated in a Ringer-type medium, and the measure of the efflux is given by (HARRIS 1950; McLENNAN 1957)$^1$:

\[
\text{fm. } [Na^*_t], \text{ where } [Na^*_t] = [Na^*_a] + [Na^*_e], \text{ and } j = \frac{[Na^*_a]}{[Na^*_a] + [Na^*_e]}
\]

This indicates that the desorption of Na from the cell surface is the rate controlling step. A semi-logarithmic plot of the radioactivity remaining in the muscle after varying times of incubation yields a curve with an

$^1$ See Appendix.