The Initiation of Propagated Potentials in Single Nerve Fibres: Comparative Aspects

The demonstration, by HODGKIN[1], of subliminal non-conducted responses in crustacean axons, at a time when only indirect evidence was available for the existance of local responses in frog nerves (see: KATZ[2]) led some physiologists to think of a fundamental difference between medullated and non-medullated nerve fibres, in the way by which propagated impulses are generated in their surface membrane. KATZ[3], however, showed that non-propagated, i.e. local, responses could be recorded from the frog's sciatic if an appropiated technique was employed. His results have been confirmed recently by the direct demonstration of local responses at the nodes of Ranvier of myelinated nerve fibres of the frog (DEL CASTILLO-NICOLAU and STARK[4]). HUXLEY and STÄMPFLI[5] have observed similar potentials in the same preparation, and SCHOEPFLE and ERLANGER[6] have recorded local responses originated at single nerve fibres in the phalangeal nerve of the frog. One may, therefore, conclude, that there is little or no difference between invertebrate and amphibian nerve fibres as regards the mode of initiation of propagated potentials. In both kinds of fibres, the cathodic stimulation causes quite distinct effects. If its strength is weak, only a polarization potential, directly proportional to the strength of the shock, is produced. When the stimulus strength approaches threshold, a subliminal response, in form of an additional wave of negativity of non-linear characteristics, is added to the polarization potential. The propagated spikes rise from the cathodic potential when the local response generated by the stimulus reaches a critical level.

Local responses due to excitation, of analogous characteristic with those mentioned above, have been found to occur in the surface membrane of striated muscle fibres (KUFFLER[1]).

The initiation of nerve impulses in mammalian medullated fibres seems to take place in a similar manner. ROSENBLUETH and LUCO[2], in a recent paper, have demonstrated that local responses can be recorded from strands of fibres dissected from the cat's spinal roots. It is, therefore, of some interest to see whether local subliminal potentials can be recorded from single nodes of Ranvier of isolated mammalian axons.

A motor fibre is isolated from a mouse sciatic-gastrocnemius preparation in a similar manner to that described by TASAKI[3] and STÄMPFLI[4] for the frog sciatic. The isolated fibre is placed across two vaseline ridges separating three pools filled with Ringer's fluid so that one single node of Ranvier is submerged in the central pool, being separated from the adjacent ones by the vaseline ridges. The node in the central pool is stimulated by brief cathodic shocks, and the resulting potential changes are amplified and displayed on the screen of a cathode ray oscillograph. The set-up of the preparation and the electrical apparatus are described with more detail in another paper (DEL CASTILLO-NICOLAU and STARK[5]).

The size of the vaseline ridges and the distance between them had to be modified according to the dimensions of

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[2] A. ROSENBLUETH and J. V. LUCO, J. Cell. comp. Physiol. *36*, 289 (1950).
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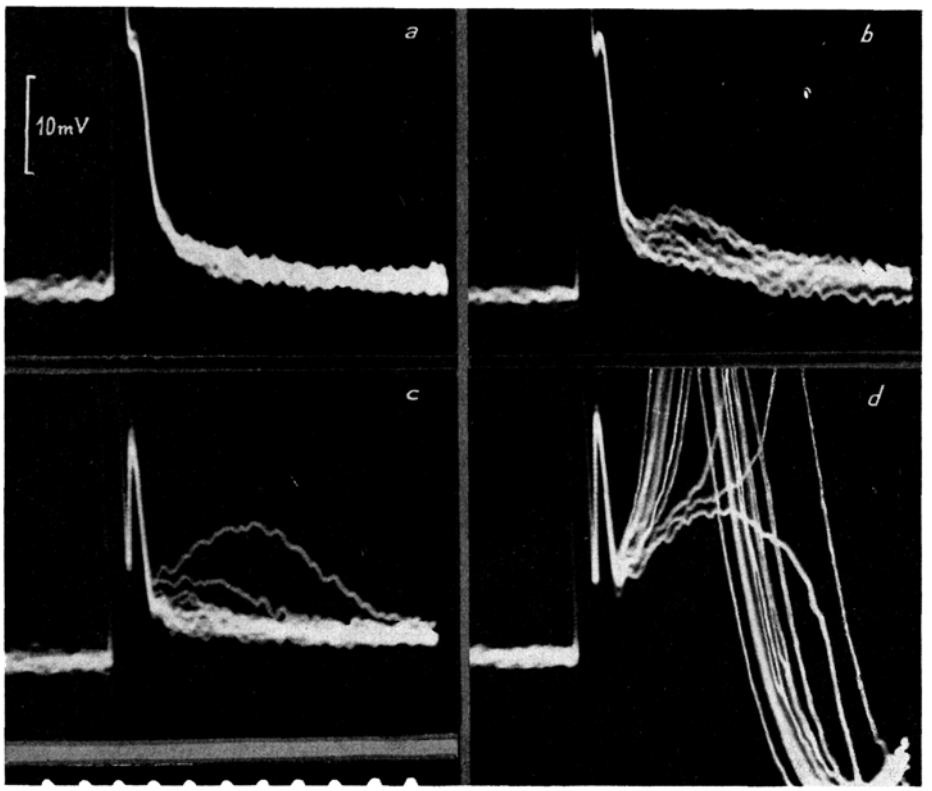
[4] R. STÄMPFLI, Helv. physiol. pharmakol. acta *4*, 411 (1946).
[5] J. DEL CASTILLO-NICOLAU and L. STARK (in preparation).



the fibres used (about 8–9 μ diameter, the internodal distance being less than 1 mm). The experiments were carried out at room temperature (20–23°C). Under these conditions the isolated nerve fibres remain excitable and action potentials can be recorded for several hours after dissection.

Figures *a*–*b*–*c*–*d* illustrates the results of one of the experiments. Each of the photographs is obtained by the superimposition of the potentials elicited by 10 successive stimuli, cathodic shocks of brief duration (about 60 μs). Record *a* shows the local potential changes due to shocks of strength equal to 0·5 threshold. After the initial shock–and capacitative–artifacts, a lasting polarization (electrotonic potential) can be observed which declines in an approximately exponential way. If the strength of the shock is now increased to about 0·82 threshold–Figure *b*–a hump in the decaying polarization potential appears, corresponding to a local response which develops above the passive electrotonic potential. In this record a fluctuation in the amplitude of the local response is evident; the size of the potentials generated by shocks of the same strength vary within a wide range. This fluctuation is even more evident if the potentials are produced by shocks of higher intensity (0·85 threshold in Figure *b*). Most of the potentials so elicited are only slightly higher than those of Figure *b*, whereas two of them have grown into huge humps which illustrate particularly well the phenomenon of the local response. In Figure *d* the strength of the shock was slightly above threshold, and propagated action potentials arising after various delays can be seen. A potential change is also seen in this record which propagated away although it did not grow to a full spike at the directly stimulated node. Apparently, the local response of this node of Ranvier stimulated by electrotonic spread the adjacent node, whose excitability was higher.

A comparison of these results with those already quoted from amphibian medullated fibres, non-medullated invertebrate axons and striated muscle fibres, reveals a fundamental similarity of the events which after cathodic stimulation lead to the onset of propagated potentials in all the excitable tissues which have so far been studied.

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Zusammenfassung

Lokale Potentiale, welche für die Entstehung fortgeleiteter «Spikes» verantwortlich sind, konnten an einzelnen Ranvierschen Schnürringen motorischer Fasern des Mäuse-Ischiadicus nachgewiesen werden.

Diese Befunde stützen die Ansicht, dass die Entstehung fortgeleiteter Potentiale in allen erregbaren Membranen auf ähnliche Weise stattfindet.

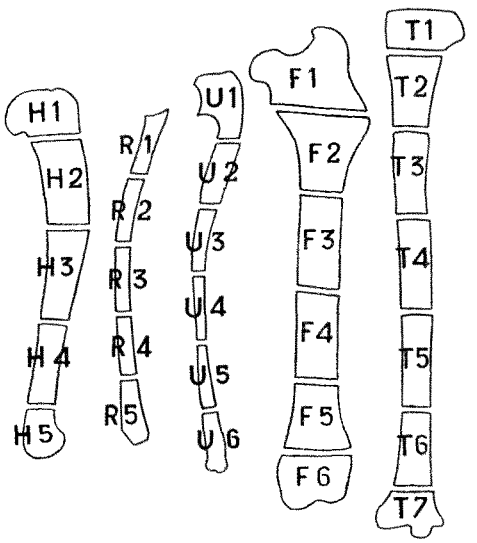
Distribution of Radiophosphorus in the Long Bones of Adult Rabbits[1]

The earliest experiments made with radiophosphorus[2] have shown that, immediately after administration of the isotope, the specific activity of the epiphyses of the long bones is always found to be higher than that of the diaphyses.

Several authors[1] add that the specific activities of the phosphorus are reduced to uniform values after some days or a few weeks.

As far as we can ascertain, this latter statement rests on experiments made with growing animals, and its general validity should not be accepted before experiments are made with fully grown animals.

Since it has been shown that bone marrow[2] and periosteum[3] have a high phosphorus specific activity, care must be taken to deal with bone tissue completely freed from the soft tissues.



This figure shows how the bones were divided. *H* = humerus; *R* = radius; *U* = ulna; *F* = femur; *T* = tibia.

Furthermore, it seems advisable to estimate the specific activities, not just in the shaft as compared with the epiphyses, but in as many portions of the long bones as is compatible with accurate measurements.

Procedure. Three fully grown rabbits (skeletal state checked by X-ray examination), weighing an average of 4·800 kg, were injected subcutaneously with carrier-free P 32 in solution made up in normal saline at pH 7 (supplied by Atomic Energy Research Establishment, Harwell). The one to be sacrificed 6 days afterwards received 2 mC in two days. The two others received 4 mC in three days.

The bones were cleaned with a knife and divided with a band-saw into portions as indicated by the Figure. These portions were boiled for one hour, digested for 24 hours at 37° in a 1 per cent. solution of papain renewed after 12 hours, boiled again for a few minutes, dried, and extracted in chloroform in a Soxhlet apparatus for 24 hours. They were then dried, weighed and dissolved in nitric acid. An aliquot was used for radio-assay while the remainder of the solution was used for chemical determination of phosphorus according to the method of Fiske and Subarow.

Results. The bones, before going to nitric acid, ap-

[1] This work was supported in part by grants from the Fonds National de la Recherche Scientifique of Belgium.

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