INTERMITTENT CONDUCTION IN NARCOTIZED NERVE FIBRE

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It is known among clinicians that the time necessary for peripheral blocking of the sensory impulses is different according to the modality of sensation, while the disappearance of sensation is always gradual irrespective of the modality. The latter phenomenon, in which we are interested here, must be due to a gradual reduction in the number of active fibres, on the one hand, but, at the same time, perhaps also to some gradual change in pattern of impulses in each fibre. There is no doubt about the first factor, but almost nothing is known about the second. For clarifying this, it is appropriate to send test trains of impulses into a narcotized region of nerve, and examine the patterns of impulses at both sides of that region at various stages of narcosis. Long ago Wedensky (13, 14) and others carried out extensive studies of this kind on motor nerves, and obtained a peculiar phenomenon, which has been widely known as ‘Wedensky’s inhibition.’ But the materials were of course nerve ‘trunks,’ which could not give any clear-cut result as single fibres do nowadays. Recently, Tasaki and Takeuchi (12) carried out new experiments of the same kind on single nerve fibres, but the number of stimuli applied was not more than a few.

The present investigation was undertaken to fill the above-mentioned gaps. As test-impulses, the muscle afferent impulses evoked by muscle-loading were employed, because it was considered to be significant to examine physiological cases with particular patterns of impulses.

METHODS

For material, Matthews’ (9) toe-muscle-and-nerve preparation of the frog (Rana nigromaculata) or of the toad (Bufo vulgaris) which is said to contain just one muscle spindle, was chosen. A narcotic was applied to a part of the attached nerve. The leading-off electrodes were placed outside the narcotized region, one on either side. The shapes of the impulses were expected to be diphasic or monophasic according to whether the impulses passed the region or not. As experienced hitherto, the frequency of the impulse was high in the initial period of stretching and gradually low in later periods. The range of variation was about 250-15/sec.

The holder of the preparation, a small bakelite case, consisted of five compartments, C₁₋₅, separated by watertight walls, W₁₋₄ (fig. 1). Compartments C₁ and C₅ were filled with Ringer’s fluid, while C₂₋₄ were made moist. The muscle was fixed in compartment C₁ by pinning the tarsus, and the nerve was

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Fig. 1. Narcotizing chamber with a preparation set in it. C1-5, water-tight compartments, of which C1, C5, Ringer-filled, and C2, 3, 4, moist chambers; C3, narcotizing chamber; E1,2, leading-off electrodes (E2W3 = 1.5 cm, > E1W3 = 1.25 cm); M, muscle; N, nerve; Pu, pulley.

stretched horizontally from notch to notch, which were prepared on each upper margin of the walls, and further to a pair of silver wire leading-off electrodes (E1,2). The compartment C3, for narcotizing, was made as wide as 1 cm, so that the length of the narcotized part of the nerve was 1 cm or more. This is the length required by Huruyama (6) for making the so-called ‘extinction time’ invariable, in the case of single myelinated fibres of the toad. It was perhaps sufficient in the present experiment, too, because the conditions are similar (the narcotized part was very thin and parallell-fibred, and had very few branches so that the fibre in question would have been narcotized almost uniformly, like isolated fibres).

The most important point to be assured beforehand is that the record of an impulse appears actually monophasic if interrupted inside C3. For this, at least the length E2W3 should be larger than E1W3, but it is much better to make E2W3 sufficiently large (larger than 1 cm, if judged from Hodgkin’s (4) or Tasaki’s (11) result). The values actually chosen were as follows: E1W3 = 1.25 cm, E2W3 = 1.5 cm, and so E1E2 = 2.75 cm. The narcotic employed was the chloretone vapour evaporating from a small crystal laid in C3, covered.

The experimental procedure was almost the same as that in the previous work (7). A repetitively sweeping Braun-tube, and a Yokogawa’s electromagnetic oscillograph were employed for observation and recording respectively, each combined with a IV-staged resistance-capacity-coupled amplifier. For stretching the muscle, the distal tendon was pulled via pulley (Pu) by a lever suitably loaded. The duration of loading was adjusted by releasing the supporter S1 of the lever electromagnetically for the desired period (fig. 2). The proper vibration number of the lever was small enough (ca. 2/sec.), not to disturb the results.
RESULTS

A) Preliminary observations on the resting discharge

A small chloretone crystal was introduced into C3. Then, C3 was covered, and the impulses due to resting discharge were carefully observed. At first, all the impulses appeared diphasic, but after a time some of them appeared monophasic before all of them did so later (fig. 3). It was rare that all the impulses became monophasic at a time. When the chloretone crystal was removed from C3, and C3 was covered again for preventing from drying, the diphasic picture began to reappear after some time, at first in a small number and then in all of the impulses (fig. 4).
Thus it was brought to light that there certainly exists a period in the course of narcosis as well as of recovery, where the passed and blocked impulses appear mixed. For convenience, we shall call this period the 'period of intermittent conduction (p.i.c.).'

The frequency of the resting discharges was quite random, but the range of variation was roughly 1-10/sec. Thus we see that the p.i.c., which appears in a certain range of narcosis, is a period where the impulses of such low frequencies as 1-10/sec. cannot pass freely.

B) Appearance of the p.i.c. in the case of muscle loading

The p.i.c. observed in the case of resting discharge, was found to appear also in the case of loading (fig. 5). This is the most essential fact observed in the present experiment. Let us call the interval between the application of narcotic and the onset of the p.i.c. (that is, the appearance of the first monophasic impulse) $t_1$; the duration of the p.i.c., $t_2$; the interval between the removal of the narcotic and the reappearance of the p.i.c. (that is, the appearance of the first diphasic impulse) $t_4$; and the duration of the p.i.c., on the way of recovery, $t_5$. The correlation among $t_1$, $t_2$, $t_4$, and $t_5$, may be an important matter, but unfortunately no significant result could be obtained so far, except that 1) $t_1$, $t_2$, $t_4$, and $t_5$, varied widely from preparation to preparation, and showed no regularity; 2) The weights (0-4 g.) exhibited no appreciable effect on the values of $t_1$, $t_2$, $t_4$, $t_5$; 3) In most cases, $t_5$ was larger than $t_3$; 4) The interval $t_5$, interposed purposely between the onset of complete narcosis and the removal of the narcotic had little effect on the values of $t_4$, $t_5$, as far as $t_5$ was varied in the range of 45 sec.-2.5 min. Examples of these results are given in Table 1.
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TABLE 1. Values of $t_1, t_2, t_4, t_5$ as Examined for a Constant $t_3(=3')$
Animal, the Frog; Temperature, 12→13°C.

<table>
<thead>
<tr>
<th>No. of observations</th>
<th>Weights (g.)</th>
<th>Time</th>
</tr>
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<tbody>
<tr>
<td></td>
<td></td>
<td>$t_1$</td>
</tr>
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<td>7′00″</td>
</tr>
<tr>
<td>7</td>
<td>0.00</td>
<td>7′45″</td>
</tr>
<tr>
<td>Mean (Total/7)</td>
<td></td>
<td>12′06″</td>
</tr>
</tbody>
</table>

* cf. C), 1), a)

C) Detailed observations on the p.i.c. in the case of loading

1) The influence of transmitted impulses upon the appearance and disappearance of the p.i.c.

In order to execute the experiments as above described, it is necessary to send trains of test impulses into the nerve, by stretching the muscle now and then. It was revealed, however, that the test impulses themselves exert influences upon the appearance and disappearance of the p.i.c. This fact was ascertained by degree through the following observations:

a) About 5 min. after the application of narcotic, without loading, a 5 g. weight was hung suddenly by mistake. Quite unexpectedly, most of the impulses appeared monophasic, making a good contrast to the resting discharges which were all diphasic until that time. After about 15 sec., all the impulses became monophasic (cf. table 1). This fact indicates that impulses of a low frequency can pass freely through a narcotized region, while those of a high frequency cannot. Fig. 5 is an example of this kind of observation. It is particularly noteworthy that on this occasion there were mingled some impulses which were transmitted, before a complete block was reached. It is clear that the phenomenon cannot be a simple matter of impulse interval. It gave us an impression that the impulses which have passed through, might have left some kind of effect behind them, and so have acted to accelerate the narcotizing process.

b) When the muscle was loaded at a stage of recovery where all the resting discharges regained the diphasicity, a number of impulses, sometimes even the majority, appeared unmistakably monophasic (fig. 6). This can be interpreted in the same way as above, that is, as indicating that some transmitted impulses opposed the recovery process, so that the narcosis was deepened, although temporarily.
Fig. 5. Intermittent conduction in the case of loading (course of narcosis). a, just after application of chloretone (all impulses diphasic); b, 26 min. after a (onset of intermittent conduction in the initial impulses); c₁, perhaps ca. 1 min. after b (see text) (onset of intermittent conduction in later impulses); c₂, 1.5 min. after b (notice the diphasic impulses due to resting discharge appearing after the complete blockage of the later impulses); c₃, ca. 2 min. after b (see text); d, 2.5 min. after b (note the conduction suggestive of the phenomenon observed by Wedensky, and some resting discharges which passed); e, 3.5 min. after b (completely blocked); time, 0.1 and 0.01 sec.; room temperature, 15°C; the lower record in each picture marks the onset of loading.
c) On the contrary, diphasic impulses never happened to appear when the muscle was loaded at a stage of narcosis or recovery, where the resting discharge were all monophasic. This indicates that the impulses reaching but not passing through the narcotized region, have no effect of weakening the narco-
tizing process. It will be shown later that these impulses probably accelerate the narcotic action, too.

Thus, it was made certain that the p.i.c. appears earlier if impulses are passed through, or, in other words, that impulses accelerate the process of narcotization and oppose that of recovery.

It should be remarked here that both the diphasic and monophasic impulses in the records certainly originated from one and the same fibre, and not from different fibres. This was a matter examined carefully in the previous work (7), but it appears to be certain also from the fact that the well-known frequency-time-curve characteristic of impulses from a single muscle spindle, manifests itself only when the mono- and diphasic impulses are counted together, but not when just mono- or diphasic impulses are taken.

2) Observation on the initial impulses

The ‘initial impulses’ means here the impulses which appear, usually in 2-4 groups, in the initial period of loading, lasting for about 0.1-0.15 sec. The groups are separated from one another by intervals of about 0.02-0.03 sec. The frequency of impulse in each group is not fixed (250-100/sec.), but generally higher in the preceding group (fig. 7). The first impulse in each group appears generally diphasic, while most of the followers monophasic, although they are eventually diphasic, especially in later groups. This diphasicity is lost in deeper narcosis, whereby the appearance of the first diphasic and the second monophasic impulses in combination is kept longest, even until after the disappearance of the p.i.c. in the later period of loading. It is needless to say that all the impulses, including the first of the first group, become monophasic in sufficiently deep narcotization.

The initial impulses, as a whole, appear so differently from those in the later period, which will be described in the next paragraph, that we cannot help considering that something essentially different must underlie both sets of phenomena. Above all, we do not know how to interpret the ‘grouping’ in the initial period. If we disregard it, then the initial period turns out to be a p.i.c. as a whole, which lasts much longer than the p.i.c. in the later period. But if the ‘grouping’ is really grouping due to discontinuity or fluctuation of the generator mechanism itself, then we should treat each group separately. In this case, the groups may represent repetitions of a particular phenomenon like, Anfangszuckung’ observed by Bernstein (2) on normal and by Wedensky (13) on narcotized preparations. This point will be referred to again.

Fig. 7. Initial part of fig. 5 enlarged, for showing the pattern of initial impulses. a, b, c, corresponding to the same in fig. 5.
3) Observations on the later impulses, and the 'ratio of passage'

The 'later impulses' means here the impulses of relatively low frequencies, which follow the initial impulses. The frequency was usually within the range of about 50-15/sec., therefore almost all the impulses could be expected to pass through the narcotized region, if the least interval only was taken into consideration. As a matter of fact, however, the later impulses showed an intermittent conduction, and that with the following characteristics: a) the intermittent conduction could occur in very low frequencies, and b) the impulses were transmitted and interrupted in groups alternatively. The number of impulses in each passed group diminished gradually, though not regularly, one after another, and at the same time the interval between two passed groups (that is, the duration of the blocked period) increased more and more. Repetitive impulses could thus lead the nerve to complete narcosis much sooner than when rested. The opposite effect was observed in the course of recovery, namely, repetitive impulses sent in at a stage of incomplete recovery did prolong the p.i.c. and thus retarded the recovery.

For obtaining quantitative informations, it will be appropriate to examine the temporal variation of the ratio \( n_p/n_t \) (\( n_p \) representing the number of passed impulses and \( n_t \) the total number of impulses), which we may call the 'ratio of passage' for convenience. But as there was no proper scale of time to employ, two different procedures were tried, as follows: 1) examination of the ratio as a function of time, and 2) examination of the ratio as a function of 'group' in succession. In the former case, one second was taken as unit of time, excluding the very first 0.1 sec., which was treated separately because of its particularity as the 'initial period.' In the latter case, two successive groups, passed and interrupted, were taken as a pair, and the ratio in each pair was examined one after another.

The two sets of results did not coincide in details, but they showed a satisfactory agreement in gross features, as follows: 1) In very weak narcosis, the ratio ran up steeply from the initial value to a much higher value, even to 100%, to remain there practically constant (fig. 8, b, fig. 9, b). In a little stronger narcosis, the rise of the ratio was gradual and much less, and after forming a plateau-like elevation, it fell down gradually towards zero (fig. 8, c1, fig. 9, c1). The height and duration of the elevation depended on the depth of narcosis. 2) In intermediate strength of narcosis, a 'valley' appeared before the elevation mentioned above (fig. 8, c2,3, fig. 9, c2,3). 3) In strong narcosis, the ratio diminished more or less rapidly towards zero in a simple manner without forming any elevation (fig. 8, d, e, fig. 9, d, e). These facts could be observed, eventually even much more clearly, in the recovery course, too. A detailed description is omitted for lack of space.

For explaining these facts, we have to take at least two factors into consideration: Firstly, the least interval in relation to 1) the impulse frequency, which is very high initially but very low finally, and 2) the depth of narcosis, which can elongate the least interval to a considerable extent; Secondly, the narcosis-promoting effect of each transmitted impulse, which will accumulate or rather disperse according to the impulse frequency, high or low, or, increasing
FIG. 8. Ratio of passage as a function of time. The material data derived from fig. 5, a, b, c1–3, d, e correspond to the same of fig. 5.

FIG. 9. Ratio of passage as a function of 'group' (about details, see text). The data derived from fig. 5. Abscissa denotes the No. of the group-pair, and ordinate the number of impulses. a, b, c1–3, d, e correspond to the same of fig. 5.
or decreasing. In actuality, these two factors must be co-operating and making the matter complicated. But it seems also certain that in the initial and following short period, which is practically free from the second factor mentioned above, the main cause of blocking will be the least interval, more or less lengthened by narcosis, while in the later period, the primary cause will be the effect of impulses accumulated to a certain degree, because the impulse frequency here appears to be too small to regard the least interval as responsible. Based on such reasoning, the whole of the $n_p/n_t$-curve obtained above can be made comprehensive, although grossly, by the following considerations:

In very weak narcotization, the least interval will be the only effective factor in operation. Hence, the ratio of passage, which is relatively small in the initial period because of the high frequency at that time, will rise steeply to a high value in company with the marked decrease of impulse frequency. And, remaining there practically invariable, it will make a complete plateau (fig. 8, \(b\), fig. 9, \(b\)). With a little stronger narcosis, the effect of the transmitted impulses will begin to exert its influence, which will result in making the plateau lower and in curtailing it by degrees (fig. 8, \(c_1\), fig. 9, \(c_1\)). With a still stronger narcosis, the effect of impulses will be of a considerable strength at about the end of the initial period, which will block a number of impulses and thus make the 'valley' (fig. 8, \(c_{2,3}\), fig. 9, \(c_{2,3}\)). But about here the impulse frequency begins to run down markedly, so that the dispersion of the effect will become prevalent rather than accumulation (rise of the ratio after the valley). Thereafter, accumulation and dispersion will be compatible for a while (elevation formation) until finally block occurs in larger and larger numbers of impulses as the result of narcosis advanced with accumulation of the impulse effect (fall of the ratio in the later part of the later period). The plateau-like elevation in the curve of the ratio of passage can thus be found out (fig. 8, \(c_2\), fig. 9, \(c_2\)). Finally, the fact observed in strong narcosis, that is, the more or less rapid fall of the ratio to zero (fig. 8, \(c_3\), \(d\), fig. 9, \(c_3\), \(d\)) may be partly due to the prolongation of the least interval, but the fact of grouping which is still observable in this case, too, appears to indicate that the effect of transmitted impulses is in operation, too.

In the above explanation, it was presumed that each transmitted impulse leaves some narcosis-promoting influence behind it. This is only a hypothesis at present, but there is some evidence in support of this idea:

1) The ratio of passage showed a tendency of gradual decrease even after the frequency of impulses has attained a steady level, after loading. This indicates decisively that repetitive impulses act to make the passage difficult.

2) When a nerve was rested for a while by unloading the muscle after a complete block occurred, then there appeared some diphasic impulses, at least in the initial period, in the next loading (compare fig. 5, \(c_2\) and \(c_3\), or \(c_3\) and \(d\)). This indicates that a) the complete block observed in the previous loading was due to the impulses impinging upon the narcotized region, and b) the nerve recovered a little from narcosis during the rest, in spite of the permanent application of the narcotic. The fact a) suggests of something which was added by each impulse and acted to sustain the blockage, and the fact b) indicates that
the ‘something’ disappeared during the rest, independently of the temporal progression of narcosis. Presumably, the blocked impulses were exerting a similar effect as the transmitted impulses, which, upon unloading, ceased to accumulate and began to disperse.

3) Diphasic resting discharges could be observed by unloading the muscle after a complete block was reached. (fig. 5, c2,3). This seems to be another indication that impulses of relatively high frequencies are effective for promoting the narcotizing process, or at least for sustaining the state of blockage, even if they are blocked at the entrance of the narcotized region. If not, the nerve would recover sooner or later from the complete block, and at least some of the impulses, which had been blocked at the entrance, would begin to pass through. Actually, however, it was never the case.

**DISCUSSION**

It is not quite certain if the facts stated above take place in situ, too, but there is no particular reason, to believe that they would not. Then, the fact of intermittent conduction seems to be highly suggestive of the gradual depression of sensation in the case of block anesthesia. Of course the group-wise interruption alone of the impulses may not necessarily bring froth any weakening of sensation, but the gradual diminution of the number of impulses in successive passed groups will be effective in so doing.

Now, as a phenomenon closely connected with our experience, there is the so-called ‘Wedensky’s inhibition,’ which has been confirmed repeatedly by many workers. The results are not directly comparable with ours, because in their experiments the nerve ‘trunk’ was used, and, moreover, the stimulus interval was uniform and generally much shorter than ours. Only the myogram 7 presented by Wedensky (13) and a record offered by Fröhlich (3) (Tafel XIII, Kurve 1) may be related to our results, because they show some inhibitory effect in spite of the relatively low stimulus frequency (perhaps 8 c/sec. in the former, and 18 c/sec. in the latter). Tasaki and Takeuchi (12) observed, employing single nerve fibre preparations, a phenomenon which appears to be identical with the ‘intermittent conduction’ in the present experiment. In their experiment, however, the number of stimuli was not more than a few, so it is impossible to relate it to ours. Moreover, the stimulus interval (5-10 msec.) was well within the range of ‘least interval.’ So, their results could perhaps be compared to ours obtained in the initial period, that is, directly after the loading, where the impulse frequency is high. However, the phenomenon of intermittent conduction in the later period or in the resting discharge seems to be unexplainable simply from the view-point of least interval, not only because the impulse frequency is too small, but also because the impulses appeared in groups, and that with gradually decreasing number of impulses in the passed groups. Fröhlich (3) said that the refractory period could be prolonged even to 0.1 sec. or more, because the ‘Anfangszuckung’ appeared when the asphyxiated or narcotized nerve was stimulated by a frequency of 10/sec. But even if this is correct, still it is incapable of explaining the grouping phenomenon encountered in the present experiment.
Now, there are two major phenomena to be explained, namely, 1) the plateau or elevation formation as regards the ratio of passage, and 2) the group formation as regards the passed and blocked impulses. It was described before that the plateau formation can be related to the least interval, and the elevation formation to the accumulation and dispersion of the narcosis-promoting effect left behind by each transmitted impulse. The group formation, too, may be explained in a similar way, namely, the grouping of blocked impulses as due to accumulation of the effect left by the impulses running in advance, and the grouping of passed impulses as the result of dispersion which took place during the preceding blocked period.

Thus we can understand the whole picture fairly well, assuming a narcosis-promoting action of each impulse. This action of impulse seems to be related with the permeability increase accompanying activity, that it, perhaps with a temporary increase of penetration of the narcotic. The narcotic if gathered inside the membrane to a certain degree, may exhibit a narcotizing action, but it will diffuse away if left alone, which may be nothing but the recovery.

The above reasoning presumes that the narcotic action is conditioned by penetration of the narcotic. But this is not without question. We have had a number of theories about the mechanism of narcosis, but the opinions are not quite settled yet. It appears to have been made certain that the narcotic does not act upon the protoplasm (Marsland (8)), but it is still unknown whether it acts on the membrane from outside or inside or from both. Further, the mechanism may be different from drug to drug. The facts observed in the present experiment and the above reasoning about them, are in support for the penetration theory, but they need be ascertained by some proper pharmacological methods.

Next, we have to quote a few works reported by Matthews and his collaborators (1, 5, 10). They observed the fact of intermittent conduction, happening in the nerve fibres in the spinal cord when repetitive impulses were sent in from a peripheral nerve. The central fibres in this case were only direct continuations of the peripheral fibres, with no intervening synapse. The phenomenon was observed even in such low frequencies of stimulation as 10 c/sec. (Barron and Matthews) or 9-24 c/sec. (Holmgreen). So, the phenomenon is very similar to ours, and this is why the term ‘p.i.c.’ was borrowed from them to be employed in the present paper. However, there is a basic difference between their observations and the present author’s namely, that theirs were made in normal nerves, and ours in narcotized nerves. There are also some minor differences, for example, that in theirs there were some cases where conduction was recovered by an increase of the stimulus frequency. But as far as the phenomenon of ‘intermittent conduction’ is concerned, their fact resembles ours so well that the present author cannot help thinking that some common factor must be underlying. Whatever it may be, it should be remembered that the phenomenon of ‘intermittent conduction,’ which they attributed to a property of the central nerve fibre, could be observed in peripheral nerve fibres, too, although in a special condition.

Finally, as the cause of grouping in the initial period, the author has sup-
posed a discontinuity or fluctuation of the generator mechanism itself, as stated above. If not, then, we have to attribute the 'grouping' to the property of the nerve fibre itself and admit that the normal nerve fibre is able to respond and conduct intermittently on some occasions. Matthews (9) happened to observe grouped impulses in the 'later period' (in the present author's sense) by changing the condition of the bathing fluid of muscle of his toe-muscle-and-nerve preparation. He supposed then that the end organ was rhythmically producing a state of excitation, under the special condition given. This is very probable and the present author thinks so, too. But strictly speaking, it is not obvious whether the change of condition of the bathing fluid acted on the end organ or on the nerve fibre. Here is a point to be clarified.

**SUMMARY**

Employing Matthews' toe-muscle-and-nerve preparation as the material, observations were made on the afferent impulses fired off from the muscle spindle and impinging upon a narcotized region of the nerve trunk. Chloretone vapour was used as narcotic. By a pair of electrodes placed at proper distances from the distal and proximal ends of the narcotized, region, the impulses could be led off in diphasic or monophasic shape according to whether they passed through the narcotized region or not. The impulses were observed and recorded by means of a Braun-tube and an electromagnetic oscillograph respectively. The results obtained are as follows:

1) There appeared a 'period of intermittent conduction (p.i.c.)' before a complete block was reached.

2) The p.i.c. appeared earlier when repetitive impulses were sent into the nerve to pass through the narcotized region.

3) The intermittent conduction in the initial period appeared earlier and lasted longer than that in the later period.

4) The lower the frequency, the easier the passage of impulses.

5) Generally, repetitive impulses sent into the nerve make the passage of impulses gradually difficult. Blocked impulses, too, appear to have the same effect, although little.

6) The intermittent conduction in the initial period is comparable, though not exactly, with the similar fact observed by others in the case of high frequency, whereas the intermittent conduction in the later period or in the resting discharge is characterized by very low frequencies and by alternative grouping of passed and blocked impulses. This fact can not be understood from the concept of least interval.

7) As for the reasons for intermittent conduction, in general, the author supposed a) prolongation of the least interval by narcosis and b) narcosis-promoting effect of impulses. The former may be the primary factor in the initial period (a period of high frequency and of weak b)-effect just mentioned), and the latter, in the later period (a period of low frequency and of strong b)-effect).

8) The existence of the p.i.c. was interpreted as a cause of the gradual decay of sensation in block anesthesia.
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REFERENCES