KFKI-1983-29

M.-M. HEGYHÁTI

ACETYLCHOLINE AS A POSSIBLE DIGITAL ELEMENT IN THE NERVOUS SYSTEM ACTIVITY

Hungarian Academy of Sciences

CENTRAL
RESEARCH
INSTITUTE FOR
PHYSICS

BUDAPEST

KFKI-1983-29

ACETYLCHOLINE AS A POSSIBLE DIGITAL ELEMENT IN THE NERVOUS SYSTEM ACTIVITY

M.-M. HEGYHÁTI

Central Research Institute for Physics
H-1525 Budapest 114, P.O.B.49, Hungary

HU ISSN 0368 5330
ISBN 963 372 060 5

ABSTRACT

The digital role of acetylcholine in the process controlling the excitable membrane permeability during electrical activity at the synapses is discussed.

АННОТАЦИЯ

Показана дигитальная роль ацетилхолина в процессе контроля пропускания мембран во время активности синапсов.

KIVONAT

Sémát javaslunk az acetilcholin digitális elem müködésére a gerjeszthető membrán permeabilitás szabályozására a szinapszisok elektromos aktivitása alatt.

It was shown by extended Hückel-type calculation [1] that there are two island groups in the acetylcholine (ACh) molecule, the sigma-electron donor choline part and the pi-electron acceptor acetate-group. The first excited state of ACh proved to be an intramolecular one-electron charge-transfer (CT) state between the two island groups. In the presence of an electron-donor acting group (e.g., the serine OH in which the nucleophilicity of the serine-oxygen atom is enhanced by hydrogen-bond formation between the hydroxyl group and an imidazole group [2] the ACh molecule is being hydrolysed with alkyl-oxygen cleavage "remembering" its island groups. Let us consider the question: Why must the ACh molecule hydrolyse?

According to von Neumann's opinion [3], the processes going through the noervous system change their character from digital to analog and vice versa repeatedly. The digital part of the nervous system connected with the nerve-pulses and the analog part connected with the chemical changes or the mechanical dislocations due to muscular contractions may give the activity of the nervous system a hybrid character.

It is thought that in the activity of the nervous system the ACh acts as a *digital* element [1]. The ACh can respondt to any nerve-pulse only by either "YES" or "NO". "YES" means the onset of the first excited CT state. The electrical pulses initiated by this state in the nerve cell constitute the *analog* part of the process. Since a digital element must necessarily make an unambiguous logical choice it must have a good memory; - this is privided by the two island groups. The response "NO" means the *hydrolisis* of ACh when "remembering" the island groups it splits via *alkyl-oxygen cleavage*. The response "NO" ensures the *reversible* functioning of the nervous system, that is, it permits the nerve-

pulse to go sensibly in a single direction without a disturbing feedback of the induced field, and simultaneously it restores at the synapses the state preceeding the arrival of the nerve-pulse.

In a nerve fibre the action potentials are conducted in both directions, but action potentials *in a neuron chain* are conducted in only one direction owing to the unidirectional conduction at the synapses, and it is thought that *this direction* is determined by the responses "YES" or "NO". In this sense, the synapse is a "one way valve".

The role of ACh can be described in terms of the Nachmanson hypothesis [4] as shown in Figure 1.

LITERATURE CITED

[1] M.-M. Hegyháti, Charge-transfer mechanism for hydrolysis of ACh, KFKI Közl., 17, 26 (1969) and
M.-M. Hegyháti, J. Chem. Phys., 52, 2775 (1970)

[2] I.B. Wilson, Ann.N.Y.Acad.Sci., 144, 664 (1967)

[3] J. von Neumann, "The Computer and the Brain", Silliman Lectures, Yale University Press, 1958

[4] D. Nachmansohn, "Chemical and Molecular Basis of Nerve Activity", Academic Press, New York, 1959

[5] M.-M. Hegyháti and M. Farkas, J.Chem.Phys., 52, 2778 (1970)

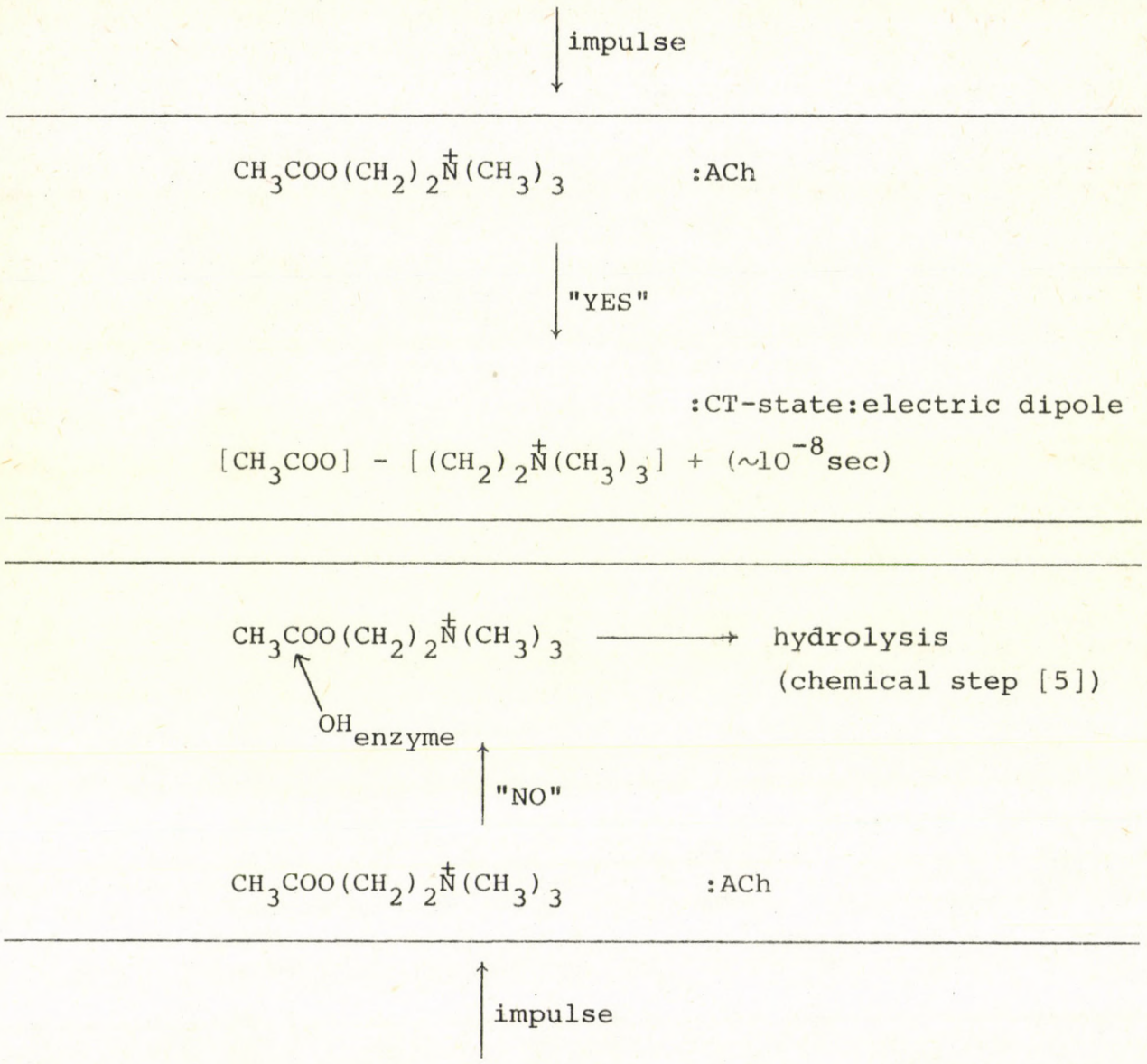
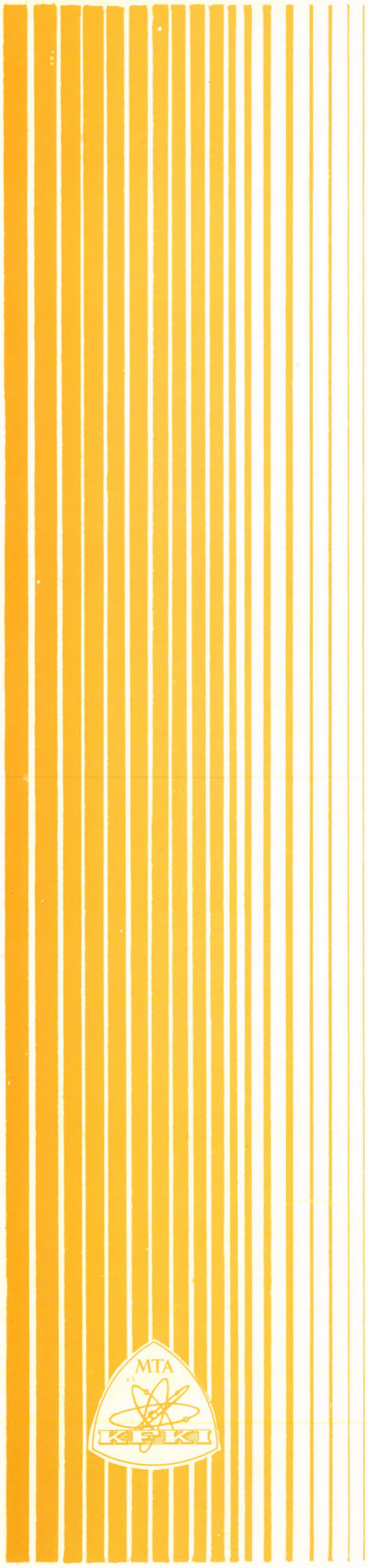


Fig.1. Schematic presentation of the *digital* role of ACh in the process controlling the excitable membrane permeability during electrical activity at the synapses.

In resting condition, ACh is bound loosely e.g. to a storage protein in the pre-synaptic membrane. Then ACh is excited by the current flow of the nerve impulse. The excited local double ionic intramolecular CT state results in the change leading to a shift of charge in the post-synaptic membrane to increase its permeability: the post-synaptic potential (local PSP), by which is generated the indirectly ACh-controlled conducting digital action potential. This is the trigger action - "YES" - by which the ionic concentration gradient becomes effective. After returning to its ground state, the ACh molecule is attacked by the acting group of the cholinesterase enzyme. The *hydrolysis* of the ester - "NO" - permits the reestablishing of the permeability barrier.



Kiadja a Központi Fizikai Kutató Intézet
Felelős kiadó: Kroó Norbert
Szakmai lektor: Sütő András
Nyelvi lektor: Kósa Somogyi István
Gépelte: Beron Péterné
Példányszám: 180 Törzsszám: 83-164
Készült a KFKI sokszorosító üzemében
Felelős vezető: Nagy Károly
Budapest, 1983. március hó