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THE EFFECT OF CHANGES IN SODIUM CHLORIDE CONCENTRATION ON THE SMOOTH MUSCLE OF THE GUINEA-PIG'S TAENIA COLI

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Studies of variation in the ionic environment of nerve and skeletal muscle have contributed much to our knowledge of the ionic basis of their activity (Hodgkin, 1951). Few such studies have been made on smooth muscle and, in particular, there is little information regarding changes in NaCl concentration. Vogt (1943) found that hypertonic NaCl solution caused a tonic contraction in the circular muscle of the rabbit jejunum, but concluded that this was mainly of nervous origin. Prosser, Smith & Melton (1955) found that replacement of half the NaCl in normal solution with choline chloride prolonged the negative phase of the complex action potential recorded in the rat ureter.

This paper discusses the effects of changes in NaCl concentration on the guinea-pig taenia coli, which was found to be able to maintain its spontaneous activity when the Na ion concentration was reduced to 1/9 of normal. Unlike nerve or skeletal muscle the spike potentials were unaffected by the Na ion concentration over a wide range, though they were not maintained if all the Na ions were removed.

METHODS

The smooth muscle used for all experiments was the longitudinal intestinal muscle of the guinea-pig's caecum, the taenia coli. Lengths from 4 to 6 mm were mounted isometrically in an organ bath of 2 ml. capacity through which solution flowed continuously at the rate of 2 ml./min and at a constant temperature of 37° C.

The normal solution contained (mM): NaCl 134, KCl 4·7, $MgCl_2$ 0·1, $NaHCO_3$ 16·3, NaH_2PO_4 1·1, $CaCl_2$ 2·5, glucose 7·8; and was aerated with CO_2 5, O_2 95%. Throughout the paper changes in NaCl concentration are referred to as, for example, 3 × NaCl which means 402 mM, etc. When the NaCl was reduced, either sucrose or choline chloride was used to adjust tonicity. Unless otherwise stated, the remaining components of the solution were unchanged.

Membrane potential was measured with intracellular electrodes whose resistance ranged from 10 to 50 MΩ. Tension was measured with a mechano-electronic transducer valve (RCA 5734) mounted in the manner described by Bülbring (1955).

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RESULTS

Excess sodium chloride

The immediate effect of increasing the NaCl concentration of the bathing solution was excitation, that is, the spike frequency and tension were increased. The large tonic contraction so produced was similar to that described by Vogt (1943). The effect was not influenced by atropine (5×10^{-5}). The contraction reached a maximum after 7–12 min and then spike frequency and tension gradually fell. If high concentrations of NaCl were used (2 or 3 × NaCl) all spikes ceased after 20–30 min exposure. If the exposure was continued for longer periods, after the spikes had ceased, the tension did not continue to fall but remained at a fairly high level. On washing out with normal solution recovery was slow. At first there was no change but after 10–15 min the tension fell abruptly to a much lower level where it remained until spikes appeared again. The effects of excess NaCl were completely reversible.

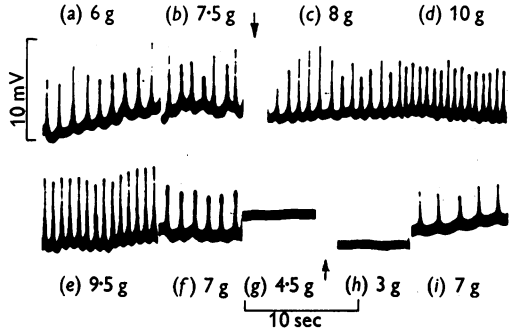

Fig. 1. Electrical activity of taenia coli (*a*) and (*b*) in normal solution; (*c*) to (*g*) during exposure to 2 × NaCl, at 5, 6, 10, 23 and 40 min from start (first arrow); (*h*) 25 min, (*i*) 40 min after readmission of normal solution (second arrow).

Changes in electrical activity produced by doubling the NaCl concentration are illustrated in Fig. 1. The response to excess NaCl was an initial increase in spike frequency, a subsequent slowing and a final cessation of spikes. The tension, which in the normal solution fluctuated between 6 and 8 g, rose to a maximum of 10 g and then fell to 4·5 g. About 10 min after washing out, when there was still no spike discharge, the tension fell to 3 g. The last record in Fig. 1 was taken 40 min later, when spikes had reappeared and the tension had returned to normal (7 g).

These three phases: (1) increased spike frequency and tension, (2) maintenance of tension without spikes, and (3) relaxation after a latent period following washing out, were seen very distinctly in 2 or 3 × NaCl. This is shown in Fig. 2, in which the spike frequency and tension are plotted against time for three sections of an experiment with 3 × NaCl. The tension remained at

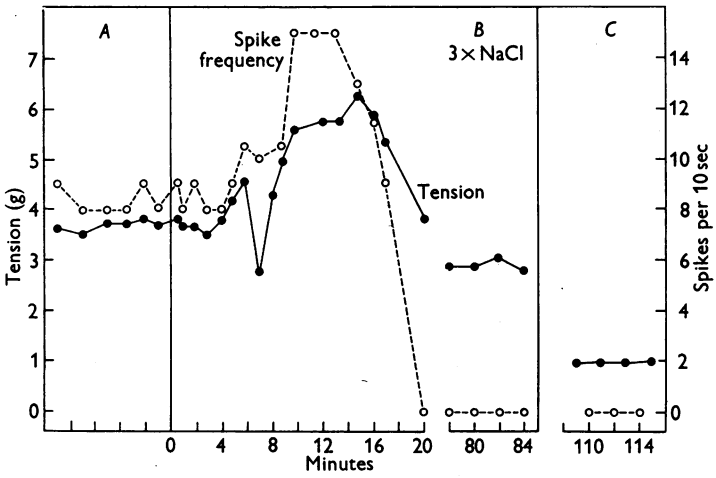

Fig. 2. Changes in spike frequency (○--○) and tension (●–●) during an experiment in which the NaCl concentration was increased to 3 × NaCl. (*A*) illustrates variation during the control period; (*B*) during exposure to excess NaCl; (*C*) the level to which the tension fell after washing out with normal solution. Excess NaCl was introduced at zero min and normal solution was readmitted at 85 min.

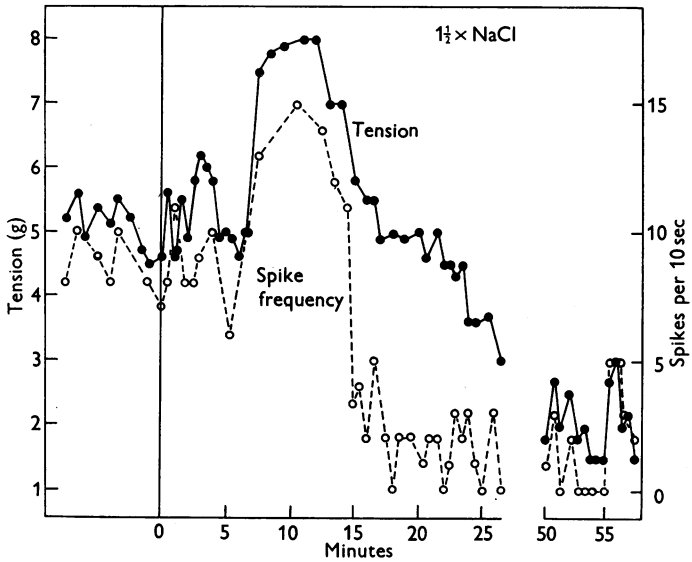

Fig. 3. Changes in spike frequency and tension during an experiment in which the NaCl was increased to 1½ × NaCl at 0 min. (Symbols as in Fig. 2.)

3 g for 10 min after changing back to normal solution and then fell during the next 10 min to reach the steady level shown in section *C* of the graph. Prolonged exposure to $1\frac{1}{2} \times$ NaCl (see Fig. 3) did not abolish the spike discharge completely, through the frequency became very low and irregular. Every burst of spikes was accompanied by a small increase in tension. Some fall in tension on washing out was noted in several experiments after exposure to $1\frac{1}{2} \times$ NaCl.

In Table 1 changes in spike frequency and tension during excitation are summarized from the results of sixteen experiments. A similar increase in spike frequency was produced by all three concentrations, but the initial increase in tension was greatest in $1\frac{1}{2} \times$ NaCl, i.e. a mean increase of 57% compared with 26% in $3 \times$ NaCl. In general the time during which frequency and tension were greater than normal was shortest in $3 \times$ NaCl.

TABLE 1. Excitation produced by excess NaCl

Control. Mean values			Excess NaCl			
			Maximum value		Percentage increase	
Spike frequency (per 10 sec)	Tension (g)	Concentration of NaCl	Spike frequency (per 10 sec)	Tension (g)	Spike frequency	Tension
9	2·8	1·5 × NaCl	17	4·5	90	61
10	5·6		Increase observed	Increase observed	—	—
9	5·5		15	8·0	66	46
9	2·9		14	4·8	55	65
				Mean	70	57
12	4·6	2 × NaCl	30	6·2	150	35
11	8·0		17	11	55	38
9	7·5		15	10	66	33
10	4·8		15	5·9	50	23
10	5·2		20	—	100	—
9	6·0		17	7·2	90	20
				Mean	85	30
10	3·5	3 × NaCl	18	4·9	80	40
12	9·5		24	10·1	100	6
12	3·5		16	4·4	33	26
8	5·3		14	6·7	75	26
9	4·0		15	6·3	66	57
11	9·0		17	9·4	55	4
				Mean	68	26

Fig. 4 shows changes in spike configuration which occurred during excitation. The normal records show the range through which frequency and tension fluctuated spontaneously. The next record was taken during exposure to $1\frac{1}{2} \times$ NaCl at maximum tension (8 g, off the record). The spikes were longer in duration than normal and the frequency greatly increased. The next record was taken a few minutes later. The spikes were much smaller and of still longer duration. The last record in Fig. 4 was taken after 23 min exposure to the high NaCl solution. Spikes of this type continued in irregular bursts throughout the period of exposure and were not dissimilar to those recorded in a

normal preparation. Thus, in general, the spikes changed at first to a shape typical for excitation and then reverted to the normal shape. The last few spikes recorded during exposure to higher concentrations of NaCl also appeared to be perfectly normal.

The level at which the tension remained during the period after the spikes had ceased depended on the NaCl concentration. In 2 × NaCl some relaxation occurred and the tension reached a steady level well below that of the control period. But in 3 × NaCl a higher tension was maintained, and in several experiments it did not fall below the minimum level during the control period.

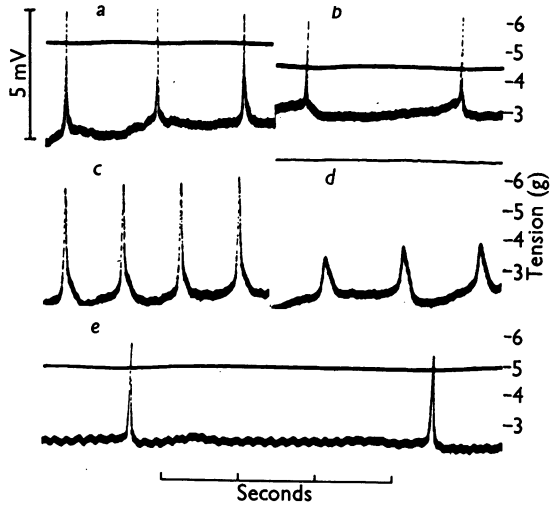

Fig. 4. Changes in spike configuration and tension during an experiment in which the NaCl concentration was increased to 1½ × NaCl. (*a*) and (*b*) illustrate the range of activity in normal solution; (*c*)–(*e*) were taken 13, 15 and 23 min after changing to excess NaCl.

The mean percentage fall below the control level was 24% at this concentration compared with 40% in 2 × NaCl. In Table 2 the level of tension reached during prolonged exposure to high NaCl is compared with the level after washing out. The fall in tension after readmission of normal solution was the more pronounced the higher the concentration of NaCl had been (43% compared with 21%). It is interesting that the total fall in tension at both concentrations was similar (60 and 67%).

Owing to the wide scatter of readings from a normal preparation the resting potential often failed to show consistent changes during exposure to excess NaCl. Many of the experiments with 2 × NaCl gave inconclusive results. When 3 × NaCl was used, however, the long period of relaxation after washing out made it possible to obtain a large number of readings. These could be compared with determinations carried out during a similar silent period in high NaCl. Under these conditions a large increase in resting potential was observed when the preparation had fully relaxed after washing out with normal

TABLE 2. Comparison of tension maintained after cessation of spikes in excess NaCl with tension reached after further relaxation on washing out with normal solution

Concn. of NaCl	Control period. Mean tension (g)	Period after cessation of spikes (excess NaCl solution) Mean tension (g)	Fall* (%)	Period after further relaxation (normal solution) Mean tension (g)	Further fall* (%)
2 × NaCl	4·6	3·1	33	2·0	24
	8·0	5·4	33	4·2	15
	7·5	4·5	40	3·0	20
	4·8	3·2	33	2·6	13
	5·2	2·9	44	1·4	29
	6·0	2·7	55	1·3	23
		Mean	40	Mean	21
3 × NaCl	3·5	2·2	37	1·2	29
	9·5	7·8	18	6·0	19
	3·5	2·9	17	1·1	51
	5·3	4·0	25	1·2	58
	4·0	3·0	25	0·8	55
	9·0	6·8	24	2·8	45
		Mean	24	Mean	43

* Fall calculated as percentage of mean control tension.

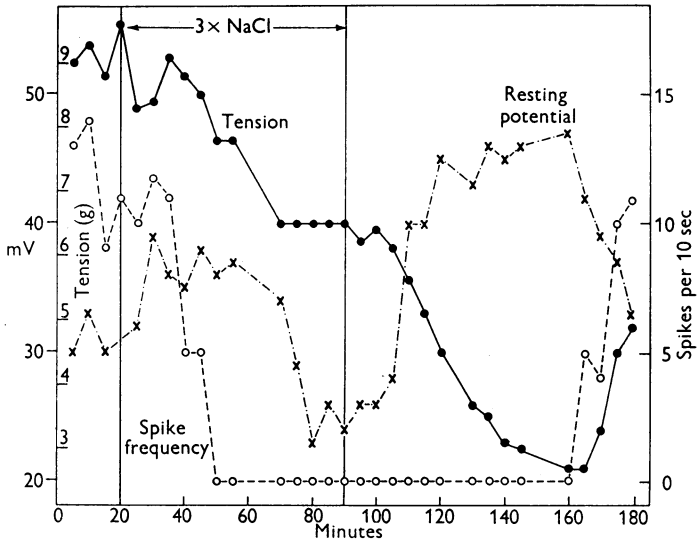

Fig. 5. Changes in resting potential, spike frequency and tension during an experiment where the NaCl concentration was increased to 3 × NaCl. The excess NaCl solution was introduced at 20 min and washed out 70 min later. Each point represents the mean of all readings taken during a period of 5 min. (Symbols as in Fig. 2 and ×–·–×, resting potential).

solution. This is shown in Fig. 5. The period of excitation on exposure to 3 × NaCl was not marked in this preparation since the spontaneous activity and tension were already high in normal solution. When the spike frequency and tension declined, the resting potential rose at first but then it also declined and continued to fall after spikes had ceased. For 10 min after washing out, tension and resting potential were little changed. After about 12 min the resting potential began to increase and at this time the muscle relaxed. During the next hour the resting potential rose steadily and was then maintained at a level well above normal. When spikes appeared again and the tension rose, the resting potential began to fall.

The results of four such experiments with 3 × NaCl are set out in Table 3. The largest increase in resting potential was seen in Expt. 18 where the mean potential rose from 26 to 43 mV. This table also shows a small decrease in resting potential during the period of excitation when spike frequency and tension were greater than normal.

TABLE 3. Changes in resting potential during experiments in 3 × NaCl. Values (mV) are means for each period

		3 × NaCl				
Spike frequency	Normal	Greater than normal	Zero	Zero	Less than normal	Normal
Tension	Normal	Greater than normal	Less than normal (steady)	Fully relaxed	Less than normal	Normal
Expt. 18	37	29	26	43	32	29
19	59	—	41	53	41	50
20	52	50	30	—	—	—
21	41	39	31	44	39	36

Addition of sucrose to normal solution

In order to determine whether the effects described above were due to hypertonicity alone, the addition of sucrose to normal solution was tested. The immediate effect of the sucrose was a brief relaxation due to an inhibition of spike frequency. The muscle recovered again, but throughout the next 30–60 min spike frequency and tension gradually fell. There was no indication of any excitation. The time which elapsed before all the spikes ceased was variable. In the experiment illustrated in Fig. 6 spikes occurred in irregular bursts up to 60 min. In another experiment all spikes had ceased after 15 min. No differences were noticed between the two concentrations studied which were equivalent to 2 and 3 × NaCl. After washing out, spikes reappeared within 10 min and frequency and tension returned to normal during the next 40 min. There was no further fall in tension. The resting potential showed the usual scatter throughout these experiments but there were no obvious changes during or after exposure to the sucrose solutions.

Low sodium chloride: replacement with sucrose

The effect of sucrose in a low NaCl solution was very similar to that which it produced when added to normal solution. In Fig. 7 spike frequency and tension are plotted from an experiment in which the NaCl was reduced to 1/3 and tonicity was restored with sucrose. Spike frequency and tension fell

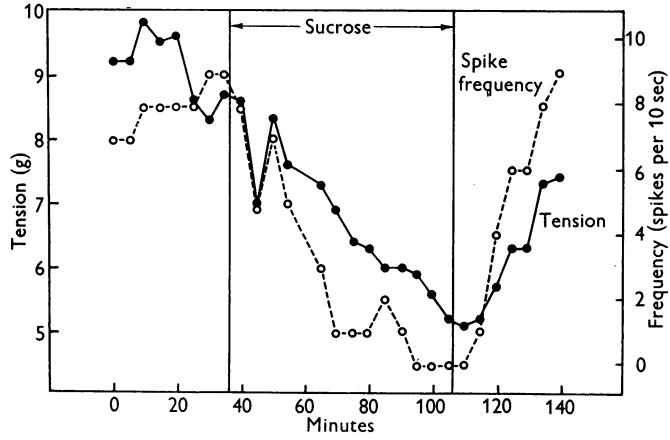

Fig. 6. Changes in spike frequency and tension produced by sucrose which was added to make a solution of the same tonicity as 2 × NaCl. The sucrose solution was introduced at 37 min and washed out 70 min later. Each point represents the mean of all readings taken during a period of 5 min. (Symbols as in Fig. 2.)

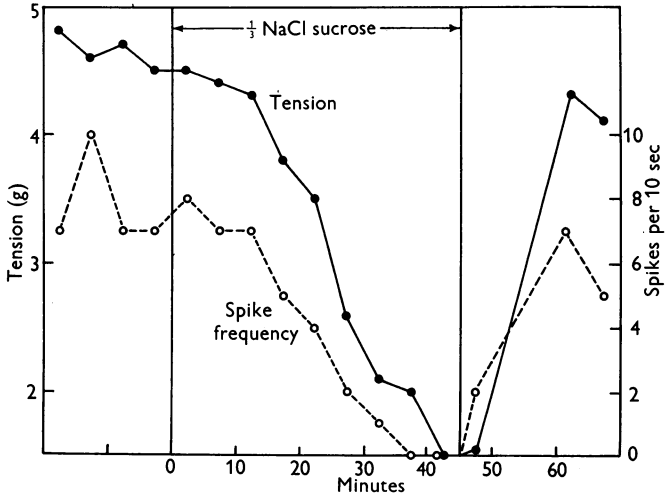

Fig. 7. Changes in spike frequency and tension during an experiment where the NaCl concentration was reduced to 1/3 of normal and sucrose used to maintain tonicity. The low NaCl solution was introduced at 0 min and washed out 45 min later. Each point represents the mean of all readings taken during a period of 5 min. (Symbols as in Fig. 2.)

throughout the period of exposure. In this experiment all spikes ceased after 40 min.

The effect of replacing 1/3, 2/3 and 9/10 of the NaCl was determined. In the experiment where 9/10 of the NaCl had been replaced by sucrose all regular activity ceased after 10 min; a few spikes were detected during the next 20 min. In this experiment recovery was very slow. After 2 hr spike frequency and tension were still well below normal.

Fig. 8 shows some typical spikes from an experiment where 1/3 of the NaCl was replaced by sucrose. Spikes occurring during the test period were indistinguishable from normal—there was no change in spike height or configuration.

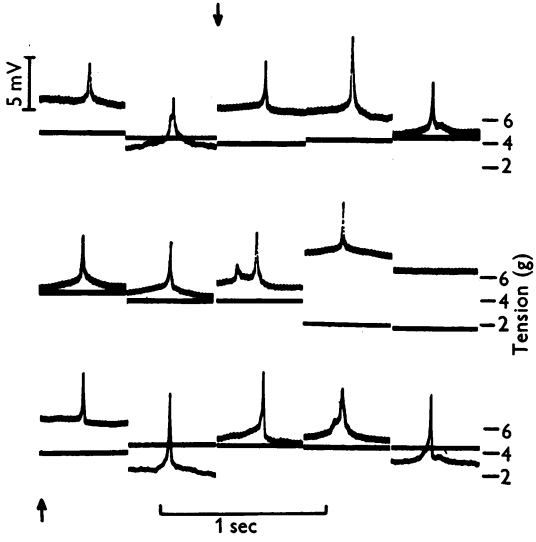

Fig. 8. Records of spikes and tension from an experiment in which the NaCl was reduced to 1/3 of normal and sucrose used to maintain tonicity. The first two records were taken in normal solution. The low Na solution was introduced at the upper arrow and the next records were taken 4, 5, 8, 9, 18, 22, 33 and 38 min later. At the lower arrow normal solution was reintroduced and the last records were taken 7, 8, 13, 18 and 20 min later.

Low sodium chloride: replacement with choline chloride

When choline chloride was used to replace the NaCl a very different result was obtained: there was no cessation of spikes during exposures up to 150 min. The immediate effect of the choline chloride solution was one of excitation in spite of the presence of atropine (10^{-4}). During this period the spike duration was increased. This is shown in the second record of Fig. 9, which was taken 5 min after exposure to a choline chloride solution containing 1/3 NaCl. The last record in Fig. 9 was taken about 30 min later. About this time some decline in spike frequency and tension was noted. This soon passed off and throughout the remaining exposure spike frequency and tension were greater than normal.

Except for the initial period of excitation the spike potentials were indistinguishable from normal. A similar result was obtained whether 2/3, 9/10 or all the NaCl had been replaced by choline chloride.

When all the NaCl had been replaced the solution still contained 17 mM-Na, derived from bicarbonate and acid phosphate. Thus the taenia coli was able to maintain its spontaneous activity, although the concentration of Na ions was only 1/9 of normal. Even at this low concentration, after the initial excitation

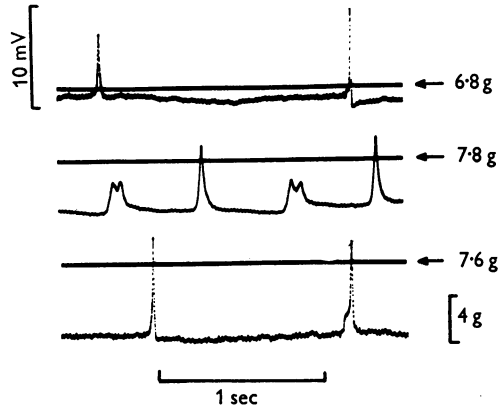

Fig. 9. Records from an experiment in which the NaCl was 1/3 of normal and choline chloride was used to maintain tonicity. Top record, normal; second record, after 5 min in the low NaCl solution; bottom record, after 45 min exposure.

had passed, there was no change in spike height or configuration. In Fig. 10 the records were taken from an experiment where the choline chloride solution remained in contact with the muscle for 150 min. The first record was taken towards the end of the excitation period. The next record was taken during the period of lower spike frequency which followed excitation; the next was taken 100 min later. Spike frequency and tension were greater than in the final normal record (lowest record) but the spikes still showed normal configuration. The resistance of all the electrodes used during this experiment was 20 MΩ. The mean height of the spikes occurring throughout the test period (allowing 30 min for equilibration and excitation) was 8·7 mV. In two further experiments with 1/3 NaCl (similar electrodes) the mean spike height was 8·5 and 10·4 mV. In 1/10 NaCl the mean height was 10·3 mV. Mean values for the control periods during these experiments ranged from 5·0 to 12·8 mV.

Total replacement of sodium ions by choline

Before it was possible to replace all the Na ions by choline it was necessary to choose a new (K-buffer) 'normal' solution, containing only 5 mM of buffer in the form of K salts, and no KCl. The following solution was prepared: NaCl,

150 mM; $KHCO_3$, 5·0 mM, aerated with CO_2 1, O_2 99%; concentrations of $CaCl_2$, MgCl and glucose as before; the pH was 7·3 at 35° C.

This solution was tested on a preparation in an isolated organ bath where the tension only was recorded on a kymograph with an isometric lever. The

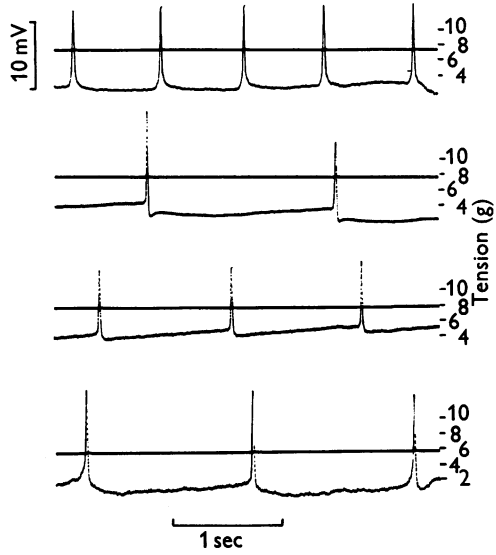

Fig. 10. Records from an experiment in which all the NaCl present in 'normal' solution had been replaced with choline chloride. The first three records were taken at 10, 45 and 100 min after changing over to the choline chloride solution; the last record was taken 20 min after washing out with normal solution.

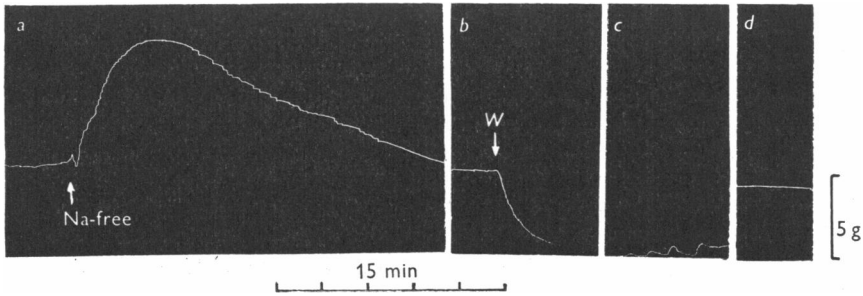

Fig. 11. Kymograph record of an experiment where the removal of all Na ions was tested: (*a*) tonic contraction, (*b*) level of tension before washing out with normal solution and abrupt fall to zero, (*c*) first increase in tension 20 min after washing out, (*d*) tension 80 min later. The muscle was exposed to Na-free solution for 75 min.

behaviour of the muscle was perfectly normal. No changes could be detected when K-buffer solution was alternated with the 'original' normal solution.

Fig. 11 shows a kymograph record of the effect of removing all Na ions from the bathing fluid. In this experiment the tonic contraction was very marked,

the initial tension being low. Prolonged exposure produced a fall in tension to a level a little below normal. On replacing the (K-buffer) normal solution a further very abrupt fall in tension occurred, in this case to zero. Such a fall had also been noted in other experiments when the choline solutions were washed out.

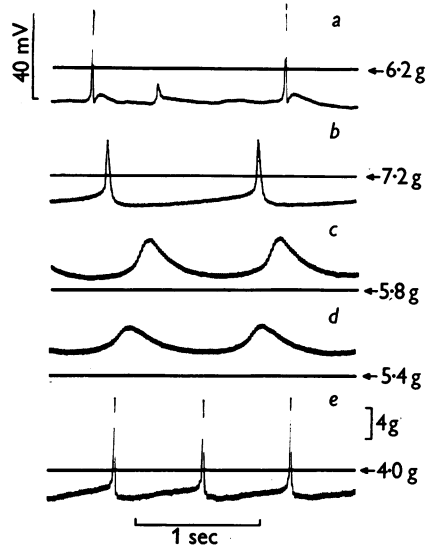

Fig. 12. Changes in spike configuration during an experiment with Na-free solution. (*a*) normal, (*b*) after 25 min exposure to Na-free solution; (*c*) after 35 min and (*d*) after 40 min exposure; (*e*) 60 min after washing out with normal solution.

The corresponding changes in electrical activity are shown in Fig. 12. During the tonic contraction the spike duration increased and spike height fell, but instead of returning to a normal configuration as in those experiments where 1/9 of the Na ions were still present the spike height continued to fall. The rate of repolarization was reduced initially, and after about 20 min the rate of depolarization also began to decrease. After 30 min the spikes had become very small. They continued for some time but grew steadily longer in duration and smaller in height. After about 50 min they could no longer be detected. No further activity was seen. On washing out, the tension fell without delay. Spikes appeared again 10–20 min later, usually in bursts of fairly high frequencies. Recovery was complete in 60–80 min.

DISCUSSION

It is well known that the electrical activity of many vertebrate tissues depends on the presence of Na ions in the external solution. In cardiac muscle reduction of the concentration of Na ions slows the rate of impulse production (Clark, 1913) and when the Na ions are reduced to 20% of normal, the spon-

taneous activity of Purkinje tissue is abolished (Draper & Weidmann, 1951). It was surprising, therefore, to find that the smooth muscle of the guinea-pig taenia coli was able to maintain its spontaneous discharge of spike potentials at normal frequency when the Na ion concentration was reduced to 11%. This suggested that the processes underlying the production of spontaneous activity in taenia muscle were different from those involved in cardiac muscle.

The variation of the height of the action potential with the Na ion concentration has been studied in vertebrate nerve (Huxley & Stämpfli, 1951), skeletal muscle (Nastuk & Hodgkin, 1950) and cardiac muscle (Draper & Weidmann, 1951). In all these tissues the height and rate of rise of the action potential declined as the Na ion concentration was reduced. When the concentration was between 10 and 20% of normal, the action potential was reduced to about half its normal amplitude. At lower concentrations propagation failed.

The spikes recorded from a normal taenia have been shown to differ from those of nerve and striated muscle, in that they were variable in height and duration and generally caused only a partial depolarization. However, though changes in spike height and configuration occurred spontaneously, definite changes beyond the normal range could be recognized during stimulation or inhibition by pharmacological agents (Bülbring, 1957). However, in the complete absence of NaCl (leaving only 17 mM Na) there was no change in the spike height nor in the spike configuration.

Only when the taenia was bathed in a solution completely free of Na ions, which was changed continuously by constant flow, the spikes gradually decreased in height until they degenerated into small oscillations. The relatively slow time course of the decay in spike height (about 40 min) might have been due to a delay in the removal of all the Na ions from the extracellular space, which in taenia coli has been found to be equal to 36% of the total wet weight (E. Bülbring & G. V. R. Born, personal communication). Nevertheless, the ultimate fall in spike height to zero suggested that the presence of Na ions in the external solution was necessary for the spike production.

According to the ionic theory of activity in nerve (Hodgkin, 1951) the rising phase of the action potential is due to an inward movement of Na ions which carries the membrane potential towards the Na equilibrium potential (determined by the ratio $[Na]_o/[Na]_i$). In nerve and skeletal muscle the initial increase in Na permeability is followed by an increase in K permeability. This enables K ions to move out of the cell and as a result the membrane potential is restored to its original level. The rising phase of the spike in taenia coli is very slow compared with nerve or striated muscle, and normally only leads to a partial depolarization. This suggests that there may be an increase in K permeability at a rather variable membrane potential, but well before the Na equilibrium potential is reached. Provided there is sufficient Na outside the cell to keep the Na equilibrium potential below the resting potential, an

increase in Na permeability would then still lead to a partial depolarization. If the concentration of Na ions in the intracellular water of smooth muscle is similar to that of other tissues (about 20 mM) then a depolarization might still have been possible when the Na ion concentration was reduced to 11% of normal (17 mM). If the Na carrier mechanism were similar to that in nerve and striated muscle a marked slowing in the rate of depolarization should have been apparent when the external Na concentration was only 17 mM. No such change was detected in the present experiments at this concentration, although changes in spike configuration did occur after prolonged exposure to Na-free solution. This suggests that the Na carrier may be saturated at very low external Na concentrations.

Another explanation may be put forward. Shaw & Simon (1955) have shown that frog sartorius muscle can adjust its internal Na when placed in low Na solution, so that the ratio $[Na]_o/[Na]_i$ is restored to normal levels. It is possible that the taenia is capable of adjusting its internal Na in this manner.

The effects of excess NaCl on the taenia were complex. During the initial rise in tension spike configuration changed to that typical of excitation (Bülbring, 1957). As the tension fell, however, spikes reverted to their original shape; there was no increase in spike height.

The rise in tension produced by high concentrations of NaCl was followed by a period during which the tension remained high although the spike discharge was abolished. Born & Bülbring (1956) have shown that, in taenia, contraction is associated with an increase in the rate of loss of cell K, and relaxation with an increase in the rate of uptake of K. In the presence of excess NaCl the maintenance of tension without spikes may have been due to a continuous loss of K from the muscle. Shaw, Simon, Johnstone & Holman (1956) have shown that toad sartorius muscle, after prolonged exposure to high NaCl (5 × normal concentration), lost 90% of its intracellular K. The fall in resting potential which was caused by high NaCl in taenia suggests that here also, there was a loss of K from the muscle. This explanation is further supported by the observation that the tension level was much lower in 2 × NaCl than in 3 × NaCl, when the loss of K from the cells should have been less. The delayed relaxation which occurred after washing out the excess NaCl with normal solution was associated with an increase in resting potential. This may have reflected an increase in activity on the cell pumps, removing the excess Na and taking up K.

Vogt (1943) previously reported a contraction of smooth muscle in response to excess NaCl. Working with rabbit jejunum she found that a 20% increase produced a strong tonic contraction in the circular muscle, but was without effect on the longitudinal muscle. This contraction was not affected by atropine but was abolished by large doses of nicotine and by cooling. She concluded that the most likely site of stimulation was the nerve plexus. Our

experiments do not exclude the possibility that the initial excitation produced by excess NaCl was of nervous origin, but this is unlikely because it occurred in the presence of atropine. It seems more probable that the high Na concentration stimulated the muscle directly by causing an increase in intracellular Na and a loss of K.

Vogt found a similar contraction of the circular muscle when sucrose was used to make the bathing solution hypertonic. She noted, however, that the longitudinal muscle was inhibited under these conditions. The taenia, which is the longitudinal muscle of the guinea-pig caecum, was also relaxed by sucrose, whether it was added to normal solution or used to replace NaCl. The time which elapsed before all spikes ceased was variable in both cases but the effect was most marked in the experiment where only 1/10 of the normal concentration of NaCl was present. This suggests that in low NaCl solutions the inhibition may have been due to a movement of sucrose into the cells and a disturbance of osmotic balance.

The present experiments indicate that the spike in taenia is due to a similar mechanism to that of the action potential in nerve or striated muscle because the presence of Na ions appears to be essential. Some differences, however, must exist since the spontaneous activity is abolished only after prolonged exposure to a Na-free medium and the spike discharge can therefore proceed at an extremely low Na ion concentration in the extracellular fluid. The normal spikes in taenia have a very slow rate of rise and their configuration is independent of the Na ion concentration over a wide range. These observations suggest that the Na carrier mechanism may not be as highly developed in smooth muscle as in tissues where rapid conduction occurs. Further investigation concerning the nature of the spike potential is at present in progress.

SUMMARY

1. Resting potential, spike discharge and tension have been recorded in the isolated taenia coli of the guinea-pig.

2. Excess NaCl in the bathing solution caused a fall in resting potential, increased spike frequency and increase in tension. Prolonged exposure to high concentrations of NaCl abolished the spike discharge but a high tension was maintained, associated with a low resting potential. Following readmission of normal solution relaxation occurred, after a latent period. This was associated with an increase in resting potential.

3. Hypertonicity produced by the addition of sucrose to normal solution did not cause excitation but it depressed spike frequency and tension.

4. Reduction of NaCl with the addition of sucrose to maintain normal tonicity produced a similar depression.

5. When choline chloride was used to replace NaCl (the other components of the bathing solution being unchanged so that 17 mM-Na remained) spike

frequency was not depressed and tension remained high for exposures of up to $2\frac{1}{2}$ hr.

6. No changes in spike configuration were detected when the concentration of Na ions was varied between 17 and 150 mM, irrespective of whether choline chloride or sucrose was used to maintain tonicity.

7. When all the Na ions were removed the spike potentials decayed and were completely abolished after 40 min exposure.

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