

REGARDING THE ACTION OF HYDRATE OF SODA,
HYDRATE OF AMMONIA, AND HYDRATE OF
POTASH ON THE VENTRICLE OF THE FROG'S
HEART. BY SYDNEY RINGER, M.D., *Professor of
Medicine at University College, London.* Pl. XII., XIII.

IN No. 1, Vol. III., of the JOURNAL OF PHYSIOLOGY Dr. Gaskell records some experiments regarding the respective action of antiarin, hydrate of soda, muscarin, and digitalin on the ventricle of the frog's heart.

In this paper I record some experiments on the action of soda, ammonia, and potash on the same structure. In most respects my experiments with soda hydrate agree with those of Dr. Gaskell; in some respects, however, my tracings differ from his tracings. These experiments were made with Roy's tonometer. I tied the ventricle to the cannula by a ligature passed round the auriculo-ventricular groove, so that I experimented only with the ventricle.

I used dried bullock's blood dissolved in water so as to represent normal blood; to this solution I added saline solution in the proportion of one part of blood to two of saline. Of this mixture I employed three ounces in each experiment.

These experiments were made in June.

The tracings run from left to right.

I find that soda, ammonia, and potash affect the ventricle in much the same way. There are, however, differences in their action. I shall first describe the characters in which they all agree, and then point out in what respect the action of potash differs from the action of soda and ammonia.

Ammonia.

The general effect of all these substances is indicated in Fig. 1, Pl. XII., which shows the modifications produced by ammonia. The solution added to the blood contained 1 per cent. of strong liquor ammonia¹.

¹ I added a few drops of the 1 per cent. solution (soda or ammonia or potash) from time to time to the three ounces of blood. The quantity of the salt used is given with the explanation of plates.

Ammonia (see B) prolongs each contraction, and the summit of each rise becomes rounder; at the same time, during each diastole, the trace rises a little, but after each rhythmic contraction falls again to its old level as regards the base-line. If the rhythmic contractions cease for a time, the trace then rises as before and becomes undulating (see *a*). An inspection of the heart explains this undulating line. After the last rhythmic contraction the ventricle slowly lessens in size, and then rather more suddenly dilates, first at the apex, and then the dilatation extends to the base, or the dilatation begins at the base and extends to the apex; then the ventricle again slowly retracts and again dilates, and so on. After a larger dose of ammonia (see C, D and E) the rise in the trace during diastole becomes still more evident, and may, indeed, become so great that the ventricle shrinks almost to the dimensions it assumes at the termination of a rhythmic contraction. During a long diastolic pause the undulations in the trace become much more marked. Under the influence of a still larger dose the undulations disappear; the trace slowly rises after the dilatation, following a rhythmic contraction, and then continues at the same height during the remainder of the diastolic pause. After each rhythmic contraction the ventricle dilates to a far greater degree than immediately before the contraction. Under larger and larger doses the diastolic dilatation after each rhythmic contraction becomes less and less, until finally the diastolic dilatation (see E) fades away, and the trace becomes a slightly wavy line.

Fig. 2 shows the production of some further effects when ammonia is added in larger doses. In this trace there are no long diastolic pauses. This trace shows that with frequent ventricle beats, there is no diastolic contraction of the ventricle, as seen in Fig. 1, there being no time allowed for this diastolic retraction. But the effect of ammonia is shown in a lessened expansion of the ventricle in each diastolic dilatation.

After a large dose of ammonia (see C and D), the amplitude of the trace varies from time to time; at one time very small, it then grows gradually larger and again diminishes, and so on: the increase in the size of the trace is due entirely to an increase in the diastolic dilatation, this varying from time to time.

These variations in the size of the rhythmic contractions correspond to the undulations seen in Fig. 1 (B, a. C, b) during a prolonged diastolic pause. The undulating trace during a prolonged diastolic pause of course indicates corresponding changes in the size of the ventricle,

quite distinct from rhythmic contractions. When the undulation is at its highest, it shows that the ventricle is more contracted, and when the wave dips again, it shows that the ventricle is somewhat more relaxed. This change in the ventricle I hope to show is a true muscular contraction, a prolonged but varying spasm. This persistent but varying spasm, induced by ammonia, explains Fig. 2, C and D, where there occurs a series of rhythmic contractions, gradually increasing in amplitude and then diminishing again.

When the persistent spasm is most marked, the diastolic dilatation following each rhythmic contraction grows less, and the trace becomes small. When the persistent spasm grows less, then the diastolic dilatation following each rhythmic contraction increases, and the amplitude of the trace becomes greater, and so the amplitude of the trace grows from time to time larger, and then again grows less. When the slow persistent contraction induced by the alkali is least marked, the diastolic dilatation after each rhythmic contraction becomes greater, and the subsequent rise in the next rhythmic trace is increased, but when the persistent contraction from the alkali increases again, then the diastolic dilatation after each rhythmic contraction is lessened, and the rhythmic trace is much diminished. Indeed, the trace given in the above diagram corresponds in character to the trace recorded in Fig. 1. Indeed, C and D, in Fig. 2, correspond to Ba, Cb, Da, in Fig. 1, only in Fig. 2, whilst changes occur corresponding to those in Fig. 1, the rhythmic contractions continue.

After all rhythmic contractions have ceased, the trace gradually falls and attains the position in regard to the base-line it held before the ammonia was administered.

To what is this slow, persistent, varying contraction, occurring in long, diastolic pauses, due?

Is it due to a mere physical change which causes a shrinking in the ventricle, or is the contraction vital, and, indeed, a form of muscular contraction?

I hope to show that the slow diastolic contraction is vital—is a true muscular contraction:—

1st. These substances, hydrate of potash, hydrate of soda, and hydrate of ammonia, produce no such effect on the dead ventricle.

2nd. If the contraction were a mere physical change, the trace should remain at the same level during the whole diastole.

The great fall of the trace after a rhythmic contraction might possibly be explained on the supposition that, on the sudden relaxation of the

ventricle, the rush of blood into the ventricle dilates it considerably, owing to some increase in its elasticity induced by the alkalies, to be followed by slow retraction of the ventricle.

This explanation, however, is not feasible, since (see Fig. 1, E aa) after a rhythmic contraction a marked fall occurs, when so slight has been the rhythmic contraction that its relaxation would not admit of sufficient blood to distend the ventricle. When the rhythmic contraction relaxes it causes, likewise, relaxation of the persistent spasm induced by the alkali.

Further, in a long diastolic pause the trace undulates (see Fig. 1, C b, D, Fig. 4, B), and on examining the ventricle, one sees that it slowly dilates, first at the apex or base, and then the dilatation extends to the rest of its walls; finally the whole of it again slowly contracts, to again relax, so that the condition of the ventricle during diastole is seen to be a true muscular contraction, and not a mere physical phenomenon.

The alkali evidently induces a persistent contraction or spasm in the muscular structure of the ventricle, but this contraction slowly remits, and so gives rise to an undulating trace under a small dose. After a rhythmic contraction this spasm completely relaxes, so that the trace falls to its original position to the base-line; after a larger dose the spasm relaxes to a less and less degree, so that after each rhythmic contraction the fall grows less and less. (See Fig. 1, E b.)

If it should prove that a tonus exists in the muscular substance of the heart, I suggest that the spasm induced by these alkalies is an increase of this tonicity; but as this spasm can be induced in the apex of the ventricle, a part free from nerves, so it follows that the tonicity must be independent of nervous agency.

Dr. Chas. Richet (*Lancet*, May 21, 1881) argues that contracture is only an exaggerated tonicity of the muscles, and if so, this condition induced in the ventricle may be compared to contracture.

Hydrate of Soda.

Hydrate of soda affects the ventricle just like ammonia, as Trace 3 shows.

Hydrate of Potash.

Hydrate of soda and hydrate of ammonia induce a spasmodic contraction in the muscular tissue of the heart, and after still larger doses

all muscular contractility, rhythmic and spasmodic, ceases, and the heart dilates again, the trace falling towards the base-line till it reaches the same position it held before the addition of the alkali. In other words, soda and ammonia at first induce spasm and later weaken and paralyze muscular contractility.

Potash, also, induces spasm followed by paralysis. The paralytic action, however, becomes much sooner apparent. Shortly after the trace becomes modified the heart fails to contract completely with each rhythmic contraction, and, consequently, the trace does not rise so high as before the addition of the potash.

Potash is, indeed, a far more powerful paralyser than either soda or ammonia. The effects of hydrate of potash are well seen in Figs. 4 and 5.

A small quantity of potash, like soda and ammonia, prolongs each contraction and makes its summit rounder (see Fig. 5, B). As soon, however, as the potash induces the spasmodic condition, the rhythmic contractions lessen in height and become pointed once more (see Fig. 5, C). Indeed, the ventricle can be seen to empty itself much less completely. In some instances the beats become very irregular in force.

When the ventricle in Roy's tonometer is stimulated by the continuous application of faradization, it gives a trace very similar to a tetanus curve of the skeletal muscles when the excitations are not very numerous. The ventricular trace, however, differs from a true tetanus trace in this respect. In a tetanus trace the contractions are as numerous as the excitations, or in other words, as the breaks in the current, but it is not so with the ventricle. I used a Du Bois Reymond's induction coil, and the interruptions were very frequent, far more frequent than the ventricular contractions¹.

Soda and ammonia increase the readiness with which this condition can be induced, as is seen in Figs. 6 and 7, Pl. XIII., where I give, first the effect of faradization alone, and then of faradization after the heart has been drugged with a solution of hydrate of soda.

These tracings show that soda and ammonia greatly enhance the effects of faradization. In other words, soda and ammonia increase the irritability of the ventricle.

This increased irritability persists even when the ventricle has grown very weak, almost to the point of stopping, for even then, as seen in

¹ In the charts, the line above the trace indicates the time the faradization was continued, and the figure above the line the point at which the induction coil stood.

Fig. 6 F, Fig. 7 F, the ventricle when faradized gives a tetanus-like trace, though the point to which it rises above the base-line is only a little higher than that reached in a spontaneous rhythmic contraction, and far less high than before the addition of either alkali. The heart, though weak, is made irritable by the alkali. The alkali induces a condition similar to that occurring in disease in the nervous and muscular tissues, and termed, by the old writers, irritable weakness.

Prolonged faradization of course weakens the ventricle, and so the persistent spasm becomes weakened as well as the rhythmic contractions; hence, after prolonged faradization the trace sinks nearer the base-line, and as the heart recovers from the weakening effect of faradization, the trace again gradually rises higher and higher above the base-line. This effect of faradization on the trace favours the suggestion that the diastolic rise after ammonia or soda is due to muscular contraction, and not to a mere non-vital physical change.

Prolonged faradization affects a heart poisoned by potash differently from a heart poisoned by either soda or ammonia.

With some hearts there occur after potash for a short time a similar effect to that induced by the other alkalies; that is to say, the ventricle is more irritable, and the trace remains raised longer than before the addition of potash. Soon, however, when the effects of potash become marked, and when diastolic contraction is induced, potash has the opposite effect, and the ventricular irritability is diminished, and continuous faradization weakens the ventricle, and the trace sooner falls towards the base-line than before the potash was added. A little later the faradization arrests all contractions whilst it is continued, but these return when the faradization is discontinued. (See Fig. 8, C D.)

In other cases the heart at once, after potash, grows less influenced by faradization, and in a short time the contractions are arrested by faradization.

EXPLANATION OF PLATES.

· PLATE XII.

- Fig. 1.—*Ammonia*.—A. Before the addition of ammonia to the blood.
 B. After the addition to the blood of successive doses of 0·1 c. c. of the 1 p. c. ammonia solution repeated seven times.
 C. After 1·4 c. c. of the solution.
 D. „ 2·6 „ „
 E. „ 3·8 „ „

- Fig. 2.—*Ammonia*.—A. Before the addition of the ammonia solution.
 B. After the addition of 0·8 c. c. of the ammonia solution.
 C. " 1·8 "
 D. " 3·0 "
 E. " 2·2 c. c. of the ammonia solution
 32 minutes after the first dose of ammonia.

- Fig. 3.—*Soda*.—A. Before the addition of 1 p. c. soda solution.
 B. After the addition of 1·2 c. c. of the soda solution.
 C. " 2·0 "
 D. " 4·0 "
 E. " 4·6 c. c. (in all) ,,
 F. " 7·0 c. c. of the soda solution.

All contractions then ceased and the heart gradually dilated, the curve falling until it ultimately touched the base line.

- Fig. 4.—*Potash*.—A. Before the addition of potash.
 B. After the addition of 1·0 c. c. of the 1 p. c. potash solution.
 C. The effect of additional doses of the potash solution.

- Fig. 5.—*Potash*.—A. Before the addition of the potash solution.
 B. After the addition of 2·5 c. c. of the potash solution.
 C, D. Effects of additional doses of the potash solution.

PLATE XIII.

- Fig. 6.—*Soda*.— α , β , γ . Before the addition of the soda-solution, effect of faradization of ventricle.

The lines above the curve indicate the duration of the faradization, the numbers above the line the distance between the secondary and primary coils, *i.e.*, the relative intensity of the current.

- A. After the addition of 2·0 c. c. of the soda solution.
 B. " 3·0 c. c. of the soda solution ;
 14 minutes after the first dose of soda.

No more of the soda solution was added to the blood, but the following tracings were taken at intervals.

- C. Eight minutes after the first dose of soda.
 D. About 27 minutes after the first dose of soda.
 E. " 36 " "
 F. " 63 " "

Fig. 7.—*Ammonia*.—A, B. After the addition of small doses of the ammonia solution.

C. After the addition of 1·3 c. c. of the ammonia solution in successive doses ; tracing taken about 11 minutes after the first dose of ammonia.

D, E. Additional doses of ammonia.

F. After 3·2 c. c. of ammonia solution ; 36 minutes after the first dose.

G. At a still later period.

Fig. 8.—*Potash*.—A. Before the addition of the 1 p. c. potash solution.

B. After the addition of the 1 p. c. potash solution in successive doses, 3·0 c. c. in all.

C. After the addition of 3·8 c. c. in all.

D. Tracing taken from another heart after the addition of 50 *minims* of the potash solution.

Fig. 1, A.

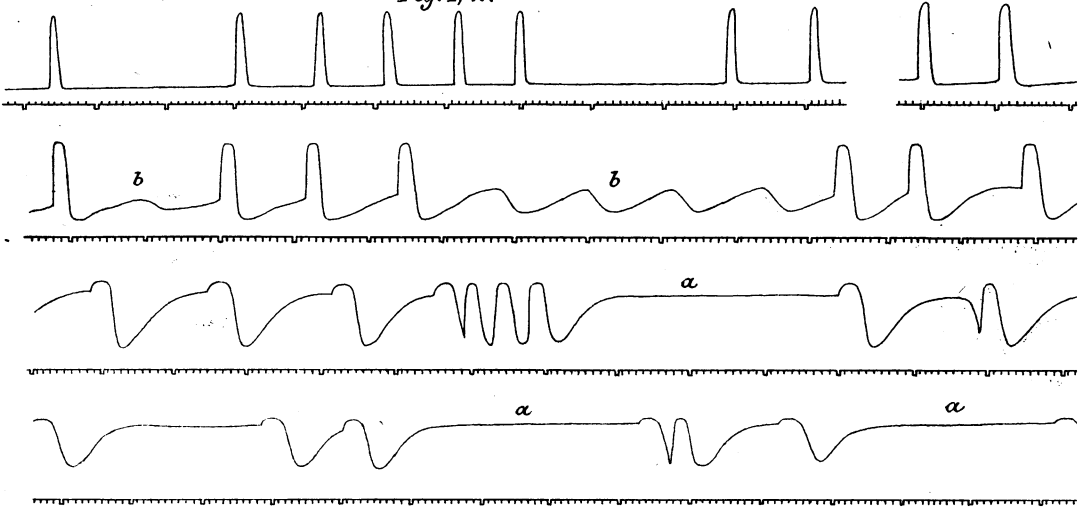


Fig. 2, A.

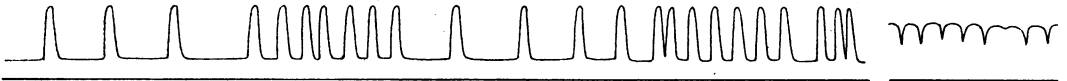


Fig. 2, B.

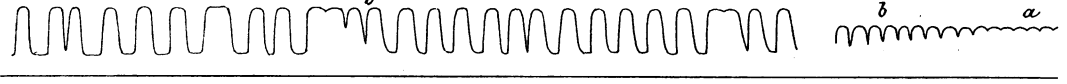


Fig. 2, E.

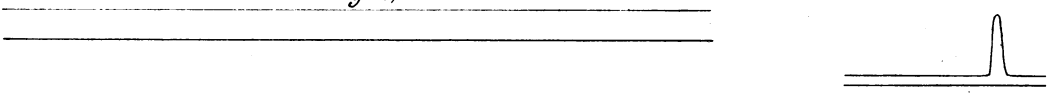


Fig. 3, E.

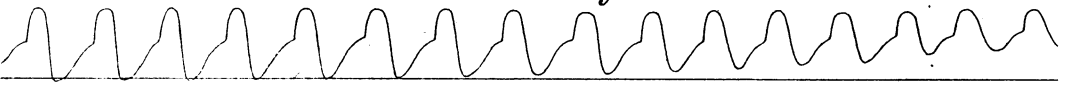


Fig. 4, A.

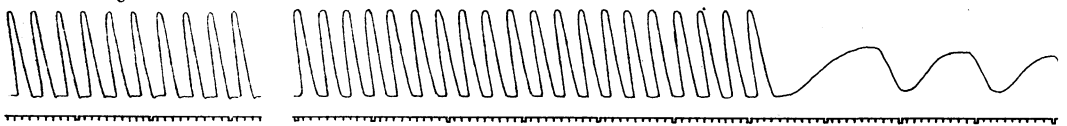


Fig. 4, C.

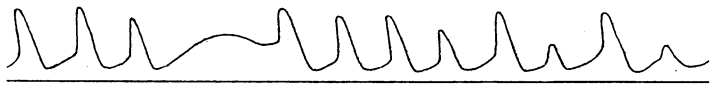
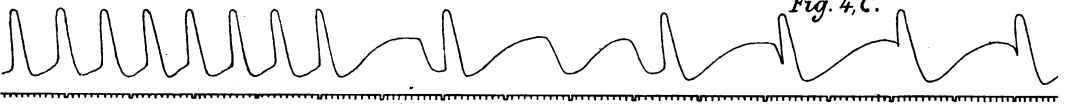


Fig. 1, B.

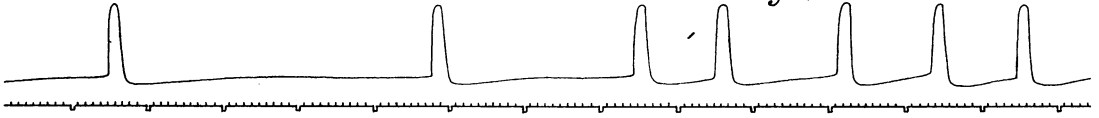


Fig. 1, C.

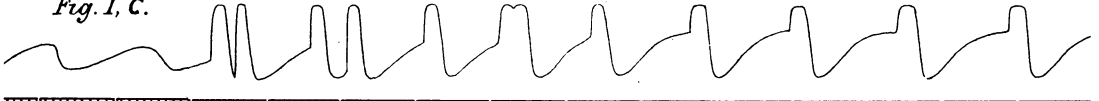


Fig. 1, D.

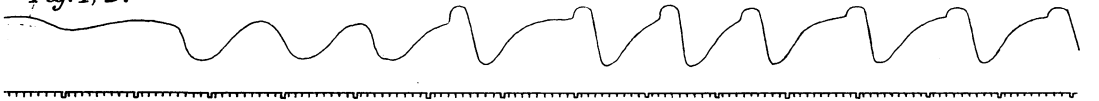


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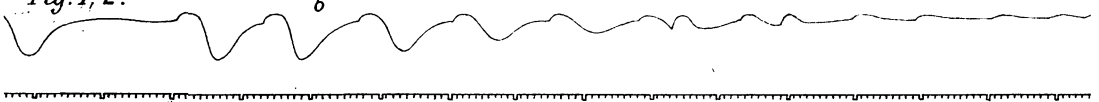


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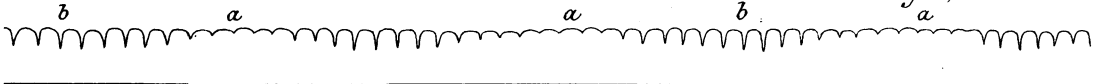


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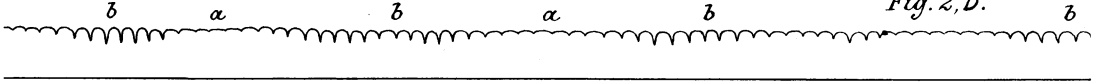


Fig. 3, A.

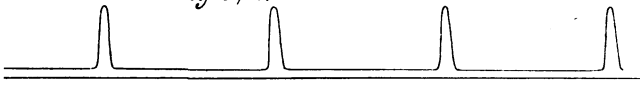


Fig. 3, B.

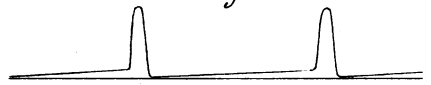


Fig. 3, F.

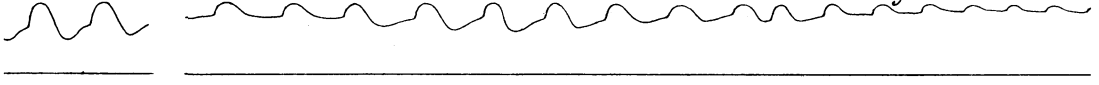


Fig. 4, B.

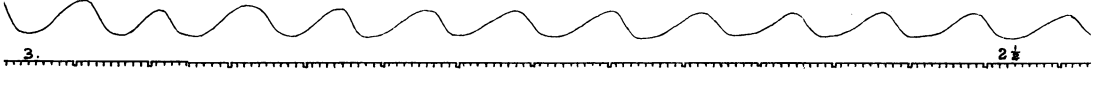


Fig. 5, C.

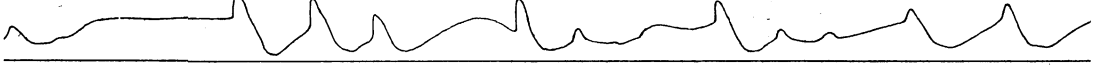
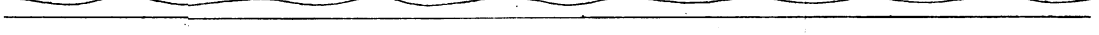


Fig. 5, D.



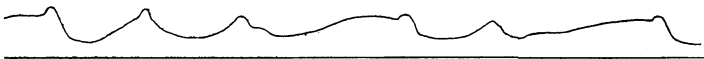
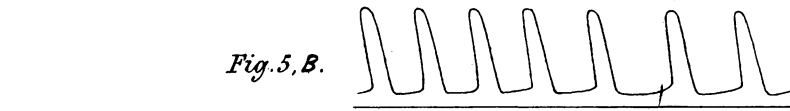
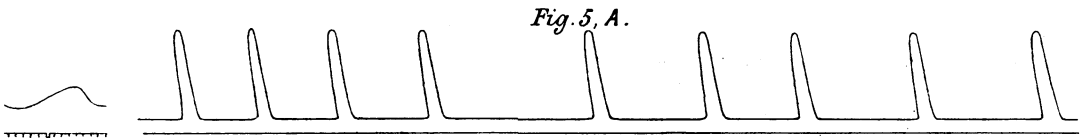
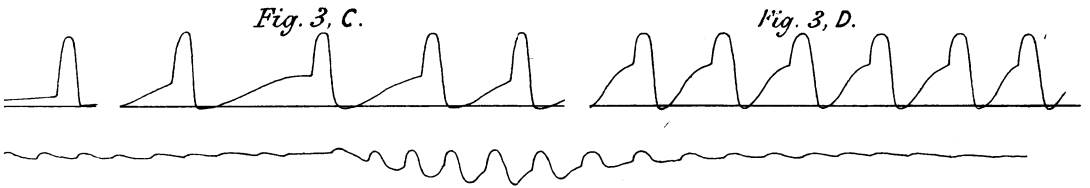
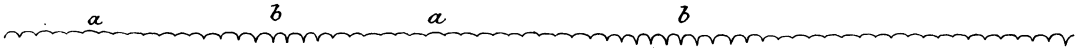
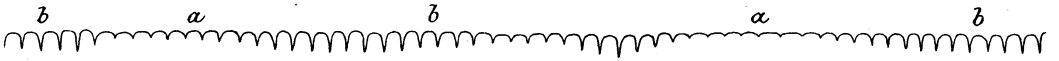
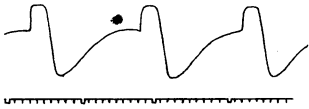


Fig. 6. A.

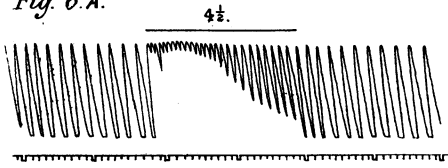


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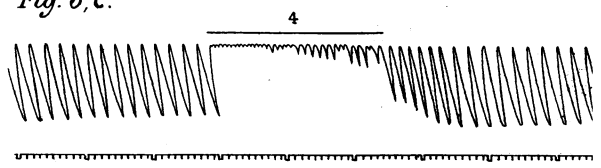


Fig. 6. B.

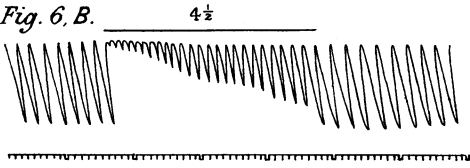


Fig. 6. D.

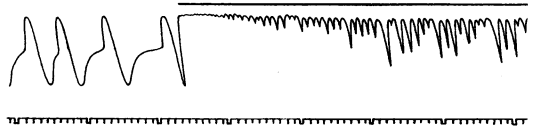


Fig. 6. F.

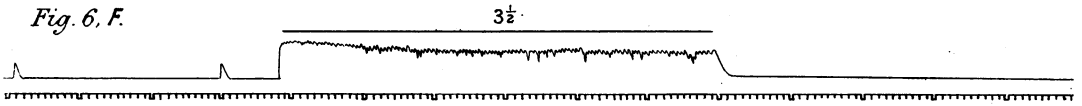


Fig. 6. alpha.

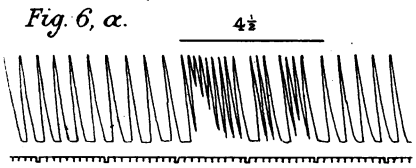


Fig. 6. beta.

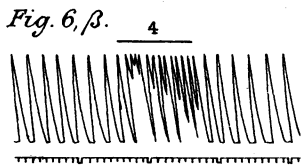


Fig. 6. gamma.

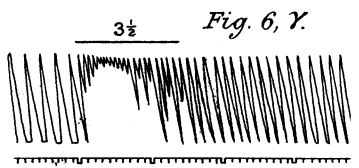


Fig. 7. A.



Fig. 7. B.

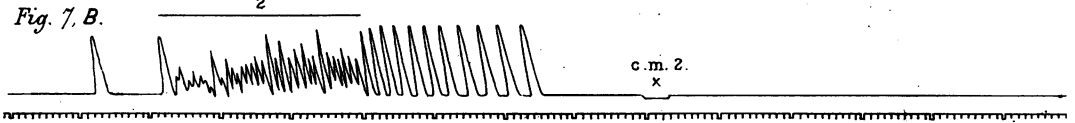


Fig. 8. A.

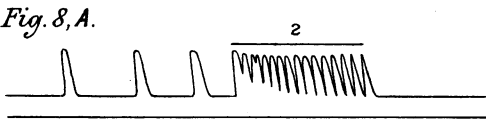


Fig. 8. B.

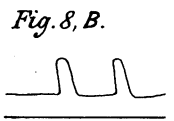


Fig. 8. C.

