extracellular phases had been removed by 90 min efflux. The linearity of influx indicated that there was no significant backflux of Ca from the intracellular compartment in the course of the influx over 30 min. The curve of influx did not pass through the origin even when measured at times as short as 30 sec, indicating that influx in the first half-minute was different to the subsequent, linear process. Mg influx was of approximately the same magnitude as that of Ca, but differed markedly in its time course (Figure) although corrected for efflux and calculated in the same way as Ca influx. Although less data was available in the case of Mg the qualitative differences in influx were clearly indicated in the time-dependence; an initially high rate of influx, up to 10 min incubation, then declined gradually but steadily so that between 20 and 30 min the rate was considerably less than that of Ca. Even though based on less data the curve of Mg-influx showed a strong tendency to pass through the origin if extrapolated, so that it differed also in this respect from Ca. It can be concluded that the influx of both Ca and Mg are at least biphasic under these conditions, and that the distribution of the two metals is significantly different within muscle compartments even after the surface phase and at least part of the extracellular phases of uptake have been subtracted.

The complex nature of both influxes meant that comparisons of rates of entry, over the short periods suitable for studies of stimulation and contracture, would not be valid, and therefore the influence of these treatments was assessed on the basis of total influx occurring in 10 min. The Table summarizes the results of these experiments.

Both stimulation and caffeine contracture significantly increased the influx of Ca over the resting values. The control values for Ca influx, calculated on the same rate basis as used by BIANCHI and SHANES[1], were somewhat less (0.03 as compared to $0.09 \times 10^{-12} M/cm^2$ fibre surface/sec). Neither stimulation nor caffeine contracture significantly increased the influx of Mg. It may be concluded that Mg does not use the mechanism of increased influx available to Ca during excitation, at least at the respective concentrations (2.0 mM, 1.8 mM Ca) obtaining under these conditions. The question still remains whether Mg may inhibit the influx of Ca at high extracellular concentrations of Mg relative to Ca. This would provide a mechanism of Mg blockage of muscular activity without alteration of membrane potential; such a competitive effect has been postulated for smooth muscle[10].

Effects of electrical stimulation and of caffeine on influx of Ca and Mg in frog sartorius

	Ca (μM/g wet weight)	Mg
Control	0.00537 ± 0.00073	0.00454 ± 0.00035
Stimulated	0.00768 ± 0.00102 (6)	0.00539 ± 0.00077 (6)
P[a]	< 0.05	n.s.
Control	0.00620 ± 0.00063	0.00460 ± 0.00031
Caffeine	0.00835 ± 0.00068 (15)	0.00499 ± 0.00060 (4)
P[a]	< 0.01	n.s.

(mean, ± S.E., No. experiments)

[a] Significance of differences between control and treated muslces, by paired-sample t-test. All muslces were incubated in frog-Ringer with ^{45}Ca or ^{28}Mg for 10 min at 20 °C. Stimulation was applied for the last 6 min of incubation at frequency 0.5/sec, i.e. 108 twitches. Caffeine was present in Ringer at 5 mM. Influx was measured after the muscles had been left 90 min in nonradioactive Ringer.

Resumen. La representación del influjo de Ca y de Mg en músculo esquelético en reposo de rana as cualtitativamente diferente; sin embargo la magnitud de dicho influjo as inicialmente similar. Estímulo mediante pulsos eléctricos o cafeina aumenta significamente el influjo de Ca pero no el de Mg durante un período de 10 min.

J. M. O'DONNELL

Agricultural Research Council, Babraham, Cambridge (England), 3 August 1972.

[10] M. P. SPARROW, J. Physiol., Lond. *205*, 19 (1969).

Some Functional Characteristics of the Electroreceptors (the Ampullae of Lorenzini) of Elasmobranchs

It is well known that the elasmobranchs have a well developed system of the ampullae of Lorenzini high-sensitive to the electric current[1-3].

The aim of this communication is to report some new functional characteristics of the electroreceptors of the elasmobranch fishes *Raja clavata* and *Trigon pastinaca*, from the Black Sea. The fish were fixed on a special platform placed in a lucite box, filled with water.

For regular respiratory movement of the fish, a plastic tube was introduced into the mouth of the fish and an adjustible flow of water led into the mouth. The ampullae of the mandibular or dorsal group were used, because of the ease of the dissection and the length of the fine nerve available[4].

The electrical activity of the receptors was recorded from single nerve fibres or bundle of fibres connected to the receptor cell of the ampullae. The nerve impulses were amplified and displayed by conventional means. To stimulate the sensory organs, 2 small silver wire electrodes were used. All experiments were performed at 17 °C. Hitherto it is only the tonic electroreceptory fibres with spontaneous activity that were detected in the elasmobranchs[4,5]. We, however, observed that according to the type of responses all the fibres were divided into the phasic and tonic (Figure 1; 1st and 2nd recordings). The current-threshold of the clear-cut responses were equal to 10^{-9}–10^{-10} A/mm^2.

It is known that some electroreceptory fibres respond to the animal's own breathing potentials[6]. In such fibres the bursts of impulses are known to appear in time with respiration (Figure 1, 3rd recording). Along with these fibres (type 1) we also observed fibres in which the spontaneous activity was suppressed in time with respiration (type 2, Figure 2, 1st recording).

[1] S. DIJKGRAAF, Biol. Rev. *38*, 51 (1963).
[2] M. V. L. BENNETT, A. Rev. Physiol. *32*, 471 (1970).
[3] G. N. AKOEV, N. P. ALEKSEEV, O. B. ILYINSKY, Progr. physiol. Sci. (Russian) *2*, 122 (1971).
[4] R. W. MURRAY, J. exp. Biol. *39*, 119 (1962).
[5] R. W. MURRAY, J. Physiol., Lond. *180*, 592 (1965).
[6] S. DIJKGRAAF and A. J. KALMIJN, Z. vergl. Physiol. *53*, 178 (1966).

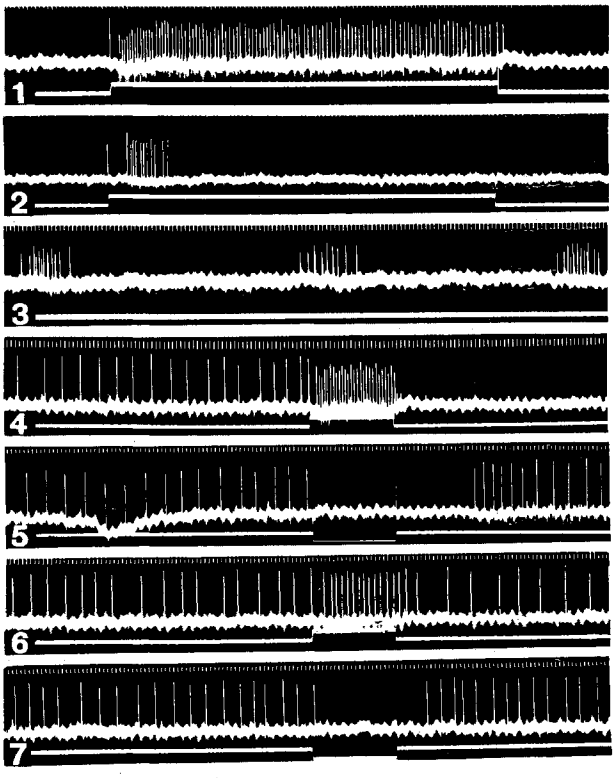

Fig. 1. – The impulse activity of a single fibres of the ampullae of Lorenzini from the *T. pastinaca* mandibular group resulting from the electrical stimulation. 1. The responses of a tonic fibre to the pulse of cathodic current of 5×10^{-8} A/mm^2. 2. The responses of a phasic fibre to the current of 1.3×10^{-7} A/mm^2. 3. The periodic bursts of impulses in time with respiration in the afferent fibre of the type I. 4–7. The responses of a tonic fibre to the pulses of cathodic and anodic current of 5×10^{-8} A/mm^2 (4,5) and of 2.5×10^{-9} A/mm^2 (6,7). Time scale 10 msec. for 1–7.

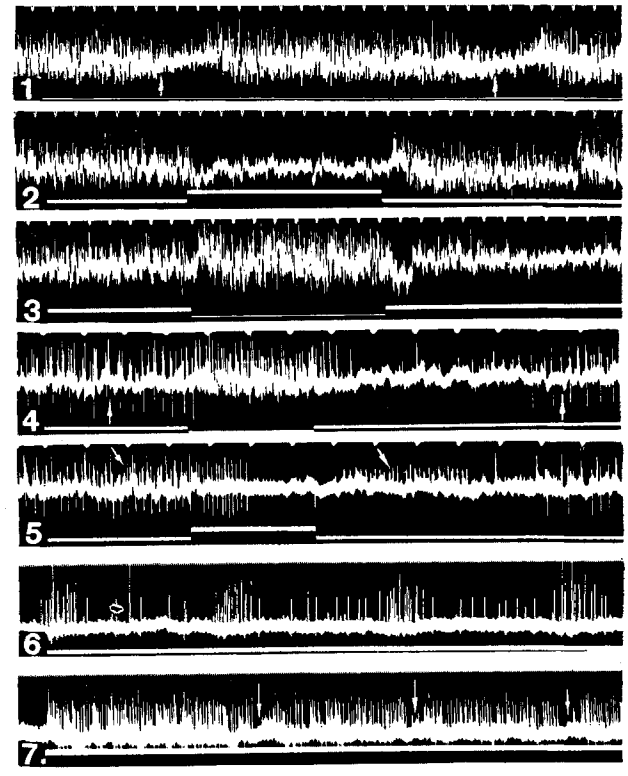

Fig. 2. – 1. The inhibition of the spontaneous activity in time with respiration (arrows) in a bundle of fibres of type II from the dorsal ampullae of *R. clavata*. 2 and 3. The responses of a bundle of fibres of the type II from the *R. clavata* dorsal group to the pulses of cathodic and anodic current of 1.3×10^{-7} A/mm^2. 4 and 5. The responses of a bundle of *R. clavata* fibres to the pulses of anodic (4) and cathodic (5) current of 1.3×10^{-7} A/mm^2. Note that electrical activity of 1 type of fibres is suppressed by the anodic and of the other by the cathodic current (arrows). 6. The periodic bursts of impulses in the *T. pastinaca* fibre of type I. 7. The periodic inhibition of the evoked activity of fibre type I (arrows) instead of the periodic discharges (see the record 6) during the long cathodic current of 5×10^{-8} A/mm^2. Time 100 msec for 1–5; 10 msec for 6 and 7.

The character of responses to the electrical stimulation in the fibres of the type 1 was reversed to one in the fibres of the type 2. The main features of the responses in the former were as follows. The cathodic stimulation of the sense organs increased the frequency of responses, switching off the current suppressing the responses (Figure 1, 4th and 6th recordings). The anodic stimulation, however, suppressed the spontaneous activity, switching off the current resulting in burst of impulses (Figure 1, 5th and 7th recordings).

In contrast, in the fibres of the type 2 the electrical responses were suppressed by passing the cathodic current and increased in frequency by switching it off (Figure 2, 2nd recording). The anodic stimulation resulted in a burst of impulses when passing the current, and in an inhibition when switching it off (Figure 2, 3rd recording). In some instances the insertion of the thin wire electrode into the ampullary canal succeeded in recording the activity of 2 different types of fibres connected with the tube involved.

The responses of the 2 types of fibres to the electric stimulation was also reversed. Under the cathode the electrical activity of the one type of fibres increased while the activity of the other decreased; yet, under the anode the activity of the former decreased while of the latter increased (Figure 2, 4th and 5th recordings).

Under some conditions the fibres of the type 1 displayed the features of the type 2. This transformation was noticeable when the bursts of impulses in time with respiration were registered at regular intervals. In this case the application of the long pulse of cathodic current led to the activity in time with respiration (observed against the background of the responses of the fibre to stimulation) suppressed rather then appearing as periodic bursts of impulses (Figure 2, 6th and 7th recordings).

Further experiments are still necessary to clarify the mechanism underlaying this phenomenon.

ВЫВОДЫ. Исследовались свойства электрорецепторных волокон черноморских скатов. Обнаружены фазные и тонические волокна. Показано, что одни рецепторы (тип I) возбуждаются при катодических толчках тока, а другие (тип II) – при анодических.

G. N. AKOEV and O. B. ILYINSKY

Pavlov Institute of Physiology,
Academy of Sciences of the USSR,
Nab. Makarova 6, Leningrad V-164 (USSR),
8 May 1972.