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A study of membrane permeability changes during nerve action potential by means of computer simulation

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We wish to report a new method of analytical description of single nerve action potential suitable for computer simulation, with which we have been able to calculate the sodium and potassium permeability changes postulated by Hodgkin and Katz (1949). Using the data from the paper by Oshima, Makimo and Kondo (1988) a new formula which describes the single nerve action potential for Na^+ and K^+ ions in nerve membrane was derived (Wrzeciono, Gorzelańczyk & Markiewicz-Wrzeciono, 1990):

$$E_m(t) = 26mV \ln\left[\frac{1+\left(\frac{\mathrm{r}-1}{\mathrm{r}+1}\right)e^{-\alpha\xi(t)ft}}{1-\left(\frac{\mathrm{r}-1}{\mathrm{r}+1}\right)e^{-\alpha\xi(t)ft}}\right],$$

where $r = P_{Na^+} / P_{K^+}$, $f = \left[2r / \left(r^2 - 1\right)\right] \cdot \ln r$, $\alpha = P_{K^+}\left(1 + r\right)A / V$, $E_m(t)$ [mV] - single nerve action potential, P_{Na}^+ [cm/s], P_K^+ [cm/s] – absolute membrane permeability of Na^+ and K^+ ions, A – membrane area, V – considered volume, $\xi(t)$- newly introduced parameter. As starting data of our simulation program we used the exponential course of $E_{me}(t)$ for the single nerve action potential and approximate values for $r(t)$. By the simulation procedure an approximation error $\Delta E = |E_m(t) - E_{me}(t)|$ was minimized during each step until the decrease of total ΔE value was less than 1.10^{-7} mV (Wrzeciono et al., 1990). On the basis of our simulation we obtained the exact numerical values of absolute membrane permeability $P_{Na}^+(t)$ [cm/s] and $P_K^+(t)$ [cm/s]. Our numerical results agreed with experimental data (Hodghin & Katz, 1980). The numerical program presented was found useful to calculate $P_{Na}^+(t)$, $P_K^+(t)$ as a combination of experimental $E_{me}(t)$ and modelling data.