FURTHER STUDIES ON PERFUSION OF ISOLATED FROG'S HEART WITH MODIFIED RINGER SOLUTIONS (GLUCOSE-RINGER, MALTOSE-RINGER AND LACTOSE-RINGER)

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The present series of experiments have served to elucidate unequivocally that the performance of isolated frog's heart improves considerably on reduction of sodium chloride to 60 mM/L in the perfusate, and that probably this improvement is not affected by the presence of disaccharides and glucose added to the perfusate so as to maintain isotonicity, although further work is required to corroborate the latter.

McDowall, Munro and Zayat (1955) suggested that the cardiac muscle has a limited amount of energy at its disposal and a cut in the energy expended for active sodium extrusion would leave more energy available for mechanical work. Kahali and Bhargava (1956) found that when the content of sodium chloride in the Ringer's fluid was lowered to 0.3%, tonicity being maintained by the addition of iso-osmotic amount of sucrose, performance of the perfused hearts improved. Kahali and Kothari (1960) reported that the performance of mammalian hearts was best when the concentration of sodium chloride in the Ringer-Locke solution was reduced to 0.7%. Improved performance of the heart in these experiments has been attributed solely to reduction in sodium chloride and thereby effecting a cut in the energy spent for sodium pump mechanism. It was contemplated to extend the work further to elucidate whether better performance of the heart was solely due to the reduction in the concentration of sodium chloride and if it remained unaffected by substituting sucrose with monosaccharides like glucose and disaccharides like maltose and lactose. For the sake of comparison sucrose was included in the present series also.

MATERIALS AND METHODS

Experiments were performed on isolated hearts of frogs—Rana tigrina. The usual technique (Harris, 1956) was employed.

Four series (A, B, C and D) of solutions were prepared out of 1% aqueous solutions of potassium chloride, calcium chloride, sodium bicarbonate, sodium chloride and 5% aqueous solution of glucose and 10% aqueous solutions of maltose, lactose and sucrose. Chemicals used were of analytical grade. Series A, B, C and D contained the sugars, glucose, maltose, sucrose and lactose respectively. Each series contained eight solutions numbered 1 to 8. No. 1 solution did not contain

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any sugar while No. 8 had no sodium chloride. Solutions A, B, C, and D, were Ringer solutions with the following composition :

1% Potassium chloride	0.75 ml
1% Calcium chloride	1.00 ml
1% Sodium bicarbonate	1.00 ml
0.6% Sodium chloride	97.25 ml i.e. 58.35 ml of 1% Sodium chloride.
Total volume	100 ml

In the subsequent numbers sodium chloride was either partly or wholly replaced by sugars in such a way that while the concentration of sodium chloride decreased, the total molar concentration was kept constant. However, the volumes of potassium chloride, calcium chloride and sodium bicarbonate remained unaltered. Volumes of sodium chloride and sugar solutions added to prepare 100 ml of the fluid, the millimolar concentrations of these substances and the total milliosmolar concentrations of these substances per litre of the final solution are given in the following table.

Table showing volumes of solutions of sodium chloride and sugars added and their concentrations as mM/L and total milliosmolar concentration in the perfusion fluid.

S. No.	Sodium chloride		Sugar Solutions				Total	
			5% Glucose		10% Disaccharides			
	Vol. of 1% Sod. chlor.	Conc. mM/L	Vol. ml	Conc. mM/L	Vol. ml	Conc. mM/L	Millimolar concentration	Milliosmolar concentration
1	58.35	99.8	Nil	—	—	—	99.8	183.7
2	52.61	90.0	3.54	9 8	3.36	9.8	99.8	176.4
3	46.76	80.0	7.15	19.8	6.70	19.8	99.8	168.7
4	40.92	70.0	10.75	29 8	10.21	29.8	99.8	159.7
5	35.07	60.0	14.36	39.9	13.64	39.9	99.5	152.7
6	29.23	50.0	17.96	49.8	17.06	49.8	99.8	144.3
7	23.38	40.0	21.56	59.8	20.48	59.8	99.8	136.8
8	—	—	35 97	99.8	34.17	99.8	99.8	99.8

The room temperature during the period of investigations varied from 19°C to 23°C, but has not been taken into account. Perfusion was carried out with all the eight solutions in each of the groups A, B, C and D, ten observations being made with each solution. All the experiments were carried out under identical experimental conditions.

OBSERVATION AND RESULT

Some of the typical responses obtained on perfusion of the heart with the entire series of the solutions A, B, C and D are presented in the accompanying graphs.

A Series (Glucose Ringer) :—It was observed that solutions A_2 and A_3 gave responses which were in no way different from those of A_1. But there was a distinct improvement in heart beats as soon as the heart was perfused with the solution A_4 and A_5. There was a marked increase in the amplitude of the heart beat. The improvement in the performance of the heart could be observed with solutions A_6 and A_7 also. As expected the heart came to a standstill on being perfused with solution A_8, the heart having stopped in systole.

B Series (Maltose-Ringer) :—No significant difference could be noticed in the performance of the heart when it was perfused with solutions B_1, B_2 and B_3. Working of the heart improved with solutions B_4, B_5, B_6 and B_7. The amplitude was markedly increased. The heart again stopped in systole when it was perfused with solution B_8.

C Series (Sucrose-Ringer) :—This series was included in the present work for the sake of comparison only. No difference in the performance of the heart was observed with perfusion fluids C_1, C_2 and C_3. However a marked improvement was noticed in the amplitude of the heart beats with solutions C_4, C_5, C_6 and C_7.

D Series (Lactose-Ringer) :—Here again not much of difference was observed in the cardiograms obtained with solutions D_1, D_2 and D_3. However a slight increase in the amplitude was observed when the heart was perfused with D_4 and marked improvement in amplitude was observed when the solutions D_5, D_6 and D_7 were used for the perfusion of the heart.

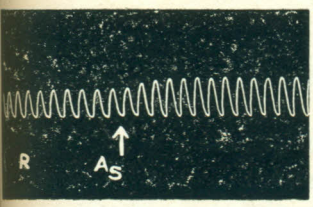
In general it was observed that the amplitude of the heart beats increased distinctly on perfusion with solutions 5 to 7 irrespective of the series. The optimum solution appeared to be No. 5 of all the series, however in case of series C and D (Sucrose and Lactose) increase in the amplitude of heart beats could be observed even with solution No. 3.

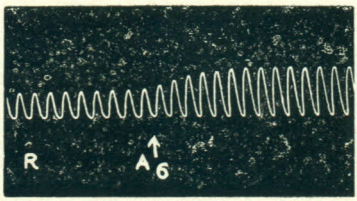
In all the series perfusion with solution No. 8 brought the heart to a standstill in a contracted condition.

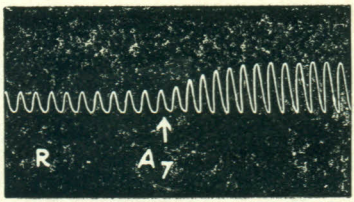
DISCUSSION

In the earlier work it had been shown experimentally that the performance of the perfused hearts improved when concentration of sodium chloride in the Ringer solution was reduced, the tonicity being maintained by addition of iso-osmotic amount of sucrose. In the present work it has been shown that the performance of the isolated frog's heart also improved when concentration of sodium chloride in the Ringer solution was reduced but tonicity was maintained by addition of iso-osmotic amounts of other sugars like glucose, lactose or maltose. The present

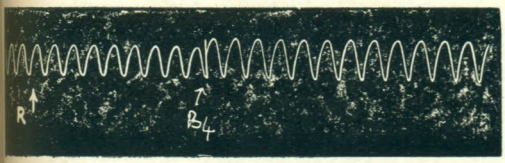
Some of the typical cardiograms obtained on perfusion with modified Ringer Solutions

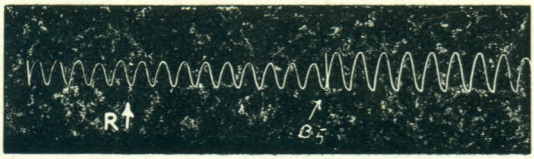




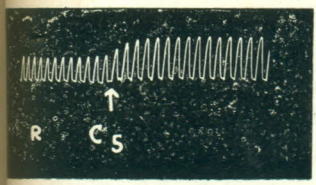


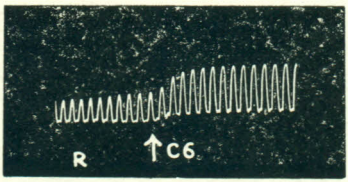
A. Glucose-Ringer

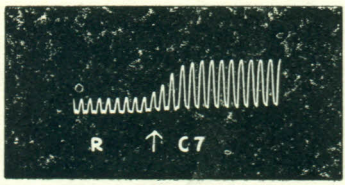




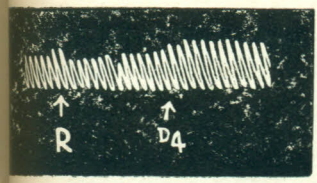
B. Maltose-Ringer

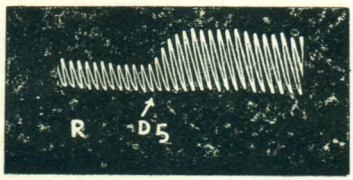


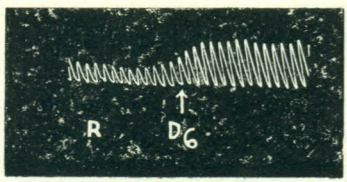




C. Sucrose-Ringer







D. Lactose-Ringer

experimental evidence thus lends support to the views of Mc Dowall et al. (1955), Kahali and Bhargava (1956) and Kahali and Kothari (1960), that reduction of sodium chloride concentration in modified Ringer fluids effects an economy in the energy of heart muscle which would have been otherwise expended for the sodium pump, improving the performance of the heart.

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