I therefore suggest that "exchange diffusion" should be reserved for the appropriate deviation, in passive conditions, of the flux ratio from the independence relationship. The term seems to be justified by the thermodynamic significance of the observations. On the other hand, the fall in the flux of a solute when the solute is removed from the *trans* side of the membrane has of itself no clear thermodynamic significance; it need neither mean that exchange diffusion is taking place nor require the existence of carriers. One should therefore say simply that the flux decreased when the solute was removed from the *trans* side of the membrane.

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Demonstration of Sodium and Potassium Conductance Changes during a Nerve Action Potential

WE wish to report a new method with which we have been able to measure the sodium and potassium conductance changes postulated by Hodgkin and Huxley[1] in the course of a single action potential. To measure the membrane conductance at any desired time during the course of the action potential, we have designed a membrane potential control system which can be turned on and off quickly with an electronic switch.

The electronic switch consists of two transistors (PNP and NPN). The emitters of these transistors are electrically connected together to the output of the control amplifier. The collector of the PNP transistor makes electrical contact with the current supplying wire, which is inside the axon. The collector of the NPN transistor is connected through a resistance to the input of the control amplifier. Both bases are electrically connected together and to a positive constant voltage which holds the PNP transistor "closed" and the NPN transistor "open"; application of a rectangular negative voltage pulse to the bases reverses this situation and the membrane potential control is turned on during the pulse.

Giant axon fibres from the squid *Dosidicus gigas* were used in this work (for details of the combined perfusion technique and voltage clamp procedure, see refs. 2 and 3).

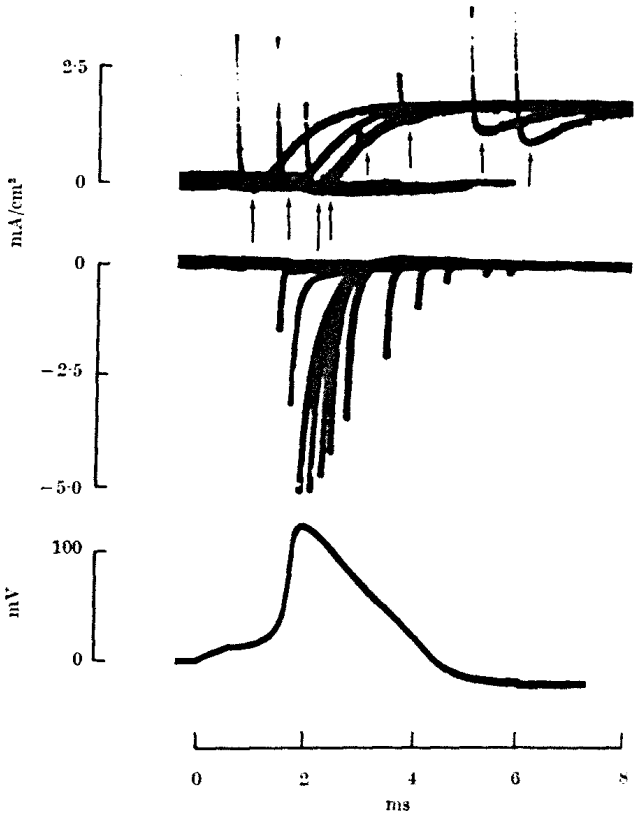

Fig. 2. Upper traces represent unretouched records of ionic currents when the membrane potential during the control period was 60 mV. Lower traces represent records of the ionic currents when the membrane potential during the control period was −80 mV. The capacitative current transients in the upper traces are apparent because a Z-input intensifier was used with the oscilloscope. No series resistance compensation was used. The resting potential was −60 mV. The temperature of the external seawater was 8° C.

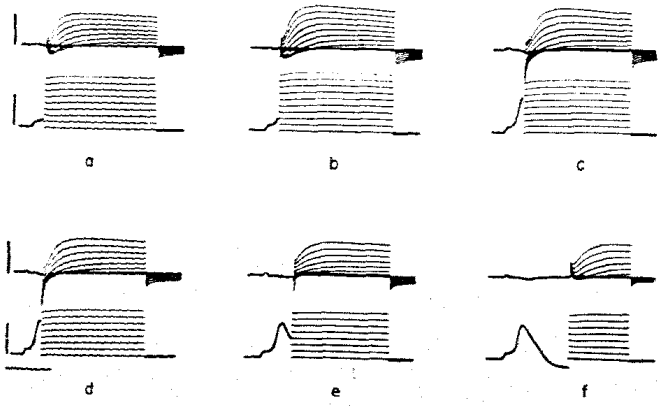

Fig. 1. Upper traces represent records of ionic currents; lower traces represent records of membrane potential before and during the period of membrane potential control. Compensated feedback was used to correct for the voltage drop through the resistance in series with the axolemma. It was set to compensate for only 4 Ω·cm². Ordinate for current traces: 2·68 mA/cm². Ordinate for membrane potential traces: 100 mV. Abscissa: 4 ms. The axon was internally perfused with 550 mM KF and externally perfused with potassium-free artificial seawater at 8° C. The resting potential was −60 mV.

Fig. 1 illustrates the results obtained with this switch. Membrane currents are shown in the upper traces; membrane potentials before and during the time in which the membrane potential was under control are shown in the lower traces. The individual traces were taken at intervals of 1 s for depolarizations from the resting potential to −40 through 80 mV in 20 mV steps. Capacitative current transients lasted for about 20 μs and are not apparent in these current records. From these records we have determined six (*a*–*f*) current–voltage relationships measured 50 μs after the control system was turned on. The slopes of these current–voltage curves were found to be approximately linear and represent the instantaneous conductance at various times during the action potential. The time course of the instantaneous conductance measured in this way is essentially the same as found by Cole and Curtis[4] utilizing bridge techniques and as calculated by Hodgkin and Huxley[1].

The total membrane conductance during a membrane action potential can be split into its "sodium" and "potassium" conductance by the following method. If the potential is switched to −80 mV, which is approximately equal to the potassium equilibrium potential, there is no potassium current, and the current is almost entirely in the sodium channel. Similarly by switching to 60 mV, which is approximately the equilibrium potential of the

sodium channel, there is no sodium current, and the current is almost entirely in the potassium channel. Fig. 2 shows the current records obtained when the membrane potential during the control period was either the potential at the peak of the action potential (60 mV, upper traces) or the potential at the underswing of the action potential (−80 mV, lower traces). The points indicated by the arrows on the upper set of transients are proportional to the potassium conductance and show its time course. The beginning of each transient on the lower set of membrane current records is proportional to the sodium conductance and shows its time course.

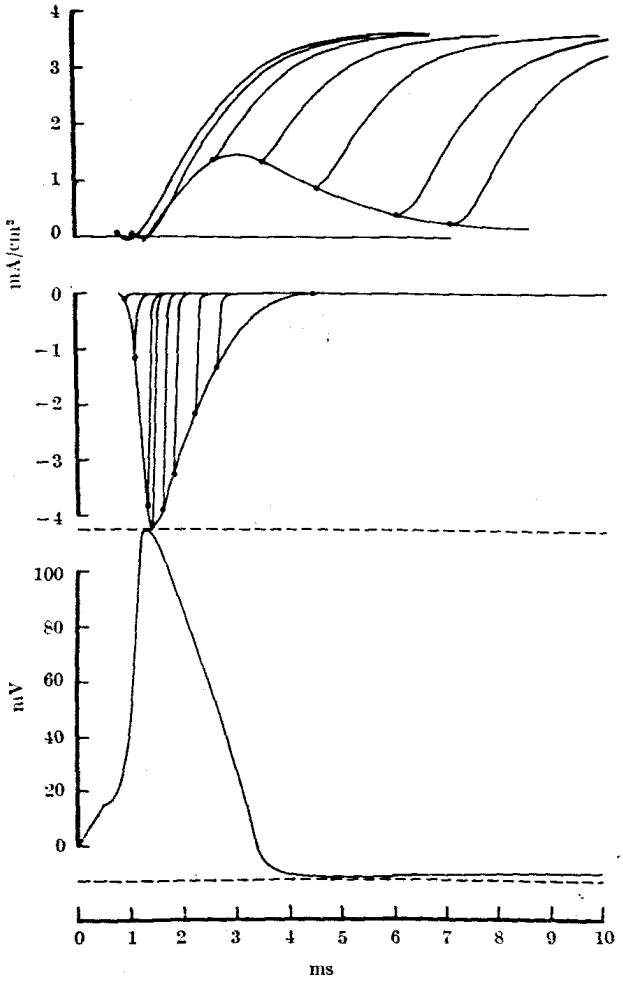

Fig. 3. Ionic currents and membrane action potential calculated utilizing the Hodgkin and Huxley equations[1]. The curve drawn through the points on the upper curves (initial potassium currents) is proportional to the potassium conductance change. The curve drawn through the points on the centre curves (initial sodium currents) is proportional to the sodium conductance change. Resting potential equal to −60 mV. The temperature was 6·3° C.

The results of a similar experiment performed on the model axon are shown in Fig. 3. Ionic currents were calculated utilizing the Hodgkin and Huxley equations[1], but some of the parameters used to compute the action potential were determined for a *Dosidicus* axon. The upper set of curves represents the total ionic currents when the potential during the control period is equal to 55 mV (peak of the action potential) and the lower set of curves represents the total ionic currents when the potential during the control period is equal to −71 mV. The calculated ionic currents are remarkably similar to those shown in Fig. 2 which were obtained on a real axon. Fig. 3 also shows the envelope curves drawn through the points of the initial potassium and sodium currents. The quantitative comparison will be published later, but it is clear that the calculated time course of the potassium or sodium conductance change agrees closely with the measured time course.

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Histochemical Differentiation of Motor Neurones and Interneurones in the Anterior Horn of the Cat Spinal Cord

The neurones of the anterior horn are a heterogeneous population of physiologically different cells. Alpha and gamma motor neurones, Renshaw cells and interneurones are recognized components[1]. Alpha motor neurones have been divided further into F and S types according to the fast and slow contractile properties of the muscle fibres that they innervate[2]. Anatomic investigations, largely by retrograde chromatolysis, have shown that the different neurones are intermingled, and that the larger are mainly alpha motor neurones while the smaller are a heterologous group of gamma motor neurones, Renshaw cells and interneurones[3,4]. Staining techniques selective for the Golgi body differentiate motor neurones from interneurones by the direction of their axons, but standard histological methods result in uniform staining without significant morphological distinction. We have used histochemical staining reactions to attempt neuronal differentiation in the anterior horn.

The histochemical techniques for phosphorylase, diphosphopyridine and triphosphopyridine diaphorases and α-glycerophosphate menadione-mediated dehydrogenase have been described previously[5]. Those for succinate, malate, lactate and glucose-6-phosphate dehydrogenases, with minor modifications, were performed as summarized by Pearse[6]. The tissue investigated was the lumbar seven spinal cord segment of the cat, fresh frozen and serially sectioned at 20 μm.

Marked differences in the activities of phosphorylase and succinate dehydrogenase were found among the neurones in the anterior horn (Fig. 1*a* and *b*). Consistent patterns of cell distribution for each enzymatic reaction were found according to cell size and area of grey matter (Fig. 2). In the ventrolateral pool the large (more than 50 μm) and medium (30 to 50 μm) neurones were high in phosphorylase and low in succinic dehydrogenase. The small (less than 30 μm) neurones were negative for phosphorylase but exhibited high activity of succinic dehydrogenase. These results were confirmed for individual neurones when identified in serial sections, histochemical staining providing clear separation of two types of neurones otherwise lying interspersed. The staining reactions were located in the perikaryon and, with succinate dehydrogenase, also in (or on) the dendrites. Neurones of the ventromedial grey matter were uniformly