A FURTHER CONTRIBUTION REGARDING THE INFLUENCE OF THE DIFFERENT CONSTITUENTS OF THE BLOOD ON THE CONTRACTION OF THE HEART.

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After the publication of a paper in the Journal of Physiology, Vol. III., No. 5, entitled "Concerning the influence exerted by each of the Constituents of the Blood on the Contraction of the Ventricle," I discovered, that the saline solution which I had used had not been prepared with distilled water, but with pipe water supplied by the New River Water Company. As this water contains minute traces of various inorganic substances, I at once tested the action of saline solution made with distilled water and I found that I did not get the effects described in the paper referred to. It is obvious therefore that the effects I had obtained are due to some of the inorganic constituents of the pipe water.

Water supplied by the New River Water Company contains 278·6 parts of solids per million.

They consist of:

Calcium	38·3	per million.
Magnesium	4·5	,,
Sodium	23·3	,,
Potassium	7·1	,,
Combined Carbonic Acid	78·2	,,
Sulphuric Acid	55·8	,,
Chlorine	15	,,
Silicates	7·1	,,
Free Carbonic Acid	54·2	,,

This water is faintly alkaline to test-paper from bicarbonate of lime. Saline made with this water I found at first rounds the top of the trace of each contraction and later greatly prolongs diastolic dilatation, and that these effects are completely obviated by about 1 c. c. of 1 °/₀ solution of potassium chloride solution to the 100 c. c. of circulating saline. So that with this addition the saline thus made forms an excellent artificial circulating fluid for the heart, as in some experiments I found the ventricle fed by this mixture would continue beating well for more than four hours, indeed at the end of that time the contractions were almost as good as at the commencement of the experiment, when the ventricle was fed with blood mixture.

In this paper I have investigated the action, on the contraction of the ventricle, of calcium and sodium salts when added to saline solution.

The saline solution contained 0·75 % of sodium chloride.

The lime water I used was prepared from calcined marble and from an analysis by Mr Lawes contained 1 part of CaO in 700 parts of water or 1 part of Ca in 980 parts.

Mr Page kindly prepared some bicarbonate of lime, by diluting lime water with an equal quantity of distilled water and passing carbonic acid through this till the precipitate was completely dissolved, this solution therefore contained half as much lime as lime water.

I used "pure anhydrous" calcium chloride prepared by Hopkins and Williams. My solution contained 1 part of calcium chloride in 390 parts of water or 1 part of Ca in 1082.

I used a 1 % solution of potassium chloride. The salt was obtained of Morson.

The sodium carbonate and the sodium bicarbonate each contained one half per cent. of the salt. The sodium bicarbonate was pure and obtained of Hopkins and Williams.

The distilled water was prepared by Hopkins and Williams.

The distilled water, the saline solution made from it, the calcium chloride solution and the potassium chloride solution were all neutral to delicate test-paper.

The contractions marked in the figures with an asterisk were excited by a break induction shock. Those without the asterisk were spontaneous beats.

These observations were made in October and November.

The traces run from left to right.

These observations were made with Roy's tonometer, and the ventricle was tied on the cannula, as nearly as possible in the auriculo-ventricular groove.

I find that calcium, in the form of lime water, or bicarbonate of lime or chloride of calcium, even in minute doses produces the changes in the ventricular beat described in my former paper. Each of these at first rounds the top, and also broadens the trace of the beat; next it greatly prolongs diastolic dilatation.

Cold greatly favours the action of calcium salts as is well seen by comparing Fig. I. when the temperature was low with Fig. X.

As this slow diastolic dilatation occurs with calcium chloride solution added to saline solution, both neutral solutions, it is obvious that lime possesses the property of retarding dilatation, and that in the case of bicarbonate of lime, the prolongation is not due to alkalinity. The effects produced by lime salts on dilatation, and even the persistent spasm induced by the alkaline preparations, are completely removed by a minute trace of a potassium salt, 1 in 10,000 to 15,000.

A small quantity of calcium bicarbonate or calcium chloride (of chloride 1 in 19,500 parts), added to saline solution with 1 part of potassium chloride in 10,000 parts, makes a good artificial circulating fluid and the ventricle will continue beating perfectly for more than four hours, with calcium bicarbonate.

The solution composed of saline solution, with calcium chloride and potassium chloride is neutral, hence the ventricle will beat perfectly when supplied with a neutral fluid, and therefore alkalinity of the circulating fluid is not necessary for contractility.

The alkaline reaction of the blood is no doubt necessary indirectly, for contractility, for muscular contractions develope acidity and this must give an acid reaction to a neutral fluid, and the heart cannot contract when supplied with an acid circulating fluid.

When the circulating fluid is composed of saline solution the ventricle grows weaker and weaker and contractility ceases in about twenty minutes. Calcium bicarbonate, or calcium chloride in physiological doses, or even in smaller quantities than are present in the blood, restore good contractions, even when contractility has been lost for seven or eight minutes, and the ventricle no longer responds to strong induction shocks.

Sodium bicarbonate added to saline broadens the beat and rounds its summit and slightly prolongs both contraction and dilatation. Owing to the increased breadth of the beat, if the contractions are frequent, there occurs partial fusion of the beats. Sodium bicarbonate also induces some persistent spasm (contracture) if the contractions are frequent.

All of these effects of sodium bicarbonate are obviated by a physiological quantity of potassium chloride.

When a ventricle supplied with saline has lost its contractility, it can be restored for a short time by adding to the 100 c.c. of saline solution 5 c.c. of sodium bicarbonate solution.

On the addition of the potassium chloride solution the effects of the sodium bicarbonate are removed but the contractions quickly grow weak and soon stop; and I have not been able to discover a mixture consisting of saline solution, sodium bicarbonate solution and potassium solution, which will keep the ventricle beating for more than a short time, although I have mixed these solutions in very various proportions.

Calcium chloride solution added to the saline, sodium bicarbonate and potassium chloride solution, after the ventricle has lost contractility, restores good spontaneous beats which will continue for a long time.

A mixture containing 100 c.c. saline, 5 c.c. sodium bicarbonate solution, 5 c.c. calcium chloride solution with 1 c.c. potassium chloride solution also makes an excellent artificial circulating fluid, for with this mixture the heart will continue to beat perfectly.

The heart's contractility cannot be sustained by saline solution nor by saline containing potassium chloride, nor with saline solution containing bicarbonate of soda, nor by saline solution containing bicarbonate of soda and potassium chloride; but after contractility has ceased, the addition of a lime salt will restore good contractility. The addition too of a calcium salt to any of the above solutions will sustain contractility. I conclude therefore that a lime salt is necessary for the maintenance of muscular contractility.

But whilst calcium salts are necessary for the proper contraction of the heart, yet if unantagonized by potassium salts the beats would become so broad and the diastolic dilatation so prolonged that much fusion of the beats would occur and the ventricle would be thrown into a state of tetanus.

As the ventricle will continue to beat perfectly for hours without any sodium bicarbonate, it is evident that the normal trace is the result of the antagonizing action of calcium and potassium salts.

If these two salts are not present in the correct proportions then the trace becomes abnormal. If too little potassium is present, the contractions become broader &c. and there results fusion of the beats. If too much potassium is present, or too little lime salts, then the contraction of the ventricle is imperfect, and by increasing the quantity of potassium salt the beat becomes weaker and weaker till it stops.

As the heart will continue to beat quite normally for hours without albumen or hæmoglobin, it is obvious that these substances are not immediately necessary for contraction, but of course they are necessary to reconstruct the tissues from the loss due to contractions.

The action of simple saline on the ventricle.

Saline is incapable of sustaining the contractions of the heart, for when blood mixture is replaced by saline, the contractions speedily grow weaker, and in some cases contractility ceases altogether, for no contraction can be excited by even a strong break induction shock. In most cases however the beat returns and slowly improves, but rarely becomes so good as with the blood mixture, see Fig. I A and B. Soon the contractions again grow weaker (see C and D), and in about twenty minutes contractility is lost, for the ventricle neither beats spontaneously nor will respond to strong induction shocks. After the contraction is considerably weakened the end of the diastole is a little prolonged (see C), and when the contraction is still further weakened both contraction and dilatation are slightly prolonged (see D), this prolongation being still more marked in cold weather.

Lime water added to saline at first broadens the trace of each contraction and rounds its top, next it excites slight contracture, later the dilatation becomes prolonged. These effects are well seen in Fig. II, in which experiment 0·5 of lime water was added to 100 c. c. of saline. As with saline alone, the strength of the contractions rapidly decreased, but they soon recovered much more rapidly than with saline alone (Fig II A). In about eight minutes the trace became broader and rounder at its top and there occurred a little contracture, see B. Twenty-four minutes after the employment of the saline and lime solution the dilatation of the ventricle became much prolonged and was especially slow at its middle third (see C). 0·5 c. c of $1^{0}/_{0}$ solution of chloride of potassium, rapidly affected the diastole, rendering it as rapid as with blood mixture, and also removed the contracture (see C).

Larger doses of lime water prevent the fall in the trace occurring soon after replacing blood mixture by saline solution, but these larger doses subsequently produce a considerable amount of contracture.

On substituting saline solution for blood mixture, the contractions rapidly weaken and often do not recover or only partially recover and then again grow weak and soon contractility ceases. If when the ventricle has become weak or its contractility has ceased, a small dose of lime water is added to the circulating fluid contraction soon recommences or becomes stronger, as is well seen in Fig. III B where the contractions rapidly increased in height after the addition of 1·1 c. c. of lime water to 200 c. c. of saline.

The effect of lime on the diastole is often earliest witnessed at the end of the dilatation as is well seen in Fig. IV and Fig. V.

Bicarbonate of lime also greatly retards the dilatation of the ventricle. I first took a blood trace and then substituted for the blood mixture 200 c. c. of saline solution containing 20 c. c. of bicarbonate of lime solution. There occurred none of that weakening of the contractions which always ensues with saline solution alone. In about nine minutes after replacing the blood mixture by the saline and lime mixture the dilatation became greatly delayed (Fig. VI). About fifteen minutes after the employment of the saline and carbonate of lime solution, I added to 100 c. c. seven minims of 1°/₀ solution of potassium chloride. This soon quickened diastolic dilatation, but as it still remained somewhat prolonged at its termination, I added another three minims of potassium chloride solution and entirely removed the effect of lime on the dilatation, the trace becoming just like that with blood mixture (see Fig. VI).

I find that from 7·5 c. c. to 10 c. c. of bicarbonate of lime solution to the 100 c. c. saline will prevent the weakening of the contraction occurring when saline solution is alone used.

Is this effect on rhythmic dilatation due to the alkalinity of the calcium hydrate and the calcium bicarbonate or is it due to a property of lime salts? To answer this question I made two sets of experiment. I tested the action of calcium chloride, a neutral preparation of lime, and also the effect of other alkaline salts, as sodium carbonate and bicarbonate. I find that calcium chloride prolongs the dilatation of the ventricle and broadens the trace, rounding its top, but it does not excite any contracture in the small doses I used. To affect the ventricle it must be used in doses considerably larger than lime water. This result is well shown in Fig. VII. I replaced the circulating blood by a mixture containing 100 saline with 3·5 c. c. of calcium chloride solution. The contractions quickly grew weaker but very speedily recovered, so that in about four minutes after the employment of saline and calcium chloride solution the ventricle had recovered. In twenty-four minutes after replacing the blood, the dilatation of the ventricle became prolonged and this prolongation was still more marked eight minutes later. This prolongation was speedily removed by adding to the 100 c. c. circulating fluid 0·33 c. c. of 1°/₀ solution of potassium chloride.

Like calcium hydrate, calcium chloride strengthens the beats weakened or arrested by simple saline solution. This is well seen in Fig. VIII. I first took a trace with blood mixture (A) and then replaced the blood by saline solution. The contractions rapidly grew weak and almost stopped. They then improved somewhat. In eight minutes after the substitution of saline solution I added to 100 c.c. saline 3·5 c.c. of calcium chloride solution. This rapidly increased the strength of the beats (B).

It is obvious therefore that the slow dilatation, and the improvement of contractions caused by lime salts when added to saline solution are not the result of alkalinity, but these effects are due to lime, for the calcium chloride is neutral.

The previous experiments show that calcium oxide, or calcium bicarbonate, or calcium chloride, added to saline solution, prevent the weakening and arrest of the ventricle which occurs with saline solution alone.

They also show that after a ventricle fed with saline solution has become very weak or has stopped, a calcium salt will restore good contractions.

But with calcium salts added to saline the trace of a contraction becomes broader, its summit rounded, and the dilatation is much delayed. All these effects are speedily removed by a physiological quantity of potassium chloride or any potash salt.

I next tried the effect on the trace of substituting for blood mixture saline solution containing a calcium salt and potassium chloride.

I first employed the following mixture, 200 c.c. saline solution containing 20 c.c. calcium bicarbonate solution and 1·5 c.c. potassium chloride solution. On substituting this mixture for blood mixture the beats for a short time grew weaker, but soon recovered and became stronger than with blood mixture. No prolongation of diastolic dilatation occurred, this being obviated by the potassium chloride. The ventricle continued beating perfectly for fifty-six minutes, when I was obliged to discontinue the experiment, see Fig. IX.

I next tested the effect of a mixture composed of 100 c.c. saline, 5 c.c. calcium chloride solution, 0·75 c.c. potassium chloride solution. I first took a trace with blood mixture and then replaced the blood with the above mixture.

The contractions were very little weakened and soon recovered and remained unchanged, no prolongation of the diastole occurring. An hour after the replacement of blood by the saline, lime, and potash mixture the ventricle beat spontaneously, the beats being quite as good as at the commencement of the experiment with blood. See Fig. X.

This solution was quite neutral to test-paper, hence it is evident that it is not necessary for the proper contraction of the ventricle that the circulating fluid should be alkaline.

With saline containing a calcium salt after the diastole becomes retarded the contraction grows weaker, but potassium chloride not only prevents the delay in dilatation but also the weakening of the contractions.

I next investigated whether any other salts added to saline would sustain the contraction of the ventricle.

I tested saline to which I added potassium chloride, 200 c. c. saline with 1·5 c. c. of potassium chloride 1 % solution. As with simple saline the contractions grew weak and then slowly recovered to a considerable extent, and then again grew weak, and in fifteen minutes after replacing the blood mixture with saline and potassium chloride solution the ventricle almost stopped, the trace becoming a mere wavy line. Potassium chloride added to saline therefore does not prevent the ventricle losing its contractibility. After the ventricle had almost completely lost its contractility I added to 100 c. c. of the circulating fluid 5 c. c. of the calcium chloride solution and very speedily spontaneous contractions began which quickly increased in strength.

I next tested the action of sodium carbonate. I employed a 0·5 % solution. This acts much like sodium hydrate. It rounds the top of the trace, produces persistent spasm and arrests the ventricle in systole. A small dose of potassium chloride, 0·5 c. c. of 1 % solution antagonizes the effect of sodium carbonate.

I then tested the influence of sodium bicarbonate added to saline solution.

In these experiments I employed 2·5 c. c. of ½ % solution of sodium bicarbonate in 100 c. c. of saline.

The influence of sodium bicarbonate varies according to the frequency of the contractions. If the ventricle beats infrequently, or not beating spontaneously, it is stimulated only occasionally then when fed with saline and sodium bicarbonate solution, the beats grow weaker and weaker till they stop, but contractility lasts longer I think than with saline solution alone. When the contractions are much lessened the dilatation becomes rather prolonged, especially at its termination, but the character of the trace is very different from that produced by lime salts.

When the ventricle beats with normal frequency, the contractions on first replacing blood mixture by saline and sodium bicarbonate solution rapidly grow weak, but soon recover and in many instances become as good as with blood mixture. The trace of each contraction becomes broader and its summit rounder, the trace then becomes still broader till partial fusion occurs (see C, Fig. XI), and the whole trace becomes much raised above the base line. There also occurs much persistent spasm. On the addition of 5 min. of 1 $^0/_0$ solution of potassium chloride solution, the effect of the bicarbonate of soda is quite obviated, and the trace falls to its old position as regards the base line, but the contractions are much feebler than at the beginning of the experiment (see C).

If no potash is added to the circulating fluid, but the ventricle throughout is fed with saline and sodium bicarbonate solution, then after a time the beats grow less frequent, so that fusion disappears and the persistent spasm declines; the trace falls to its primary position as regards the base line, and the beats grow smaller and smaller till they cease. If the beats do not become less frequent, the persistent spasm gradually declines, the trace falls again to the base line, though some fusion persists, and the beats become smaller and smaller till they cease.

When a ventricle is not beating spontaneously, contracture can be developed by exciting several contractions quickly one after the other, but after the contractions have ceased, contracture gradually declines, but will again appear on exciting a fresh series of contractions. When contracture has quite subsided, then the dilatation of the first excited contraction is not prolonged, but the dilatation of the succeeding contractions becomes prolonged as the persistent spasm becomes developed, showing that probably the prolongation of the dilatation in this instance is due to the contracture, see Fig. XII.

Sodium bicarbonate will restore contractions to a ventricle that has lost its contractility when fed with saline solution. 2·5 c. c. of the $\frac{1}{2}$ $^0/_0$ solution of sodium bicarbonate added to 100 c. c. of circulating fluid is enough for this purpose. As the contractions return the effect of the sodium bicarbonate becomes manifest, for both contracture and fusion of the beats occur, and after a short time, about seven to twelve minutes, the ventricle stops in partial systole.

As potassium chloride obviates the effect of sodium bicarbonate and prevents contracture and fusion, I determined to try if I could produce an efficient circulating fluid by the addition of some potassium chloride to the saline and bicarbonate solution. I have, however, been unable to do this, though I have added the potassium chloride in various quantities; with any dose that is enough to obviate the effects of the sodium bicarbonate, the contractions become much weakened and soon cease. After the ventricle supplied with saline and bicarbonate solution to which potassium chloride solution has been added, had stopped, I could always restore good contractions by the addition of from 3·5 c. c. to 5 c. c. of calcium chloride solution to the 100 c. c. of circulating fluid, and the contractions became as good as at the commencement of the experiment with blood mixture.

We have seen that a perfect contraction can be obtained with a neutral circulating fluid composed of saline solution with a minute trace of calcium chloride and potassium chloride. Bicarbonate of soda, on which the alkalinity of the blood is supposed to depend, when added to saline is not sufficient to sustain the ventricle's contractility nor even when potassium chloride is added. I next proceeded to learn how a mixture containing saline solution, calcium, chloride and sodium bicarbonate solution affects the ventricle. I find that the sodium bicarbonate appears to exert no influence, and that the whole effect is due to the lime, for after the usual interval and before the ventricle is weakened in any degree, the diastolic dilatation becomes much prolonged, and this prolongation is obviated by a very small dose of potassium chloride, so that good contractions are produced.

In these experiments I used 100 c. c. of saline solution with 3·5 c. c. of calcium chloride solution and 5 c. c. of sodium bicarbonate solution.

On replacing blood mixture with this mixture, the contractions are but little weakened, and only for a short time. The trace of each contraction becomes rounder at its summit, and the dilatation prolonged; but on the addition of 5 minims of 1 °/₀ solution of potassium chloride, the trace becomes of the same character and as good as with blood mixture. With the mixture the spontaneous beats continue, see Fig. XIII.

In the blood therefore sodium bicarbonate must exert a very small influence, if any direct influence on the cardiac contraction, and this is regulated by the antagonizing action of calcium and potassium salts. Still the sodium bicarbonate plays a very important indirect influence, by neutralizing the acid reaction produced by the contraction, for without this neutralizing effect the tissue and blood would soon become acid, when all function becomes impossible; hence sodium bicarbonate and other alkaline salts will prevent these tissues poisoning themselves by producing an acid condition.

I next tested the effect of a solution containing 100 c. c. saline solution, 5 c. c. calcium chloride solution, 2·5 c. c. sodium bicarbonate solution and 0·75 c. c. potassium chloride solution, see Fig. XIV.

I replaced blood mixture by this solution. Very little weakness in the contractions ensued on the replacement and this was speedily recovered from, and the ventricle continued contracting perfectly and spontaneously, ninety minutes after replacing blood mixture by this solution. No rounding of the top, or delay in dilatation occurred, these effects of lime being quite obviated by the potassium chloride.

EXPLANATION OF THE FIGURES, PLATE I.

Fig. I.

A. Trace with blood mixture and showing the effect of replacing the blood mixture by saline solution. The replacement was made at the point indicated by an arrow.

B. Trace eight minutes after replacing blood by saline solution.

C. Trace fourteen minutes after the replacement.

D. Trace eighteen minutes after the replacement.

E. Shows the effect of adding 5 c. c. of calcium chloride solution to 100 c. c. of circulating saline solution. Contractility returned, the beats became after one stimulation spontaneous and owing to the prolongation of diastole the beat fused.

After the beats ceased the diastole is seen to be enormously prolonged. This is well seen after a single contraction; there also occurred some persistent spasm, for the whole trace is raised somewhat above the base line. The calcium chloride was solution added at the arrow.

F. Shows the effect of 3 minims of potassium chloride solution added to the 100 c. c. of circulating fluid. It quickly removed the persistent spasm and brought the trace nearer to the base line and somewhat hastened diastolic dilatation. The potassium chloride was added at the arrow.

G. Shows the effect of nine minims of potassium chloride solution to the 100 c. c. of circulating fluid. The diastolic prolongation is almost entirely removed.

I obtained the same results in another experiment, but only added 2·5 c. c. of calcium chloride solution, and consequently the diastolic dilatation was less prolonged than with double the quantity of calcium chloride.

Fig. II.

A. Showing the effect of substituting 100 c. c. saline containing 0·5 c. c. of lime water.

At the point indicated by an arrow the blood mixture was replaced by the saline and lime mixture.

B. Eight minutes after substituting saline and lime mixture for blood mixture.

C. The trace twenty-four minutes after replacing the blood mixture with saline and lime solution, and also showing the effect of the addition of 0·5 c. c. 1 °/₀ solution of potassium chloride to the 100 c. c. of saline and lime solution. The potassium chloride was added at the point indicated by an arrow.

Fig. III.

A. Trace with blood mixture.

B. Trace seven minutes after replacing the blood mixture with saline solution. At the point indicated by an arrow 0·5 c. c. of lime water was added to the 100 c. c. of circulating saline and the trace rapidly increased in height.

Fig. IV.

A. With blood trace.

B. Effect of 1 c. c. of lime water added to 300 c. c. of saline, twenty-four minutes after replacing blood with the saline and lime solution.

Fig. V.

A. Trace with blood mixture.

B. Trace eighteen minutes after replacing the blood mixture by 200 c. c. of saline with 2 c. c. of calcic chloride solution.

Fig. VI.

A. Trace with blood mixture.

B. Shows the trace about fifteen minutes after replacing the blood mixture by 100 c. c. saline and 10 c. c. of bicarbonate of lime solution. Also shows the effect of 0·5 c. c. of 1°/₀ solution of potassium chloride added or the point indicated by an arrow.

C. Shows the further effect of another three minims of potassium chloride solution.

FIG. VII.

A. Trace with blood mixture.

B. Trace 40 minutes after replacing blood mixture with 100 c. c. saline with 3·5 c. c. of calcium chloride solution. At the point indicated by an arrow 0·33 c. c. of potassium chloride solution was added to the 100 c. c. of saline.

FIG. VIII.

A. Trace with blood mixture and shows the effect of substituting saline for blood mixture. The saline was substituted at the point indicated by an arrow.

B. Shows the effect of 3·5 c. c. of calcium chloride solution. The calcium chloride was added at the arrow.

FIG. IX.

A. Trace with blood mixture, showing the immediate effect of replacing blood mixture by 200 c. c. saline, 20 c. c. calcium bicarbonate solution with 1·5 c. c. potassium chloride solution. Blood replaced at the point indicated by an arrow.

B. Trace eight minutes after the replacement.

C. Trace fifty-six minutes after replacement.

FIG. X.

A. Trace with blood mixture. These contractions were excited by induction break shocks.

B. Trace taken an hour after replacing blood mixture by 100 c. c. saline 5 c. c. of calcium chloride solution and ·75 c. c. potassium chloride, The contractions occurred spontaneously.

FIG. XI.

A. Trace with blood mixture.

B. Sixteen minutes after the substitution of 100 saline containing 2·5 c. c. of $\frac{1}{2}$ °/₀ solution of sodium bicarbonate in place of blood mixture.

C. Eight minutes later. Also showing the effect of adding to the 100 c. c. five minims of 1°/₀ solution of potassium chloride.

Fig. XII.

Trace showing the effect of contracture on the prolongation of diastolic dilatation.

The first contractions were spontaneous; on their stopping contracture declined. The two following series were excited by break shocks. With the first there is no prolongation of dilatations, but there is some with the second contraction and still more with the third.

Fig. XIII.

A. Effect of replacing the blood mixture by 100 c. c. saline containing 3·5 calcium chloride solution and 2·5 c. c. $\frac{1}{2}$ °/₀ sodium bicarbonate. The blood replaced by the saline &c. solution at the point indicated by an arrow.

B. Trace twenty-four minutes later, showing the prolonged diastole from the effect of the lime and also showing the antagonizing effect of 3 minims of 1 °/₀ solution of potassium chloride, which was added at the point indicated by an arrow.

C. Shows the further effect to two additional minims of potassium chloride solution, five in all. This trace was taken, 44 minutes after the blood was replaced by the saline lime and sodium bicarbonate mixture.

Fig. XIV.

A. Trace with blood, and also shows the effect of replacing blood mixture with 200 saline containing 10 c. c. of calcium chloride solution, 5 c. c. sodium bicarbonate solution ($\frac{1}{2}$ °/₀) and 1·5 c. c. potassium chloride solution (1 °/₀). These beats were excited by induction break shocks. Blood replaced at the arrow.

B. Trace ninety minutes after the replacement.

These beats spontaneous.

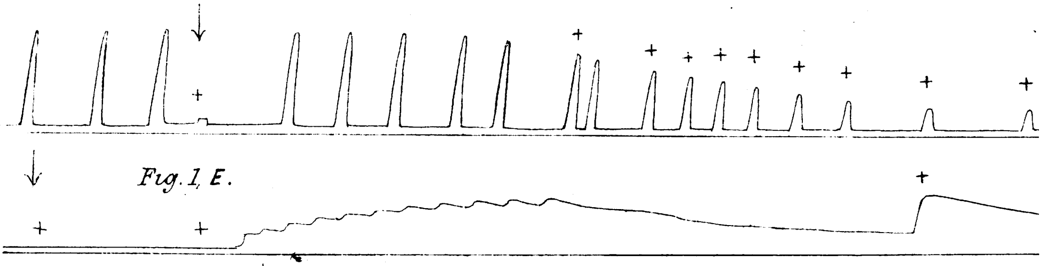


Fig. 1, E.

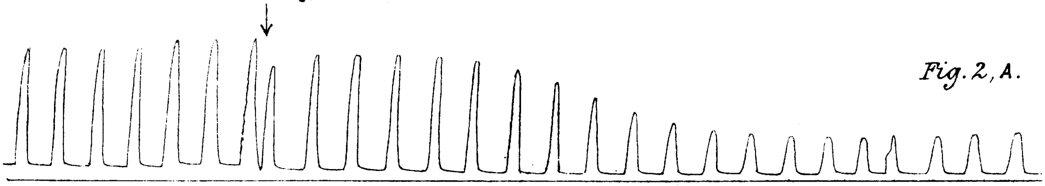


Fig. 2, A.

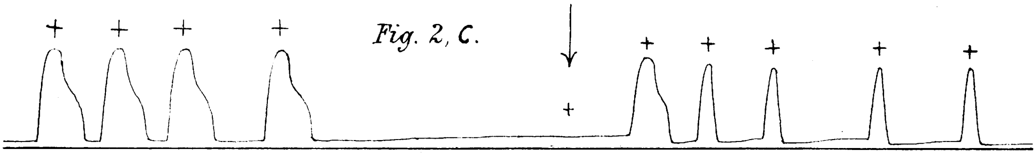


Fig. 2, C.

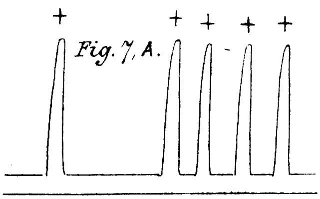


Fig. 7, A.

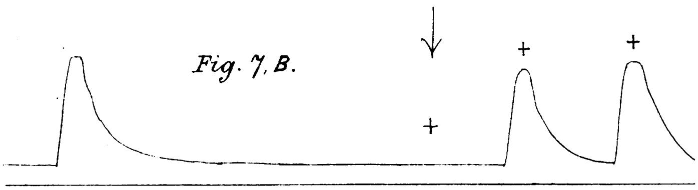


Fig. 7, B.

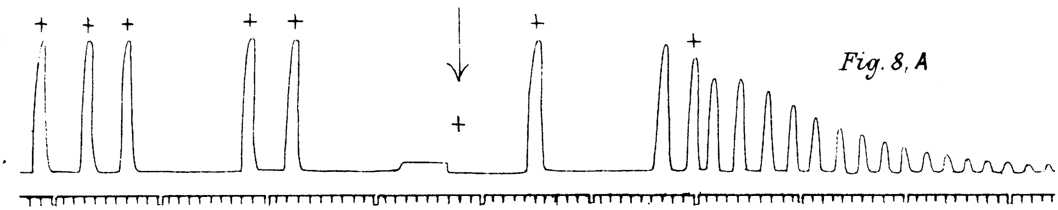


Fig. 8, A

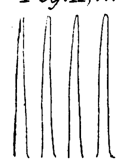


Fig. 11, A.

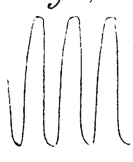


Fig. 11, B.

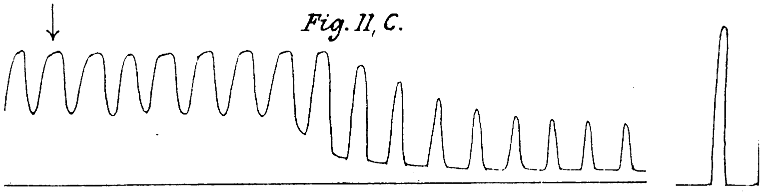


Fig. 11, C.

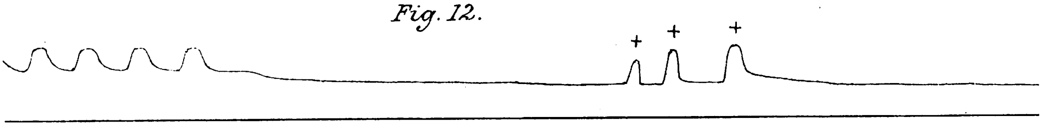
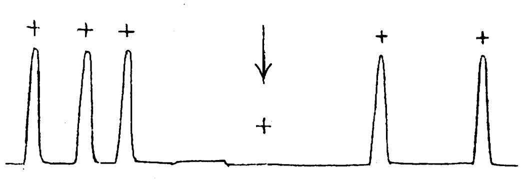


Fig. 12.



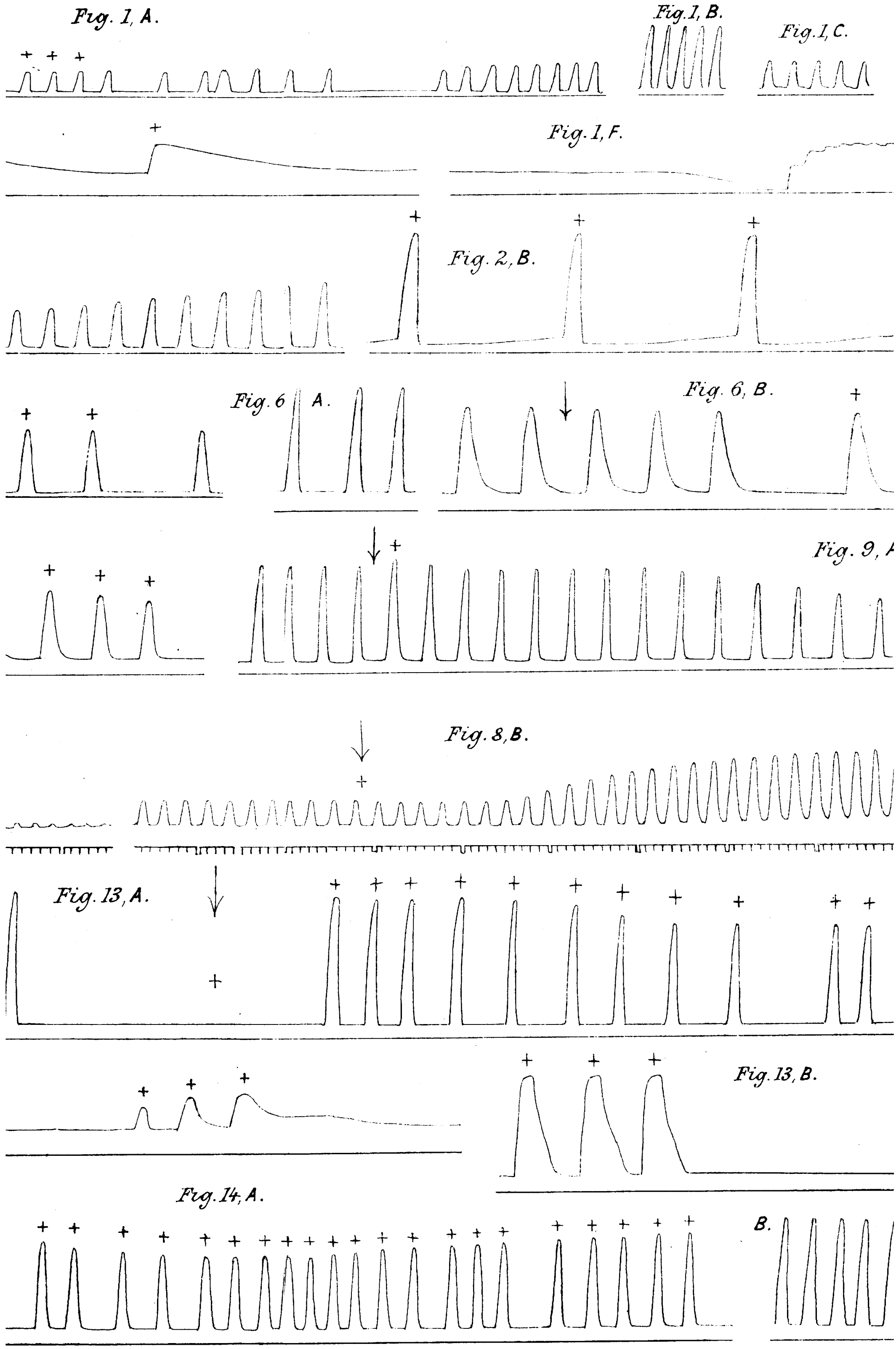
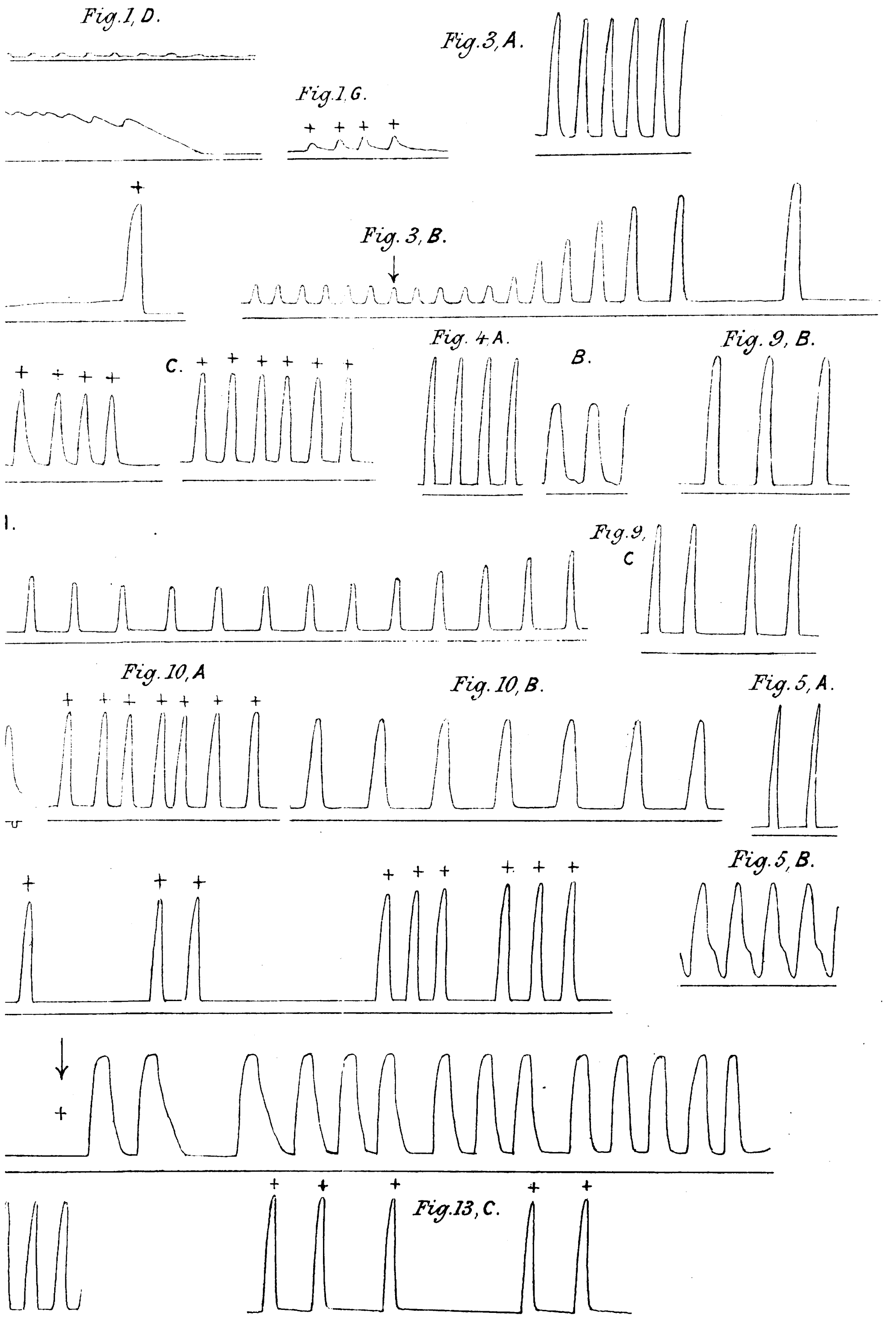


Fig. 1, A.
Fig. 1, B.
Fig. 1, C.
Fig. 1, F.
Fig. 2, B.
Fig. 6 A.
Fig. 6, B.
Fig. 9, A
Fig. 8, B.
Fig. 13, A.
Fig. 13, B.
Fig. 14, A.
B.



F Huth Lith.r Edin.r