regressive periods should be found in all phases of CAR and not only during the 4th to 7th day. Therefore 2 oscillatory processes may be assumed during the CAR; 1st the spontaneous background activity in the CNS[6], and 2nd an autoregressive periodicity during the 4th to 7th day of CAR (consolidation phase), which is perhaps based on negative feedback mechanisms (overlying of activating and relaxing processes which tend to an equilibrium). It was pointed out[7] that a system with negative feedback presents periodicities which are damped harmonic. Therefore it is possible that the level of unspecific activity is reduced during the 4th to 7th day of CAR to an optimum of learning, which means an enhancement of learning in the consildation phase.

Zusammenfassung. Es wurden Reaktionszeiten, die während einer instrumentellen Konditionierung bei Ratten automatisch gemessen wurden, hinsichtlich ihrer Autokorrelations- und Spektraldichtefunktion untersucht. Die autoregressiven Oszillationen der Reaktionszeiten vom 4.–7. Tag des Trainings basieren auf einem nicht-zirkulären MARCOV-Prozess.

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[6] H. DRISCHEL, *Biologische Rhythmen*, Sitzungsber. Sächs. Akad. Wiss., Math.-Naturwiss. Kl. *109* (5), Berlin 1972.
[7] G. M. FRANK, *Oscillatory Processes in Biological and Chemical Systems* (in Russian) (Nauka, Moscow 1967), p. 81.
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Does Axonal Sprouting Occur in Dystrophic Mouse Muscles?

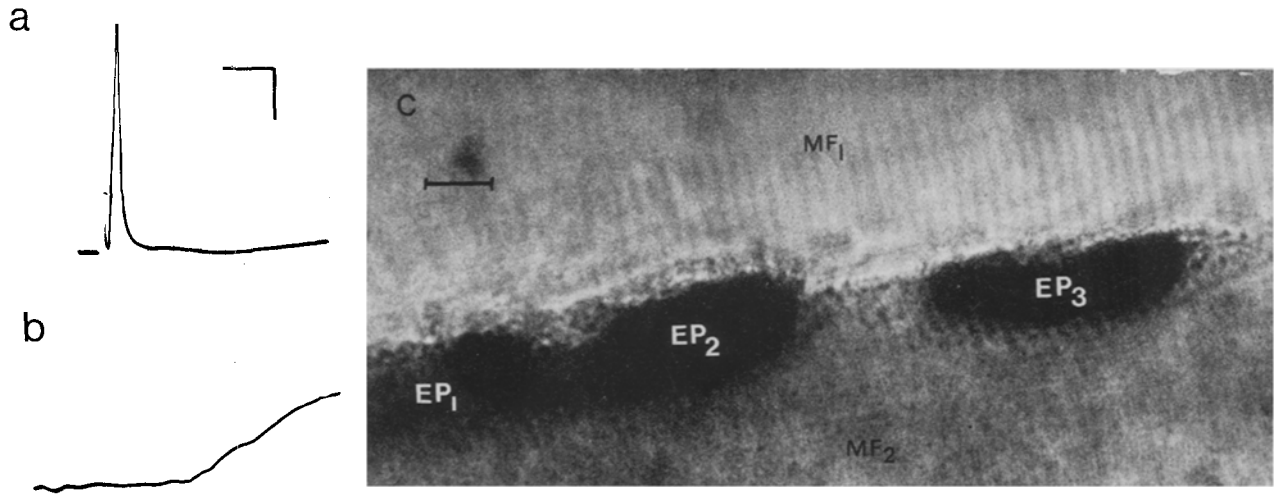
Muscles of dystrophic mice are known to contain some fibres which are 'functionally denervated'. No action potential appears in such fibres when the motor nerve is given supramaximal stimulation[1–5]. However, the functionally denervated fibres of the dystrophic soleus muscle change their properties when the muscle is denervated[5]. Although it is possible that such muscle fibres are entirely without motor innervation, they could be supplied by sprouts from remaining motor neurons. In the latter case there should be an increase in the size of individual motor units. Furthermore, if functional denervation and axonal sprouting are gradual processes of nerve deterioration and recovery during which the release of acetylcholine (ACh) is incomplete, there should exist transitional periods when end-plate potentials (EPP) can be detected among the dystrophic muscle fibres upon supramaximal stimulation of the innervating nerve.

Materials and methods. Soleus nerve-muscle preparations[5] from male mice of the Bar Harbor 129 Re-J/dy strain were used. Both the dystrophic mice, and their normal litter-mates were 3–4 months old at the time of sacrifice.

Fibres in dystrophic muscles were impaled with microelectrodes and checked for innervation by stimulating the motor nerve with a voltage pulse of 0.2 msec., delivered at twice the strength necessary for a maximal muscle twitch. If no sign of an action potential was observed, the fibre was considered to be 'functionally denervated' (see Figures a and b).

Staining of muscles for acetylcholinesterase was used to compare the number of motor end-plates in the normal

[1] A. J. MCCOMAS and K. MROZEK, J. Neurol. Neurosurg. Psychiat. *30*, 526 (1967).
[2] A. J. MCCOMAS, R. E. P. SICA and S. CURRIE, Nature, Lond. *226*, 1263 (1970).
[3] J. HARRIS and P. WILSON, Nature, Lond. *229*, 61 (1971a).
[4] J. HARRIS and P. WILSON, J. Neurol. Neurosurg. Psychiat. *34*, 512 (1971b).
[5] P. K. LAW and H. L. ATWOOD, Expl. Neurol. *34*, 200 (1972).



a) Intracellular recording of action potential from innervated dystrophic soleus fibre. b) Suprathreshold indirect stimulation failed to evoke an action potential from a functionally denervated soleus fibre. The movement artifact indicates that the recording microelectrode was displaced slightly during muscle contraction. Calibrations: 20 mv and 4 msec. c) Acetylcholinesterase staining of dystrophic soleus muscle to show the presence of more than 1 motor end-plate on a muscle fibre. Calibration mark, 25 μm. MF_1, MF_2, muscle fibres; EP_1, EP_2, EP_3, end-plates.

Comparison of motor end-plate numbers, motor axons numbers, and average motor unit size between the normal and dystrophic soleus muscles of the mouse

	Number of motor end-plates	Number of myelinated axons	Estimated number of motor axons	Average motor unit size
Normal	237 ± 33 (9)	72 ± 5 (6)	25 ± 2 (6)	9
Dystrophic	210 ± 44 (6)	58 ± 2 (8)	20 ± 1 (8)	10
t-test (one-tailed)	N.S.	0.01	0.01	

Mean values are given with standard deviations. The numbers of muscles or nerves used are quoted in brackets. N.S., not significant.

and the dystrophic soleus muscles. The histochemical technique followed that of GINSBORG and MACKAY[6]. The numbers of nerve axons supplying the normal and the dystrophic soleus muscle were determined and compared, using a modification of RANVIER's gold chloride method[7]. These axons comprised myelinated somatic afferent and efferent fibres[8,9] of which 36% were estimated to be motor[4,10].

Results and discussion. Some functionally denervated fibres which were impaled at several different places along their length showed localized end-plate potentials or abortive spikes when the nerve was stimulated. The amplitudes of these potentials decreased with increasing distance from the end-plate region. Abnormal neuromuscular transmission is indicated for such fibres.

The end-plates in the dystrophic soleus muscles were sometimes relatively irregular in size and shape, with a shrunken and granulated appearance. Individual muscle fibers with two end-plates were occasionally seen (Figure c).

The mean number of motor end-plates for the normal soleus muscle was slightly greater than that for the dystrophic soleus, although the difference was not statistically significant (Table). Since the numbers of muscle fibres reported for normal and dystrophic mouse soleus muscles are about 800 and 400 respectively[11], it seems likely that not all end-plates were stained and counted in the present study. Thus, the figures represent comparative, rather than absolute values.

The nerve supplying the normal soleus muscle had significantly more axons than the nerve to the dystrophic muscle (Table). An estimate of the average size of the motor units, made by taking the ratio of observed motor end-plates to motor axons, gave a slightly greater motor unit size for the dystrophic muscle.

It is possible that in the dystrophic mouse, the motor nerve fibres which do not disappear during dystrophy, sprout in the terminal regions to provide nearby denervated fibres with trophically effective, but functionally incomplete, innervation. This would explain the previous finding that surgical denervation leads to change in membrane resistance in fibres throughout the muscle, while functional denervation does not[5]. The phenomenon of axonal sprouting has been reported in partially denervated muscle[12] and in humans with certain neuromuscular diseases[13,14].

About 62% of the motor axons were estimated to have degenerated in the nerve supplying the 'fast' tibialis anterior muscle of the dystrophic mouse[3,4], compared with only 20% for the 'slow' soleus muscle. This result indicates that the motoneurons innervating a 'fast' muscle degenerate faster than those innervating a 'slow' one during the course of dystrophy. This conclusion is consistent with fact that the 'red' muscles are less susceptible to dystrophy than the 'white' ones[15].

Zusammenfassung. Nachweis, dass im M. soleus dystropher Mäuse die Zahl motorischer Endplatten normal ist, dass jedoch eine verminderte Zahl motorischer Axone vorhanden ist. Einige Muskelfasern zeigen anstelle von Aktionspotentialen lokale Endplattenpotentiale. Es wird angenommen, dass nach Verlust der ursprünglichen Innervation, dystrophische Muskelfasern von kollateralen Zweigen vorhandener Motoneuronen innerviert werden.

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[6] B. L. GINSBORG and B. MACKAY, Bibl. Anat. *2*, 174 (1960).
[7] L. RANVIER, Q. Jl microsc. Sci. *20*, 456 (1880).
[8] J. B. HARRIS, C. WALLACE and J. WING, J. Neurol. Sci. *15*, 245 (1972).
[9] I. A. BOYD and M. R. DAVEY, in *Composition of Periferal Nerves* (Livingstone; Edinburgh and London 1968), p. 1.
[10] I. A. BOYD and M. R. DAVEY, in *Composition of Periferal Nerves* (Livingstone; Edinburgh and London 1968), p. 37.
[11] R. W. D. ROWE and G. GOLDSPINK, J. Anat. *104*, 531 (1969).
[12] M. V. EDDS, JR., J. exp. Zool. *113*, 517 (1950).
[13] C. COERS and A. L. WOOLF, *The Innervation of Muscle: A Biopsy Study* (Blackwell Scientific Publications, Oxford 1959).
[14] R. E. P. SICA and A. J. MCCOMAS, J. Neurol. Neurosurg. Psychiat. *34*, 469 (1971).
[15] O. W. TIEGS, Physiol. Rev. *33*, 90 (1953).
[16] We thank Dr. A. J. MCCOMAS for helpful discussion. This work was supported by grants and scholarships from the National Research Council of Canada and the Muscular Dystrophy Association of Canada. P. K. LAW is presently a MDAC postdoctoral fellow in the Department of Neurology, McMaster University Medical Centre, Hamilton 16, Ontario, Canada.

Kreisende kortikale Potentialfelder beim epileptischen Anfall

Die bioelektrische Tätigkeit beim epileptischen Anfall zeichnet sich durch eine weitgehende Homogenität des elektrischen Musters über grösseren Hirnrindenarealen aus. Analysen der Phasenbeziehungen dieser Tätigkeit[1–4] haben jedoch ergeben, dass sich die den EEG-Wellen zugrunde liegenden Potentialfelder mit Geschwindigkeiten im cm/sec bis dm/sec Bereich über die Hirnrinde verschieben. Die Ursache dieses Phänomens ist noch nicht geklärt. Zwei Möglichkeiten kommen in Betracht: Einerseits eine sukzessive Anregung von nur