Discovery of vortices in the nervous system

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The paper presents the original results of neuro-modeling of volumetric propagation of axonal spikes in myelinated axons . Shown much more complex , than is commonly believed at present , the nature of the distribution , moreover , substantiates the significance of the influence of the features , associated precisely with the volumetric propagation , namely , the vortex character ion currents and corresponding electromagnetic fields propagating spikes . Based on the analysis and neuro-modeling of electrochemical transfer mechanisms for the first time is assumed , that the long substrate memory can be myelin sheaths of axons , which is important in understanding the development of relevant pathologies , including diseases Parkinson's and Alzheimer's .

Dedicated to
with love of eternal bright memory
my Mom and closest Friend
Saveliev - Novoselova
NINA ANDREEVNA

Introduction

Until now, the propagation of axonal spikes was considered only in longitudinal section of the axon , by default considering it , thus , in one-dimensional space . Unidimensional spike propagation is good Exploring matter with time studies A . Hodgkin's and A . Huxley , for which they were awarded the Nobel Prize 1963 g . More refined equations generation and conduction of an electric active junction , however , also by one-dimensional axonal fiber , were proposed by Yu . R . Antomonovym and A . B . Kotova [1]. Subsequently, the equation of propagation of the spike many times refined and modified , up to the present time [2], however , not going beyond the one-dimensional model . However , the symmetry of the transverse cross-sections of the electrical axon impulse is far from ideal , and therefore dimensional consideration only its propagation along the length of the axon , means loss of a significant amount of information . In addition , the ratio of length to diameter They are not negligible , especially , for short axons , characteristic for the neocortex . And , finally , how it will be shown below , as a result Surround the nature of the propagation of spikes, super-effects can appear , cardinal influencing the distribution itself , and its results .

Methods

Methods of mathematical and simulation modeling were used with involvement of expert data obtained by identification of parameters dynamic distributed models of real biological tissue in culture .
Spike propagation was investigated using *neuroexistential* algorithms , implemented in a number neuroprocessors [3, 4]. In particular , conduction along the axon was studied taking into account the quasi - reciprocal [5], as well as reciprocal [6] propagation due to the reflection of spikes from Ranvier's interceptions .

A similar scheme is also applicable to simulate propagation
electric wave , generated by the spike pulse in the radial
directions of the axon section, taking into account the identification of differing parameters
distribution media for each individual direction .
Neyromodel , designed to simulate the nerve bundle [7] into force
fractal and quasi-fractal properties of neurons [8] with a sufficiently high
the degree of accuracy reflects the properties of volumetric conduction in a solitary axon
taking into account the parallel - longitudinal propagation of the spike wave components and
cross interactions between them . Discreteness of spike components
was reproduced by a neural network neuroprocessor [9], which simulates
the distribution of the initial zone of the appearance of the spike and their peculiarities
total spread . The same neuromodel provides sampling
the distributed wave of the spike in the cross section of the axon . A number of neuromodels ,
detecting componentwise - discrete composition of the spike , were proposed and
investigated by us in [10]. Passive spikes , for example , between
interceptions of Ranvier or within the plane of the section of the axon , was modeled
neuroprocessors [11-14], taking into account the phenomena of volumetric interference
electric waves [15, 16], as well as a gradual subthreshold neuroprocessor
commissural neuron [17]. We also used data from neurophysiological
research using microelectrode technology and electron microscopy
sections of brain tissue of animals and humans , as well as methods of optical
intravital cell culture microscopy .

Results

Simulation showed the complex dynamic structure of the spreading
over the section of the axonal commissure . The entry of Na^+ - current from the extracellular environment into
the internal space of the axon in the section of the anterior front of the commissure has
centripetal character . Simultaneously , accumulation is positive
charged Na^+ ions behind the leading edge creates an excess concentration
positive ions , since the release of K^+ ions into the extracellular space
occurs with some delay after the entry of Na^+ ions at the leading edge
spike .

Fig . 1. Schematic representation of the delay in the release of positively charged ions
K + from the inner space of the axon and the formation of the axial component
incoming sodium currents .

This forms a positively charged region of the membrane that follows
directly behind the spike , as a result of which , as well as the centripetal
incoming sodium currents , their axial cumulative component is formed
(fig . 1). It is known , that axons in areas below the initial segment does not contain
ubiquitous organelles - granular endoplasmic
reticulum and free ribosomes . Compared to large dendrites in axons
contains many neurofilaments parallel to their longitudinal axis and
relatively few microtubules . Neurofilaments usually
have a diameter of about 0.1 nm and various indefinite lengths . Research
Schmidt and Davidson [18] have shown , that each represents neurofilament
spirally twisted thread , built of globular protein subunits . IN
prenatal period of ontogenesis, axons contain a large amount

microtubules and a relatively small number of neurofilament threads .
Further , with the development of the organism, this quantitative ratio is significantly
shifts in favor of neurofilaments , which , moreover , begin to combine into
groups . With age, the number of these groups increases and the location
neurofilament becomes more dispersed . It is also known , that as the
growing up of the body, the cross sections of the membranes of axons are increasingly different from
perfect circle . Electrical activity of an axon during a spike discharge
accompanied by powerful streams incoming along the leading edge of the spike
sodium ion currents .

Fig . 2. Schematic representation of the cross-section of an axon at the time of occurrence
the leading edge of the spike . **A** - mutual balancing of incoming sodium currents ,
ideal case ; **B** - the appearance of the vortex component of the incoming sodium current ,
corresponding to the leading edge of the spike in the real case .

Potassium output current , as shown , is included later accompanies
the posterior falling edge of the spike before reaching the peak of the refractory period , therefore, in
the formation of the leading edge of the spike pulse, it practically does not play a role
plays . Thus , the leading edge of the spike is formed exclusively
incoming sodium current . If the cross-sectional view of the axon (Fig ア 8 . 2),
It is seen , which form non-ideality axonal membrane , differing from a circle ,
promotes unbalanced mutual compensation of vectors of incoming
sodium currents . At the same time, such an obvious essential asymmetry
cross-section of real biological axons , determines
unevenness as quantitative characteristics of the incoming axon
spike sodium currents , and their qualitative unevenness , that is, their
directions . Moreover, as a result of algebraic summation , the appearing
the eddy component of the sodium current is twisted in one direction or another , in
depending on the specific ratio and direction of the vectors of the incoming
currents . Moreover , this effect enhances the inhomogeneity of the cytoplasm , comprising
various types of inclusions and organelles , as well as electromagnetic influences from
closely spaced neighboring axons , packed in syncytium [19].
Thus , a spike in a cross section is a rather complicated
multidimensional vortex formation , due to the corresponding
spiral flow of the resulting ionic currents . The presence of the mentioned
spiral twist of neurofilamentary filaments also confirms this fact
respectively known experience in . Schauberger with the placement of the thread in the pipe with
spiral flow of liquid , which, as a result, also swirled in
three-dimensional spiral [20]. It was also an experiment , showing
combining such threads (if there were several of them) into groups with a spiral
flow , which is well observed as axons mature in ontogenesis .
For the wave equation with potential and inclusion
of an abelian gauge field, the action functional is defined :
(one)
, Is a real Abelian gauge field ;
and the functional will be minimal when the system of equations is fulfilled :
; (2)
Its solutions at are N- vortex .
Displays , defines a mapping , where :

y - zeros of the function ,
allows you to search for a solution in the form :
... (3)
For this mapping , therefore, the gauge field has
asymptotic form :

, where :, and the solution would be :
(four)
Substituting (3) and (4) in (2), we obtain for
(five)
Fig . 3. Solution field with a single vortex .
In the vicinity of the point, the solutions have the asymptotics :
The solution with a single vortex for φ and the gauge field has near
asymptotes :
- divergent radial potential from a point and swirling
a vortex relative to it (Fig . 3).
It is quite possible , that it is the nature of the spatial spiral spike
discharges due to the spiral twist of the myelin sheaths around
axons . In this case, the electrical activity of the axons can be
stimulating for the oligodendrocytes that form these membranes , otherwise
inexplicable is such a large number of turns of myelin , clearly
excess for electrical isolation of the nerve fiber .

A B
Fig . 4. **A :** The optic nerve of an adult rat . M y - myelin . VM - internal mesaxon .
Microtubules (T) and microfibers (F) in axons of various sizes (1-4). It is seen
a large number of layers of myelin , clearly redundant to perform the function
electrical insulation . Magnification 45,000, photo C. Nème ć ek. **B :** Fragment of myelin
shell of image **A** , a large number of layers are visible .
Hence it is clear , which play an important role EMF interactions in the nervous system ,
up to the determining factor in the known unresolved until now
the problem “ structure - function ” [21]. In fig . 4 shows a cross section of three
myelinated axons of different calibers and areas of the myelin sheath
four other axons . The spiral shell plates start with the inner
mezaxon . In the place of the mesaxon as a result of the closing of the outer surfaces
plasma membranes of the oligodendrocyte process , which forms the myelin
shell , an intermediate line is formed . It alternates with the main dense
line , which is the result of tight contact surfaces
the cytoplasmic membrane of the oligodendrocyte and ends on the outer
side at the level of the outer process of the so-called " tongue ". In fig . 4 is evident , that
the number of layers on different axons differ , while axons with less
contain fewer myelin layers , which can also be interpreted
shorter overall time of their activation . However , in all cases it is good
there is a clear excess of the number of myelin layers to perform
functions of electrical isolation of axons from the extracellular environment , which is
virtually the only , are taken into account at the moment .

Axon - epaptic logic

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Ephaptic (by means of an electromagnetic field - EMF) interactions
are practically an integral part of interneuronal interaction [22].
This can directly follow from both
physical ideas about the nature of EMF ,
given the strong electrical character
multi-neuronal extra - and intra-neuronal
activity , and from numerous results
neurophysiological experiments [23, 24] and
simulation results [3, 4]. However ,
it should be noted , that the effects ephaptic
in multi-neuronal activity are considered
mainly either in the influence of external fields [24],
or in the form of interdendritic interactions [25].
At the same time, the most powerful electric
a phenomenon in the functioning of a neuron is
axonal spike , which, moreover , by virtue of
its pronounced impulse form ,
rich content is enough
high-amplitude harmonic
components . In addition , given the dense
packing of some axonal fibers in nerve bundles (Fig . 5) or syncytia [26],
it can be assumed sufficiently strong interference EMI , generated
spikes spreading along them . Generation of each spike in such
tightly packed neuropils promote asymmetry
ion currents , flowing into each individual fiber (see . Fig . 2), which reinforces
conditions of their vortex formation .
We have carried out logical and mathematical modeling of mechanisms
self-processing of information by spike flows at the axonal level at
unification of myelinated axons into a nerve bundle . In the neuromodel according to [7],
fig . 6 , a neuristor network is implemented that simulates a nerve bundle .
Additional logic is given by the mutual topology of individual axons in the nerve
beam , which determines the nature and degree of their influence on each other at the moment
passing spikes .

Fig . 5. Segment of the nerve bundle with
astrocytic membrane (A)
around the group
myelinated (Mu) and
non-fleshy (N) neurites
(N ě me č ek S.).

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Fig . 6. Neuristor processor of the nerve bundle of fibers along a . with . 1439632 [7]: 1 - neuristors , 2 - neuristor cells , 3 - scaling blocks , 5 - blocks differentiation , 6 - delay elements . Shown is a 2 x 2 mesh fragment .

This influence can be expressed in dynamic synchronous down or an increase in the thresholds corresponding (according to the location of the fibers and the drawing of their activation) of individual neuristor cells of the neural network of the beam . When this field , connecting individual fibers , and forms this axonal neural network , moreover , the connections are logical in nature , realizing a dynamic synchronous continuous-valued logic .

This logic of the mutual work of the fiber of the nerve bundle differs from the traditional logic by the admissibility of collisions of the paradox ($A \to A$ U $A \to A$) , which in this case for such logic collisions are not (***P- logic*** [27]). Weaker limitations for this are revealed in the following ratios :

If in the correct structure S $\exists$ τηε literal L, $\forall$ $L_{\triangledown}$ I Inv ($Post$ (L)) = M , where : $M \neq \varnothing$,
$\Rightarrow \forall$ $A \in M$ *the* relation $A \to A$ is an admissible collision of the paradox in S (P-collision),
where : Inv (Inv (P)) = P is the inversion for the set of literals $LP_{i} \in$, for which each L_{i} is associated with L Inv (P) $_{i} \in$; $L_{\triangledown}$ is the principal ideal of L in the structure S (the set { L } U $Pred$ (L));

If in the correct structure S $\exists$ τηε literal L, $\forall$ $L_{\triangle}$ I Inv ($Pred$ (L)) = M , where : $M \neq \varnothing$,
$\Rightarrow \forall$ $A \in M$ *the* relation $A \to A$ is a P- collision ,
where : $L_{\triangle}$ is the main filter L in the structure S (set { L } U $Post$ (L)).

If in a correct structure S: $\left\{ \left(L \to L \right) \text{ I } \left(Pred \left(L \right) \right) \neq 0 \right\} \in S \Rightarrow \forall$ L_{b} P is a collision : $L_{b} \to L_{b}$ *is* admissible in S,
where : $L_{b} \in Pred$ (L) is a base literal .

For structures of a more general type may be cases , when the ratio of $A_{i} \to A_{i}$ should not necessarily , that = 0 = 1 $_{ii}$ A I A .

The waves of propagation of excitation in such a neural network have, along with usually considered convergent character (converging to one point), also divergent character (diverging from one point). Moreover, such symmetrical and simultaneous coexistence of convergent and divergent arousal tendencies is explained by their qualitative asymmetry [28]. This asymmetry is manifested in differences in the representation of convergence ,

manifested in the summation of excitations from many sources in the form EPSP or spikes and divergence , which are divergent waves changes in the thresholds of arousal . Thus , information may not be transmitted only in the form of direct excitation , carried by nerve impulses , but also in in the form of gradual spatial - wave changes in fiber thresholds , spread along the nerve bundle in the longitudinal and transverse directions along its volume . The emergence and conduct of spikes in this case can serve the mechanism for detecting the current values of the thresholds , playing the role of the inverse (inversion) logic [29]. It is shown , that the mutual influence on the value of thresholds by factors (EMF spikes), which are the products of these very values of thresholds , contributes to the emergence of steadily circulating nonequilibrium " threshold waves " forming stable foci of low threshold states of the membranes of some axons in the nerve bundle (Fig . 6). it can determine the self-organization and self-sustainability of a certain tonic state of nervous activity autonomously at the level of the most nervous beam . Neuromodel will also allow you to display cross-cut longitudinally - parallel propagation of microcomponents of the adhesion along one axon , simulated by a quasi - neural network neuristor structure, taking into account the volumetric spike wave .

Discreteness of spike in vortex formation

In accordance with the shown complex volumetric structure of the spike , it can be represented as the sum formation , consisting of elementary discrete components . The conditions for their generation and propagation are not uniform in the volume of the axon due to the heterogeneity of the intracytoplasmic environment distribution , all the more , given the numerous inclusions in axoplasm . These facts were modeled by us in a neuromodel [9] in Fig . 7.

Fig . 7. Axo is a somatic neuroprocessor according to a . with . 1306368 [9] contains n blocks 1 synapse modeling , each of which consists of 2 matching elements , scaling factors 3 and delay elements 4; block 5 of modeling soma , which includes weight elements 6 and input adders 7; m blocks 8 called postsynaptic potentials ; m shapers 9 spikes , each of which consists of a comparison element 10, a pulse shaper 11 and a shaper 12 threshold value , the output adder 13, the output of which is axonal output 14. Corresponding blocks 7-9 form m excitation nodes 15, and block 8 designed as a controlled integrator .

Each of the adders 7 receives signals from all *n* outputs of the blocks simulate synapse 1 with appropriate weights . This corresponds to the real neuron , in which the signal from each synapse , propagating , reaches each excitable section of the membrane of the soma or axon . Moreover, its amplitude at the moment achievement of - or excitable area is defined by location the latter on the membrane , which is reflected in the model by the value of the transfer coefficient corresponding weight element 6. At the same time , the propagation paths excitations from synaptic contacts to one excitable site are different , therefore , different parameters and the signals , coming from this portion different synapses, all other things being equal (the parameters of the synapses themselves and conditions for their stimulation), which is reflected by the selection of weight elements 6 at the inputs each i- th adder 7. Each microcomponent spike generated the local area of the somatic membrane is summed up in the intraaxon

space , forming , thereby , the resulting spike , pervasive
along the axon to the cell - targets . The number of shapers 9 spike , simultaneously
generating pulses , is determined by the number and configuration of activated
synapses , as well as quantitative and qualitative indicators of signals ,
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coming to synaptic inputs , and the parameters of the neuron itself , in particular
the number and localization of excitable nodes on the soma 15. The proposed neuromodel
can reproduce a cross section of an axon , and non-simultaneous generation
microcomponents soldering contributes to the asymmetry of the potential - current
field in the plane of the axon section , which enhances the conditions of ion - electronic
vortex formation .

Myelin and the dynamics of its formation

The myelin sheath is a strictly ordered lipoprotein system ,
its formation and regression also reveals quite clear patterns .
In the peripheral nervous system (PNS), each internodal segment (IS)
- the space between the nodes of Ranvier - corresponds , as a rule , one
Schwann cell . In the central nervous system, in comparison with other departments, the lowest
quantitative relationship between myelinated fibers and
oligodendroglia . For this reason, one process of an oligodendrocyte can
participate in the education of another internodal segment as well due to
the possible remoteness of the oligodendrocyte soma from the myelin
shell . However , the continuity of the plasma of the glial perikaryon and myelin in
anyway retained , i.e. myelin lamellae have the same properties ,
as the plasma membrane of the corresponding glia . All Schwann cells
(SK) corresponding to the axon appear only when it reaches its target ,
and it is a morphogenetic factor , as is , that axon myelination
begins with reaching its diameter in the PNS 1-2 microns and 0.3 microns in the central nervous system
. Before
all , myelination occurs in the axons , which reach their maximum
diameters in an adult organism , which indicates their longest
functioning in the form of electro - ionic activity . Increase in the number of ICs
occurs only in the process of myelination of the axon , in the future, with growth
the latter without the formation of myelin , only lengthening of the IS can occur .
Myelin at the ultrastructural level is a system periodically (with a period
12-17 nm) of alternating main dark lines and light broad intermediate
layers .

Fig . 8. Ultrastructure of myelin . A - the formation of its layers by a Schwann cell (SC)
(Sketch with electron - microscopic image after fixation preparation
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osmium hydroxide . PM - Schwann cell plasma membrane , M - main
line , I - intermediate line , S - cytoplasm of the SC ; B - molecular model of myelin
and plasmalemma SHK according to Sjöstrand; C - the location of the complex of lipid molecules : P -
protein layer , L - lipid layer (Elfvin, Finean).

A thin discontinuous layer is found inside the intermediate layer
intermediate line . The myelin lamella consists of two glial membranes and
generated by the mesaxon , which spirally covers the axon and layers on itself
myelin lamellae (Fig . 8). Myelin lamella consists of a complex in an orderly
bound lipid molecules - phospholipids (42%), cerebrosides (28%),

cholesterol (25%) and sulfatides (5%). Myelin contains much more
fats , than other membranes (78% dry substance myelin). Most
myelinated fat has a half-life of 6-12 months , for proteins - 35 days .
The main myelin line arises from the fusion of the inner sheets of two membranes with
gradual squeezing out of the intraplasmic glial medium . System
myelin membrane is in the crystalline phase . Intermediate formation
line is accompanied by the fusion of the two outer sheets of the plasmolemma with
the subsequent disappearance of the environment . Lipid band thickness
is 5-5.5 nm . The outer layer , consisting of proteinaceous molecules forms
hydrophilic surface . Polar amino , located on
the surfaces of the membranes give rise to an electrical surface charge . To them
include sialic groups of polysaccharides , phosphate '84 | {groups of phospholipids ,
carboxyl protein groups when they come into contact with the aqueous phase . Phosphate
the groups are negatively charged and located at the ends of the molecules
phospholipids .

I

II

Fig . 9. I: The initial stages of myelination in the central nervous system . VO - process of oligodendroglia . Me - mesaxon (A. Peters). II: The initial stages of myelination in the PNS . S - Schwann cell (SC) surrounding the group of axons N. B - division of the SC with the formation of long shoots , penetrating between axons . As a result, C - E to each axon corresponds to one glial element . (Elfvin).

They create a layer with a thickness of 1-2 nm , however , sufficient to respond to
external electric field , for example , from a spike discharge . Layer thickness can
be calculated in nanometers according to the Debye - Hückel equation :, where : i -

ionic strength of the solution . In the initial phase of myelination, there is a doubling of
mezaksona - plasma membrane of glial cells (Figure 9 I. A). Wherein
the fusion of the outer protein layers of both surface membranes of glia occurs .
Further, the mesaxon is lengthened and spiral wound onto the axon (Fig .
9 I In), moreover , myelination mechanisms are the same in the PNS , and in the central nervous system . Then
the cytoplasm of the glia is displaced almost throughout its entire length and remains only in
external and internal Mesaxon languages . However , sometimes islets also remain
cytoplasm , which can then become the basis of Schmidt - Lanterman notches .
Sometimes one SC surrounds a group of axons (Fig . 9 II), and then it divides ,
as a result of which the axon acquires its own glial membrane . Before
mielogeneza beginning in the cytoplasm is clearly marked , that glia creates myelin
only in the presence of a neuron , and this can be confirmed by an electrochemical
the nature of stimulation of myelogenesis by the generation of axonal spikes . Myelination is not
is simultaneous (Fig . 10) and begins earlier in phylogenetically more
old systems , which can also be associated with long-term memory , including
number , genetically determined . Neurons , associated with higher cognitive
functions , are myelinated by the latter , which determines the connection with the priorities
long-term memory of genetic programs and temporal sequence
formation of electrical activity of neurons in various parts of the nervous
systems in ontogenesis .

Fig . 10. Rat optic nerve , magnification 47000 (H de F. Webster, A. Peters, SL Palay). Some axons do not yet have a myelin sheath (A), while other fibers (A_1 - A_5) are at different successive stages of myelination . At the initial stage A_1 oligodendrocyte surrounded appendage , which forms mezakson (Vi). As myelination, this process forms a spiral . $C_{in\ the}$ - internal and C_n - external (" language ") ends of the spiral . Ol - oligldendrotsity , ool - process oligldendrotsita , Al - process astrocyte .

Furthermore , it is known , that the lamella in CNS myelin about 10% thinner , than PNS . Myelination in the central nervous system is a more complex process and much less stereotypical . The growth of the myelin sheath in the central nervous system occurs in the terminal regions
spiral formation , which is confirmed by the mutual arrangement of the outer " Language " and internal mezaksona , arranged , as a rule , in one quadrant .
This proves , that the growth of the myelin sheath does not occur continuously , but periodically , and can also confirm a connection with electrical activity axon . The sequence of growth stages in the CNS shows some variation .
In some cases, the cytoplasm disappears from the glial processes at the very beginning. myelogenesis even before the axon is completely surrounded by these processes . At the same time, the main
the dense line is formed earlier than the intermediate line , and the processes surrounding the axon glia become dumbbell-shaped in cross section (Fig . 10 A_1) due to moving the bulk of the cytoplasm inside the terminal extensions . In that the stage of formation of the mesaxon is absent and the myelin spiral has the form coils , consisting only of the main dense lines . Intermediate line can occur already in the course of further myelination when external surfaces of adjacent turns . Slippage may also occur in the central nervous system. turns of the myelin spiral relative to each other . Significant increases diameters of axons , for example , several times with experimental edema , not lead to damage to the myelin sheaths , which is impossible in the absence slip between layers .

Myelin retraction

Oligodendroglia has a very active trophism , even more active in white substance , than gray . This indicates a fairly large energy consumption , aimed specifically at the maintenance of the myelin sheaths . Hypoxia , causing ischemia of the nervous tissue , has a negative effect on oligodendroglia , in as a result of which its nutritional damage may occur , which leads to honeycombed disintegration of myelin , starting with the main line . With Wallerian degeneration, a completely different mechanism operates , initially influencing not on oligodendroglia , but directly into myelin , while it is split the intermediate line , that is, the processes of the glia are freed from the connection with myelin . This increases the activity of such enzymes , like β - galactosidase , β - glucosidase, and peptidase (CWM Adams [30]). Cholesterol metabolism (the content of which in the brain in 10 times more , than in other organs and tissues) myelin is minimal . It is known also , that glycerophosphatides myelin exhibit relatively active metabolic changes and in normal condition . However , reliably
It is known , that the in vivo myelin lamellae are not static

education , but respond to various physiological stimuli , in particular , permanent flaking or merging .

Interaction of EMF of the spike field with oligodendroglia

Glial dysfunction can lead to abnormal functional
states of neurons . This is observed , in particular , with demyelination in the case of
some genetically determined diseases with a reduced content
enzymes of myelin metabolism . There is also a strong reaction of glia to
regressive changes in neurons . So with the primary destruction of the axon , a ,
consequently , impairment of the function of conducting spikes , there is a secondary
degeneration of the myelin as well , as the transection of the axon . This order of changes
is the fastest and most pronounced , which can also serve
indirect confirmation of the connection of the electrical activity of the axon with the development and
maintaining the integrity of the myelin sheath . Islets of cytoplasm of SC and
oligodendroglial , inside the myelin sheath , may be involved , as the
the basic element , in phagocytosis degraded parts axoplasm . it
occurs by immersing them in an axon and subsequent cytosegregation of the residues
axoplasm . With electrical activity of neurons, glial cells behave
passively , the value of their membrane potential exceeds the neural potential
rest (–60 mV) and is usually –90 mV . Depolarization of the glial membrane
occurs with an increase in the external concentration of K^+ even by a small amount ,
like a sensitive potassium electrode .

Fig . 11. Cat cerebellar cortex : N - neuron , Ac - astroglia , AV - thick glial
processes , O - ligodendroglia . Arrows indicate receding glial lamellae .
Magnification 10,000 (Wolff).

The membrane potential of neurons is much less sensitive to changes
external concentration K^+ . this also results in strong hydration
glial cells , exceeding neuronal sensitivity by 5-7 times . On the
electron micrographs, this is reflected by a lower electronic
density of preparations (Fig . 11). Therefore, of all the cellular systems of the brain, this
contributes to the highest level of sensitivity to pathological
impact . Surface electrical resistance of the glial membrane
has a wide variation depending on the type and function of glia , as well as conditions
metabolism and is intermediate between resistance
intercellular space (4 Ohm / cm^2) and the resistance of the neuron membrane (5
kOhm / cm^2). Glia ion metabolism is more active , than the metabolism of the neuron , that
confirmed by increased activity of ATP - ase , activated by sodium ions and
potassium . This mechanism is directly connected through the extracellular environment with
axonal metabolism , most pronounced at the time of the passage of the adhesion
along the axon . The movement of charged ions Na^+ and K^+ can significantly
influence the EMF spike , which is powerful enough . Glia marker protein - S100,
and specifically, glial metabolic reactions are induction
glycerol - phosphate - dehydrogenase by cortisol and induction of lactate - dehydrogenase (LDH)
catecholamines . The latter act on superficial adrenergic
receptors that increase the level of cAMP inside the cell , which , in turn ,
causes a change in transcription and an increase in LDH content . Also known
glial GABA grip , allocated to the neurons , thus , glia acts
a regulatory factor in the intercellular space , which is able to model
postsynaptic response . The activity of glycolysis in neuroglial cells is much
times the activity of oxidation processes in the Krebs cycle , which causes

reduced , in comparison with neurons , oxygen consumption by glial cells . When the passage of the spike along the axon of the neuron is accompanied by an intense release of K^+ ions into the intercellular space between neurons and glia . Given the increased sensitivity of glial metabolism to K^+ ions , its increased hydration (then there is mechanical plasticity) and the ability of intensive metabolism under reduced oxygen consumption , it can be concluded , that the regulation gap junctions [31] of the glial processes with the axons of neurons are carried out exclusively from the side of the glia when this is initiated by the activation of K^+ flows , that is spike generation . This can also be attributed to islets of glial cytoplasm in myelin and myelin itself , as a specific end of the processes oligodendroglia . The perinuclear cytoplasm of the SC is characterized by the presence of π - granules (protagonistic Reich granules), which are found only in humans and some large mammals and appear in the second - third year of life . FROM their number increases with age , but the most interesting thing is that they are found in only those SCs that have already formed myelin sheaths and at the same time found a clear correlation between increasing their number in the CC , which form thicker myelin sheaths . Also known is the fact that migration and multiplication of glia with increased stimulation of neurons and their high-frequency discharges , for example , during and after excessive motor load of spinal cord motor neurons and increased afferent stimulation cerebellum [32-33].

conclusions

1. Analyzed and modeled on numerous existential neuromodels a complex dynamic volumetric structure of the spike , spreading along the axon and significantly affecting the character this spread and its result .
2. Using simulation it has been found , that , extending along the length of axon , the areas of excitation in the cross section experience rotation , that is, a kind of potential is formed - a current " vortex ".
3. It is shown , that the role of myelin as the insulator has apparent redundancy in the sense such a large (up to 400 layers !) number of axon “ wraps ” , as ontologically , and ontogenetically .
4. The most important role of potential vortices in the dynamic formation and further maintenance in the appropriate form of myelin shells of axons , in connection with which the latter can be a substrate for traces long-term memory at the neural level [34], which may have , inter alia , important in understanding the mechanisms of development of the corresponding pathologies , such as Parkinson's and Alzheimer's diseases [35].

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