(I) THE INTERACTION BETWEEN IONS DRUGS AND ELECTRICAL STIMULATION AS INDICATED BY THE CONTRACTION OF AVIAN UNSTRIATED MUSCLE. (II) ACTIVE ELONGATION OF UNSTRIATED MUSCLE

BY INDERJIT SINGH, F.A.SC., MRS. SUNITA INDERJIT SINGH
AND
M. C. MUTHANA

(From the Physiological Laboratory, Dow Medical College, Karachi)

Received December 11, 1946

THE experiment on *Mytilus*, frog and mammalian muscles have been continued on the unstriated muscle from the domestic fowl to see if any differences exist. The body temperature of the birds is slightly higher than that of mammals and this might result in certain reactions. In mammals the differences between the responses of their unstriated muscle from frog unstriated muscle may be ascribed to: (1) greater ionic content of the saline, (2) to greater body temperature. The latter results in slower adaptation which increases sensitivity, while the former produces opposite results.

EXPERIMENTAL

The saline used was as previously (Singh, 1939). The experiments were performed at room temperature (25–30° C.) as this range is optimum for most reactions. The muscles used were the duodenum and the œsophagus of the domestic fowl. The duodenum forms a U-loop enclosing the pancreas, blood vessels and nerves. One limb of the U-loop may be taken out with or without the attached pancreas and nerves; it provides a straight portion of the gut. The œsophagus was chosen, as its responses were exactly like those of the other unstriated muscle; a muscle nerve preparation was made.

RESULTS

The reactions of avian unstriated muscle resemble those of the other unstriated muscle, with the exception of a few differences.

Effect of temperature.—The optimum tempearture for alternating current for the duodenum is 29–30° C. and for the œsophagus, 25–26° C. This lower temperature for the œsophagus is presumably due to its exposed position (Singh, Singh and Muthana, 1946). In the dog stomach, the optimum temperature at Bombay, which has similar climate as Karachi, was 24–25° C.

The higher optimum temperature in the fowl is presumably related to i higher body temperature. The optimum temperature for potassium is 20° C and for acetylcholine is 25° C., in the dog the optimum temperature fc acetylcholine being 30° C. The optimum temperature is however variab (Singh and Rao, 1940). This appears to be due to adaptation, Fig. (Singh, 1946). Tone may increase or decrease at high temperatur

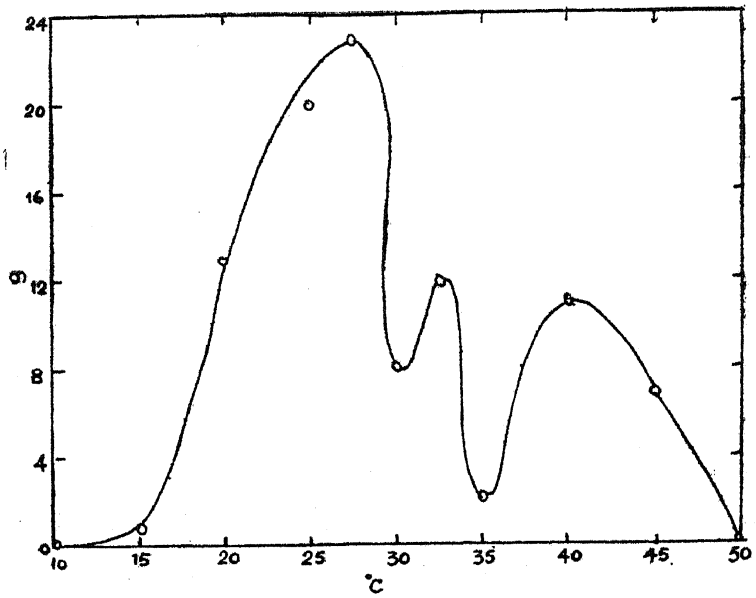

FIG. 1. *Fowl Duodenum.*—The effect of temperature on A. C. contraction

(35–39° C.). The increase resembles as in other unstriated muscle, and th decrease is probably due to adaptation, which increases at higher tempera tures (Singh, 1940). The duodenum is more affected by cold than othe unstriated muscles, a few degrees increase in temperature above 25° C may produce great increase in excitability to alternating current.

Effect of osmotic pressure.—The increase in osmotic pressure of th saline by addition of sucrose or sodium chloride beyond 20 to 40% abov normal is depressant. The results of increase up to 20% are variable. I the œsophagus increase in osmotic pressure by addition of sucrose to th saline increases the response to alternating current, decreases tone and th response to acetylcholine and potassium. With sodium chloride the respons to alternating current decreases and that to potassium and acetylcholin is variable. In the duodenum, with sucrose, the response to alternatin current increases, tone decreases, the response to acetylcholine increases an to potassium is variable. These effects are similar to those in *Mytelus* muscle.

Decrease in osmotic pressure of the saline by 20% in the œsophagus increases the response to alternating current, decreases tone and the response to potassium and acetylcholine; in the duodenum the response to alternating and tone is increased, and to potassium and acetylcholine is decreased. Further reduction in osmotic pressure is depressant to all in the œsophagus as well as duodenum, though tone in the latter may increase.

Effect of calcium.—In the œsophagus the optimum concentration of calcium for alternating current, acetyl choline, potassium, and nervous stimulation is 0·00206 *M* $CaCl_2$, though the œsophagus may become hyperirritable in the absence of calcium. In the duodenum, the optimum concentration for alternating current is three to four times that in the œsophagus but for potassium and acetylcholine it is the same. As in the dog stomach excess of calcium up to 0·02 *M* $CaCl_2$, both in the duodenum as well as œsophagus may potentiate the response to acetylcholine and potassium.

Strontium acts like calcium; barium produces tonic contraction and so causes depression of excitability. Magnesium is depressant.

Effect of lithium.—Replacement of sodium of the saline with lithium produces effects of sodium deficiency. Replacement of 20–40% of the sodium increases the response to alternating current, potassium and acetylcholine, tone decreases.

Effect of sodium.—Replacement of part of the sodium chloride (20–40%) increase the response to alternating current, potassium and acetylcholine. Further increase is depressant. Complete removal of sodium chloride causes contraction; so also isotonic sucrose, suggesting that difference in ionic concentration on two sides of the membrane causes contraction.

Effect of ammonium.—The replacement of the 20% of sodium of the saline with ammonium decreases the response to alternating current but increases that to potassium and acetylcholine. Further increase is depressant. Ammonium thus potentiates the response to potassium and acetylcholine, and may cause contraction. Withdrawal of ammonium may cause contraction.

Effect of potassium.—The optimum concentration of potassium for the response to alternating current, potassium and acetylcholine is 0·0016 *M* KCl. Further increase is depressant and causes tonic contraction. The gut muscle is rather sensitive to potassium.

Effect of hydrogen ions.—The optimum pH for alternating current in the duodenum is 8; at pH 6 it may become inexcitable. In the œsophagus this is also the optimum, but it may cause depression owing to increase of

tone, then the excitability declines as the pH is decreased from 9·24 to 8 and then increases up to pH 7 (Fig. 2). Tone decreases with increase in hydrogen ion concentration. Increase in hydrogen ions do not potentiate the response to potassium and acetylcholine.

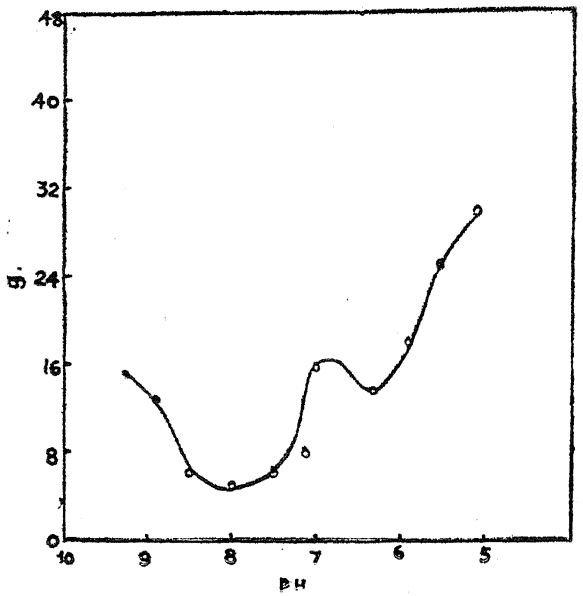

FIG. 2. *Fowl Oesophagus.*—Tne effect of pH on A. C. contraction

Effect of anions.—Small concentrations of Br, NO_3, I, SCN increase and large concentrations decrease the excitability, when they cause tonic concentration.

Effect of eserine.—There is a marked difference between the reactions of the fowl gut and œsophagus on one hand and the dog stomach on the other hand. It does not cause marked increase in excitability in the former as it does in the latter; it rather causes depression. It does not potentiate the response to acetylcholine; if at all, the potentiation is insignificant (*cf.* Brown and Harvey, 1938). It may cause depression. 1 in 10^7 potentiates the response to alternating current.

Effect of adrenaline.—It depresses the response to alternating current in concentrations of 1 in 10^6 or greater. Lesser concentrations have insignificant effect. It increases the response to potassium and acetylcholine in concentrations 1 in 10^7–10^5.

Effect of acetylcholine.—1 in 10^9–10^8 potentiates the response to alternating current. It causes depression if it produces tonic contraction.

Effect of nerves.—For some unknown reason, the muscles after one or two responses become inexcitable to nervous stimulation. The œsophagus

may become inexcitable to acetylcholine and potassium as well. The response to alternating current, however, remained. In such muscles the responses to alternating current did not differ significantly from other muscles. So it appears that alternating current produces its effect by direct stimulation of the muscle, though the latter may also be stimulated through its nerves. It is possible, however, that the inexcitability may be due to lack of conduction in the nerve (Bülbing and Burn, 1939) but adrenaline did not restore the responses. Potassium stimulated the duodenum which was inexcitable to nervous stimulation; so it directly acts on muscle (Singh and Muthana, 1946). Excess of calcium may make the muscle inexcitable to nervous stimulation, but hypersensitive to acetylcholine.

Active Elongation

An interesting feature was noticed that in sodium deficient solutions the muscle elongated when stimulated with alternating current. This was produced as follows: An isometric lever was used. The hook at the bottom of the muscle chamber reached up to the narrow part of the chamber. The muscle was directly tied to the hook, and it rested on the hook; it was put under slight tension of about 5–10 g. If a part of the sodium chloride (20–60%) of the saline was replaced with sucrose or lithium chloride, the muscle elongated when stimulated with alternating current (8 volts). The elongation was continuation of relaxation after contraction. It occurred in 3 out of 55 experiments in duodenum in sucrose saline and in one out of 6 experiments in lithium saline, and was once observed in rabbit gut in ordinary saline. It has never been produced if the muscle was placed in a trough isotonically and then stimulated. The conditions for its occurrence are not understood. It appears that some initial tension is necessary.

The elongation may be due to two causes: (1) contraction of circular muscle, (2) active elongation of longitudinal fibres. The latter is the correct explanation, as there was no evidence of marked contraction of circular muscle throughout the gut. In one experiment it was relaxed throughout. In sodium deficient solutions, tone decreases, so that it appears that elongation is an active process, as it is in skeletal muscle (McDowall, 1944 ; Lloyd, 1946). The fact that it occurs in sodium deficient solutions supports the view that the latter may be responsible for tonus (Singh and Singh, 1946).

Summary

1. The responses of avian plain muscle in general resemble those of mammalian plain muscle.

2. Eserine has little or no potentiating effect on the action of acetylcholine.

3. In sodium deficient solutions, the gut elongates activity when stimulated with alternating current.

4. In a muscle inexcitable to nervous stimulation, alternating current produces its usual effects.

References

Brown, G. L., and A. M. Harvey	..	*J. Physiol.*, 1938, **94**, 101.
Bülbring, E. and J. H. Burn	..	*Ibid.*, 1939, **97**, 250.
Lyod, D. P. C.	..	*Howell's Text-Book of Physiology*, London, 1946, p. 39.
McDowall, R. J. W.	..	*Handbook of Physiology and Bio-Chemistry*, London, 1944.
Rao, M. S., and Singh, I.	..	*J. Physiol.*, 1940, **98**, 12.
Singh, I.	..	*Ibid.*, **96**, 367.
————	..	*Proc. Ind. Acad. Sci.*, 1946, **23**, 58.
——— & Mrs. Singh, I.	..	*Ibid.*, 1946, **23**, 312.
Singh, Mrs. Singh, I. and M. C. Muthana	..	*Curr. Sei.*, 1946. **15**, 235.
Singh, I. and M. C. Muthaua	..	*Ibid.*, 1946, **15**, 169.