TWO CONTRACTILE SYSTEMS IN MUSCLE

By

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There is considerable evidence that unstriated muscle is a composite structure. Thus it shows two kinds of tone; one declines if the muscle is asphyxiated, but the other is unaffected by such a treatment; it may even increase (Singh, 1949). This shows that the former tone requires energy for its maintenance, but the latter is maintained without such expenditure of energy. It may last till the death of the muscle. The former tone can be relaxed by adrenaline in dog's and frog's stomach muscle, but the latter is insensitive. This may give a wrong idea about the presence of active surface receptors for a drug, as the drug may activate these areas, but the contractile machanism may be unable to relax. Similarly a wrong conclusion may be arrived at as to the nature of nerve supply to an organ. Stimulation of sympathetic may not result in any relaxation for the above reason. These experiments therefore point to the existence of two contractile machanisms in unstriated muscle.

The next question arises as to the origin of the phasic response. The phasic response disappears if the muscle is asphyxiated, so that it would appear to be produced by the first contractile mechanism mentioned above. This is shown by another experiment. In dog's stomach muscle, it is possible to destroy tone by quick stretch, without affecting the phasic response, and the tone which is thus destroyed is that which is resistant to asphyxia (Singh and Singh, 1949 a). In the frog's stomach muscle, if the tone which is sensitive to asphyxia, is destroyed by quick stretch, then the phasic response is also damaged, but if the asphyxia-resistant tone is so destroyed, then the phasic response is unaffected (Singh and Singh, 1950 a ; 1951 a, b). This clearly indicates that there is one contractile machanism which is responsible both for the phasic response and the tone which is diminished by asphyxia, and the other contractile mechanism which is responsible for the asphyxia-resistant tone. In *Mytilus* muscle, damage to tone which is resistant to asphyxia also damages the phasic response, so that in this muscle, the same contractile mechanism has become modified to give dual responses, one sensitive and the other resistant to asphyxia (Singh, 1951).

During investigations on the effect of adenosinetriphosphate on unstriated muscle, it was found that the effect of ions on such muscle which has been refrigerated in 50 percent glycerine, was different from that on striated muscle, and this led to the present series of investigations on the effect of ions on the contractile mechanism of unstriated muscle. The effect of ions on the contractile mechanism of unstriated muscle has been previously studied by the dying muscle technique (Singh and Singh, 1949 b ; 1950 b ; Singh and Sharma, 1953). In this method, the muscle is allowed to die in the exprimental solution. As the muscle dies, the substances in the surrounding medium enter the muscle fibres and act on the contractile mechanism. The effect of ions on the contractile mechanism has also been investigated by destroying the excitatory system of muscle by heating to 50°C. (Singh and Singh, 1954 a, b).

METHODS

These experiments were performed on transverse pieces of the stomach muscle of the frog, *Rana tigrina*, and on frog's sartorius muscle. Some experiments were also performed on dog's stomach muscle. The pieces were immersed in 50 p.c. glycerine for 48 hours or longer at 12°C and then the effect of various ions was tested.

The experiments were performed on unloaded muscle pieces, freely floating, so that relaxation, if any, was active. They were performed at room temperature 30°C.

RESULTS

Effect of Potassium. Potassium chloride causes contraction of glycerine-soaked striated muscle (Bozler, 1951). Similarly treated frog's stomach muscle from the cardiac end, actively relaxes by about 60 percent in isotonic (0·112 **M**) potassium chloride (Table I). Calcium or magnesium (0·01 **M**), antagonises this action, so that the relaxation is reduced to 40 percent. The action of potassium on glycerine-soaked frog's stomach muscle, therefore, resembles its effect on dying or heat killed muscle.

Effect of Sodium. Sodium chloride also produces active relaxation of glycerine-soaked frog's stomach muscles. This preparation therefore, does not differentiate between sodium and potassium (Table I). Magnesium (0·01 **M**) partly antagonises the action of sodium, but calcium has no significant action. The action of sodium on glycerine-soaked frog's muscle resembles its action on the heat-killed muscle, but differs markedly from its effect on the dying muscle which is caused to contract.

Effect of distilled water Like the dying and the heat-killed frog's stomach muscle, glycerine-soaked muscles relaxes in distilled water by about 36 percent (Table I).Re-immersion.

TABLE I.

Active relaxation of frog's stomach muscle, soaked in 50 p.c. glycerine, by various substances. Figures indicate length after soaking as percentage of initial length.

Reagent	No. of observations	Length ; p.c. of initial	Part of stomach
0·112 **M** NaCl	25	159 ± 11	Cardiac
0·01 **M** $MgCl_2$ + NaCl	18	149 ± 19	– do –
0·01 **M** $CaCl_2$ + NaCl	25	157 ± 13	– do –
0·112 **M** KCl	25	160 ± 8	– do –
0·01 **M** $MgCl_2$ + KCl	27	141 ± 14	– do –
0·01 **M** $CaCl_2$ + KCl	27	143 ± 14	– do –
H_20	22	196 ± 25	– do –
1% Urea	25	230 ± 33	– do –
0·224 **M** glucose	25	186 ± 21	– do –
0·112 **M** NaCl	9	137 ± 9	Pyloric
0·112 **M** KCl	9	139 ± 10	– do –
H_20	8	172 ± 14	– do –

in 50 percent glycerine causes it to recontract; though not to same extent as before. Muscle actively relaxes in distilled water, presumably due to denaturation, the process of relaxation and denaturation being similar, in that both are accompanied by unfolding of the polypeptide chains. Glycerine prevents relaxation as it prevents denaturation (Singh and Singh, 1954 a). Such denaturation in muscle, which leads to relaxation is therefore a reversible process, the process of contraction being presumably due to renaturation. The effect of distilled water on glycerine soaked muscle resembles that on dying and heat-killed muscle.

Effect of urea. Urea, 1 percent causes marked active relaxation of glycerine-soaked frog's stomach muscle by about 130 percent. (Table I).This is presumably due to denaturation mentioned above. The effect of urea on glycerine-soaked muscle is similar to that on dying or heat-killed muscle. As urea and distilled water are supposed to rupture hydrogen bonds in proteins, contraction may be presumed to be produced by the formation of such bonds. The action of sodium and potassium chlorides suggest the formation of salt linkages in contraction.

Reactions of the frog's stomach muscle from the pyloric end. The muscle from the pyloric end of the stomach relaxes less than that from the cardiac end in all the above solutions (Table I). The living muscle from the pyloric end, however, contracts more strongly than that from the cardiac end (Fig. 1).

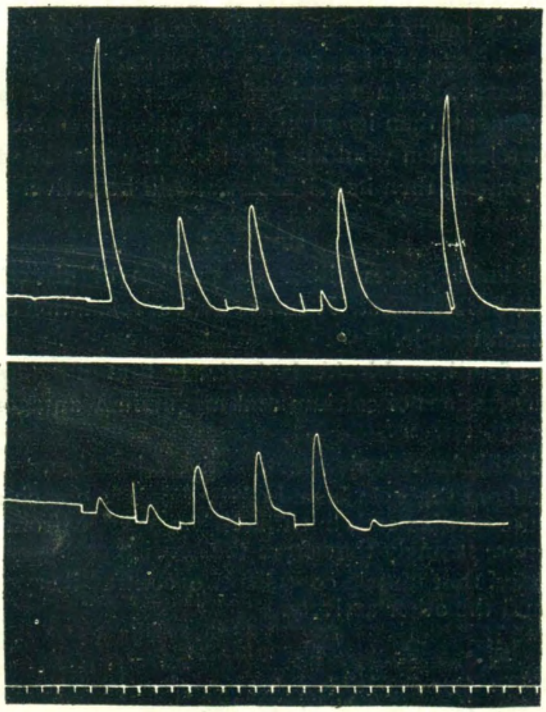

Fig. 1.

Reactions of frog's sartorius and dog's stomach muscle. Glycerine-soaked frog's sartorius does not relax in potassium chloride. The contractile mechanism of striated muscle is therefore different from that of frog's unstriated muscle. Dog's stomach muscle may relax by 10 to 20 percent in potassium chloride. This muscle is therefore intermediate between frog's sartorious and frog's stomach muscle.

DISCUSSION

The action of potassium chloride on glycerine-soaked rabbit's psoas or frog's sartorius muscle is quite different from that on frog's stomach muscle. The frog's stomach muscle contains some different actomyosin or some new protein complex, which is not present in striated muscle. This component can relax actively.

The muscle from the pyloric end of the stomach contracts more strongly than that from the cardiac end, but relaxes less. This suggest that it contains a greater quantity of the contractile and less of the actively relaxing component than the muscle from the cardiac end, the diminution of the mechanical response in the latter being due to simulteaneous contraction and active relaxation (Singh and Singh, 1956). It would, therefore, appear that the chief difference between striated and unstriated muscles is that the latter contains an actively relaxing component in addition to a contractile one ; various unstriated muscles differ from one another in containing different proportions of these two systems. If an unstriated muscle contains predominantly the contractile component, then its properties would resemble those of striated muscle, and the relaxation would be passive. If any striated muscle contains the second component, then its relaxation would be active.

SUMMARY

1. Potassium chloride causes either contraction of glycerine-soked striated muscle, or it has no effect. It causes active relaxation of glycerine soaked frog's stomach muscle.
2. The action of sodium chloride is similar to that of potassium.
3. Small concentrations of calcium and magnesium antagonise the action of sodium and potassium.
4. Urea and distilled water also cause active relaxation.
5. The muscle from the pyloric end of the frog's stomach relaxes less than that from the cardiac end, but the living muscle from the pyloric end contracts more strongly than from the cardiac end.
6. It is concluded that muscle contains two contractile systems, one relaxes passively and the other actively.

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