“CIRCULATION” OF NERVE IMPULSE IN LATERAL GIANT AXONS OF THE CRAYFISH: A REMNANT OF AN EVOLUTIONARY PAST?

BY

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ABSTRACT

The high-frequency repetitive discharge of the lateral giant axons evoked in isolated abdominal nerve cord of the crayfish by a single short electrical pulse has been described forty years ago in two independent papers (Burmistrov, 1965; Kusano & Grundfest, 1965). This phenomenon never was commented, though it seems hardly compatible with recent evidence concerning the lateral giant circuitry underlying the tail-flip escape reaction in modern crayfish. This paper is an attempt to explain the repetitive discharge of the lateral giants in the light of recent data about their structure and functions. It is concluded that (1) long repetitive high-frequency discharge of the lateral giants obtained in the isolated ventral nerve cord can hardly occur under natural conditions; (2) nevertheless, this phenomenon, caused by “circulation” of nerve impulse in loops of the lateral giants resulting from their ladder-like structure, needs to be explained; (3) one may suggest that it is a remnant of the evolutionary past when the lateral giants had chemical connections with their output neurons (fast flexor and swimmeret motor neurons); (4) this easily reproduced phenomenon may be used for the experimental study of functional abilities of commissural junctions as well as for model studies of reverberatory processes in various structures.

RÉSUMÉ

La décharge répétitive à haute fréquence des axones géants latéraux, en réponse à une unique courte impulsion électrique, connue dans la corde nerveuse abdominale isolée de l’écrevisse, a été décrite il y a quarante ans dans deux articles indépendants (Burmistrov, 1965; Kusano & Grundfest, 1965). Ce phénomène n’avait jamais été commenté, bien qu’il semble peu compatible avec la mise en évidence récente des circuits géants latéraux responsables de la réaction d’échappement (coup de queue) chez les écrevisses. Cet article est un essai d’explication de la décharge répétitive des axones géants latéraux à la lumière des données récentes sur leur structure et leurs fonctions. La conclusion est que (1) la longue décharge répétitive à haute fréquence des axones géants latéraux obtenus sur la corde ventrale nerveuse isolée peut difficilement être produite dans des conditions...
naturelles; (2) néanmoins, ce phénomène, causé par la “circulation” de l’influx nerveux dans des boucles fermées des géants latéraux résultant de leur structure «en échelle» doit être expliqué; (3) on peut suggérer qu’il s’agit d’un reste du passé évolutif quand les circuits géants latéraux avaient des connexions chimiques avec leurs neurones efférents (neurones de flexion rapide et ceux de nage, c’est-à-dire, des pléopodes); (4) ce phénomène facilement reproduit peut être utilisé pour l’étude expérimentale des capacités fonctionnelles des jonctions commissurales ainsi que les études de processus de répercussion dans des structures variées.

INTRODUCTION

The neuronal circuitry responsible for the escape tail-flip of the crayfish has been extensively studied, especially for the last fifty years, and it is now one of the best-known ‘simple nervous systems’ in the animal kingdom (Krasne & Wine, 1977; Wine & Krasne, 1982; Reichert & Wine, 1983; Wine, 1984; Edwards et al., 1999; Krasne & Edwards, 2002). However, several authors noted some “inconsistencies between neural connectivity and behavior” (Takahata & Wine, 1987) and “puzzling features” (Fraser & Heitler, 1989) inherent to this system. We would like to call attention to one more puzzling feature revealed in this nerve net, that has remained unremarked for many years.

In 1965, two independent papers described the same phenomenon: high-frequency repetitive discharge of the lateral giant axons (LGs) of the crayfish, caused by a single electrical stimulus applied to an LG. The way in which this repetitive discharge was produced was termed “circus reexcitation” (Kusano & Grundfest, 1965), or “circulation” (Burmistrov, 1965) of nerve impulse within the loop of the LGs. Let us recall the main facts reported in our own work (Burmistrov, 1965), that appears to be unknown to the English-speaking scientists.

Abbreviations. — LG, lateral giant axon; MG, medial giant axon.

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A single electrical stimulus applied to an LG in the connective between the last thoracic and the 1st abdominal ganglion of the isolated ventral nerve cord of the crayfish, Astacus leptodactylus (Eschscholtz, 1823) was followed by activation of the contralateral symmetrical LG (fig. 1). Then two nerve impulses were detected by wire electrodes placed on the interganglionic connectives (bipolar recording): in the first (directly excited) LG, impulse (1) propagated in caudal direction; and in the second (synaptically activated) LG, impulse (2) passed in both directions from the point of transition. While recording from different sites along the length of the ventral cord, it was possible, in each particular case, to determine at which ganglion