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Action Potentials of the High-Speed Conduction in *Mimosa pudica* and *Neptunia plena*

By

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With 6 Figures

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Key words: High-speed conduction, action potential, *Mimosa pudica*, *Neptunia plena*

Summary

UMRATH K. & KASTBERGER G. 1983. Action potentials of the high-speed conduction in *Mimosa pudica* and *Neptunia plena*. — Phyton (Austria) 23 (1): 65—78, with 6 Figures. — English with German summary.

Action potentials of the high-speed conduction were demonstrated in the pinna, the petiole and in the stem of *Mimosa pudica* and in the stem of *Neptunia plena*.

The product of the conduction velocity with the rising time of the action potential, its rising length, is longer in the high-speed system than in the slow system. In the petiole and in the stem of *Mimosa pudica* it is longer as in any other conducting system of plants or animals. This in connection with the absent or very poor electric excitability of the high-speed system excludes an electrical mode of conduction.

The arguments against a transmission by a mechanical pressure wave are chiefly the occurrence of action potentials and the wanting of the big cells („Schlauchzellen" of HABERLANDT) in *Neptunia*.

Arguments for a chemical transmission, which in other tissues would support an electrical transmission, are given.

Zusammenfassung

UMRATH K. & KASTBERGER G. 1983. Aktionspotentiale der High-speed conduction bei Mimosa pudica and Neptunia plena. — Phyton (Austria) 23 (1): 65—78, 6 Abbildungen. — Englisch mit deutscher Zusammenfassung.

Aktionspotentiale der High-speed conduction wurden im sekundären Blattstiel, im primären Blattstiel und im Stamm von *Mimosa pudica* und im Stamm von *Neptunia plena* nachgewiesen.

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Das Produkt der Leitungsgeschwindigkeit mit der Anstiegszeit des Aktionspotentials, seine Anstiegslänge, ist überall im high-speed System länger als im langsam leitenden System. Im Blattstiel und im Stamm von *Mimosa pudica* ist sie länger als in irgend einem anderen Leitungssystem von Pflanzen oder Tieren. Hierdurch wird, in Verbindung mit der fehlenden oder sehr geringen elektrischen Erregbarkeit des high-speed Systems, eine elektrische Art der Leitung ausgeschlossen.

Argumente gegen eine Leitung durch eine mechanische Druckwelle sind hauptsächlich das Vorkommen von Aktionspotentialen und das Fehlen der HABERLANDTschen Schlauchzellen bei *Neptunia*.

Argumente für eine chemische Leitung, die in anderen Geweben eine elekrische Leitung unterstützen würde, werden angeführt.

Introduction

LINSBAUER 1908 was the first to show that cutting the petiole of *Mimosa pudica* elicits conduction of impulses with considerably higher speed than heating or other weak stimuli do. UMRATH 1925 found different conduction velocities in different conducting systems, a slow and a fast one. Their conduction velocities were different in different parts of the leaf, but constant in every part.

According to SNOW 1924 and BALL 1927 two "fast systems" have to be postulated in the stem of *Mimosa pudica*, a faster "high-speed system" in the phloem or cambium (SNOW 1924) and a not so fast "rapid system" (BALL 1927) probably located in the protoxylem. The excitation in the slow system and that in the rapid one can be elicited by all stimuli and they are accompanied by action potentials (BALL 1927, UMRATH 1928). The intracellularly recorded action potentials from the phloem and the protoxytem of the petiole by SIBAOKA 1962 belong to the slow system as revealed by the simultaneously recorded extracellular action potentials. In all parts of the plant the high-speed conduction can be elicited by cutting, in some parts also by burning. The high-speed system of the stem and the leaf is located in the phloem (SNOW 1924, UMRATH 1925). In the petiole and in the pinnae it is located in the phloem of the main bundle and in the ridge-bundles, where its conduction velocity is not as high as in the main bundles. Electrical stimulation was never successful in initiating high-speed conduction. With electrical stimulation LINSBAUER 1908 got only the slow conduction of impulses. UMRATH 1937 got with threshold stimulation and with more than the tenfold voltage only excitation of the slow system in the petiole and in the pinna and never a higher conduction velocity. In connection with this peculiarity of the high-speed system a safe proof of its action potentials is desirable.

A supplementary investigation of the high-speed conduction in the stem of Neptunia plena turned out to be useful.

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The recent reviews (SIBAOKA 1969, STOECKEL 1976, ROBLIN 1979) mention a fast conduction in *Mimosa pudica* observed by several authors. In this connection small action potentials recorded by UMRATH 1966 are cited as not quite satisfactory. We therefore resumed this investigation using an oscilloscope with a higher input resistance.

Materials and Methods

Mimosa pudica was grown in the greenhouse described by UMRATH 1928 without any shading. This yields plants with a well developed high-speed conduction.

Neptunia plena was grown in the same greenhouse in soil just submerged in a water basin. The shoots floating on the water had an aerenchym. The experiments were done on shoots which had reached the border of the basin and grow in air, without aerenchym.

The experiments were performed from August 20th to September 9th 1980 and from August 3rd to 11th 1981, at 18 to 34° C, mostly at 25 to 30° C.

The action potentials were led off by steel electrodes 0.5 mm in diameter and recorded by an oscilloscope (Tectronix 5103 N) with an input resistance of 1 MΩ. The electrodes were connected with the oscilloscope by coaxial cables parallelly placed except the last 10 cm. The noise of the 50 Hz alternating current was about 0.1 mV. It is scarcely visible on the figures. In the experiments with the petiole its movement was registered by tension recording. For that a Piezo-transducer (type 9203 and 500 1, Kistler) was connected with the petiole by a thin rubber band.

Scissors with an isolated handle were used for cutting the pinna and mostly also for cutting the stem. Sometimes the stem was cut with non-isolated scissors to make the artefact of the cutting better visible.

All figures given in the results are means ($\bar{x}$) with their standard errors ($s_{\bar{x}}$). The number of individual figures is given as n.

Results

1. The stem of *Neptunia plena*

In the stem of *Neptunia plena*, in the air, without aerenchym, three steel electrodes were inserted. The two apical electrodes had distances from one another of 1.0 to 3.5 cm and were connected with the inputs of two oscilloscopes. The basal electrode, 1.0 to 3.0 cm from the nearer of the two other electrodes, was connected with the joint earth. The stem was cut 1.2 to 2.8 cm from the apical electrode. One experiment is reproduced in fig. 1. The mean conduction velocity was 2.59 ± 0.16 cm.sec^{-1}, n = 25. It was independent from the distance between the cut and the leading off electrode. The mean rising time of the action potential was 1.26 ± 0.14 sec, n = 8.

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2. The stem of *Mimosa pudica*

In the stem of *Mimosa pudica* three steel electrodes were inserted. The two apical electrodes were connected with the imputs of two oscilloscopes and were 0.4 to 5.5 cm from one another. The basal electrode was connected with the joint earth and it was 0.3 to 5.8, mostly 2.0 to 3.8 cm below the lower of the two first mentioned electrodes. The cut through the stem was made usually at a region where it was still soft, without hard wood, 0.4 to 6.7 cm, generally 1.0 to 3.0 cm, over the uppermost electrode. From the cut to the first electrode conduction fell out very rarely even up

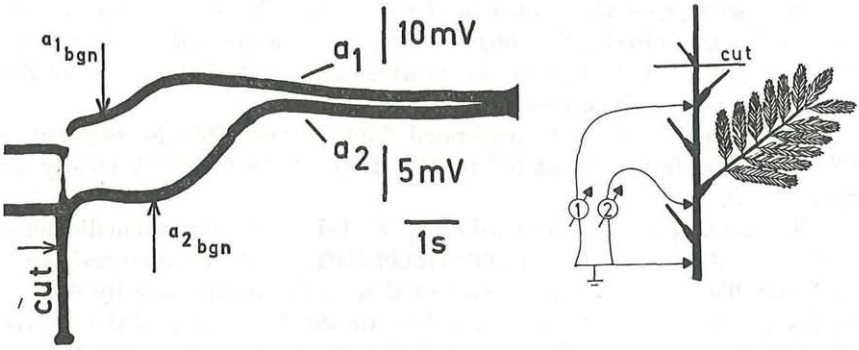

Fig. 1. 11. 8. 81. Monophasic action potentials of the high-speed conduction in the stem of *Neptunia plena*, led off with 3 electrodes. The distance from the cut on the stem to the first electrode was 1.5 cm, from the cut to the second electrode 2.7 cm and from the cut to the third electrode with the joint earth it was 5.6 cm, 25° C. a_1 action potential led off with the first electrode, a_2 action potential led off with the second electrode, magnified twice as much as a_1. a_{1bgn} beginning of the action potential a_1, a_{2beg} beginnung of a_2, cut artefact of cutting the stem

to a distance of 6.7 cm. To the second electrode, where the excitation had to pass the first electrode, the action potential fell out to a just detectale higher percentage at 5 cm from the cut and to 50% at 6 to 8 cm from the cut. Over 9 cm from the cut no action potential was detectable. This agrees with the spread of the high-speed conduction judged by the leaf movements after cutting the stem. Diphasic action potentials occured seldom, partly because of the great distance of the cut from the third electrode and apparently because the excitation had to pass two electrodes before.

The conduction velocity was 31.15 ± 1.42 cm.sec^{-1}, n = 148, independent of the distance covered by the excitation. The mean rising time of the action potential was 0.253 ± 0.011 sec, n = 51. An experiment from the stem of *Mimosa pudica* is reproduced in fig. 2. It shows two monophasic action potentials led off by two electrodes.

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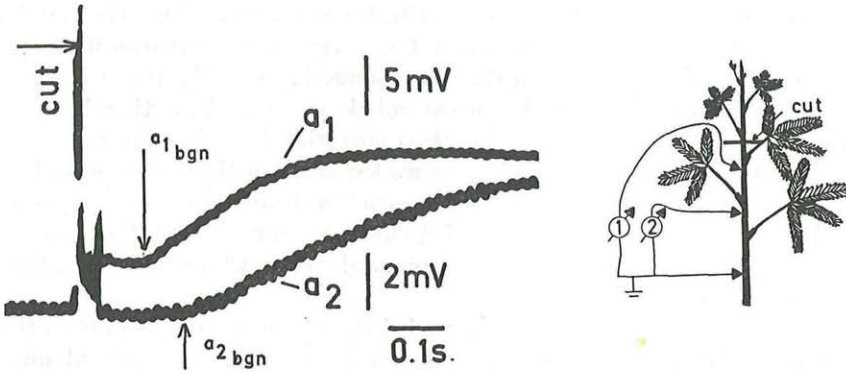

Fig. 2. 10. 8. 81. Monophasic action potentials of the high-speed conduction in the stem of *Mimosa pudica*, led off with 3 electrodes. The distance from the cut on the stem to the first electrode was 2.4 cm, from the cut to the second electrode 4.6 cm and from the cut to the fird electrode with the joint earth it was 7.8 cm, 26° C. Designations as in fig. 1

3. The petiole of *Mimosa pudica*

We performed three sorts of experiments for leading off action potentials from the petiole. As the petiole is short we had to cut a pinna as a stimulus. This elicited in our plants in most but not in all cases the high-speed conduction in the petiole. The petiole is so thin, that the insertion of the electrodes made more harm to it as it did to the stem.

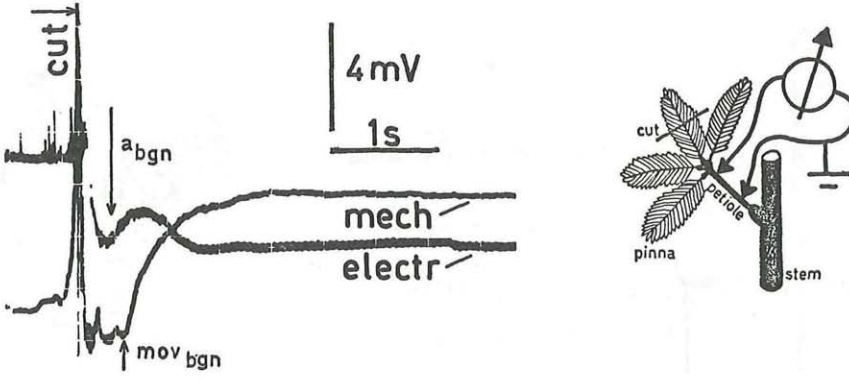

Fig. 3. 17. 9. 80. Monophasic action potential of the high-speed conduction in the petiole of *Mimosa pudica*, led off bipolarly, electrode distance 3.7 cm. Stimulus cutting a pinna 1.1 cm from the secondary pulvinus, 20° C. a_{bgn} beginning of the action potential, cut artefact of cutting a pinna, electr electrogramm, mech mechanogramm, mov_{bgn} beginning of the movement

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In same experiments we led off with three electrodes from the petiole. The two apical electrodes were connected to the inputs of two oscilloscops, the basal to the common earth. The conduction velocity was calculated from the distance between the two apical electrodes and the time between the beginnings of the monophasic action potentials led off by them.

In a second sort of experiments we led off from the petiole with two electrodes to one oscilloscope. We got sometimes monophasic action potentials as in fig. 3, if the excitation died out between the electrodes. In some other cases we got diphasic action potentials, from which the conduction velocity could be calculated.

In a third sort of experiments we led off from the petiole and from the stem. In this case the records are influenced by events in the main pulvinus. SIBAOKA 1951 found on action potentials of the slow system a brief negative-positive deflexion at the moment of the excitation of the pulvinus. We could confirm this in experiments with one electrode on the stem and the other on the petiole or on a pinna. We burned a pinna, exciting a high-speed system in the pinna, which can release only the slow conduction in the petiole (UMRATH 1925). SIBAOKA 1951 did not find such a quick deflexion on the action potential if the pulvinus was excited shortly before the experiment. SIBAOKA 1954 attributed this quick deflexion to different resistences around the conducting cell strands in the petiole and in the pulvinus. We found that the high-speed conduction in the petiole, when reaching the main pulvinus evokes mostly an electropositive deflection, but we can not exclude that negative-positive deflections may also occur.

Fig. 4 shows a predominantly monophasic action potential of the high-speed system. The monophasic form of the action potential indicates, that

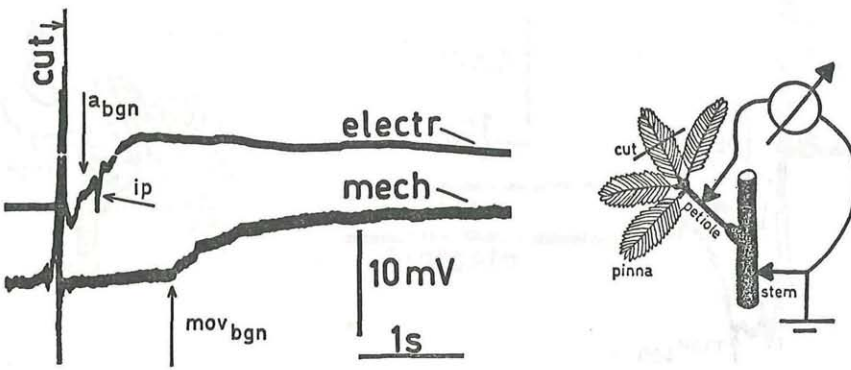

Fig. 4. 25. 8. 80. Predominantly monophasic action potential of the high-speed conduction in the petiole of *Mimosa pudica*, led off from the petiole and from the stem. Stimulus cutting a pinna 2.0 cm from the secondary pulvinus, 30° C. Distance from the electrode on the petiole to the main pulvinus 5.0 cm. Designations as in fig. 3. i_p positive deflexion impinging from the pulvinus

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in most of the conducting cell strands the excitation died out between the electrodes, but in some strands it reached the pulvinus and evoked the quick electropositive deflexion, marked ip. The movement, mov_{bgn}, began with an unusual long latency, probably because the pulvinus was excited only through a few conducting cell strands. In fig. 5 the action potential of the high-speed system is cut down by the positive deflexion, ip, and a small negative elevation afterwards shows that the action potential was diphasic in most of the conducting strands and monophasic only in a small part of them. This corresponds to the short latency of the movement, from ip to mov_{bgn}. The following action potential of the slow conducting system

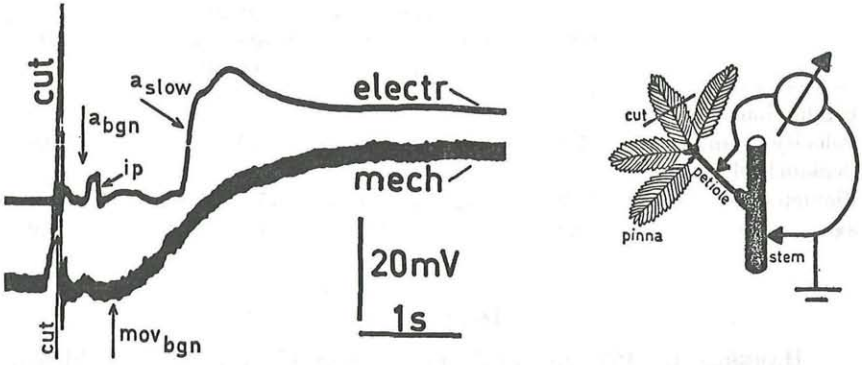

Fig. 5. 25. 8. 80. Diphasic action potential of the high-speed conduction in the petiole of *Mimosa pudica*, led off from the petiole and from the stem. Stimulus cutting a pinna 2.0 cm from the secondary pulvinus, 26° C. Distance from the electrode on the petiole to the main pulvinus 5.1 cm. Designations as in fig. 3. a slow action potential of the slow system, i_p positive deflection impinging from the pulvinus

has no quick negative-positive deflexion on its falling phase, because the pulvinus was excited shortly before.

In this third sort of experiments on the petiole we measured the conduction time from the beginning of a negativity after the artefact of the cut, a_{bgn}, to the steep positive deflexion, ip, indicating the arrival of the excitation at the pulvinus. This positive deflexion, ip, was followed briefly by the movement of the pulvinus, mov_{bgn}.

The conduction velocities from these three sorts of experiments were not significantly different. The first sort gave values from 20 to 22 $cm.sec^{-1}$, the second from 3 to 46 $cm.sec^{-1}$ and the third from 6 to 23 $cm.sec^{-1}$.

The mean conduction velocity was 17.33 ± 2.82 $cm.sec^{-1}$, $n = 15$. The mean rising time of the action potential was 0.402 ± 0.067 sec, $n = 19$.

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4. The pinna of *Mimosa pudica*

We led off from the pinna and the stem. The electrode on the pinna was inserted 1.7 to 3.7 cm apically of the secondary pulvinus, the cut was made 2.0 cm to 5.5 cm apically from the electrode. The conduction time was measured on the records from the artefact of the cut to the foot of the action potential. So we got for the conduction velocity 3.0 ± 0.4 cm.sec^{-1}, $n = 13$. For the rising time of the action potential we got 0.53 ± 0.06 sec, $n = 11$.

Table 1

	stem	petiole central/ridge bundle		pinna central/ridge bundle		leaflet
conduction velocity cm.sec^{-1}	31,2	17,3	3,2	3,0	0,45	0,7
Schlauchzellen diameter μ	18,9	17,2	14,9	17,0	12,4	15,6
$s_{\bar{x}}$	$\pm$0,9	$\pm$0,7	$\pm$0,6	$\pm$1,1	$\pm$1,1	$\pm$0,9

Discussion

HABERLANDT 1890 assumed that certain big cells, the "Schlauchzellen" of *Mimosa pudica* are the conducting cells and that a mechanical pressure wave is the conducting agent. BORZI 1899 and FITTING 1906 found that *Neptunia* has no such big cells ("Schlauchzellen"), but has conduction of excitation. This disproved the conception of HABERLANDT.

Later, than different conducting system in *Mimosa* were known, HOUWINK 1935 suggested, that the big cells in Mimosa pudica may be implicated in the high-speed conduction. But as early as 1928 UMRATH described in the leaf of *Neptunia* a slow system, which can be elicited by electrical stimuli and a high-speed system, which can be elicited by burning but not by electrical stimuli. Now we found in the stem of *Neptunia plena* a high-speed system which can be elicited by cutting. In collaboration with Prof. Sh. WATANABE we found in our *Neptunia plena* again no Schlauchzellen in the stem, petiole and rachis. Table 1 shows for different parts of *Mimosa pudica* the high-speed conduction velocities and the diameters of the Schlauchzellen with their $s_{\bar{x}}$ measured by Prof. Sh. WATANABE. Both the conduction velocity and the diameter of the big cells are smallest in the ridge bundle of the pinna and greatest in the stem. But the ratio of the extreme values is 70 in the case of the conduction velocities and 1.5 in the case of the cell diameters. All the values are greater in the main bundles as in the ridge bundles. In the petiole the ratio of the conduction velocities

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is 5.4, that of the cell diameters is 1.15, in the pinna the respective ratios are 6.7 and 1.37. In the main bundles of the petiole and of the pinna the ratio of the conduction velocities is 5.8, that of the cell diameters is 1.01. All this suggests no direct dependence of the conduction velocity on the diameter of the Schlauchzellen.

Mac DOUGAL and FITTING, quoted by HOUWINK 1936 and HOUWINK himself did not succeed in stimulating a *Mimosa* by changing the pressure in the vessels of the stem.

Now as action potentials are proved for the high-speed conduction of *Mimosa pudica* and of *Neptunia plena* one may ask how to distinguish the high-speed conduction from other sorts of conduction. In the stem of

Table 2

	slow conduction			high-speed conduction		
	conduction velocity	action potential rising time	action potential rising length	conduction velocity	action potential rising time	action potential rising length
Neptunia plena						
pinna	0.110	3.80	0.42	1.22	1.25	1.53
petiole	0.109	4.52	0.49	0.99	1.14	1.13
stem	0.178	4.8	0.85	2.59	1.26	3.26
Mimosa pudica						
pinna	0.40	2.4	0.96	3.0	0.8	3.2
petiole	2.1	0.61	1.28	17.3	0.40	6.9
stem	0.88	1.1	0.97	31.2	0.25	7.9

Mimosa pudica there is a slow, a rapid and a high-speed system. The slow and the rapid system can be excited by most stimuli, also by electrical ones. The high-speed system is excitable only mechanically, by cutting, and in some parts by burning; by this it can be distinguished from the two other systems. The conduction velocities in the rapid system and in the high-speed system are higher as in the slow system. If we know from a system only that it conducts faster as the slow system, we speak of a fast system. In the legend of fig. 6 "fast system" is employed in this sense, e. g. "*Mimosa spegazzinii*, fast system" or "*Cassia tomentosa*, fast system".

Table 2 shows the conduction velocities, the rising times of the action potentials and the product of both, the rising lengths of the action potentials, of the slow and of the high-speed system in different parts of *Neptunia plena* and of *Mimosa pudica*.

The high-speed conduction velocities in the stem and in the petiole of *Mimosa pudica* are particularly high, but conduction velocities of a

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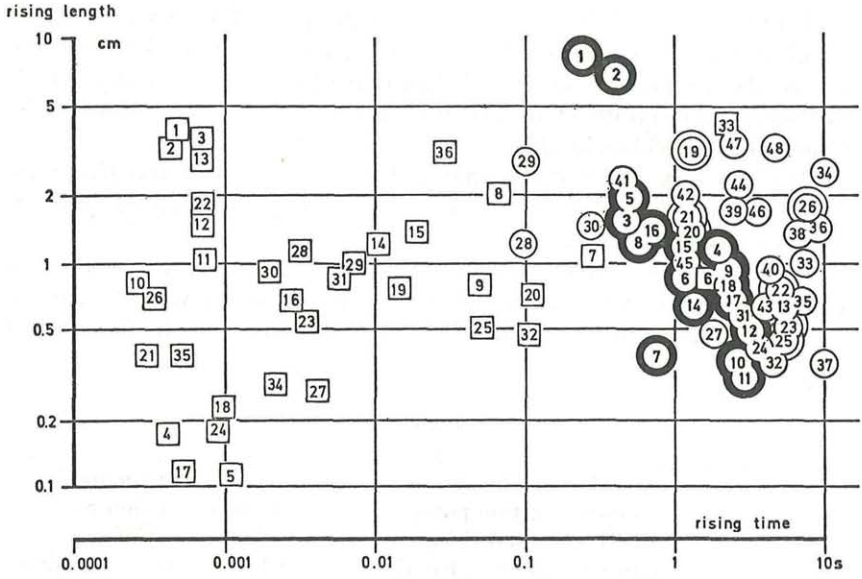

Fig. 6. The rising length of action potentials plotted against their rising times. 48 circles from plant tissues, 36 squares from animal tissues. Full rings: *Mimosa* spp.; 1—12 *Mimosa pudica*, 1—4 high-speed system, 1 stem, 2 petiole, 3 pinna, 4 leaflet, 5 rapid system stem, 6—12 slow system, 6 stem basipetal cond. 7 acropetal cond. 8 petiole, 9 pinna, 10 leaflet, 11 cotyledon, 12 hypocotyl, 13 *Mimosa invisa*, slow system, pinna, 14—18 *Mimosa spegazzinii*, 14—16 fast system, 14 stem, 15 petiole, 16 pinna, 17, 18 slow system, 17 petiole, 18 pinna, 19—26 double circles, *Neptunia plena*, 19—21 high-speed system, 19 stem, 20 petiole, 21 pinna, 22—26 slow system, 22 stem, 23 petiole, 24 pinna, 25 cotyledon, 26 hypocotyl, 27 *Biophytum sensitivum*, rachis, 28 *Aldrovanda vesiculosa* lamina, 29, 30 *Dionaea muscipula*, 29 lamina inner part, 30 whole lamina, 31 *Drosera binata* lamina, 32, 33 *Drosera rotundifolia*, 32 lamina, 33 petiole, 34 *Pinguicula* lamina, 35—37 *Phyllanthus urinaria*, 35 leaflet, 36, 37 short sprout, 36 basipetal cond. 37 acropetal conduc, 38 *Clematis zeylanica* stem, 39 *Vitis discolor* stem, 40 *Vitis vinifera* tendril, 41 *Cucumis melo* stem, 42, 43 *Cassia tomentosa* petiole, 42 fast system, 43 slow system, 44, 45 *Lathyrus latifolius* 44 stem, 45 tendril, 46 *Dolichos giganteus* petiole, 47 *Phaseolus vulgaris* petiole, 48 *Desmodium gyrans* petiole. — 1, 2, 19 our determinations, 28 from SIBAOKA 1980, all other data from UMRATH 1959. — Squares: animal tissues, 1—7 dog, 1 saphenus nerve, 2 tibialis nerve, 3 phrenicus nerve, 4 Purkinje-fibres, 5 papillary muscle, 6 retractor penis, 7 ureter, 8 horse splenic nerve, 9 *Testudo graeca* retractor penis muscle, 10—20 *Rana temporaria*, 10—13 sciatic nerve, 10 whole neve, 11 γ fibres, 12 β fibres, 13 α fibres, 14—19 muscles, 14—16 sartorius, 14 at 3.6° C, 15 at 1.7° C, 16 at 19° C, 17, 18 semitendinosus, 19 hyoglossus, 20 heart ventricle, 21 *Rana nigromaculata* intracutaneus muscle, 22—24 *Bufo vulgaris*, 22 sciatic nerve, 23 sartorius muscle, 24 sartorius muscle intracell. record., 25 *Esox lucius* olfactory nerve, 26 *Loligo forbesi* giant nerve fibre, 27—31 cephalopod tegumentary nerves, 27, 28 *Eledone moschata*, 29, 30 *Octopus*

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comparable magnitude were found by SIBAOKA 1980 in *Dionaea muscipula*, 25 cm.sec^{-1}, and in *Aldrovanda vesiculosa*, 12 cm.sec^{-1}.

Concerning the rising lengths of the action potentials their ratios of the values in the high-speed system to those in the slow system are smaller as the respective ratios for the conduction velocities. Nevertheless the rising lengths of the action potentials of the high-speed system in the stem and in the petiole of *Mimosa pudica*, fig. 6, rings 1 and 2, exceed all other rising lengths markedly, whereas those of *Aldrovanda*, fig. 6 circle 28, and of *Dionaea* circle 29 and 30 are inside the limits marked by the bulk of other tissues. Of course the rising times of the action potentials of *Aldrovanda* and *Dionaea* are the shortest of all plant tissues, circles in fig. 6.

Long rising lengths of action potentials are of interest as UMRATH 1925a and BRÜCKE 1930 stated, that the rising lengths of the action potentials vary in narrow limits, mostly between 0.1 and 4 cm in plant and animal tissues, whereas the rising times vary between 0.0003 and 10 sec. and the conduction velocities between 0.1 and 8330 cm.sec^{-1}. In fig. 6 the rising lengths of the action potentials are plotted against their rising times. From 84 exemples 48 are from plant tissues, marked by circles, and 36 from animal tissues, marked by squares. As can be seen from the figure most of the rising lengths are between 0.3 and 3 cm.

In electrically excitable systems a too long rising length of the action potential lowers the efficiency of the action potential to excite the adjacent yet unexcited part of the conducting system. If we consider the rising lengths over 3 cm, we have from animals number 1—3 and 13, nerve fibres of the dog and of the frog. All these have saltatory conduction from Ranvier node to Ranvier node. The saltatory conduction rises the conduction velocity and with it also the rising length of the action potential over the value of normal, uniform conduction. Number 33, the rising length of the craw of *Aplysia* can be overestimated if DITTLER 1911 (quoted by BRÜCKE 1930) registered instead of a single action potential a narrow group of action potentials.

From plant tissues the rising lengths of the action potentials of the high-speed system in the stem and in the petiole of *Mimosa pudica*, rings

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vulgaris, 31 *Scaeurgus tetracirrus*, 32 *Anodonta* connective nerve, 33, 34 *Aplysia*, 33 craw, 34 axons, 35 crayfish, giant nerve fibre, 36 *Sipunculus nudus*, retractor. — 4.5 from TRAUTWEIN, W., GOTTSTEIN, U., DUDEL, J., 1954 Pflügers Arch. **200**, 40—60. 10 from TANAKA, U. 1925 Z. Biol. **83**, 399—414. 17, 18 from HAKANSSON, C. H., 1957 Acta Physiol. Scand. **39**, 291—312. 21 from TAKAGI, Y., 1958 Jap. J. Physiol. 8, 340—246. 22, 23 from UCHIZONO, K., 1954 Jap. J. Physiol. **4**, 59—64. 24, 25 from UCHIZONO, K., 1957 Jap. J. Physiol. **7**, 172—180. 26 from BARKER, P. F., HODGKIN, A. L., SHAW, T. J. 1961 Nature **190**, 885—887. 34 from GOLDMAN, L., 1961 J. Cell. Comp. Physiol. **57**, 185—191. All other numbers from BRÜCKE 1930, table 3

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1 and 2 in fig. 6, with 7.8 and 6.9 cm are longer as anyone other found till now. Also the value from the high-speed system in the stem of *Neptunia plena*, the double circle 19 in fig. 6, is remarkably high, 3.26 cm. The two other high values, number 47 and 48, are from the petioles of *Phaseolus vulgaris* and of *Desmodium gyrans*. Here, as in many other plant tissues, we can not say till now if the conduction has the properties of a high-speed conduction.

If we perceive that the high-speed system are not electrically excitable and have in some cases particularly long rising lengths of the action potentials we have to consider another sort of conduction, perhaps a chemical one.

The view, that in the high-speed conduction an exciting chemical substance is produced and spreads into the adjacent parts, is supported by the finding of UMRATH 1937, 1959 that after cutting one or several leaflets of a pinna of *Mimosa pudica* the excitation in the high-speed system passes the farther the more leaflets were cut. It seems that the conduction of excitation in one bundle of cells aids the conduction of excitation in a neighbouring bundle by the spreading of an excitatory substance, which is probably the substance discovered by RICCA 1916.

It may often be, that a chiefly electrical conduction of excitation is aided by the production of an excitatory substance. For a very slowly conducted train of action potentials in the slow system of the petiole of *Mimosa pudica* UMRATH 1937, 1959 found a conduction velocity of 0.26 cm. sec^{-1} basipetally and of 0.51 cm. sec^{-1} acropetally. Since in all other cases of conduction of excitation in plants the velocity is equal in both directions or higher in basipetal direction this suggests an aiding through the translocation of an excitatory substance by the water movement in the cellulose walls of the cells. A zone of the petiole deadened by steam can not be transversed by this very slow conduction of excitation but it can be crossed by the exciting substance carried by a vigurous water current.

On animal nerve substances which interact with acetylcholine and with cholinergic transmission from nerve to muscle can block the conduction of excitation in nerve under certain circumstances (ROSENBERG & EHRENPREIS 1961, RIEDEL 1962). Such a block can be prevented by picrotoxin (RIEDEL 1962). These findings point to a participation of an excitatory substance in conduction of excitation in nerve.

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