A Teorell - Oscillator System with Fine Pore Membranes

P.Langer and G.Wiedner

Max-Planck-Institut für Biophysik,Kennedy-Allee 70,
6000 Frankfurt 70, West-Germany

The Teorell - Oscillator has been regarded as an analogue to excitation phenomena in biological membranes (nerve and muscle fibres,certain algae). It is, however,uncertain,whether the mechanisms of the broad pore (e.g.glass sinter) membranes employed by Teorell (1) and other investigators are applicable to fine pore biological tissue.Therefore the behaviour of some fine pore membranes (pore diameter between 40 and 1000 Å) was studied. A Teorell Oscillator system can be described as follows: A porous membrane of low internal charge separates two electrolyte solutions of different concentrations.There are two counteracting driving forces in the system: one is the electric potential difference across the membrane,due to a constant electric current,which generates an electroosmotic volume flow through the membrane,and the other is the hydrostatic pressure difference which arises from the difference of the levels of the solution in each compartment and causes a volume flow in the opposite direction.Both forces depend on the net volume flow because it is responsible for filling the membrane with either concentrated or dilute solution.Thus oscillations of the electric potential,the hydrostatic pressure and the volume flow can be observed.If the electric current and the hydrostatic pressure difference is kept constant,the volume flow and therefore the membrane potential are completely determined,i.e. the system is in a stationary state.Depending on the level on which current and pressure have been fixed,the membrane is either in a state of low or high electric conductivity.If now the magnitude of the electric current is altered by a sufficient amount,a transition from one state to the other occurs. These stationary state voltage current curves were recorded,and flipflops were only found in membranes whose hydrodynamic permeabilities were above a certain value.Another crucial parameter for the occurrence of flip-flops is the fixed ion concentration of the membrane.A theoretical description,agreeing well with the experimental findings,is given in terms of the Nernst-Planck-Schlögl-equations (2);flip-flops are predicted only if the hydrodynamic permeability is above and the fixed ion concentration is below a critical value.Those critical values depend on the hydrostatic pressure and on the ratio of the cation and anion diffusion coefficient D_+/D in the membrane.Excitation behaviour observed in some biological membranes may well be brought about by the same mechanism on which the Teorell Oscillator is based,if only $D_+/D \gg 1$ or $\ll 1$. In case this condition is not fulfilled, flip-flops are only to be expected in membranes of a hydrodynamic permeability much higher and a fixed ion concentration much lower than found in biological membranes.

1.Teorell,T. (1959) J.Gen.Physiol. 42: 831 and 847

2.Schlögl,R. (1955) Z.physik.Chem.N.F. 3:73