

# DIFFERENTIATION OF TONIC FROM PHASIC ALPHA VENTRAL HORN CELLS BY STRETCH, PINNA AND CROSSED EXTENSOR REFLEXES

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THE QUESTION of whether some alpha ventral horn cells are specialized for tonic activity, and others for phasic activity, has many times been raised. Thus Granit *et al.* (13), in a survey of 100 extensor motoneurons responding to brief maintained stretches of the gastrocnemius-soleus muscles, found that 53 per cent of these cells discharged only at the onset of muscle stretch. The remainder discharged throughout the duration of the stretch, or could be made to do so in the state of post-tetanic potentiation set up by previous tetanization of the afferent nerve fibres from the muscle. In these experiments, as in those of Granit (12), the phenomenon of post-tetanic potentiation of ventral horn cells was revealed in a new aspect: in addition to the well-known post-tetanic increase in the size of the monosynaptic reflex (18), due to recruitment of additional motoneurons from the subliminal fringe, there occurred also prolongation of the motoneurone discharge evoked by sustained stretch of the muscle, a kind of "spastic" exaggeration of the response.

Until recently the various claims in favour of a subdivision of the  $\alpha$ -motoneurons into tonic and phasic cells have lacked critical evidence, so that the standpoint in this question cannot be said to have altered since 1925 when it was aptly formulated by Cobb (3) in reviewing the results of the Sherrington school and other workers: "From all this evidence it can be seen that static and kinetic movement can be explained on the basis of one neuromuscular mechanism. 'Tonic' and 'phasic' reflexes, though unlike, are separated by no fundamental difference in physiological mechanism." The gamma motor system, which definitely is another neuromuscular mechanism, was, of course, unknown at that time. The probability that "phasic" and "tonic" are specific properties rather than graded responses of motoneurons will be strengthened if it can be shown: (i) That either type of behaviour always characterizes individual motoneurons pushed to maximum performance in natural reflex action. (ii) That tonic behaviour persists

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after cutting the ventral roots, *i.e.*, that it does not depend on tonic reflex excitation of the  $\alpha$ -motoneurone due to tonic excitation of the muscle spindles by the  $\gamma$ -motoneurones. (iii) That the supposedly tonic motoneurones are really  $\alpha$ -motoneurones and not members of the  $\gamma$ -group which is well-known to display tonic characteristics but designated to control muscle spindles (see *e.g.*, 11 for a summary). (iv) That tonic and phasic motoneurones differ in any other points of structure or function.

Recent papers from this laboratory dealing with the stretch reflex (12, 13) have contributed evidence in all four of these categories. (i) Post-tetanic potentiation by tetanization of muscular afferents has been found to be an efficient method of conditioning the appropriate motoneurones for maximum performance in subsequent stretch reflexes. In these reflexes, "tonic" and "phasic" motoneurones always ran true to type. Increase of extensor tonus by ablation of anterior lobe of cerebellum could not make a "phasic" neurone discharge tonically, even in the state of post-tetanic potentiation, although it exaggerated the tonic properties of those that before operation had responded repetitively, in the potentiated state, to maintained stretch. (ii) The tonic behaviour did not depend on the integrity of ventral roots. (iii) The considerable experience with  $\gamma$ -cells in this laboratory made it possible to avoid the serious error of mistaking  $\gamma$ -cells for tonic  $\alpha$ -cells. The  $\gamma$ -spikes are much smaller than any of the  $\alpha$ -spikes and are either inhibited (8, 17) or else not influenced by stretch nor do they show the effects of post-tetanic potentiation by which the tonic  $\alpha$ -fibres are identified. (iv) One further differential property was seen in the fact that, when a ventral root filament contained one phasic and one tonic spike, the phasic spike was large and the tonic small. On the notion that the size of the root fibre (= size of the spike) is related in some simple manner to the size of the cell from which it emanates, the result means that the tonic fibres mostly arise from smaller  $\alpha$ -ventral horn cells than those from which the phasic ones stem.

The foregoing evidence derives from experiments confined to the stretch reflex. How far is the distinction between "tonic" and "phasic" motoneurones to be upheld in a wider reflex context? In this paper, the investigation is extended to "potentiated" extensor motoneurones in two tests additional to the stretch reflex, namely, the pinna reflex and the crossed extensor reflex. The relevance of this line of analysis is clear. If "tonic" and "phasic" motoneurone properties depend on factors such as relative numbers and density of end feet, there would seem to be no reason to expect that two separate polysynaptic reflex pathways in this respect should agree with the reflex pathway from the muscle afferents. In this case, one would expect that a cell might be found to behave tonically in one reflex, phasically in another, with a variety of behaviour greater in proportion to the number of afferent sources tested. On the other hand, if "tonic" and "phasic" behaviour were specific motoneurone properties or specific properties of a common organization, individual responses should remain true to type in the several reflexes.

## METHODS

Filaments were isolated in the ventral roots of decerebrate cats, de-efferented from L5 to tail end. The leg used was denervated with the exception of the medial and lateral nerves to the ankle extensors gastrocnemius and soleus, usually unseparated and only dissected free from the plantaris. The muscle was attached to a strain gauge myograph (see *e.g.*, 12) at light initial tension, the test consisting in pulling the myograph 10 mm. against a stop in order to elicit the test reflex to stretch. The root fibres were thus also identified by stretch. Whenever the latencies of the reflex spikes were tested by shocks to the gastrocnemius nerves, they were found to be of the order ascribed to monosynaptic relays (which need not mean that stretch is a purely monosynaptic variety of activation). The same stimulating electrodes were used to tetanize the muscular afferents at rates between 250 and 435 per sec. for 10 sec. Testing consisted in eliciting the stretch reflex at regular intervals of 10 sec. in the post-tetanic potentiation period. Another pair of electrodes was placed on the crossed sural nerve which was stimulated at the same frequency for the same duration as the gastrocnemius nerves. This, in the same manner, was followed by testing with stretch.

Two double-beam cathode-ray tubes were available, one pair of which gave a standing-spot record on running paper of reflex spike discharge and myogram, the other pair being swept at right angles to the movement of the paper in order to resolve the picture into samples at sweep speeds fast enough to make identification of the spikes possible. This is a useful control.

Some records were also taken with internal microelectrodes, high-resistance KCl-filled capillaries, in the manner introduced by Eccles and his collaborators (6), here applied as in the recent work by Granit and Phillips (12) on the cerebellar Purkinje cells. With sufficient fixation of the preparation in a frame of parallel bars, we were able not only to tolerate the natural breathing of the decerebrate cat but also to stretch the muscle without dislodging the intracellular electrode. We found it necessary to clamp the skull, one dorsal spine, two lumbar vertebral bodies (through incisions in skin and muscle), both femoral trochanters, the drill at lower end of femur and the clamp at the ankle. The technique for intracellular recording has been as described by Phillips (19) and by Granit and Phillips (14).

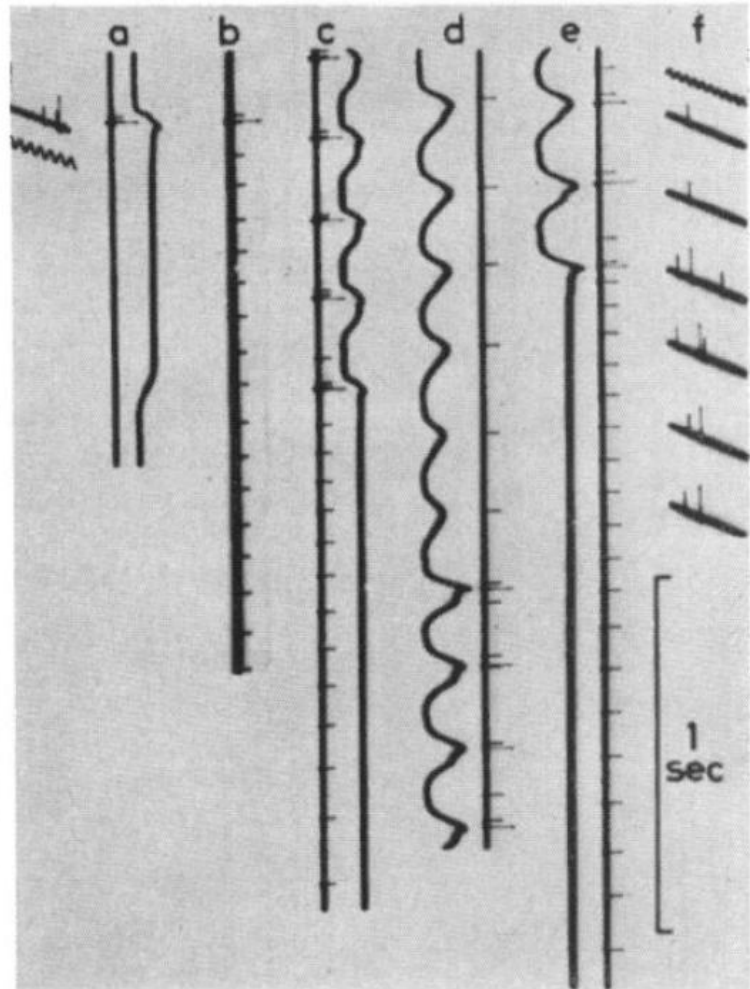
## RESULTS

1. *Post-tetanic potentiation by stretch.* The fact that stretch itself leaves a state of post-tetanic potentiation has been noted by Granit (12). It was now confirmed in many ways and developed into a method of throwing the ventral horn cells into the potentiated state. Figure 1*a* is the control stretch reflex which elicits two small spikes and one large spike in the filament isolated. The large spike often tends to be feebly delineated at the slow film speed used but the adjacent sweep shows it clearly. The muscular afferents were then tetanized and stretch repeated in record *b*, the muscle being maintained stretched for the duration of the picture. It is seen that the large spike responded once and the small spike tonically. So far this is merely a repetition of the previous work (12) to show the characteristic responses of a large phasic and the small tonic spike in the potentiated state. Figure 1*c* illustrates that repetitive brief stretches also induced the potentiated state in which the small fibre responded tonically when in the end stretch was maintained.

This method of potentiation often proved to be even more efficient than a 10 sec. electrical tetanus, particularly if repeated series of 10 or more brief stretches were made to follow one another until the tonic properties showed up. Figure 1*d* refers to another experiment, the record being directly con-

tinued in *e*. There are 13 brief stretches, made at somewhat different rates in order to demonstrate that the phasic fibre responded only when stretch was fast enough. Samples on the sweep are shown in record *f* separating the two spikes and demonstrating that the tonic one, here as in nearly all cases, had the lower threshold. When in *e* this stretch was maintained after the

FIG. 1. *a*, characteristic large, phasic and small, tonic reflex spikes (left) in response to stretch shown on myograph (right); sample sweep on the left for isolating the two spikes. *b*, same pair of spikes responding to stretch 30 sec. after 9.1 sec. tetanization of the gastrocnemius nerves at rate of 220/sec. (myogram not included). *c*, repeated brief pulls followed by maintained stretch to activate tonic spike. *d-f*, another experiment on tonic and phasic spikes identified on sample sweeps taken during the brief pulls at different rates of rise, shown in *d* and beginning of *e*. Sustained stretch in *e* activates the tonic spike to sustained activity. Records *f* actually correspond to bottom part of *d*. Note that phasic spike in last but one stretch has collided with tonic spike. Sweep time 100 c./sec. Film speed in this and all figures 5 cm./sec.

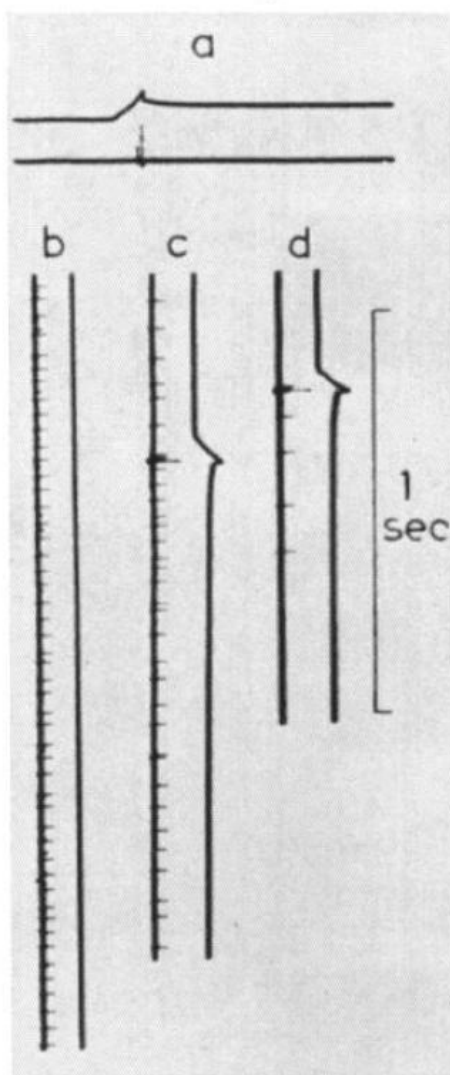


13th pull on the myograph stand, the tonic fibre, which had given only a couple of spikes in the control, responded repetitively as long as, within limits, the muscle was held under tension. Actually, in the present experiments, this natural way of potentiating the fibres was the method regularly used.

Clearly, since stretch in itself throws the ventral horn cells into a state of post-tetanic potentiation (12), an increase in the rate of repetition of testing by stretch will tend to prolong the time-course of the "natural" post-tetanic potentiation. The interval chosen empirically, 10 sec., has been found to be well adapted for the present purpose though in highly sensitive animals it may maintain some potentiation almost indefinitely. In a large percentage of the animals a very long-lasting effect can be obtained with highly tonic cells by repeating the test by stretch every 5th sec. A pause of from 0.5 to

1.0 minute generally suffices to bring the response back to an original control value of a few tonic spikes. This accumulation or temporal summation of post-tetanic potentiation was described by Granit (12, his Fig. 4). It would seem to be of wide general significance.

It is necessary to realize that experiments on tonic cells require excellent



preparations. Any deterioration in the state of the animal is immediately reflected in failure to obtain tonic responses. This is very well known from the earlier studies of reflex behaviour. It was, for instance, pointed out on pp. 51-52 of the summary of the Oxford school (4) that the phasic component of the stretch reflex has far higher resistance than the tonic to almost any kind of interference with the state of the animal. Tonic reflexes do not stand much anaesthesia (see *e.g.*, 1, 12).

2. *Testing by crossed extensor and pinna reflex.* In Fig. 2 there is first the unpotentiated control *a*. The small spike could be stirred by repeated stretch to tonic action in the usual manner; the large one remained phasic. Record *b* shows the intense effect of pinna twist on the small tonic spike. In *c*, 30 sec. later, there is still a good after-discharge when testing by stretch is carried out. This tonic reflex was potentiated for a couple of minutes after cessation of the pinna twist. When the

FIG. 2. *a*, typical large and small spikes to control stretch (myograph above oscillograph record). *b*, tonic spike responds during pinna twist. *c*, 30 sec. later, in after-discharge, muscle stretched. *d*, stretch 30 sec. after 9.1 sec. tetanization of crossed suralis at rate of 220/sec.

response had returned to control type (*a*), the crossed sural nerve was tetanized for 10 sec. The record *d* was taken 30 sec. later. Clearly, although the base line was silent, the tonic reflex behaved just as if it had been potentiated by stretch or by tetanizing the muscular afferents. The long-lasting after-discharges to pinna twists—in fact, it lasted about 1 minute in this case—are not always seen but hardly ever does one in good tonic preparations miss the concealed potentiation by pinna stimulation of the stretch reflex and it is always confined to the tonic cell, though the phasic cell may be stirred up briefly during actual stimulation. The important point, however, is that the tonic cells have these long-lasting concealed remainders which, after a twist of the pinna, do not as a rule linger on for as long as after potentiation by repeated stretches or by repetitive stimulation of the gastrocnemius afferents.

The very regular effect on the tonic cells of repeated stretch and of pinna twists have made these two tests the standard ones in our experiments inasmuch as it has been necessary to have a quick way of identifying tonic cells and differentiating them from phasic ones, whatever the final aim of our analyses. The crossed extensor is useful only in the best preparations which are far more quickly tested by merely pulling on the muscle a few times or twisting the animal's ear. However, fundamentally there is no difference between any of the three tests. Thus Fig. 3 deals with a pair of spikes, large and small, of which the small spike in response to a pinna twist had fired for nearly 1 minute afterwards. Their respective phasic and tonic properties are illustrated by the reflex response to stretch in *a*. In *b* is shown the after-discharge to 10 sec. stimulation of the crossed sural. It, too, lasted for nearly 1 minute. Again the phasic cell was silent.

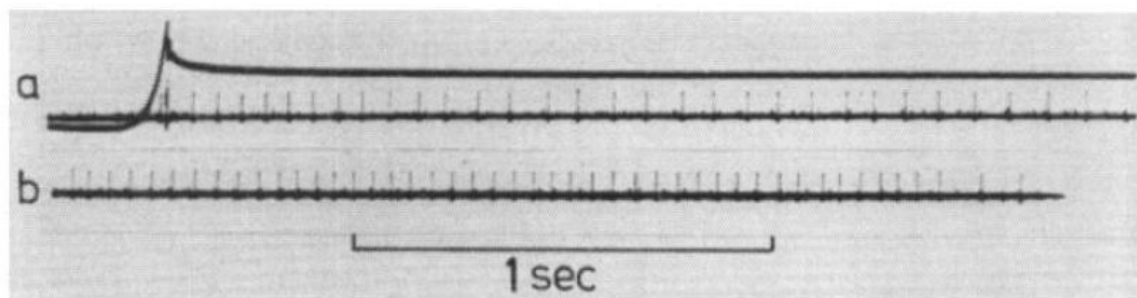
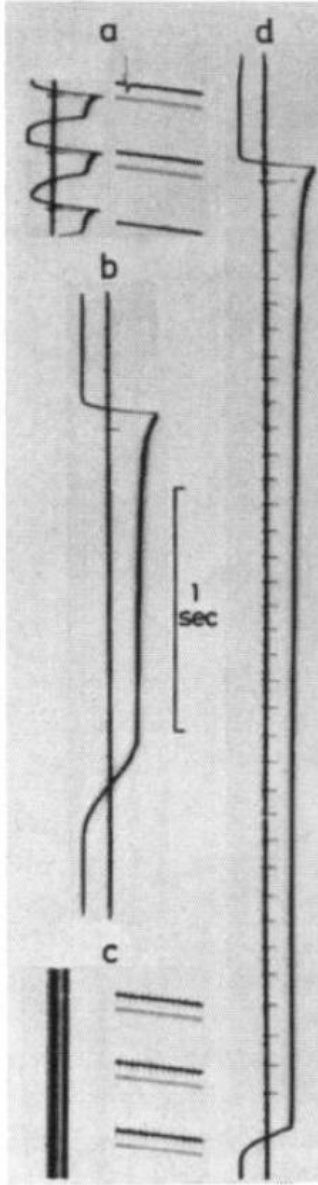


FIG. 3. *a*, large phasic and small tonic spike responding to stretch. *b*, after-discharge of small spike following 9.1 sec. tetanus of crossed sural nerve at rate 250/sec.

Figure 4*a* demonstrates a large and a small spike responding to a few brief stretches. Sweep and stretch are not synchronized but in the first sweep record the pair of spikes has appeared. To a single isolated stretch (*b*) the phasic cell did not respond regularly and the tonic only once. Then the crossed sural nerve was tetanized and both cells responded initially but at the end of the stimulation period, illustrated in *c*, the discharges of both cells were suppressed. Only shock artefacts are seen. Nevertheless, when, in *d*, testing by stretch was tried 10 sec. after the sural tetanus, the phasic cell responded but once but the tonic cell was activated almost for the duration of stretch illustrated. Again, as with pinna twists, it was possible to create a concealed state of long-lasting residual facilitation of the tonic ventral horn cell.

These examples will suffice to show that repeated stretch, tetanization of the muscular afferents, pinna twists or crossed extensor from the sural nerve had fundamentally identical effects on tonic ventral horn cells. In all these tests the phasic cells also behaved similarly, *i.e.*, responded once or twice to testing by stretch in the period following cessation of the stimulus. Often one saw some potentiation of the phasic cell in the sense that to brief repeated stretches or tetanization of the muscular afferents it responded for a while more readily than in the non-potentiated state but its general type

of discharge remained unchanged. In all these cases the relative size of the spikes in filaments containing one tonic and one phasic axon—the only legitimate basis of comparison—served to distinguish phasic from tonic ventral horn cells, confirming our previous observations (12).



It is not our intention to maintain that under no circumstance can phasic cells respond more than once or a few times. In fact, to the 10 sec. rapid electrical tetanization of the muscular afferents or to a forceful twist of the pinna the phasic cell may respond repetitively. These, however, are either very strong or else unnatural stimuli, in spite of which a very common experience with tetanus is that the phasic cell ceases to respond early while the tonic generally goes on to the very end, though at slow rates below 10–20 per sec. When stirred up in this fashion the phasic cell generally responds at much faster rates, 30–60 per sec., for the brief time it can respond at all. There may well be powerful motor organizations capable of firing the phasic cells repetitively but we have not yet studied the innumerable combinations of trigger points required for further generalizations.

3. *Intracellular recording of tonic activity.* While it proved easy to enter ventral horn cells and obtain good penetrations and also to pull on the muscle without dislocating the intracellular electrode, it was difficult to find, amongst the mass of neurones, one that responded tonically to gastrocnemius-

FIG. 4. *a*, small tonic and highly phasic spike requiring rapid rate of stretch; the pair once caught on sweep (right). *b*, without potentiation tonic spike responds only once to stretch. Note just visible small gamma spike inhibited by stretch. *c*, during end of 9.1 sec. sural tetanus at rate of 350/sec. to show absence of discharge, marks on sweep circuit being shock artifacts. *d*, 20 sec. later small spike proved to be tonic when tested by stretch. Sweep time, 40 msec.

soleus stretch. Very few experiments were made, the aim merely being to find out how large, if any, changes in the steady level of membrane potential could be obtained with a tonic motoneurone firing repetitively. In one highly tonic animal two such neurones were encountered, one of which is illustrated in Fig. 5.

The records of Fig. 5 begin with calibration to 75 mV. on both beams, then follow antidromic (AD) and orthodromic (OD) responses before (*a*) and after (*b*) completion of the experiment on stretch and post-tetanic potentiation. The decerebrate animal had good extensor tonus and we hap-

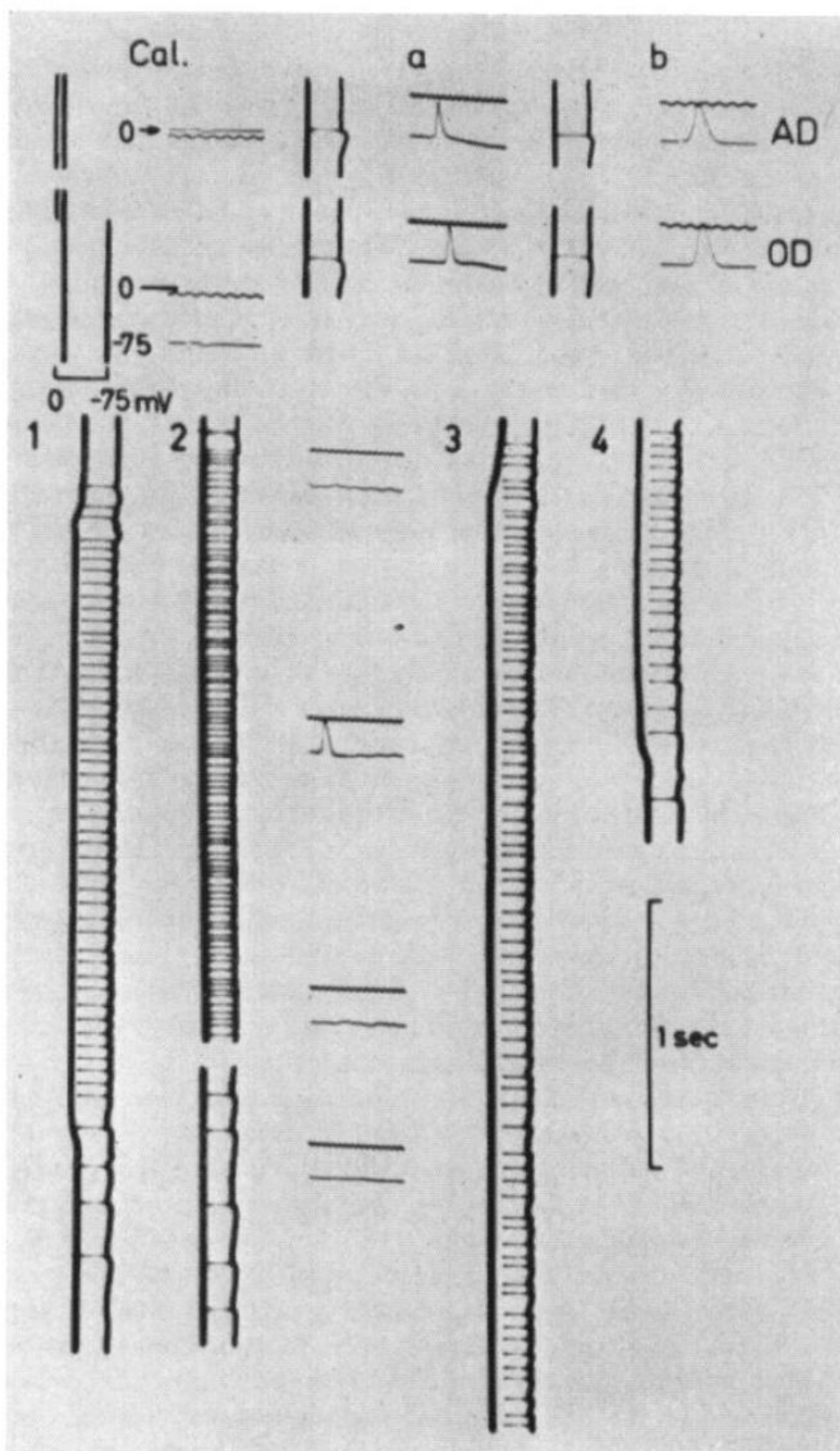


FIG. 5. Intracellular record of tonic cell, silent unless activated. *Cal.*, calibrations to  $-75$  mV. on both side beam and sweep. *AD*, antidromic, *OD*, orthodromic monosynaptic activation of this cell before (*a*) and after (*b*) completion of experiment, part of which illustrated below. Shock artifact visible only in antidromic records. 1, response to stretch, myograph being on left side. 2, response to 9.1 sec. tetanus of gastrocnemius nerves at rate of 320/sec. followed by after-discharge cut out separately. Shock artifacts invisible. 3 and 4 (directly continued), response to stretch 30 sec. after previous tetanus. Sweep time in msec.

pened to strike a cell that (in record 1) responded repetitively to control stretch. In record 2 is shown the beginning of the high-frequency electrical tetanization of the gastrocnemius nerves followed by part of the after-discharge from the cell, separately at the end. On the sweeps should be noted the subliminal oscillations of membrane potential corresponding to the stimulation frequency (320 c./sec.). These rhythmic synaptic potentials during the stimulation period are in contrast with the irregular "synaptic noise" (record 2) seen during the after-discharge. Record 3 (continued in 4) was taken 30 sec. after tetanization, the optimum time for potentiation.

Now this cell was very active from the beginning, firing at rates of 23 per sec. in record 1, so that post-tetanic potentiation had but little to add. The maximum was 26 spikes per sec. Tetanization in 2 pushed the rate up to 38-40 impulses per sec. which is high for an intact (unpunctured) tonic cell. Thus there is in these records a range of from 0 to 40 impulses per sec. which actually is nearly the full working range of tonic cells. Rates around 10-20 per sec. are the most common in our experiments. However, with this range at our disposal it should have been possible to see large steady depolarizations if these were a striking feature of the behaviour of the soma membrane. Only in record 2, at around 40 per sec., is there a slow shift of baseline of the order of 1-2 mV. which can be explained equally well by intense excitatory synaptic bombardment prematurely interrupting the so-called positive after-potentials following each spike. Similarly in intracellular records from Betz cells Phillips (19) did not see significant variations in steady level of depolarization when the rate of discharge varied. Very high discharge rates were obtained by Eyzaguirre and Kuffler (9, 10) in the stretch receptors of the lobster. There were actually then shifts of level of depolarization, but they were small compared with the variations of firing frequencies. It was assumed that very much larger generator potentials had arisen in the dendrites surrounding the muscular elements activating the stretch receptors.

From our own results and the comparisons referred to it is not concluded that slow generator potentials do not exist in the dendrites of ventral horn cells. Our conclusion is merely that even if they did exist, it is hardly feasible to base a method of discriminating between phasic and tonic cells on the duration of slow states of depolarization of the soma membrane. At this site they are too small at the firing frequencies of motoneurons which, after all, tend to be well below 50 per sec. There is no other obvious reason why intracellular recording should be used for the present type of problem. The use of isolated ventral root filaments is preferable, in which simultaneous records of one phasic and one tonic spike provide the analytical optimum in addition to the certainty that the cells and the converging presynaptic apparatus are uninjured by puncture.

#### CONCLUSION AND COMMENTS

At the present juncture our conclusion is that there are two systems of ventral horn cells for extensor muscles, large phasic and small tonic cells. The latter are easily activated in the tests tried, capable of gradually building

up slow states of long duration and firing at slow rates at the slightest provocation, provided that the general extensor tonus is sufficiently high. Otherwise tonic reactions are of shorter duration. It is characteristic of these slow states of residual facilitation, set up by repetitive stretch, pinna twist or crossed extensor reflex, that they generally are concealed and thus easily missed unless brought to light by a suitable test such as, in our case, repeated short periods of maintained stretch. The phasic cells are high-threshold, the tonic ones low-threshold, when tested by stretch. Some phasic ones require very high rates of stretch.

The experiments of Denny-Brown (5) made us suspect that highly tonic cells might always be soleus neurones, as he had used them for electromyographic recording of sustained stretch reflexes; but this did not prove to be the case. It could easily be shown, after separation of the gastrocnemii from the soleus, that units responding to gastrocnemius stretch alone were also on the tonic system.<sup>3</sup> It is important, in view of the significance of repetitive activity from muscular afferents, to realize that this is normally controlled by the gamma system (see *e.g.*, 11). Thus this tonic system will operate a special set of tonic ventral horn cells over the loop through the spindles utilizing post-tetanic potentiation.

If one adheres to this line of thinking, further reasoning will have to be developed as follows. Is post-tetanic potentiation, set up by natural or artificial means, the common denominator for all these states of slow accumulation or temporal summation so easily demonstrable with tonic cells? There is nothing to contradict this view, which, of course, is well established for tetanized muscular afferents with the aid of various criteria (12). The post-tetanic potentiation for pinna and crossed suralis would be polysynaptic. Now polysynaptic potentiations are known to occur (7, 15, 20). A consequence of this view is that the polysynaptic chains concerned must contain tonic interneurones, since only if this is the case can a state of post-tetanic potentiation to a *natural* stimulus, such as, *e.g.*, pinna twist, be carried forward to the effector end station. Phasic interneurones would, after the first synapse, translate the repetitive activity of the natural stimulus into a single volley and thus fail to transmit states of post-tetanic potentiation. Another consequence is that pinna reflex, crossed extensor and stretch are likely to have a common link in the polysynaptic chain (*cf.* 20), since, according to present concepts, post-tetanic potentiation is essentially

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<sup>3</sup> In two papers J. C. Eccles, R. Eccles and A. Lundberg have since studied the small tonic and larger phasic ventral horn cells. In the first paper ("The convergence of monosynaptic excitatory afferents on to many different species of alpha motoneurones," *J. Physiol.*, 1957, 137: 22-50), they show by intracellular recording and identification with antidromic shocks into different muscle nerves that the small  $\alpha$ -spikes of slow conduction velocity tend to activate red muscle and that their motoneurones, as we have concluded (12, 13), are run by the  $\gamma$ -spindle-nuclear bag (annulo-spinal, A2) afferents more effectively than the others. In the second paper ("Durations of after-hyperpolarizations of motoneurones supplying fast and slow muscles," *Nature*, 1957, 179: 866-868) they show that the tonic muscles have motoneurones with (intracellular) after-hyperpolarizations of greater duration than the phasic ones and plot a diagram illustrating direct proportionality between duration of after-hyperpolarization and conduction time.

presynaptic. Three reflexes operating as these do during concealed states of several minutes by mutual re-enforcement are therefore likely to converge through the same penultimate neurone onto the same ultimate neurone. The latter (see diagram of Fig. 6) is the effector (motoneurons) or *second* common final path with respect to these sources of activation. The post-tetanic state would be located to the synaptic end feet belonging to the *first* common final path in order for the reflexes to give concealed residual

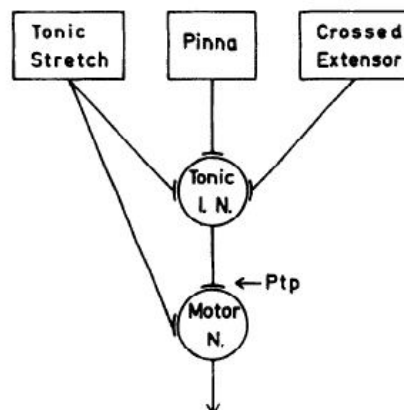


FIG. 6. Diagram illustrating convergence of three afferent sources on common tonic interneurons (*IN*) projecting as first final common path onto motoneurons (*Motor N*) which provides second final common path. Site of post-tetanic potentiation (*Ptp*) marked, as described in text. Also indicated, monosynaptic path to ventral horn cell.

facilitations for the long durations encountered. This corollary is perhaps not as strict as the requirement that the interneurons for polysynaptic potentiations must be tonic, because we do not yet possess enough information of the nature of pre-synaptic potentiation. Nevertheless it has proved strict enough for practical use in the large number of papers dealing with post-tetanic potentiation (summarized in 6; 12, 16). The potentiation to muscular afferents has hitherto been assumed to be purely monosynaptic (18).

#### SUMMARY

The impulses in individual alpha ventral root fibres responding to gastrocnemius stretch in *de-efferented*, decerebrated animals are either large, phasic ones or small tonic ones. By post-tetanic potentiation these differences are emphasized in that only the small tonic ventral horn cells in the potentiated state have the repetitive discharge necessary for supporting sustained stretch reflexes.

The tonic *de-efferented* ventral horn cells can also be activated to sustained activity by a few brief stretches followed by maintained stretch.

Both to artificial electrical tetanization and to natural activation by repeated stretch the active states set up are maintained over minutes as concealed residual facilitation or post-tetanic potentiation.

Similar states can be produced in tonic ventral horn cells by tetanization of the crossed sural nerve or by pinna twist, after which sustained stretch reflexes can be evoked in tonic ventral root fibres.

Since three different afferent sources activate tonic and phasic ventral horn cells without change of their tonic and phasic properties respectively, it is concluded that the methods used have divulged the existence of real systemic differences between tonic and phasic ventral horn cells.

The tonic cells, in particular, are low-threshold cells with respect to the three sources of afferent approach, and slowly declining states of temporal summation are part of their natural mode of operation.

Post-tetanic potentiation or temporal summation is considered to be the common denominator of the effects described.

Intracellular recording from tonic cells is described.

#### ACKNOWLEDGMENT

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