

Tabelle I. Beispiel: *Anodonta cygnea* Ausgangsintensität: 690 Lux

Verdunklung in %	Reaktion	Bemerkungen
4,0	–	– keine Reaktion
5,5	– +	– + mehr Ausfälle als Reaktionen
6,7	+ –	+ – mehr Reaktionen als Ausfälle
7,7	+	+ stets Reaktionen
8,3	+	

Tabelle II. Beleuchtung: 550 Lux; Wassertemperatur: 14°C

Absorption der Grauscheiben	Reaktionszahl in %			
	10%	20%	30%	40%
Transportgeschwindigkeit 1 cm/s	38,1	38,5	41,2	50,0
«Bewegungsloses» Herab- klappen der Grauscheiben .	4,3	5,0	17,4	40,0

Tabelle III. Beleuchtung: 950 Lux; Wassertemperatur: 17,5°C

	Absorption der Grauscheibe	Transportgeschwindigkeit		
		2,9 cm/s	1,2 cm/s	0,3 cm/s
Muschel IV	10%	–	–	+
	20%	–	+	+
	30%	–	+	–
	40%			
	50%			
Muschel III	10%	–	–	+
	20%	–	–	–
	30%	–	–	+
	40%	–	–	+
	50%			
Muschel V	10%	–	–	–
	20%	–	–	–
	30%	–	?	–
	40%	–	+	+
	50%	–	+	+

Tabelle IV. Beleuchtung. Ausgangsintensität: 450 Lux;
Wassertemperatur: etwa 16°C

Absorption der Grauscheiben	Transport- geschwindig- keit	Reaktion	Bemerkungen
10%	2,7 cm/s	– –	
10%	2,7 cm/s	– –	
10%	2,1 cm/s	– –	
10%	2,1 cm/s	– –	
10%	1,3 cm/s	? –	
10%	1,3 cm/s	(+) ?	(+) sehr schwach
10%	1,3 cm/s	+ ' –	+ ' mit Latenzzeit
10%	0,7 cm/s	+ + "	+ " mit Grab- bewegung
10%	0,7 cm/s	+ +	
10%	0,4 cm/s	+ +	
10%	0,4 cm/s	+ +	
20%	2,7 cm/s	+ +	
20%	2,7 cm/s	+ +	

Tabelle III zeigt deutlich die verschiedene Empfindlichkeit der Muscheln einer Art (*A. cygnea*), zeigt aber auch, dass mit der Abnahme der Geschwindigkeit eine Zunahme der Reaktionen eintritt.

Für zwei Muscheln der Art *P. complanata* wurden zum Beispiel folgende Werte gewonnen (Tab. IV), die das Gesagte auch für diese Spezies bestätigen¹.

Aus diesen Experimenten darf gefolgert werden, dass den untersuchten augenlosen Muscheln (Anodontiden) ein Wahrnehmen von Bewegung dann möglich ist, wenn sie gleichzeitig mit einer Beschattung verbunden ist. Ein solches «Bewegungssehen» hat v. BUDDENBROCK² für den Röhrenwurm *Branchiomma* vermutet. Es ist dieses «Bewegungssehen» aber schon bei einem einfachen Hautlichtsinn denkbar. Auch bei einem solchen besteht die Möglichkeit einer Reizrichtungswahrnehmung durch das Nacheinander-Gereiztwerden von Sinnes- oder Nervenzellen.

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Summary

The eyeless mussels *Anodonta cygnea* and *Pseudanodonta complanata* do not show any phototaxis. In the "Zweilichterversuch" (two-light-experiment) they react to the decrease of light intensity. If light is increasing, the mussels will not react; if put in the shade, they immediately do so. If the shadow is moved, the mussels even react when the intensity of light decreases much less, which demonstrates the importance of motion. From this it follows that the reception of motion may be considered as possible where there is light sensitiveness of the skin, and where the experiment connects motion with shading.

¹ Vgl. D. H. WENRICH, J. Anim. Behav. 6, 297 (1916).
² W. v. BUDDENBROCK, Z. vgl. Physiol. 13, 1, 164 (1930).

Properties and Functional Differentiation of Interneurons in the Ventral Horn of the Cat's Lumbar Cord as Revealed by Intracellular Recording

In the ventral horn of the cat's lumbar cord interneurons are located which can be activated via descending reticulospinal and propriospinal pathways, as demonstrated by LLOYD¹ who also emphasized the significant role of these neurons as correlation systems for motoneuron excitation. RENSCHAW's² finding that certain ventral horn interneurons can be fired by antidromic stimulation of motor axons, presumably via recurrent collaterals or induced current fields, further indicates a close relationship between the two types of neurons. During the course of an analysis of interneuron activity in the cat's spinal cord by means of intracellular recording, we observed that a large number of the interneurons that lie scattered among the motoneurons in the ventral horn³ could be effectively influenced by afferent stimulation from various sources. Further analysis revealed a differentiation of the neurons with respect to their response patterns, indicating important integrative functions of this interneuron system.

Our experiments were performed on non-anesthetized, decapitated cats. Capillary electrodes with a tip diameter of less than 0.5 μ were inserted into the 7th lumbar

¹ D. P. C. LLOYD, J. Neurophysiol. 4, 525 (1941), and 5, 435 (1942).
² B. RENSCHAW, J. Neurophysiol. 9, 191 (1946).
³ K. BALTHASAR, Arch. Psych. 188, 345 (1952).

segment and left in the cord for subsequent histological control of the needle track; the various depths from which recording was made during the course of the experiment were estimated with a micrometer gauge. The intracellularly recorded interneuron activity could be distinguished from similarly recorded motoneuron potentials by the absence of the typical propagated response to antidromic ventral root stimulation described by BROCK, COOMBS and ECCLES¹, and was further identified by characteristic spike forms and discharge pattern². To electric single shock stimulation of the dorsal root, the ventral horn interneuron responds—following stimulus rates up to 20–30 per s—with a single spike or a series of up to 6 or 7 discharges depending upon the stimulus strength; minimum latency observed was 1.0 ms. The average values of the membrane potentials varied between 40 and 60 MV, the spikes amounting to about 80% of these values. Occasionally membrane potential values as high as 80 MV were observed in combination with spike potentials overshooting about 10%, apparently representing ideal recording conditions. The average duration of the spike potential was 0.7 ms. (cf. WOODBURY and PATTON's³ data for type II units).

The functional analysis has been based on successful recordings from about 200 ventral horn interneurons, the resting potential values of which kept constant during 5 up to 40 min. Adequate stimulation of various extero- and proprioceptive receptors as well as electrical stimulation of different muscle and skin nerves was used. Some of the cells investigated discharged only after application of afferent stimuli, while others maintained a continuous, more or less regular discharge of maximally 50–60 per s. Whether pre-existent or induced from some known source, the interneuron activity could be either increased in frequency (up to more than 200 per s) or reduced (down to zero) by afferent stimulation. According to the pattern of response to various types of afferent inflow, a functional classification of the neurons could be made. Under given experimental conditions, certain cells were exclusively activated by the afferent inflow from one muscle (or group of synergistic muscles); others could be influenced from two or more functionally different muscles, while a great number of interneurons showed a convergence from exteroceptive (touch, pressure, pain) as well as proprioceptive sources on both ipsi- and contralateral sides. Cells responding only to exteroceptive stimuli were comparatively scarce in the ventral part of the cord. An example of a common type of response pattern is the following: the discharge frequency of a continuously firing interneuron was increased by stretch of the ipsilateral quadriceps muscle as well as by pressure applied to the contralateral pad, the two stimuli eventually summing, while an equal stimulation of the ipsilateral pad caused a decrease of the prevailing discharge rhythm, at a more intense stimulus strength leading to complete cessation of the spike activity. Descending activity from suprasegmental levels, originating e.g. from receptive areas of the foreleg, was observed to converge on the same neuron. Cells of reciprocal behaviour were situated adjacent to the cell described, an arrangement apparently characteristic of the organisation of the interneuron system studied. Not only with natural but also with artificial stimulation,

facilitatory and inhibitory processes in terms of modulation of discharge frequency were observed; thus for instance interneuron discharge maintained by afferent inflow from the gastrocnemius muscle was inhibited by electric stimulation of the sural nerve.

Data available from experiments with intracellular recordings on motor cells under identical stimulus conditions¹ indicate that mediation of activity from the interneurons is responsible for the excitation of near-by motor cells. Under these premises it is obvious that mere cessation of the interneuron activity constitutes an effective inhibitory mechanism in segmental reflex processes.

The interneurons studied were found to be susceptible to certain changes in the chemical milieu: diethyl p-nitrophenyl phosphate, an irreversible cholinesterase inhibitor, elicited bursts of discharges followed by a lowered excitability; also a decrease of the resting potential value was observed. Noradrenaline intrarterially injected in doses of a few μg per kg body-weight was observed to influence the discharge rhythm and also to change the response pattern of a given cell so that previously non-active afferent sources became effective. The direct recording of such changes in anatomically and functionally defined interneurons reveals obvious mechanisms for the effects of these substances on spinal reflexes, but, as emphasized in connection with similar studies on the frog's spinal cord², the demonstration of effects on interneuron activity *per se* does not exclude other sites of primary action.

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Zusammenfassung

Mit intrazellulären Elektroden wurden an der Katze die Funktionen der Zwischenneuronen im Vorderhorn des 7. Lumbalsegments des Rückenmarks untersucht und ihre elektrischen Eigenschaften kurz erwähnt. Auf Grund ihrer Reaktion auf adäquate afferente Reizung konnten die einzelnen Neuronen klassifiziert werden; sowohl Erregungs- wie Hemmungsprozesse – wie sie als Frequenzänderungen der Aktionspotentiale zum Ausdruck kommen – wurden demonstriert. Einige bei chemischen Milieuveränderungen bewirkte Effekte wurden auch studiert.

¹ G. M. KOLMODIN, unpublished results.

² G. M. KOLMODIN and C. R. SKOGLUND, *Acta phys. scand.* **29**, Suppl. 106, 503 (1953).

PRO EXPERIMENTIS

Die Säurefällung der Serumproteine¹

Die Prüfung des Filtrates von mit Säure geflocktem Serum¹ zeigt, dass die Fällung nur beim erhitzten Ansatz vollständig ist. Um festzustellen, welcher Anteil des Nativserums durch die Säuerung ausfällt und worauf die Veränderungen durch Hitze beruhen, wurden 5mal (Abb. 1–4: a–e) 5 ml Serum 1:10 mit Aqua dest. verdünnt und jeweils gekocht und roh mit soviel $n/100$ HCl versetzt, dass eine lineare Säureverdünnungsreihe zwischen den Punkten der beginnenden Trübung und kurz vor der völligen Klärung resultierte. Die Sedimente wur-

¹ L. B. BROCK, J. S. COOMBS, and J. C. ECCLES, *J. Physiol.* **117**, 431 (1952).

² J. W. WOODBURY and H. D. PATTON, *Sympos. Quant. Biol.* **17**, 185 (1952).

³ J. W. WOODBURY and H. D. PATTON, *Sympos. Quant. Biol.* **17**, 185 (1952).

¹ K. SIMON, *Exper.* **8**, 55 (1952).