

# RECOVERY OF EXCITABILITY FROM INHIBITION IN UNSTRIATED MUSCLE

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UNSTRIATED muscle responds to continuous stimulation by accommodation (Singh, 1938). This is presumably due to the development of an inhibitory state, as inhibitory ions increase, and excitatory ions decrease the accommodation. The muscle also responds to continuous inhibition by accommodation, so that eventually the inhibition may disappear. This is presumably due to the development of an excitatory state, as excitatory ions hasten accommodation to inhibition (Singh, 1942, 1944, 1945 *a*, *b*). In the present research, the effect of excitatory and inhibitory substances on recovery from electrical inhibition has been determined, so as to elucidate the cause of inhibition and accommodation.

## EXPERIMENTAL

Frog's stomach muscle was used. It was stimulated by alternating current, 12 volts for 10 seconds every 15 minutes. Between these responses, an inhibitory response was interpolated so as to determine the recovery, 2, 4, 6 and 8 minutes after inhibition. The inhibition was produced by alternating current passed for 5 minutes; the muscle initially contracted, and then as the current was passed, the tension subsided due to accommodation or inhibition (Singh, 1945 *b*).

## RESULTS

Recovery of frog's muscle from electrical inhibition may take place within 10–15 minutes, or it may take over an hour due to a subnormal phase. There may be a supernormal phase succeeded by a subnormal one (Singh, 1944; Fig. 1). Though a supernormal phase may not occur there may be corresponding fluctuations in excitability as shown in the figure. These phenomena resemble those found in nerve (Gasser and Grundfest, 1936). There may be several fluctuations in excitability before return to normal.

*Effect of glucose.*—Glucose may increase inhibition (Singh, 1949), so it may retard recovery from inhibition. This is actually found to be the case (Fig. 2). Cyanide therefore, hastens recovery (Fig. 3). This shows that inhibition during activity is an active process (Singh, 1949).

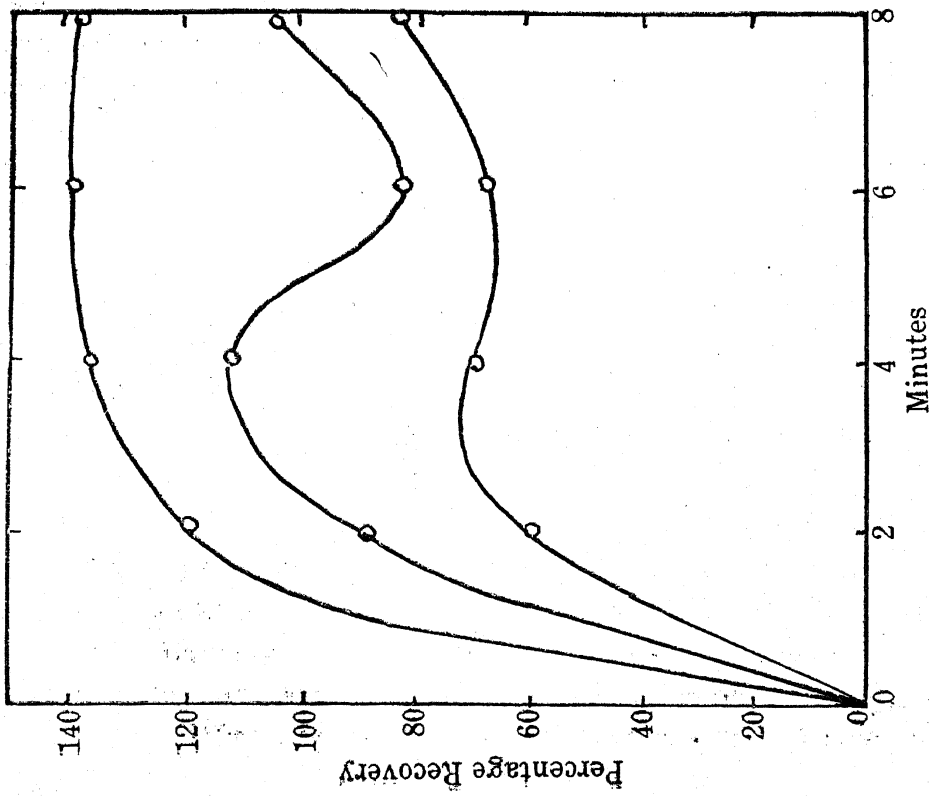


FIG. 1. Frog's stomach muscle. Shows recovery after electrical inhibition.

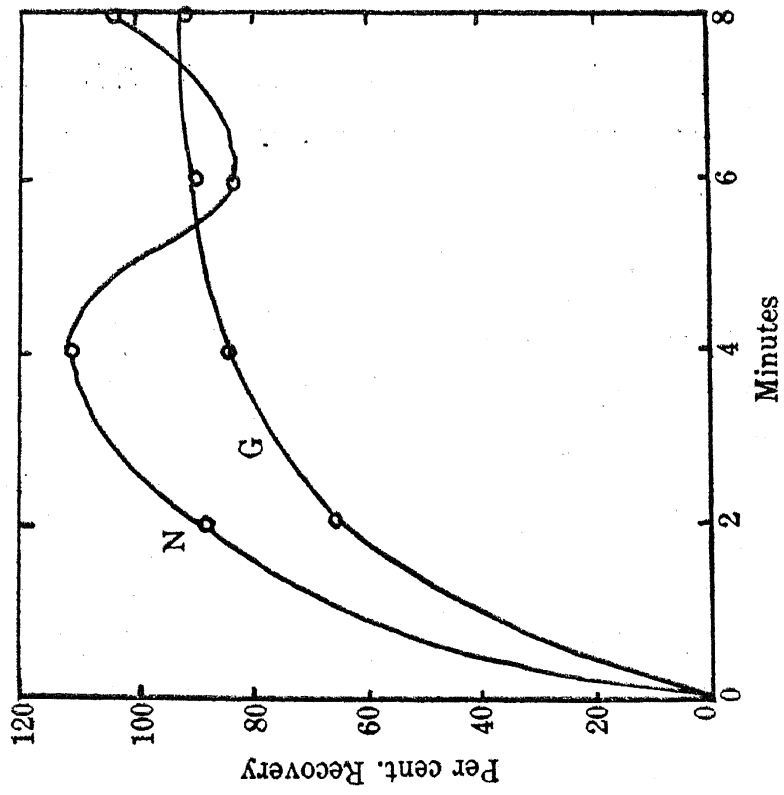


FIG. 2. Frog's stomach muscle. Shows the effect of glucose on recovery from electrical inhibition. N = Normal curve. G = Curve in 0.1 p.c. glucose.

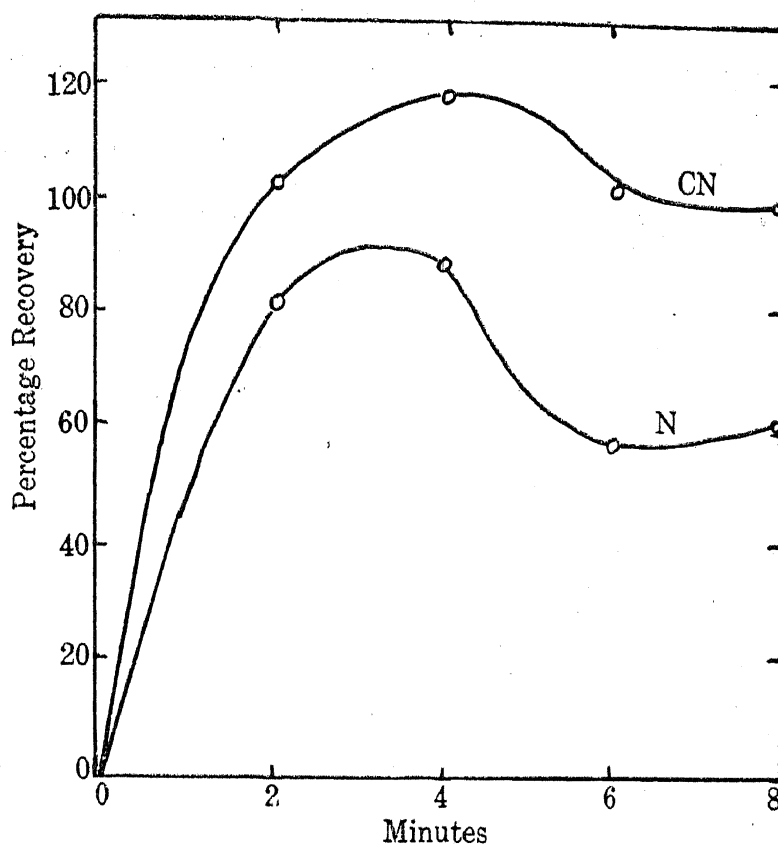


FIG. 3. Frog's stomach muscle. Shows the effect of cyanide on recovery from electrical inhibition. N = Normal curve. CN = Curve in NaCN, 1 in 100,000.

*Effect of ions.*—It has been found that stimulating ions accelerate recovery from inhibition (Singh, 1942). The present results confirm this. Substances which cause stimulation accelerate recovery from inhibition, and those that cause inhibition have the opposite action. Results of representative experiments are shown in Table I. Thus bromide, nitrate, iodide, thiocyanate, lithium, sodium, potassium, barium, calcium, eserine, pilocarpine, accelerate recovery; these substances cause stimulation. Ammonium, strontium, magnesium, hydrogen ions, adrenaline, ephedrine which cause inhibition retard recovery. Acetylcholine produces both effects.

#### DISCUSSION

These experiments support the conclusion that electrical inhibition is due to the liberation of inhibitory substances, as recovery from inhibition is hastened by stimulatory substances. As the electrical inhibition in these experiments is identical with accommodation to electrical stimulation, this shows that such accommodation is due to liberation of inhibitory substances.

TABLE I

*Percentage recovery of frog's stomach muscle in 2 minutes from electrical inhibition*

10 p.c. calcium, etc., means that 10 p.c. of the sodium chloride of the saline has been replaced with isotonic calcium chloride. 60 p.c. sodium means that 40 p.c. of sodium chloride of the saline has been replaced with sucrose. Bromide, etc., means that chloride of the saline has been replaced with bromide

No.	Name of saline, reagent	Percentage recovery	Percentage recovery in saline
1	Bromide .. .. .	110	95
2	Nitrate .. .. .	90	80
3	Iodide .. .. .	80	60
4	Thiocyanate .. .. .	85	75
5	Cyanide .. .. .	102	82
6	0.1 p.c. Glucose .. .. .	66	88
7	Potassium-free .. .. .	75	87
8	Calcium-free .. .. .	80	82
9	Lithium .. .. .	85	80
10	60 p.c. Sodium .. .. .	80	87
11	20 p.c. Ammonium .. .. .	62	95
12	5 p.c. Potassium .. .. .	97	60
13	10 p.c. Calcium .. .. .	83	72
14	10 p.c. Strontium .. .. .	70	88
15	2 p.c. Barium .. .. .	83	75
16	10 p.c. Magnesium .. .. .	65	82
17	pH 6.5 .. .. .	80	112
18	1 in 10 <sup>5</sup> Acetylcholine .. .. .	45	92
19	„ Eserine .. .. .	82	75
20	„ Pilocarpine .. .. .	85	71
21	„ Nicotine .. .. .	88	77
22	„ Adrenaline .. .. .	98	112
23	„ Ephedrine .. .. .	112	132
24	40 p.c. Hypertonic .. .. .	60	100
25	40 p.c. Hypotonic .. .. .	62	120

This is also supported by previous experiments in which it was found that accommodation was diminished by excitatory substances.

During accommodation to inhibition, an excitatory substance is thus liberated, or an excitatory state develops, so that on removal of the inhibitory substance, a rebound contraction is produced. Similarly during excitation, an inhibitory substance accumulates, and this results in a rebound inhibition on stoppage of excitation. Such phenomena can be directly seen

in unstriated muscle by changes in variation of tone which it normally shows (Fig. 4). These phenomena resemble those shown by nerve (Cole, 1933).

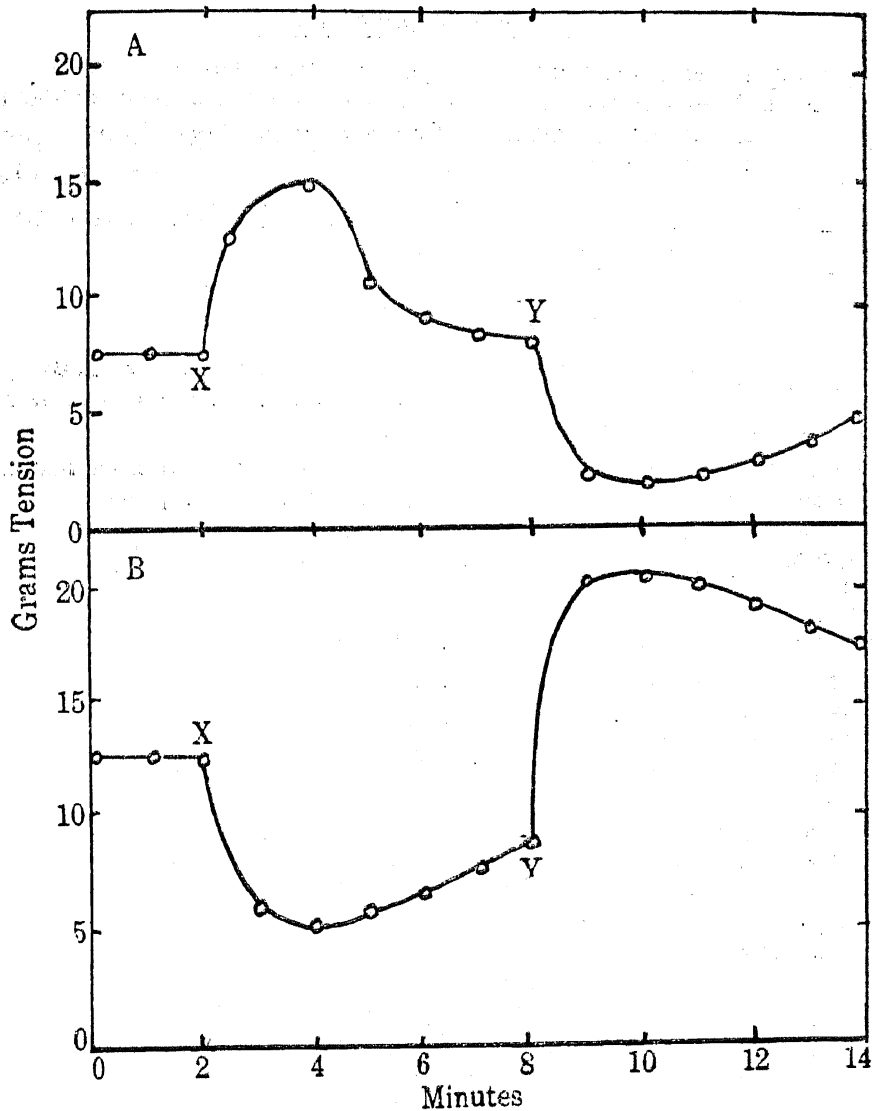


FIG. 4. A. Frog's stomach muscle. Effect of stimulation. Thiocyanate saline added at X and withdrawn at Y.

B. Guinea pig's uterus. Thiocyanate saline added at X and withdrawn at Y.

When the muscle is stimulated, accommodation results due to development of an inhibitory state. On stoppage of excitation, therefore, there will be inhibition due to the above state. If, however, excitation is continued, accommodation to this inhibitory state will occur, so that on stoppage of excitation, there will be a further contraction (accommodation to accommodation or adaptation to adaptation). Similarly on withdrawal of an inhibitory

substance, there may be further inhibition or contraction. Such a production of opposite state in the muscle will thus produce rhythmic contraction of unstriated muscle.

#### SUMMARY AND CONCLUSIONS

Substances that cause excitation, hasten recovery from electrical inhibition. As inhibition is identical with accommodation, these experiments support the view, that accommodation to excitation is due to the liberation of inhibitory substances, and accommodation to inhibition, due to liberation of excitatory substances.

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