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INVESTIGATION OF CHEMICAL SUBSTANCES OF TERRESTRIAL ARTHROPODS

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Millions of *Arthropods* are inhabitants of the Earth and some biochemical products which they produce are valuable for human practice. The aim of this work was to summarize current information about chemical substances produced by *Arthropods* such as venoms, toxins and some other chemical compounds that may be used in practice. Today such products are obtained and purified using standard biochemical methods. In this article, the information about species of the terrestrial *Arthropods* – producers of substances acting on the nervous system and used in electrophysiological investigations is presented. Some versions of arthropods' toxins classification and the table with *Araneids* toxins and effects they occur are suggested as well. Main attention was paid to some *Araneidae* venoms and toxins that block synaptic transmission in glutamatergic synapses. A review of chemical composition and some biophysical properties of such venoms and toxins was suggested and their chemical structures namely of toxins from spiders of *Nephila* family and toxins from *A. lobata* venom were described. Some biophysical properties of *Araneidae* venoms and toxins are characterized. Other components of *Arthropods'* venoms were also observed. Contemporary applications of such chemical compounds in agriculture and in the environmental monitoring systems were considered as well. The obtained results evidence that the terrestrial Arthropods is a valuable source of chemical compounds for biophysical laboratories and their great potential has to attract more attention of investigators.

Keywords: Arthropods' venoms, toxins, receptor antagonists, transmembrane electric current

Millions of *Arthropods* are inhabiting the Earth and they can produce some biochemical products that are valuable for human practice is. Pharmacological modification by toxins from the nature an important approach in electrophysiology for membrane receptors study. For example, a significant progress has been achieved in acetylcholine receptors study due to their experimental investigations with bungarotoxin. The same phenomenon has happened to toxins obtained from one group of *Arthropods* – *Araneidae* spiders; they are considered as very promising for glutamate receptors study [16, 20, 29, 59]. It is well known that glutamatergic type of signal transmission in nervous system is widely spread in nature. It was found in many organisms, even in the phylogenetically distant ones. Toxins from *Araneidae* spiders are characterized by high specificity to glutamate channel-receptor complex (CRC) that has been achieved during millions years of evolution [16, 20, 29, 59]. This specificity makes them an invaluable tool for studying the molecular nature of numbers of physiological phenomena in animal nervous system (NS). Among the most important tasks of the physiology of synapses, one can mention mediator identification, finding of the co-relations between the mechanisms of membrane channel-receptor complex (CRC) functioning and its structure, complete understanding and adequate simulation of transmission mechanism in the motor neuronal junctions, etc. An important approach to solution of this problem was a search for antagonists that can selectively block specific types of synaptic transmission, in particular, with a certain type of membrane receptor. An interest to toxins of biological origin is constantly growing among neurophysiologists and biophysics. These toxins have several advantages over snake toxins, such as low molecular weight and simple chemical structure. These qualities allow to conduct a targeted synthesis of homologous substances and investigate their effects on glutamate receptors.

Applications of different zootoxins for the neurophysiologic investigations were demonstrated in the monographs by professors P.G. Kostyuk, O.A. Krishtal, I.S. Magura, I.V. Skok [58, 63, 81]. Later on, these investigations were continued by the representatives of their scientific schools in collaboration with foreign colleagues [2, 36]. Nowadays, the results of studying some toxins from *Arthropodae* (including *Araneidae* toxins), as well as other similar phenol- and indole- derivatives were applied in agriculture [16, 20, 29, 59] and in ecological monitoring of environment [38–57], and were defended by patents [46–57]. It is necessary to emphasize that real increase in study these toxins happened in 1980th – mid 1990th. Because of the importance of studying *Arthropodae* toxins [1–19, 21–37, 60–97], a review is devoted to fundamental works of different authors who studied these toxins.

The present work is aimed at deep investigation of scientific literary sources about Arthropods' venoms, toxins and other their compounds important for biophysics, biochemistry, biotechnology, and related branches.

Venoms of the terrestrial Arthropods as a source of chemical compounds for biophysical laboratories. Many representatives of the Earth terrestrial and marine fauna contain poisons acting on animal nervous system. Among them there are microorganisms [66], fishes and marine animals [13, 73], snakes [25, 60, 81], and many predatory arthropods [19, 65, 77, 83, 84, 64, 96]. These organisms use poisons to kill their victims. Poisons' compositions and their chemical structure were selected to achieve the goal during million years of evolution: to influence the victim as effectively as possible.

A consequence of this was a high degree of specificity of toxins' structure, the composition of poisons, and their action at the molecular level [28]. This specificity makes them an invaluable tool for studying the molecular mechanisms of physiological processes in animal nervous system.

The study of terrestrial arthropod toxins has started in the 1980th [30, 31, 77, 91, 92]. For today, some mechanisms of toxins action on the NS of invertebrates and vertebrates have been studied [28, 77, 83, 84], and molecular structure of a number of toxins have been decoded [5, 23]. Besides, their synthesis in laboratory conditions has been done [26, 87]. These works became class because poisonous species are presented in the main groups of terrestrial arthropods, and approximately all of them produce toxins that influence specifically the nervous system (NS) [96].

The greatest significance as producers of biological toxins demonstrate three classes of the arthropods: polygons (*Myriapoda*), insects (*Insecta*) and Aranei (*Arachnida)* [77, 96]. Among the most important toxins produced by *Myriapoda*, is genus *Scolopendra* [96]. Among *Insecta*, the most studied toxins have some species from the family *Sphecidae*, mainly *Philantus triangulum* [8, 79, 89], and some *Braconidae* species [96]. A variety of toxins affecting NS is produced by the representatives of *Arachnidae* family – scorpions (*Scorpiones*) [64, 65] and spiders (*Aranei*) [14, 19, 28, 72, 88].

More than 20 000 species of spiders *Aranei* are known. They are all producing poisons, excluding *Uloboridae* family that lost their poison glands [96]. They are predators who either paralyze or kill their victims by poisons. The action of poison on victim's NS is determined by a spider is style of life. So, spider-hunters (*Labidognathous*) and jumping spiders (*Salticidae*) do not make the web (or it is very simple). They usually hunt on the leaves and vertical surfaces, and in order not to lose their victims they must instantly kill them. Therefore, they have very strong poisons with irreversible effects. The spiders that make the webs (families *Araneidae, Theriidae*, and others) are the alternative. It is enough for them to paralyze their victims, often to "preserve" them as meal. Their poison may be weaker and many of its components are weakly reversible [19, 96].

The arthropods' venoms have a heterogeneous chemical composition. Some of them contain the components acting on different substrates. For example, they may cause pre-, and post-synaptic effects [37, 91]. Other types of arthropods' poisons are more homogeneous taking into account chemical structure of their components and their physiological action [12].

Classification of arthropod toxins. All toxic substances of spiders can be divided in three groups according to the mechanisms of their action.

1. Ion channel antagonists. Spiders' neurotoxins from *Segestriidae* family interact specifically with sodium channels of electroexcitable membranes of vertebrates and invertebrates. Toxins slow down inactivation, and then block sodium currents completely [83, 84]. Similar properties have some scorpion toxins [64, 65]. Toxins – antagonists of calcium channels were found in the venom of *Hololena*, *Plectreurus*, *Alegenopsis* spiders [10, 11, 28].
2. Toxins – formers of channels. They are obtained from spiders' poisons of some species of *Latrodectus* genus of *Theriidae* family. The most known among them is *Karakurt* spider uhose another name is "Black Widow" *(L. fredecimguttatus).* Spiders of this family produce powerful proteases and toxins (neurotoxins).

They form channels for calcium, potassium, sodium in belayed phospholipid membranes. They are toxins with high molecular weight (4–100 thousands Da) and complex chemical structure [27, 83, 84, 90]. These toxins are used widely in laboratory studies, since they allow to simulate *in vitro* the work of ionic channels [15].

3. Toxins – chemoreceptors' antagonists. From spider venoms of *Araneidae* family specific antagonists for cholinoreceptors [91–94, 83, 84] were obtained as well as glutamate membranes receptors of neurons and muscle cells of vertebrates and invertebrates [1, 28, 30, 31, 83, 84, 91].

According to the place of their action, all toxins care divided into substances of pre- and post-synaptic action. The poisons of *Microbracons*, scorpions *Androctonus*, spiders *Steatoda*, *Asptoptichus*, *Latrodectus* belong to the toxins with the pre-synaptic effects [11, 64, 65, 96]. Toxins of the post-synaptic action include a number of substances isolated from poisons of spiders *Argiope*, *Araneus*, *Nephila* [12, 30, 31, 95]. However, with such distribution of close substances may be not correct. For example, the spider's poison from *Lityphantes paukillianus* increases a spontaneous mediator release from the presynaptic fibers by increasing their permeability for ions, mainly for calcium [91]. On can contrary, the toxins of *Plectreurus* spp. spiders cause a complete block of synaptic transmission due to the inhibition of calcium receipts in the presynaptic terminals [11].

Araneidae toxins that block a synaptic transmission in glutamatergic synapses. Classic example of a successful use of toxins for study of synaptic transmission and membrane receptors has been demonstrated on an example of the cholinergic synapses. Electrophysiological studies have shown that a neurotoxin from cobra binds specifically and irreversibly to postsynaptic membranes of the cholinergic synapses. This neurotoxin was used in early 1970's to isolate the cholinoreceptor from synapses of different origin [60, 81, 89]. Great achievements in the study of cholinoreceptors structure and its functions are due to a detection and use of another highly specific ligand – α-bungarotoxin and a number of other snake toxins [81].

A successful use of neurotoxins stimulated a study of zoothoxins affecting the synaptic transmission in other types of synapses. The toxins that block a transmission in glutamatergic synapses were of particular interest of investigators. Despite an intensive study of synapses of this type, very specific glutamate receptor antagonists have not been found during a long time, until the 1980th [62, 74, 75].

On early 1980th studies on the entomophags' venoms that block glutamatergic transmission appeared. These poisons were obtained in Japan from spiders *Nephila clavata* the Soviet Union from *Argiope lobata* spiders [1, 30–33] and in [23, 83, 86, 91]. The properties of these venoms and toxins were studied in details. Later, toxins with properties of glutamate receptors' antagonists were found in poisons of the *Araneus gemma*, *A. trifasciata* and other spiders [12, 28, 35]. On Table, a list of Araneidae species that produce antagonists of glutamergic synapses are demonstrated. Yet this list can not be considered as complete one. Representatives of this family are widespread: *N. clavata* is an inhabitant of the Japanese islands, *N. maculata* live in Papua of New Guinea, eight species, from which *A. lobata* is the best known are inhabitants of ex-USSR territory (Caucasus, Central Asia), *Argiope aurantia*, *A. florida*, *A. trifsciata*, Araneus gemma, and some other species are from the New World. So, many researchers around the world can work with *Araneidae* toxins.

Toxins from *Araneidae* and their biological effects

Токсини з *Araneidae* та їхні біологічні ефекти

Species of spiders	Venoms, toxins	Effects of venoms, toxins (known or supposed)
Fam. Araneidae *Argiope trifasciata*	argiotoxin$_{636}$ argiotoxin$_{622}$ argiotoxin$_{659}$ argiotoxin$_{673}$	Dose-dependent blocking of open glutamate channels in locusts' muscles. Block of some closed channels or competitive antagonism was supposed. Allosteric modulation of glutamate binding with CRC is possible.
Argiope lobata	argiopin$_{636}$	Blocking of open channels of CRC in muscles of locusts and larvae of meat fly. Possible blocking of closed channels or competitive antagonism. Blocking of open channels of nicotinous CRC in frog skeletal muscle.
Araneus gemma *Argiope florida* *Araneus andreusi** [8]	the same as for *A. trifasciata*	the same as for *A. trifasciata*
Argiope aurantia	argiotoxin$_{636}$	Dose-dependent blocking of non-NMDA receptors in the central nervous system of chicken. Dose-dependent blocking of transmission in glutamatergical nerve-muscle junction of locusts.
*Araneus diadematus** [95]	Integral venom	Induction of glutamate-dependent ion currents in central nervous system of chicken.
Neoscona arabeska	Venom (after boiling)	Weakly reversible blocking, dose-dependent blocking in the glutamatergic neuromuscular synapse of locusts. Reverse blocking of non-NMDA transmission in central nervous system of chicken.
Nephila clavata	JSTX-3	Irreversible antagonist of glutamate receptors in different biological species.
Nephila maculata	NSTX	The expected effect is similar to JSTX-3.
Fam. Oxyopidae *Peucetia viridens*	Integral venom	Reversible blocking of transmission of non-NMDA type in the central nervous system of chicken.
Fam. Plectreuridae *Plectreury tristes*	PLTX	Long-term blockage of presynaptic calcium channels in invertebrates.
Fam. Alegenidae *Alegenopsis aperta*	AG1 AG2 T1 T	Long-term blockage of calcium channels in nervous system. Reversible blockage of nerve and heart calcium channels. Anticonvulsant activity. Paralyzing insect toxin: presynaptic action. Paralyzing insect toxin: presynaptic action.
Hololena curta	HO1 (m.w. ~ 5000) Hololena -toxin (m. w. ~ 16000)	Long-term blocking of transmission of non-NMDA type in the central nervous system of chicken. Long-term blockage of presynaptic calcium channels in invertebrates .
*Atrax infensus** [7]	Integral poison	Swelling of tissues, increased secretion of histamine and 5-hydroxytreptamine in mammals.

Comment: Table is completed on the basis of material from [28]. Additional data are marked with *, with indication of the sources

Примітка: Таблиця укладена на основі матеріалу з [28]. Додаткові дані позначені *, зі зазначенням джерел

As antagonists of glutamatergic synapses, *Araneidae* toxins are of great value. Numerical individual toxins have been obtained and identified from different venoms. Some of them have a complex structure [12, 22].

They all are antagonists of glutamate receptors, but they differ in their characteristics of blocking. Reasonably, the application of these homologous structures of toxins allowed a progress in study of glutamate receptors. Chemical structure of some *Araneidae* toxins is shown on Fig. 1 [22, 23, 45–57]. For practical human activities, it is even more important that *Araneidae* toxins have a relatively small molecular weight – 400–700 Da and simple chemical structure [5, 12, 23]. Toxins of other arthropods are more complex, for example, the latrotoxin has a molecular weight more than 130 kDa, toxins of *Hololena* spp. spiders – 5–10 kDa [28]. This facilitates a study of *Araneidae* toxins and makes it possible to synthesize them both in laboratory and in industrial conditions [18, 26, 87]. Synthetic *Araneidae* toxins can be used in medicine and pharmacology as medical preparations, as well as pesticides in agriculture. A particular advantage of such pesticides is that the mechanism of pests populations regulating is close to natural [28, 62, 77].

Brief review of chemical composition and biophysical properties of Araneidae venoms and toxins. Chemical structures of toxins. In parallel with electrophysical studies of the properties of Araneidae venoms and toxins, the investigators improved the methods of obtaining individual toxins from the integral venoms. For today, the molecular weights and chemical structure of different *Araneidae* toxins were investigated. For applied purposes, there were not enough to have small quantities of toxins obtained from natural sources. Until 1988, three most important and the most studied araneid toxins were synthesized: JSTX-3, NSTX-3, and argiopin (AR).

A. Toxins of spiders from the Nephila family. Japanese investigator Aramaki [5] obtained and purified a number of toxins from venoms *A. clavata*, *N. maculata* by HPLC on 1986. Venom N. clavata contains four components that possess toxic properties: JSTX-1, JSTX-2, JSTX-3, JSTX-4. The poison of *N. maculata* contains three components: NSTX-1, NSTX-2, NSTX-3. The main active agent from *N. clavata* venom was toxin JSTX-3 whose concentration in the venom was the highest [5]. The chemical formula of this toxin is given on Fig. 1. Its molecule consists of dihydrophenylacetat group coupled with asparagine and through it – with polyamine [5, 28]. Other toxic components differ between themselves by a structure of polyamines, for example, in JSTX-4 molecule, argiopine to JSTX-2 is coupled with a peptide bond [5]. In the venom of *N. maculata,* the main active agent is NSTX-3 (Fig. 1) that is very similar to JSTX-3 and 2,4-dihydrophenylacetylsparaginil.

B. Toxins of A. lobata venom. A number of investigations were devoted to isolation of the poisonous fractions from *A. lobata* venom containing toxins of various effects. The main active component of the venom is argiopin (AR) (Fig. 1), whose concentration was the highest [12]. Capability of this venom to block glutamate receptors was largely determined by the properties of argiopin [62].

The molecular weight of the obtained substance – argiopin – is 636 Da. Its chemical structure was decoded, and formula is shown on Fig. 1. It is a 2,4-dioxyphenylasparagin that is linked via polyamine with terminal arginine. In addition, from venom *A. lobata* at least 5 compounds were obtained (Fig. 1). They are similar to those in their biological activity. Like argiopin, they were isolated by the HPLC method [22, 23], but from other

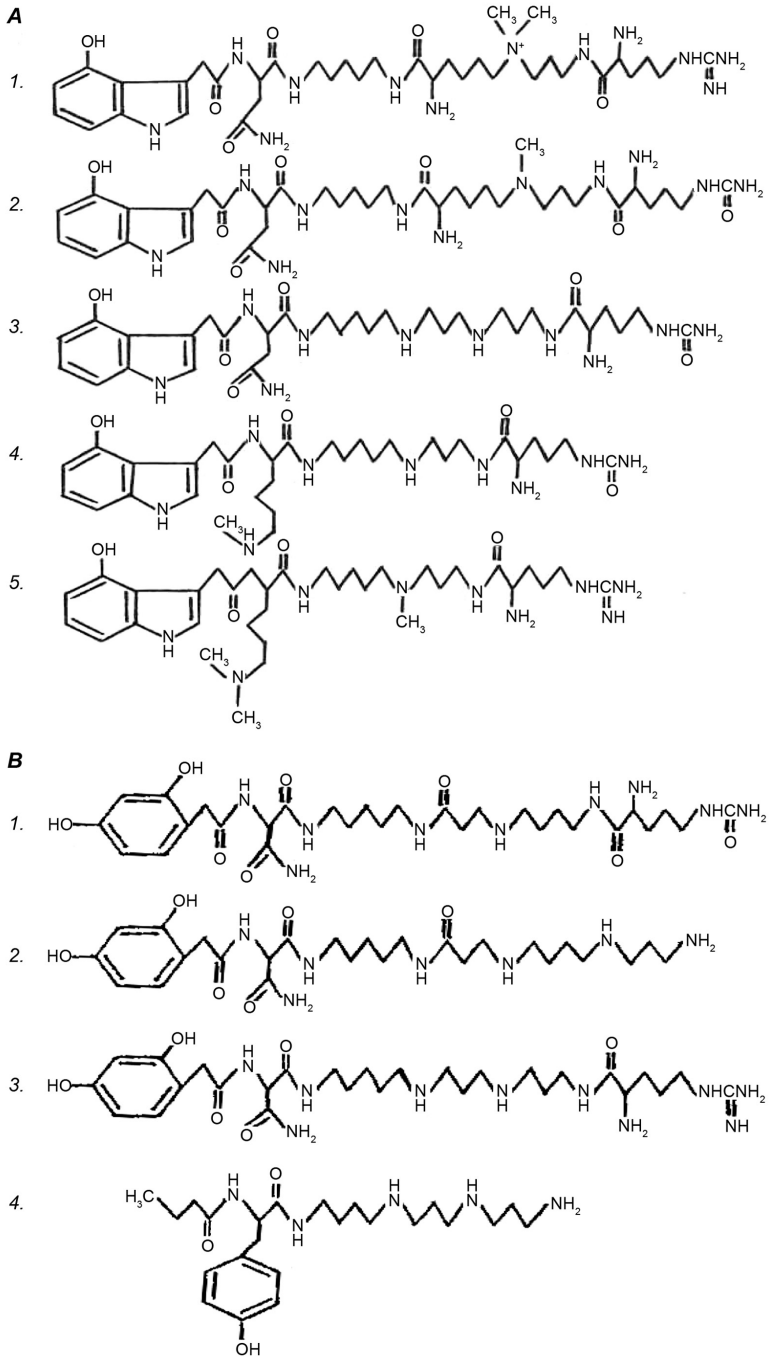

Fig. 1 Chemical structure of some toxins from *Araneidae* [23]: *A* – Family of toxins from *A. lobata* – argiopinines ARN. *B* – *1* – JSTX-3; *2* – NSTX-3; *3* – argiopin AR; *4* – PTX_{433}

Рис. 1. Хімічна структура деяких токсинів *Araneida* [23]: *A* – Сімейство токсинів з *A. lobata* – аргіопініни ARN; *B* – *1* – JSTX-3; *2* – NSTX-3; *3* – аргіопін AR; *4* – PTX_{433}

fractions of venom. Argiopin was present in fraction 1; and fractions 3.7–0 were the individual compounds. Other components were identified as well.

Biophysical properties of Araneidae venoms and toxins. Because of a format of current publication, biophysical properties of *Araneidae* venoms need more detailed observation than we would like to present now. It should be mentioned that electrophysiological experiments demonstrated an ability of JSTX-3, NSTX-3, argiopine (argiotoxin$_{636}$) of binding the glutamate receptors of the post-synaptic membrane, blocking the processes, normally initiated in it by the glutamate [23, 69, 78, 92, 93]. JSTX-3 can be accumulated in the area of synaptic contacts [24].

It was shown that JSTX-3 irreversibly blocks electrical signals' transmission in the glutamatergic synapses, and argiopine (argiotoxin$_{636}$) can be removed with partial restoring of transmission characteristics [62, 69]. Argiopine (argioxin$_{636}$) is bound mainly by the activated glutamate CRCs. It is cousidered [28] that argiopin can bind to inactive CRC, than transfer it in the presence of the glutamate into the activated state with a subsequent blocking of the activated form. The results of most electrophysiological studies demonstrate that JSTX-3 and argiopine (argioxin$_{636}$) interact with glutamate receptor in a noncompetitive mechanism [8, 12, 35, 80]. Some numerical characteristics of blocking glutamate receptors by various toxins have been described [2, 36, 46–57].

The first attempt to isolate the glutamate receptor was done using a mixture of toxins from *A. lobata* with its further incorporation into a bilayed phospholipids membrane was done in 1983. Later two families of toxins have been isolated from *Araneidae* venoms that are the derivatives of phenolic and indoleacetic acids. The best-studied toxins are from the first family that include JSTX-3, NSTX-3, argiopine (argiotoxin$_{636}$). The *Araneidae* venoms contain complex of toxins whose concentrations are diverse in different species. The argiopine (argiotoxin$_{636}$) occurs in the venoms of the most *Araneidae* species [12, 22, 28].

Most antagonists of the glutamatergic synapses of *Araneidae* venoms are low molecular weight substances of 400–700 Da. Chemical structure of some of them was studied. Such toxins as JSTX-3, NSTX-3, argiopin and some analogs were synthesized [18, 26, 87] (Fig. 1).

Venoms and toxins of *N. clavata* and *A. lobata* were studied in O.O. Bogomoletz Institute of Physiology under O.O. Krishtal supervision. All abovementioned conclusions about the effects of venoms and toxins from *N. clavata* and *A. lobata* were verified, and new information was also obtained [2, 36, 46–57]. It was demonstrated that all studied *Araneidae* venoms and toxins (*N. clavata* integral venom and toxin from it JSTX-3, as well as toxins from *A. lobata* – argiopin, argiopinin 1, argiopinin 2), blocked the glutamate- and kainate-activated ionic currents in membranes of the pyramidal neurons of the rat hippocampus (Fig. 2). All antagonists decreased the maximum amplitudes of chemo-activated currents without affecting the kinetics of their activation and desensitization [2. 36, 46–57]. Description of some such obtained results because of their large volume is supposed to be given in future publications.

Other components of Arthropods venoms. A number of studies on the chemical composition of arthropods venoms is not enough, although the physiological effect of venoms is due not only to the toxins that are part of their composition.

During a study of some arthropods from Central Asia (spiders, tarantulas, scorpions, scolopendra), the activity of numerical enzymes that are the part of the venom has

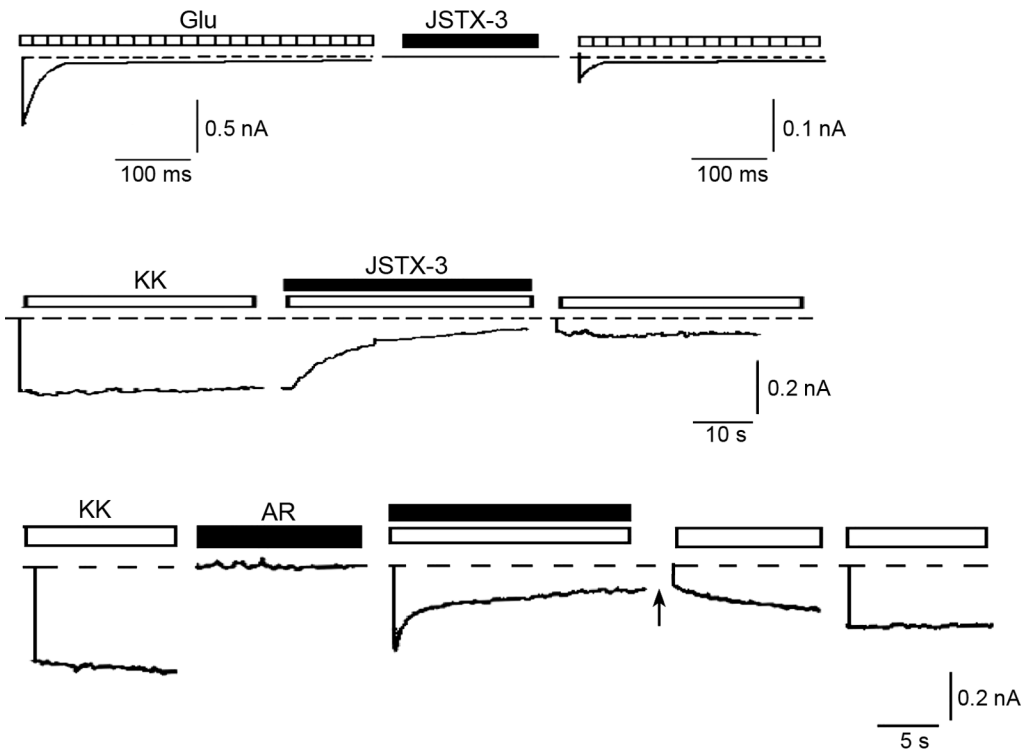

Fig. 2. Toxins JSTX-3 (from *Nemphila clavata*) and AR (from *Argiope lobata*) influence on transmembrane electric currents. Toxin JSTX-3 blocked glutamate-activated (Glu, above) and kainat-activated (KK, middle) transmembrane ionic currents. After receiving the control response to KK, toxin JSTX-3 was applied by the background of the KK-activated current. Concentrations of Glu and KK were 1 mmol/l, JSTX-3 was 10^{-4} mol/l. V_{hold} = -50 mV [2, 36, 46–57]. Toxin argiopine (AR, below) blocked the open state of KK-activated ion channels. After receiving the control response to KK, the neuron was maintained in AR during 3 minutes, then on the background of AR the KK-solution was added. Concentrations: KK 1 mmol/l, AR 1.6×10^{-2} mol/l, V_{hold} = -100 mV. Toxin was removed from the membrane through 15 sec [2. 36, 46–57]. All records were done on different neurons [41]

Рис. 2. Токсини JSTX-3 (з *Nemphila clavata*) і AR (з *Argiope lobata*) впливають на трансмембранні електричні струми. Токсин JSTX-3 блокував глутамат-активовані (Glu, запис вгорі) та каінат-активовані (KK, запис у центрі) трансмембранні іонні струми. Після отримання контрольної відповіді на KK, токсин JSTX-3 аплікували на тлі KK-активованих струмів. Концентрації Glu та KK становили 1 ммоль/л, JSTX-3 становила 10^{-4} моль/л. $V_{підтр}$ = -50 мВ [2, 36, 46-57]. Токсин аргіопін (AR, внизу) блокував KK-активовані іонні канали у відкритому стані. Після отримання контрольної відповіді на KK нейрон витримували в AR протягом 3 хв, після того на тлі AR додавали розчин KK. Концентрації: KK 1 ммоль/л, AR $1{,}6\times10^{-2}$ моль/л, $V_{підтр}$ = -100 мВ. Токсин відмивали від мембрани через 15 с [2, 36, 46–57]. Усі записи зроблені на різних нейронах [41]

been recorded [3]. The activity of hyaluronidase and cholinesterase has been registered in all these arthropods. Phosphodiesterase was found in spiders of genus *Latrodectus*. High activity of kininases had been observed in a venom of karakurt, less active kininases were found in the venoms of scolopendra and tarantulas. In addition, ATPases, 5-nucleotidases, phospholipase A [3, 79] were found in poisonous arthropods.

Proteases in large quantities is a part of spiders' venoms [3, 96]. During the biting, the spider together with its toxins, introduces into victim body a digestive secret with

proteases. This type of digestion is called an “external digestion”. Due to abovementioned, the compositions of spider venoms obtained in different ways are different considerably: in the case of “milking” or, for example, in the case of homogenization of spider poison glands [8, 12, 96]. In addition, there is a large variability in quantity of different substances, both in individual samples and in neighboring species [12, 96] which can be determined by the environmental conditions of life [96]. In addition, in *Araneidae* venoms epinephrine, epinine, and dopamine were revealed in low concentrations. *Araneidae* venoms also contain 2,4-dihydrooxyphenylacetic and 3,4-dihydrophenolacetic acids [74].These acids are the main part of *Araneidae* toxins’.

A significant number of free amino acids, mainly glutamate [8, 12], have been registered in venoms of *Araneidae* species from New World, whose concentration can reach 130–425 mM in venom [17]. In the order of concentration decreasing in the venoms, the amino acids can be arranged as [8]:

L-glutamate → arginine → lysine → alanine → tryptophan → glycine

Thus, the antagonists of glutamatergic synapses, *Araneidae* toxins are of great value for laboratory experiments. So, *Araneidae* spiders are of interest as a source of toxins – antagonists of glutamate channel-receptor complexes. Few tens of *Araneidae* spiders species that produce different toxic substances are known nowadays [16, 20, 22, 23, 29, 59].

A number of toxins – antagonists of glutamatergic synapses have been isolated from *Araneidae* venoms. The best studied toxins among them are JSTX-3, NSTX-3, argiopine (argiotoxin$_{636}$). They are supposed to be the most potent and selective glutamate receptor antagonists [5, 62, 74]. Two families of toxins have been isolated from *Araneidae* venoms. All of them are derivatives of phenolic and indoleacetic acids. The best-studied toxins are from the first family including JSTX-3, NSTX-3, argiopine (argiotoxin$_{636}$). *Araneidae* venoms contain complex composition of toxins uhose concentrations are diverse in different species. Argiopine (argiotoxin$_{636}$) occurs in the venoms of the most *Araneidae* species [12, 22, 28]. Some biochemical characteristics and biophysical effects of these venoms and toxins were characterized briefly in this publication. In 1983, the first attempt to isolate the glutamate receptor was done using a mixture of toxins from *A. lobata* with its further incorporation into a belayed phospholipids membrane.

Most antagonists of glutamatergic synapses from *Araneidae* venoms are low molecular weight substances with molecular weight of 400–700 Da and chemical structure of some of them was studied. Such toxins as JSTX-3, NSTX-3, argiopin and their analogs were synthesized [18, 26, 87]. Such properties of the glutamatergic synapse antagonists from *Araneidae* venoms, such as low molecular weight and simple chemical structure, allow them to be synthesized in industry for the purpose of new pesticides and drugs production [28]. Synthetic *Araneidae* toxins can be used in medicine and pharmacology as medical in preparations, as well as pesticides in agriculture. A particular advantage of such pesticides is that the mechanism of pests populations regulating is close to natural. Nowadays, such pesticides are enough popular in agriculture and the search of new more potent analogs is continued in different countries. These toxins were used for the biotechnological tasks [41, 42].

The toxins of *Araneidae* acted similarly on different objects. Therefore, an assumption of similarity of glutamate receptors in phylogenetically distant animals has been

suggested [28]. This review should attract attention of investigators to *Arthropodae* toxins studying and their applications these can by a source of biologically active substances for scientific laboratories and medical interest.

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ДОСЛІДЖЕННЯ ХІМІЧНИХ РЕЧОВИН НАЗЕМНИХ ЧЛЕНИСТОНОГИХ

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Мільйони членистоногих організмів мешкають на Землі, а деякі біохімічні продукти, які вони виробляють, є цінними для практики людини. Метою цієї роботи було узагальнити поточну інформацію про речовини, які продукують членистоногі: отрути, токсини та деякі інші хімічні сполуки, які можуть бути використані в лабораторній практиці. На сьогодні такі продукти отримують і очищають за допомогою стандартних біохімічних методів. У статті представлено інформацію про види наземних членистоногих – продуцентів речовин, що діють на нервову систему та вже були застосовані в електрофізіологічних дослідженнях. Запропоновано також деякі версії класифікації токсинів членистоногих, таблицю з токсинами аранеїд і ефектами, які вони спричиняють. Основна увага приділялася деяким отрутам і токсинам *Araneidae*, які блокують синаптичну передачу в глутаматергічних синапсах, короткий огляд хімічного складу і деяких біофізичних властивостей таких отрут і токсинів, а також хімічні структури відомих токсинів із цих пулів (токсини павуків з сімейства *Nephila* і токсини з отрути *A. lobata*). Деякі біофізичні властивості отрут і токсинів *Araneidae* коротко розглянуто. Також було розглянуто інші компоненти отрут членистоногих. Описано сучасні застосування таких хімічних сполук у сільському господарстві, у методах і системах моніторингу довкілля для їхньої стандартизації. Отримані результати проведеної роботи свідчать про те, що наземні членистоногі є цінним джерелом хімічних сполук для біофізичних лабораторій, і цей великий потенціал має привертати більше уваги сучасних дослідників.

Ключові слова: отрути членистоногих, токсини, антагоністи рецепторів, трансмембранний електричний струм

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