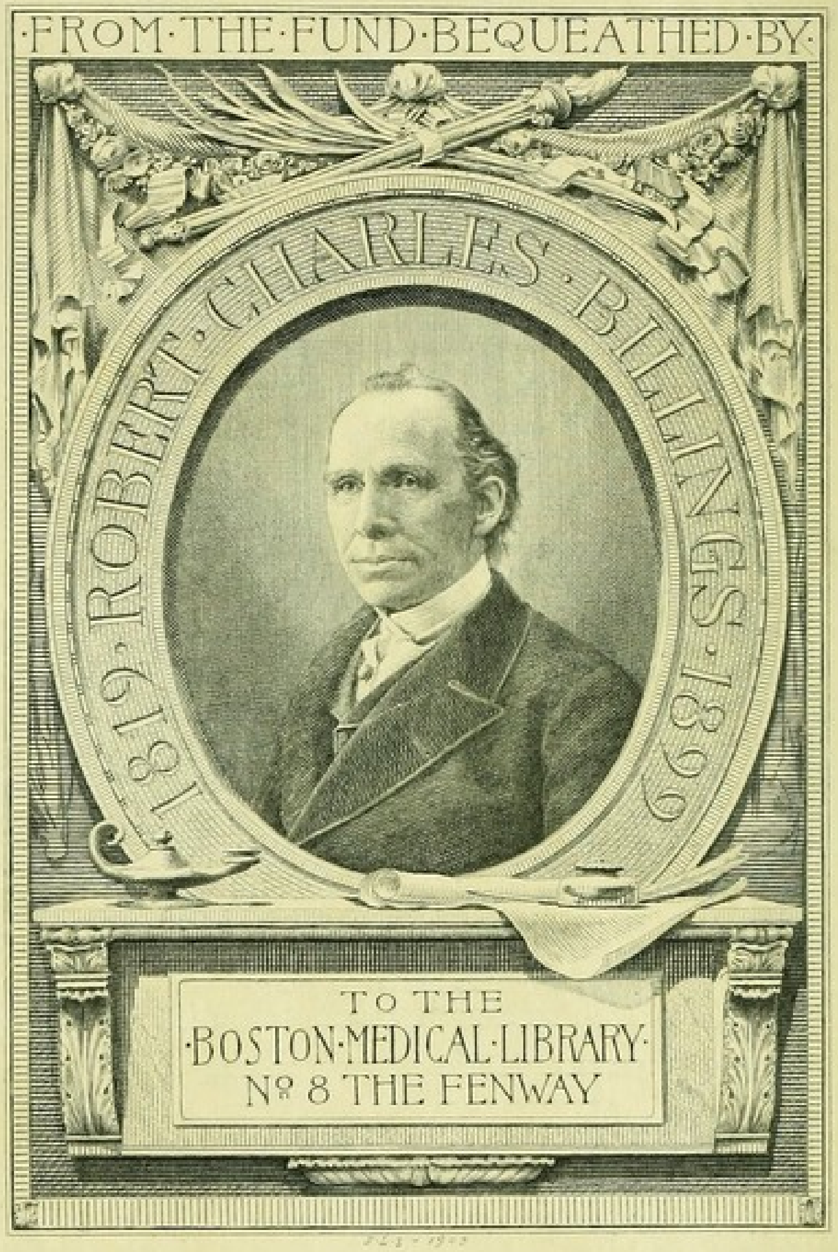
REPORT OF THE COMMITTEE APPOINTED TO INVESTIGATE THE SUBJECT OF SUSPENDED ANIMATION IN THE DROWNED

1904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AN INQUIRY

INTO

THE PHENOMENA ATTENDING DEATH BY DROWNING

AND THE

MEANS OF PROMOTING RESUSCITATION IN THE APPARENTLY DROWNED

Report of a Committee appointed by
The Royal Medical and Chirurgical Society

LONDON
LONGMANS, GREEN AND CO.
(FOR THE ROYAL MEDICAL AND CHIRURGICAL SOCIETY OF LONDON)
PATERNOSTER ROW

1904.

Printed by Adlard & Son,
London and Dorking

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Report of a Committee appointed by the Society, drawn up by Professor SCHÄFER, Chairman of the Committee [1]

Read May 26th, 1903

IT became clear in considering the manner in which the question which was placed before the Committee might best be solved, that it would be necessary for the inquiry to be pursued along two different lines—the one having for its object the determination of the most efficient and most convenient mode or modes of carrying on artificial respiration in the human subject ; and the other, the investigation of the physiological phenomena (in connection especially with respiration and the vascular system) which attend asphyxia produced by the introduction of water in place

[1] The other members of the Committee who have taken an active part in the investigation, and concur in this report, are Mr. Pickering Pick, F.R.C.S., and Mr. Henry Power, F.R.C.S.

of air into the lungs, as well as the phenomena which accompany recovery in apparent death by drowning. This branch of the inquiry could, of course, only be conducted upon animals; and for various reasons—but especially because the methods of artificial respiration which can be used in those animals are similar to those which may be employed in man—dogs are by far the most suitable subjects upon which to carry out such an investigation.

As was the case, therefore, with the report submitted by a previous Committee of the Society and published in the 'Transactions' for 1862, our report consists, so far as the experiments recorded are concerned, of two parts—one dealing with physiological experiments upon dogs (which have been conducted by Professor Schäfer and Dr. P. T. Herring in the Physiological Laboratory of Edinburgh University), and the other of experiments designed to measure the amount of air which could be taken into or forced out of the lungs in man by various methods of artificial respiration; these experiments, having been commenced in London, were subsequently also carried on and completed in Edinburgh.

Experiments to Determine the Amount of Air which can be taken into or forced out from the Lungs by Various Methods of Artificial Respiration.

Experiments of a similar character to those we have to record were instituted by the 1862 Committee, who made a number of observations upon the dead body with this object. But the method they generally employed—that, namely, of tying a tube into the trachea, this tube being connected with a balanced bell-jar—is open to the obvious objection that no such operative procedure as this could well be used in cases of apparent drowning. In such cases, moreover, there are factors connected with the upper air-passages which might influence the result; such, for example, as accumulation of mucus in the throat and glottis, or the falling back of the tongue, which might thereby block the pharynx, and which also has been supposed to cause the epiglottis to fold over the superior aperture of the larynx.[1]

On these grounds it seemed to the Committee of importance to determine, if possible, the question of the amount of air passed into and out of the lungs (under different methods and conditions of artificial respiration), with preservation of the natural channels through the nostrils and mouth. In order to effect this result the Committee employed a face-piece, or mask,[2] with tubular rubber margin which could be fitted air-tight, with the aid of vaseline, over the mouth and nostrils; and this mask was connected either to a gasometer or to a balanced bell-jar similar to that used by the 1862 Committee, with its mouth dipping under water, and so arranged that it would move up or down according as it contained more or less air. The movements of the bell-jar (and of course at the same time the amount of air upon which the extent of the movements depends) are recorded by a pen, writing upon a blackened drum slowly revolved by means of clockwork (see diagram, Fig. 1).

The earliest attempts which the Committee made to solve this question were carried out under the auspices of Mr. Pickering Pick upon bodies in the mortuary of St. George's Hospital. These attempts, however, were rendered futile, firstly by the difficulty of procuring suitably healthy subjects for experiment; and secondly, when such subjects had been found, by the impossibility of obtaining

[1] It may be here remarked that the view which was formerly current, that the superior aperture of the larynx is closed during retraction of the tongue (*e.g.* in swallowing) by a folding back of the epiglottis, is no longer held by physiologists. On the contrary, there is strong evidence that no such folding over is possible, but that the epiglottis remains, under all circumstances, erect. (T. P. Anderson Stuart and A. McCormick, 'Journ. Anat. and Phys.,' xxvi, 1892, p. 231; Anderson Stuart, "Proc. Phys. Soc.," 'Journ. Phys.,' xiii, 1891, p. 57.)

[2] A similar arrangement was tried by the 1862 Committee in one experiment at least, but they failed to get any appreciable results in this case, and they appear to have returned to the trachea method.

any but trifling fluctuations in the chest-volume, owing to the *rigor mortis* which had invariably set in before the subjects could be used for experiment.

It was then hoped by the Committee that in such a large establishment as the London County Council's Asylum at Claybury opportunities might more frequently be found for carrying out such an investigation, and the Committee accordingly invited Dr. J. S. Bolton, then one of the resident physicians, to make experiments for them

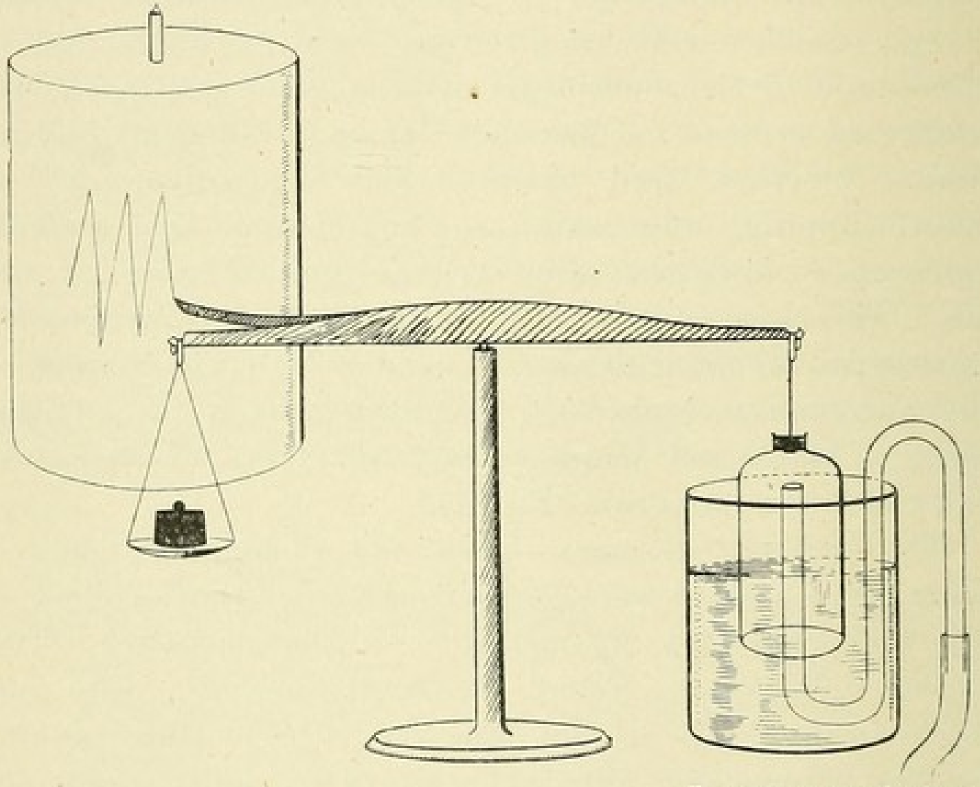

FIG. 1.—Diagram of apparatus employed to record volume of air taken into and forced out of chest in artificial respiration experiments.

upon the lines indicated. Dr. Bolton, however, after a large number of attempts, which extended over a period of more than two years, was no better able than had been the members of the Committee to obtain any results which could be relied upon. And when we examine the similar experiments which were performed by the 1862 Committee, we become at once aware that that Committee had to face difficulties of a precisely similar nature, and that in only four of the subjects upon which they experimented were they able to obtain any marked effect upon the capacity of the thorax, and that only by one method (Silvester's combined with pressure on the thorax). By other methods hardly any appreciable result was in most cases obtained. Since the difficulty of experimenting upon the dead body is so great, it occurred to the Committee that it might be feasible to carry out the inquiry upon the living subject, the conditions necessary being that the subject should remain completely passive without making any attempt at natural respiration for the short period of time during which the experiment might last, and that he should not, by involuntary closure of the glottis, prevent the free passage of air into or out of the lungs. The first of these conditions can be readily fulfilled if the subject, immediately prior to the experiment, makes several deep respirations, for he thereby renders himself temporarily apnœic, and the *besoin de respirer* is absent. Under these circumstances it is by no means difficult to perform artificial respiration for a short time without any resistance on the part of the subject, and without his making any spontaneous movements of respiration. The second condition necessary for success—the maintaining an open glottis—is at first more difficult, and with an uneducated person may be insuperable, but with educated persons it can easily be acquired with very little practice.[1]

The air may be allowed to pass to a gasometer or balanced bell-jar—the latter being the apparatus which we have generally employed—either through a face-mask fixed air-tight by rubber bands round the head, or through a flattened horn tube which is placed in the mouth and kept air-tight by the lips, the nostrils being occluded by a spring clip.

[1] The employment of the living subject for these experiments is disadvantageous from one point of view, seeing that there is not the same tendency as in the dead or apparently dead subject for the tongue to fall back and block the pharynx, when the subject is in the supine position. But it is the practice in such cases to draw the tongue forward and fix it there, and the conditions are then fairly similar in the two cases. In the prone position of the dead subject the tongue naturally falls forward and this difference does not manifest itself.

In this way experiments have been performed by various methods of artificial respiration by Professor Schäfer, with the assistance of Drs. Herring and Sutherland Simpson, upon five subjects whose ages varied from twenty-five to fifty-two; the results of these experiments are set forth in tabular form on p. 11. But before these are studied it may be well to consider the main principles upon which methods of carrying on artificial respiration in the human subject must be based.

Principles of the Methods which may be used in Artificial Respiration in Man.

The methods which may be employed in artificial respiration in man are of three kinds, viz. (1) those in which air is drawn into the lungs by increasing the capacity of the thorax (which can only be done artificially by raising the ribs); (2) those by which air is forced out of the thorax by direct compression of its walls, or indirectly by compression of the abdomen; and (3) those by which air is driven by means of a pump or bellows through the air-passages into the lungs. It has been shown by Horvath that if the nozzle of a bellows be applied to one nostril (the mouth being at the same time shut), by sharp closure of the bellows a sufficient amount of air can be forced into the thorax freely to distend the lungs, and by a frequent repetition of the process to maintain aëration of the blood. Practically, however, this method, although it might well be employed in certain cases, would not be available in most instances of apparent death from drowning; but its efficacy should not be forgotten, especially since it appears to afford a means of forcing air into the alveoli in cases in which the more gentle current of air which is produced by movements of the ribs fails to find a passage through the frothy mucus which may partially block the bronchi (cf. Experiments XXII, XXIV of the Experiments on Animals). Leaving this method for the present out of consideration, we may briefly consider the methods which depend upon enlargement and compression of the chest respectively.

1. *Method of enlarging the chest by raising the ribs: Traction method.*—This was first recommended by Dr. Silvester.[1] It consists in dragging the arms upwards; the muscles which pass from the chest to the arms are thus put upon the stretch, and tend to raise the ribs.[2]

In employing this method it is usual to place the subject in the supine position, but it is obvious that he may equally well lie prone, although the ribs will probably be somewhat less readily moved when the front of the chest is resting upon the ground. This is a point, however, which has not hitherto been experimentally determined, and we have accordingly submitted it to the test of experiment (see table, p. 11). A modification of this method consists in the employment of one arm only, the subject lying upon the opposite side.[3] It might at first be supposed that only one half of the total result yielded by the two-arm method would be obtained; but this conclusion by no means follows, for a very large part of even the half of the chest which is undermost is left free to move when the body is in the lateral position. At any rate the effect of this modification in producing movement of air into the chest has also, we believe, not hitherto been experimentally determined, and we have made observations with a view of coming to a conclusion on this point also (see table, p. 11).

2. *Methods of compression.*—The principle of the second class of method is that of squeezing air out of the thorax by pressure upon its parietes and allowing fresh air to pass in by means of the elastic reaction which follows removal of the pressure. This principle is the basis of more than one

[1] "The True Physiological Method of Restoring Persons apparently Drowned or Dead," 'British Medical Journal,' 1858.

[2] In the modifications suggested by Pacini and Bain the traction is exerted from the shoulders. (See "Report of Committee," 'Med.-Chir. Trans.,' liii, 1870.)

[3] Paasch, 'Vossische Zeitung,' Feb., 1861; Bowles, "Three Lectures on the Practical Points in the Treatment of Threatened Asphyxia," 'Lancet,' 1901.

of the methods which have been recommended for artificial respiration, *e. g.* that of Howard,[1] and also that known by the name of Marshall Hall,[2] which consists in rolling the body over from the lateral to the prone position and back again alternately, the expulsion of the air being assisted by pressure upon the back whilst the body is in the prone position. Methods which depend upon compression of the thorax, although they at first sight do not seem to imitate the circumstances of natural respiration so exactly as those which depend upon raising the ribs, nevertheless have this physiological advantage, that by producing a more or less rapid diminution in size of the lungs, they tend to stimulate the inspiratory centre to activity,[3] and the sooner this centre can be made to resume its normal functions the sooner will complete recovery follow.

It is obvious that both kinds of methods enumerated under (1) and (2) may be combined, *e. g.* the ribs may be raised by exerting traction through the arms, and when these are brought back to the side of the chest pressure may be exerted upon the chest walls; this is, in fact, the method which is generally employed, and is that which was recommended by Dr. Silvester.

There is one serious danger to which the pressure methods[4] are liable, viz. that of causing injury to the internal organs. The greatest danger is to the liver,

[1] 'Plain Rules for the Restoration of Persons apparently Dead from Drowning,' New York, 1869.

[2] 'Prone and Postural Respiration in Drowning,' London, 1857.

[3] This has been established by the researches of Hering and Breuer ('Wiener Sitzungsb.,' 1868, Bd. lviii), and particularly those of Head ('Journ. Physiol.,' 1889, vol. x). Such stimulation would, however, only come into play after the artificial respiration had effected a sufficient aëration of the blood to release the respiratory centre from the paralysis produced by complete asphyxia. Rhythmic traction on the tongue could also only operate when recovery from asphyxia was commencing.

[4] Especially that of Howard, who advocates pressure over the short ribs with both hands and the whole weight of the body, the patient being in the supine position.

which in all cases of drowning, and of asphyxia in general, is enormously congested and enlarged. Under these circumstances a very little excess of pressure—especially if it be applied to the lower part of the chest or the abdomen—is sufficient to produce rupture of the liver with concomitant extravasation of blood into the peritoneal cavity. Some of our experiments upon dogs illustrate the reality of this danger (see Exps. X, XI, XIII, and XVIII), and we believe it is not an unknown experience that, in cases of death from an overdose of chloroform in the human subject, in which various methods of artificial respiration—and these often include forcible compression of the lower part of the thorax or of the abdomen—have been resorted to in attempts at resuscitation, it has been found post mortem that the peritoneal cavity contains an effusion of blood, resulting from rupture of the liver. In all cases, therefore, in which pressure in the supine position is employed, it should be restricted to the middle parts of the chest, or if applied to the epigastrium it must be exerted only very gently and gradually. One reason why it has been thought advantageous to apply pressure to the abdomen is that by so doing the blood which tends during asphyxia to collect in the great veins is thereby pressed onwards towards the heart. But such onward pressure of the blood may in itself become another source of danger, for, as the end of asphyxia approaches, the right side of the heart is always—as has been exemplified in all our experiments on animals—enormously distended with blood; and, indeed, the ultimate failure of the heart may in a measure be due to this over-distension. It is clear, therefore, that the forcing of more blood to the right auricle may only tend to aggravate this condition of the heart, and still more effectually to obstruct its action.[1]

The methods of artificial respiration which have been tested in the manner indicated are—

[1] This has been particularly insisted on by Dr. L. Hill: "The Effects of Gravity on the Circulation," 'Journ. Phys.,' vol. xviii, 1895, p. 15; and "Address to the Society of Anæsthetists," 'Brit. Med. Journ.,' vol. i, 1897, p. 957.

(1) Simple traction (and relaxation) by both arms, the subject being in the supine position.

(2) Traction by both arms, with alternating pressure upon the thorax; supine position.

(3) Intermittent pressure on the thorax; supine position.

(4) Simple traction (and relaxation) of both arms, the subject being in the prone position.[1]

(5) Traction by both arms, with alternating pressure upon the back of the thorax; prone position.

(6) Intermittent pressure on the back of the thorax; prone position.[2]

(7) Traction by one arm only, the subject lying upon the opposite side, with the opposite arm underneath; lateral position.

(8) Traction by one arm, with alternating pressure upon the thorax; lateral position.

(9) Intermittent pressure on the thorax; lateral position.

(10) Rolling the subject alternately from the lateral or latero-supine to the prone position, with alternating pressure upon the back of the thorax.

Some results which were obtained as the average of a few trials in each of five individuals experimented upon by these several methods, are given in columns VIII to XVII of the annexed table. The remaining columns show, respectively, the designation of the subject for the purposes of the experiment, the age, weight, height, and chest-measurement—taken, after expiration of tidal air, under the armpits,—as well as the vital capacity and the average tidal air; the last two, as well as VIII to XVII, are expressed in cubic centimetres. The subjects of experiment were all medical men and physiologists.

[1] When the subject was placed in the prone position it was found advantageous to place a support, made by folding up a coat, under the thorax.

[2] The pressure in these experiments (5 and 6, recorded in columns XII and XIII of the table on p. 11) was applied over the middle of the back. Subsequently it was found to be much more effective when applied more at the side, and over the lowest ribs.

Table showing some results obtained by various modes of performing artificial respiration as practised upon five subjects of ages from twenty-five to fifty-two. The amounts of air taken in and given out are recorded in cubic centimetres, and are in all cases the averages of three or four successive respirations produced by the method stated at the top of each column. All the results given in this table were obtained on one day, and with the exception of those belonging to D the artificial respiration was carried out in all by the same individual (D). The experiments on D were performed by C. No attempt was made to imitate the natural rate of respiration, and the numbers cannot therefore be taken as an indication of the extent of air exchange which is possible at that rate.

I. Designation of subject.	II. Age.	III. Weight in kilos.	IV. Height in metres.	V. Girth of chest in mm.	VI. Vital capacity in c.c.	VII. Tidal air in c.c.	VIII. Traction only, supine.	IX. Traction and pressure, supine.	X. Pressure only, supine.	XI. Traction only, prone.	XII. Traction and pressure, prone.	XIII. Pressure only, prone.	XIV. Traction only, unilateral.	XV. Traction and pressure, unilateral.	XVI. Pressure only, lateral.	XVII. Rolling and pressure.
A	25	54·8	1·666	862	3900	300	300	580	470	360	490	360	270	600	330	640
B	29	58·6	1·666	880	3700	290	280	540	300	320	320	300	300	520	440	600
C	30	80	1·834	960	5300	400	290	390	370	240	380	400	260	320	350	490
D	39	95·8	1·742	1062	4900	360	210	380	340	260	350	400	230	350	300	450
E	52	60·7	1·710	842	3570	290	210	400	260	180	280	370	280	370	260	360
Average	35	70	1·724	921	4274	328	258	458	348	272	365	366	268	432	336	508

Remarks on the Results recorded in the Foregoing Table.

It would seem from the results here recorded that all the methods employed are competent to effect a sufficient exchange of air to maintain the oxygenation of the blood, provided that they can be performed with equal efficiency at the ordinary rate of respiration. Very few of the numbers obtained are less than the volume of the tidal air of the individual. The least amounts were those yielded by the traction method pure and simple, but the combination of this with alternating pressure gave results which are in some instances larger, in the others very nearly as large as the amount of tidal air. The marked effect of pressure in assisting the output and subsequent elastic intake of air is particularly well seen in the case of the younger subjects, which is doubtless due to the greater mobility in them of the thoracic walls. In the youngest (aged 25) especially, very much larger amounts were in all cases obtained when pressure on the chest was employed. It further appears that the prone position is advantageous in assisting the effects of pressure, probably because pressure applied to the back becomes more evenly distributed over the thorax and abdomen. Since no means were adopted to measure the actual amount of traction and pressure employed —nor could this well be done without considerably modifying the natural conditions of the experiment,—it is obvious that the several results are not rigidly comparable. The conditions were, however, so far similar that all the movements for artificial respiration, with the exception of those made upon the subject here designated D, were performed by the same operator, who was careful in no case to employ any unusual exertion; the traction on the arms was insufficient to move the subject, who was in every instance reclined upon the (carpeted) floor; the pressure on the chest was exerted slowly and gradually, and was of such a force as not to cause pain or even inconvenience.

Attention may especially be drawn to the considerable amount of movement of air which was obtained in both prone and lateral positions by the combined traction and pressure methods; an amount fully adequate (if it could be kept up at a sufficient rate) to produce aëration of the blood, judging by its relationship to the tidal air of the individual. It is further apparent that, in all the positions, intermittent pressure alone is an adequate means of effecting respiration. A striking feature of the experiments is the testimony they appear to offer to the efficacy of the rolling method, combined with pressure upon the back, the highest results in the series here given—with only one exception—having been attained by this means.[1] This is a method which depends upon the difference of pressure which is exerted upon the thoracic wall during the rolling of the body from one position to the other, a difference which is accentuated, when the prone position is fully attained, by direct application of pressure to the back; it is also a method which is very simply performed, and with less exertion to the operator than methods involving traction, especially if the subject is, as is usually the case in dealing with the apparently drowned, lying upon the ground. It has a further advantage in cases of drowning, that the movement from the lateral to the prone position offers facilities for the escape of water and mucus from the mouth and air-passages. It appeared to the Committee that either this method or, still better, the more simple method of rhythmic pressure upon the back with the subject placed in the prone position, should occupy a prominent place in any recommendations made with the view of the resuscitation of the apparently drowned.

Note added December, 1903.—The results recorded in the foregoing table, although interesting as illustrations, are too few to draw more definite conclusions from than

[1] The 1862 Committee, which experimented upon dead bodies only, obtained far smaller results by the Marshall Hall rolling method, even when combined with pressure on the back. The difference is doubtless due to the great loss of elasticity and resiliency which results from the advent of *rigor mortis,* so that variations of pressure produce far less result than during life.

those which we have above pointed out. They are especially lacking in one important factor, viz. the element of *time*, since it is obviously of importance to know what amount of air exchange can be effected by the several methods *per minute* when the normal rate of respiration is being maintained. Since this Report was read, further observations have been made which take this factor into consideration, and these distinctly show material differences of air exchange which are all in favour of the methods which depend upon alternating pressure (see Appendix to this Report).[1]

Experiments to Determine the Physiological Phenomena which occur during Asphyxia by Drowning, and in the Process of Recovery after Apparent Death by Drowning.

The experiments which have next to be recorded, and which were all made upon dogs, were performed in the following way :—The animal was first anæsthetised with ether or chloroform (or with a mixture of ether and chloroform) in a box furnished with a glass cover. When completely under the influence of the anæsthetic it was placed upon the table on its back or belly, and a cannula connected with a mercurial manometer, the float of which wrote upon a long sheet of smoked glazed paper, was tied into the femoral artery. In some cases tracheotomy was performed and a tube was tied into the trachea, and through this tube, until the drowning was commenced, the anæsthetic was now administered. In other cases the trachea was not opened, and the anæsthetic was administered on a cloth over the nostrils in the usual way. Naturally the depth of anæsthesia varied in different experiments, which would tend somewhat to affect the results ; but immediately prior to the "drowning" the anæsthesia was generally such as just to abolish the cornea reflex. During the "drowning," and for some time after in the case of

[1] The value of intermittent pressure was long ago pointed out by Erichsen ('Edin. Med. and Surg. Journ.,' 1845, p. 37).

recovery, the venous condition of the blood was itself sufficient to maintain complete unconsciousness. The drowning was effected either by complete immersion of the animal, or of its snout only, in water, or by dipping the open end of the tracheal tube into that fluid. In most of the experiments fresh water was used, but in six sea water (Experiments XXIII to XXVIII). Respiration was recorded by a stethograph in the form of a tambour fixed by an elastic band round the lower part of the chest or upper part of the abdomen; the stethograph was connected by rubber tubing to a recording tambour. There were also marked upon the paper, the time in ten-second intervals, and a signal showing the length of time during which the immersion lasted.

A variable time after the experiment was completed, if the dog had not died as the result of the immersion it was killed—usually by prussic acid, but sometimes by other means,—and either at once, or after the lapse of an hour or two, a post-mortem examination of its thoracic and abdominal organs was made and recorded. In all but the earliest experiments the volume and weight of the lungs as a whole, and also those of special parts, were ascertained, and the specific gravity calculated.

The amount of water which had been absorbed from the lungs during such immersion was determined in many of the experiments, and with a view to discovering whether the absorption of this water had produced any effect on the general composition of the blood, samples of blood were taken immediately before immersion, and, in the case of animals which survived the immersion, also immediately after recovery, and the number of red corpuscles per cubic millimetre and the percentage amount of hæmoglobin were ascertained. The instruments which were used for this purpose were respectively the Thoma-Zeiss hæmacytometer, and the Gowers-Haldane hæmoglobinometer. We have to thank Dr. Andrew Hunter for giving us assistance by making these determinations.

Along with the experiments which were performed in the above manner, and which are recorded in the succeeding pages, three others are introduced which were made for the purpose of testing the amount of air which would be passed into and out of the thorax of the dog by the employment of the means of artificial respiration which was usually adopted. This consisted in the use of traction by the fore-limbs alternated with lateral pressure on the thorax, or of intermittent pressure on the thorax, the animal being either in the supine or prone position.

Experiment I (Plate I).

Mongrel setter, male, weight 14 kilos. Anæsthetised with chloroform; ¼ grain morphia also given hypodermically. Arterial pressure recorded by cannula in femoral; respiration by stethograph round thorax. Tube tied into trachea. Animal in supine position.

(*a*) Tracheal tube occluded for 4 mins. 20 secs. Artificial respiration. Recovery very rapid. (Tracings of *a* to *f* not shown.)

(*b*) Tracheal tube again occluded during 4 mins., but incompletely. Animal recovered spontaneously.

(*c*) Tracheal tube occluded for a third time during 4 mins., at the end of which time heart and respiration had stopped and blood-pressure was at zero. Artificial respiration. Recovery in 2 mins. 20 secs.

(*d*) End of tracheal tube immersed in water during 4 mins., when the respiration had stopped but the heart was still beating. Artificial respiration. Recovery in rather less than 1 min. During artificial respiration about 10 c.c. water and mucus came from trachea. The amount absorbed was not ascertained in this experiment.

(*e*) End of tracheal tube immersed in a measured quantity of water during 1½ mins. There was at first a slight rise of blood-pressure, then a marked fall. Neither respiration nor heart had stopped at the end of the time. Tube then removed from water and escaping water collected, but only amounted to 5 c.c. Nearly 200 c.c. had been absorbed into the lungs. Respirations and heart very rapid after removal, and blood-pressure rose rapidly.

(*f*) End of tracheal tube again put into a measured quantity of water for 3 mins., during which 240 c.c. was taken in. Both heart and respirations had then stopped. Artificial respiration. Rapid recovery of heart, but natural respiration not resumed for 1½ mins. During the artificial respiration 65 c.c. of water tinged with blood escaped from trachea. Altogether 175 c.c. water was absorbed in this experiment.

(*g*) (See Plate I.) End of tracheal tube placed in a measured amount of water for the fourth time, and left in during 3 mins. Respirations ceased half a minute before heart, which shows strong inhibition. Artificial respiration. Recovery. The resumption of natural respiration did not occur until 6½ mins. after the tube was removed from the water. The response of the heart to the compression of the thorax is very noticeable in the tracing. In this experiment 100 c.c. water was taken in, and 13 c.c. was given out during artificial respiration, leaving 87 c.c. absorbed.

The animal was killed by pithing (section of medulla oblongata). This had the effect of causing instant cessation of respiration, and the animal died of asphyxia.

Post-mortem (about one hour after death).—All organs in thorax and abdomen greatly congested with venous blood. All cavities of heart, but especially those on the right side, distended by clotted blood. The lungs are deep red and congested, and on cutting into them froth and blood issues from the bronchi and cut vessels, but they do not obviously contain water, although so large an amount has been absorbed into them.

Experiment II.

Smooth retriever, male, weight 25·432 kilos. Anæsthetised with chloroform, but died whilst being put under. This animal was employed for determining the amount of air which could be made to pass in and out of the thorax by the employment of the Silvester method in the dog. The animal was placed in the supine position, and a tube was tied into the trachea and connected to a spirometer. The dragging forward of the fore-limbs with the consequent movement of the ribs caused 270 c.c. of air to enter the thorax, and a similar amount escaped on bringing the fore-limbs back against the sides of the thorax. On now compressing the thorax laterally 150 c.c. more air was ejected, so that the total exchange obtained in this animal was 420 c.c. The dog was a large one with a long, deep, easily compressed thorax, the maximum girth of which was 650 mm. (26 inches) in the resting position.

Experiment III (Plate II).

Sheep-dog, male, weight 16·361 kilos. Anæsthetised with chloroform; $\frac{1}{4}$ grain morphia also given hypodermically. Cannula in femoral. Animal in prone position, with head allowed to hang over edge of table so that the snout could be entirely immersed in water.

Snout immersed in measured amount (3000 c.c.) water during about 8 mins. (Plate II). Respiration became very shallow at 5 mins., and ceased entirely at 6 mins. 30 secs., but 1 min. 30 secs. was allowed to elapse before removal from the water and commencement of artificial respiration. During the immersion blood-pressure at first rose and then fell, and when immersion ceased had become very low, and the heart very weak and slow. Artificial respiration by the traction and pressure in prone position during three minutes before the animal showed any signs of recovery. Until now the blood-pressure remained low, but on resumption of natural respiration it rapidly recovered completely, eventually rising to a somewhat higher point than before immersion, the respirations returning to about the same rate as before immersion. (The effect of immersion upon the blood-pressure is well shown in the tracing.) During the immersion 210 c.c. water was absorbed, and during the artificial respiration 75 c.c. escaped from the mouth and nose, so that altogether 135 c.c. water was taken in.

The animal was killed by bleeding.

Post-mortem.—The lungs are pale and bloodless, and float high in water. On opening up the bronchi no froth or fluid is to be seen, nor are there any ecchymoses.

Experiment IV.

Dalmatian, female, weight 17·271 kilos. This animal died whilst being put under chloroform, and was used in a similar manner to the animal employed in Experiment II to determine the amount of air which could be made to enter and leave the chest by the employment of artificial respiration, the trachea being connected with a spirometer.

Compression of the lower part of the chest and of the epigastrium caused from 75 c.c. to 100 c.c. to escape from the thorax, and on relaxing the compression a similar amount re-entered. Dragging the fore-limbs forcibly forwards and again allowing them to lie against the chest also produced an exchange of from 75 c.c. to 100 c.c. The combination of the two methods produced in different attempts an intake and outflow equivalent to from 150 c.c. to 200 c.c. The animal was placed alternately in the supine and in the prone position, but the difference of position appeared to make little difference to the amount of air taken in and given out. The maximum girth of the thorax (at the level of the lower end of the sternum) was 550 mm. in the resting position.

Experiment V (Plate III).

Fox-terrier, male, weight 6·931 kilos. Anæsthetised with chloroform, but the animal took the anæsthetic very badly, and the respirations were rapid and shallow. The animal was placed in the prone position (after a cannula had been connected with the femoral artery), and, as in Experiment III, the snout was immersed in a measured amount of water. In less than half a minute (Plate III, first tracing) the heart stopped suddenly, and after one minute's immersion the respiration also stopped, the blood-pressure being then at zero. After removal from the water artificial respiration was practised, but, although after a time a few natural respirations and a few heart-beats followed, the blood-pressure did not recover, and both heart and respiration soon stopped permanently. It was found that 75 c.c. of water had been absorbed.

Post-mortem.—Lungs have a normal appearance and crepitation. No water exudes from them when cut, nor do the trachea or bronchi contain any froth or water, or superabundance of mucus. There are no hæmorrhages. All the cavities of the heart are filled with blood.

Experiment VI (Plate III).

Retriever, female, weight 17·725 kilos. The animal was at first anæsthetised with chloroform, which it took very badly. Ultimately the respiration stopped, and the dog had to be resuscitated by artificial respiration. Ether was then substituted for chloroform, and ¼ grain morphia was also given hypodermically. A cannula was, as usual, tied into the femoral artery, and a stethograph used to record the respirations.

(*a*) The animal was placed in the supine position with the head hanging over the edge of the table, and the snout immersed in a measured amount of water during 5 mins. At the end of this time it was removed from the water, the respirations having nearly ceased, being very shallow with long intervals. The blood-pressure, however, was still fairly high, but with large oscillations due to the slow heart-beats. The animal gradually recovered without the employment of artificial respiration, although as large an amount as 780 c.c. of water had been taken in during the five minutes' immersion. During the process of recovery 90 c.c. of water and mucus escaped from the mouth and nose, so that altogether 690 c.c. was permanently taken up in this experiment. Nevertheless the respiration, the heart, and the blood-pressure show complete recovery. (Tracing not shown.)

(*b*) After 7 mins. the experiment was repeated in the same way, the snout being again immersed in a measured amount of water (Plate III, Exp. VI *b*). This time it was kept immersed during 6 mins. 30 secs., and respiration had completely stopped 1 min. 20 secs. before removal from the water, but the blood-pressure was still fairly high, although the heart was greatly slowed. After waiting another 30 secs. without any respiration, artificial respiration was begun and continued during 3 mins., at the end of which time natural respirations recommenced, the pulse-rate and blood-pressure also gradually resuming a normal character. In this experiment 250 c.c. water was taken in and 70 c.c. escaped from the mouth and nose after removal from the water, so that 180 c.c. water was absorbed by the lungs. Eight minutes after the return of natural respiration 870 grms. blood was drawn from the femoral artery. Eleven minutes later 4 c.c. prussic acid was injected into the peritoneal cavity, and 6 mins. later this was followed by the injection of a similar quantity. The animal died 16 mins. after the second dose of prussic acid.

Post-mortem.—On opening the thorax the lungs shrink somewhat, but the basal and dorsal parts less than the apical and ventral. On cutting the dorsal parts open frothy mucus escapes from the bronchi, but there is no obvious evidence of water, although pieces taken from the dorsal parts do not float so high in water as pieces from the ventral parts. The smaller bronchi of the ventral lobes do not contain frothy fluid as do those of the dorsal lobes.

There is no perceptible amount of fluid in any of the serous cavities, nor does the stomach contain water. It may here be stated that in nearly all cases the stomach was examined with the view of determining whether any of the water taken in had been swallowed, and in no single instance was there evidence of an appreciable amount of water having passed into the stomach.

Experiment VII (Plate IV).

Fox-terrier, female, weight 6·362 kilos. Anæsthetised with ether and a little chloroform, also $\frac{1}{6}$ grain morphia hypodermically. Cannula in femoral. Stethograph applied to chest.

(*a*) The animal was held in the supine position with the head dependent and immersed during one minute in a large bath of cold water. At the end of this time the respirations had ceased and the blood-pressure and pulse-rate had sunk to a low point, but on removal from the bath the animal recovered without the employment of artificial respiration. (Tracing not shown.)

(*b*) Ten minutes after recovery the animal was immersed a second time (Plate IV, upper tracing), and kept under water during 3 mins. 30 secs., when it was removed, the respirations having already ceased for 30 secs. The blood-pressure had fallen to 23 mm., and the heart-beats had almost ceased, the original blood-pressure having been 140 mm., and the pulse-rate 120. Another minute was allowed to elapse, and, as no spontaneous respirations had occurred in the meantime, artificial respiration was commenced. It was continued for 7½ mins., after which the animal was found to breathe regularly. The heart and blood-pressure had also completely recovered. (This part of the tracing has not been reproduced.) Although it appeared necessary to continue artificial respiration for the length of time stated, the animal began to give occasional gasps after it had been continued 4½ mins. After recovery the blood-pressure was 126 mm. and the pulse-rate 84. Respirations were very rapid immediately after recovery (54 per minute), but gradually came down to 38 before the animal was killed. The dog was killed by injection of prussic acid into the peritoneum about 40 mins. after its recovery from the second immersion.

Post-mortem.—The trachea having been opened and a tube tied into it, this was connected with a glass cylinder filled with air and immersed in water, and the amount of air taken into and forced out of the chest by the employment of the traction method, which was the one used to effect recovery, was determined in the supine and in the prone positions of the body respectively. In each case the amount obtained was approximately 40 c.c. The maximum girth of the chest in the resting condition was 400 mm.

On opening the thorax the lungs are observed to be shrunken, and normal in crepitation and general appearance, except in the dorsal and basal parts, which are reddened, and here and there ecchymosed. On removing the lungs their volume collectively was found to be 180 c.c. and their weight 117·4 grms., which gives a specific gravity of 0·6522.

On cutting into the lung no water issues from it, but the trachea and large bronchi contain a considerable amount of froth, although the smaller bronchi are almost completely clear. In all probability the froth was, during life, in the smaller bronchi, and passed into the large bronchi and trachea when the thorax was opened and the lungs underwent shrinkage.

Experiment VIII (Plate IV).

Dalmatian pup, half grown, female, weight 5·454 kilos. Anæsthetic used, ether only, but the animal took it badly, and the respirations were at first rapid and shallow. Blood-pressure and respiratory movements recorded as before (Plate IV, lower tracing).

The animal was wholly immersed in a bath of water in the supine position. After about two minutes' immersion the respirations had stopped and the blood-pressure had sunk to zero, the heart soon also ceased to beat. It was removed from the water and artificial respiration was practised during 5½ mins., but it showed no sign of recovery.

Post-mortem.—The lungs are of a pale pink colour on the ventral aspect, but deep red dorsally. They are very little shrunken from the wall of the thorax, but exhibit distinct crepitation. Their volume is 190 c.c., their weight 100·4 grms., which gives a specific gravity of 0·5284. No water flows out on cutting into any part. There are no ecchymoses. The bronchial tubes are completely clear, but the trachea contains some frothy mucus.

Experiment IX (Plate V).

Fox terrier, male, weight 6·703 kilos. Anæsthetic, ether. Blood-pressure and respiration records as before.

The animal was immersed in a bath of water and kept there until completely drowned. No attempt was made to recover it. It is noteworthy that the respirations, which had stopped completely 3 mins. 50 secs. after the immersion, recommenced 3 mins. afterwards, and about nine or ten expirations succeeded by passive inspirations followed one another at fairly regular intervals, and taking the form of a "staircase." The blood-pressure tracing shows a preliminary fall, then a rise, and then again a fall to about one half the original pressure (accompanied by slow heart-beats). At that point it was maintained for nearly 3 mins., after which the heart began to fail. It ceased to beat 4½ mins. after immersion, and the blood-pressure then fell to zero, but at long intervals after, four isolated heart-beats, each one smaller than the preceding, manifested themselves.

Post-mortem (2½ hours after death).—On opening the thorax the lungs are seen to nearly fill the cavity, and exhibit little or no crepitus. The right heart and great veins are engorged with blood, the left auricle is empty, the left ventricle nearly so, but is not in a condition of rigor; the trachea is empty. The œsophagus is full of air. On cutting open the right auricle and great veins the blood within them is noticed to be still fluid, but it clots immediately on escaping into the cavity of the pleura. The blood in the ventricles is, however, already clotted. On opening the abdomen the liver, kidneys, and intestines are much congested, but the spleen is small. On removing the lungs a quantity of frothy mucus is forced into the trachea. The lungs are firm in consistence, are much congested, and do not exhibit any marked crepitus ; no water exudes from them on cutting into their substance. The total volume of the lungs was found to be 335 c.c., and their weight 227 grms., which gives a specific gravity of 0·6746.

Experiment X (Plate VI).

Fox terrier, male, weight 8·635 kilos. Anæsthetic, ether. Blood-pressure and respiration recorded as before.

The animal was completely immersed in water during nearly 4 mins. (Plate VI, upper tracing). At the commencement of the immersion the respirations stopped during 20 secs. At the end of the period of immersion, the heart and respiration having both stopped simultaneously, the dog was removed from the water and artificial respiration (by compression) practised. After 2½ mins. the animal gave several gasps, and during the first part of the artificial respiration the heart responded by contracting each time the thorax was compressed (tracing not shown). The blood-pressure, however, did not rise, and very soon the gasping respirations and the heart-beats ceased altogether. Artificial respiration was maintained during 10 mins., at the end of which time the animal was obviously dead.

Post-mortem (2½ hours after death).—The lungs nearly fill the pleural cavities; they crepitate abundantly, are nearly normal in appearance, soft, and easily pitted on pressure. The trachea is empty. The volume of the lungs is 310 c.c.; their weight 177 grms., which makes their specific gravity 0·5709. The condition of the bronchial tubes was not specially noted, and was probably normal. All the cavities of the heart are distended with blood, which is clotted. On opening the abdomen a clot of considerable size is found in the peritoneal cavity, the blood having evidently come from a rupture in the under surface of the liver, which is greatly enlarged and congested with blood. The kidneys and intestines are also greatly congested, but not the spleen; the stomach and bladder are almost empty.

Experiment XI (Plate VI).

Irish terrier, male, weight 7·612 kilos. Anæsthetic, ether. Blood-pressure and respiration recorded as usual.

The animal was immersed in water in the supine position with the head dependent. The respirations and heart-beats became at once very slow, and the blood-pressure gradually fell (Plate VI, lower tracing). After 3 mins., by which time the respiration had completely stopped, it was taken out of the bath, and artificial respiration was practised. In a few minutes' time normal respirations were resumed, and recovery soon became complete. The animal was killed half an hour afterwards owing to magnesium sulphate solution having been accidentally forced into the artery during the process of removing a clot from the cannula. During the artificial respiration the animal was placed in the prone position, but lying a little over on the right side. In this, as in many of the other cases, the animal was inverted for a few seconds in order to allow the excess of water to drain away from the mouth and air-passages.

Post-mortem (immediately after death).—On opening the thorax the lungs are seen to be shrunk within the pleural cavities in normal fashion. They crepitate on pressure. The right lung is somewhat deeper in colour than the left; the trachea is empty. The total volume of the lungs is 220 c.c., their weight 171 grms., which gives a specific gravity of 0·7772. (It should be mentioned that in this case the pulmonary blood-vessels had been tied before cutting the heart away from the lungs, so that the vessels of the lungs contained a good deal of blood, which in the other cases was allowed to drain away before the specific gravity was taken.) The right cavities of the heart and the left ventricle are full of fluid blood, but the left auricle is almost empty.

There is a quantity of clotted blood in the peritoneal cavity, which seems to have come from the liver, although this organ does not appear, post mortem, especially congested, nor do the other abdominal viscera. No doubt, however, they were all greatly congested during the asphyxial condition (which was when the artificial respiration was being practised), but this was recovered from before death, which was due, as stated, to another cause.

The stomach is distended with air; the bladder nearly empty of urine.

Experiment XII (Plate VII).

Collie, female, weight 15·907 kilos. Anæsthetised with ether; blood-pressure and respiration recorded in usual way; also a tube tied in trachea.

The dog having been placed in the prone position, and a normal tracing having, as usual, first been taken (samples of blood having also first been removed from the artery for the determination of the number of corpuscles and amount of hæmoglobin), the end of the tracheal tube was immersed in a measured amount of water during nearly 3½ mins., at the end of which time respirations had ceased, although the heart was still beating slowly; blood-pressure was down to 18 mm. Artificial respiration was then practised, and at the end of 4½ mins. more there was recovery of blood-pressure, heart, and respiration (lowermost tracing). During the 3½ mins. of drowning 110 c.c. of water was taken up into the lungs and air-passages; 15 c.c. ran out again afterwards through the tube; 95 c.c. therefore was absorbed. After complete recovery other samples of blood were taken from the artery. The following is the result of the count and hæmoglobin determination :

	Before drowning.	After recovery.
Red corpuscles per c.mm.	5,866,000	5,300,000
Hæmoglobin per cent.	84	78

The animal was killed by bleeding from the femoral artery half an hour after resuscitation.

Post-mortem.—On opening the thorax the lungs are seen to be collapsed and are normal in appearance, except that the dorsal parts appear redder. The trachea is empty, neither this nor the bronchi containing any excess of mucus or froth. The total volume of the lungs was 210 c.c., the weight 121 grms., which gives a specific gravity of 0·576. Besides taking the specific gravity of the lungs as a whole, in this and the subsequent experiments the specific gravity of portions of lung from different parts has been recorded. A piece from the dorsal part of the lung was found to have a specific gravity of 0·671 ; a piece from the ventral part of the same lung was found to have a specific gravity of 0·392. The difference in this and most other cases is largely due to the relative amount of blood contained in the vessels, although in some cases it may be partly due to frothy fluid in the bronchi, but as this when present had a tendency to cause retention of air in the alveoli, its presence would not necessarily have the effect of increasing the specific gravity of the pulmonary tissue.

The heart in this case was empty. No blood was found in the abdomen; the bladder was nearly empty.

Experiment XIII (Plate VIII).

Irish terrier, male, weight 11·362 kilos. Anæsthetic, ether; blood-pressure and respiration recorded as usual; tube tied in trachea; animal in prone position.

After taking a normal tracing the end of the tracheal tube was immersed during 3 mins. (Plate VIII, upper tracing) in a measured quantity of water, of which 365 c.c. was taken into the lungs, 25 c.c. being afterwards returned, so that the total amount of water retained was 340 c.c. This experiment is noteworthy by reason of the long delay in the advent of cardiac inhibition and the marked initial fall of pressure in spite of a rapid heart-beat. But with cessation of respiration ($2\frac{1}{2}$ mins.) the cardiac inhibition was at once very striking.

Artificial respiration was started 40 secs. after complete cessation of spontaneous respiration and 10 secs. after cessation of heart-beat. During the first half-minute of artificial respiration the heart commenced to beat feebly, but the blood-pressure did not rise, nor did the animal recover, in spite of the fact that 10 c.c. of 1 in 13,000 adrenalin chloride was injected into the lung and a second similar dose directly into the heart.

Post-mortem.—Before opening the thorax the tracheal tube was clamped, so that the lungs were not permitted to collapse. They have a normal appearance, and crepitate on pressure. At one place is a large patch of ecchymosis, probably caused by the needle of the injecting syringe. All the cavities of the heart except the left auricle are full of blood, the right cavities being enormously distended. All the abdominal organs are greatly congested, especially the liver, which has a large rupture on the under surface, from which a quantity of blood has escaped into the peritoneal cavity. The lungs were removed as a whole, and the trachea tied at its division and cut above the ligature; it was found to be free from superabundant mucus and froth. The volume of the lungs (kept full of air by the tying of the trachea) was found to be 440 c.c., and their weight 193 grms., giving a specific gravity of 0·438. On cutting open the bronchi the lungs collapse, and frothy mucus exudes from the cut tubes. The specific gravity of pieces of lung was found to be as follows:—A piece from one of the upper lobes, 0·385; a piece from one of the lower lobes, 0·526.

Experiment XIV.

Mongrel terrier, female, weight 5·681 kilos. Anæsthetic, ether. Supine position, but somewhat on right side. This animal was, prior to the drowning experiment, employed for another object, viz. the investigation of the effect of pituitary extract upon the blood-pressure and urine, a tube having been tied into the bladder and a small trocar placed in the external jugular vein for the purpose of injecting the extract directly into the circulatory system. As usual, the blood-pressure was recorded by a cannula in the femoral artery, and the respiration by a stethograph applied to the chest. A tube was also tied into the trachea.

The experiment upon pituitary having been concluded, a drowning experiment was then made, the end of the tracheal tube being immersed during 3 mins. 30 secs. During this time 390 c.c. was taken into the lungs and only 5 c.c. returned during the recovery, leaving the total amount of water absorbed 385 c.c. On removing the tracheal tube from the water recovery began to take place spontaneously, and no artificial respiration was at first practised. Since, however, the recovery was very slow and incomplete, 4 c.c. of 1 in 5000 adrenalin-chloride solution was injected into the jugular in two successive doses. This produced a large but only temporary rise of blood-pressure, with increased rate and force of heart-beat. Artificial respiration was then resorted to, and another dose of adrenalin was later administered, but produced only a very slight and evanescent effect. None of these methods of resuscitation proved successful, and the animal died about fifty minutes after the "drowning." (Tracing not reproduced.)

Post-mortem.—Tracheal tube clamped before opening thorax; lungs therefore fill pleuræ. Right lung has a congested appearance; left looks normal. Lungs removed as a whole, and trachea tied at lower end and then cut away; it contains a little excess of mucus. Total volume of lungs (filled with air) 235 c.c., weight 153 grms., therefore their specific gravity 0·651. A piece of the congested right lung had a specific gravity of 0·790; a piece of the left lung a specific gravity of 0·500. The lungs show very little crepitation, but pit on pressure. On opening up the bronchi frothy mucus tinged with blood exudes from the congested parts, but the other parts have their bronchi free from froth or mucus.

All the cavities of the heart are full of blood, the right auricle being especially greatly distended. The abdominal organs are also congested. No blood in peritoneal cavity.

Experiment XV.

English terrier, male, weight 11·362 kilos. Anæsthetic, ether. Supine position rather on left side; tube tied in trachea; blood-pressure and respiration records as usual.

End of tracheal tube immersed in water during 2 mins. 35 secs. Took in 460 c.c., and subsequently gave out 45 c.c. of blood-stained fluid from tracheal tube, so that the total amount of fluid absorbed was 415 c.c.

Immediately after removing the tube from the water 10 c.c. of 1 in 20,000 solution of adrenalin chloride was injected through the chest wall into the right lung. This had the effect of temporarily and markedly sending up the blood-pressure, which had fallen almost to zero, and this was accompanied by a few small respirations. But these effects soon passed off, and, although artificial respiration by dragging forwards the fore-limbs—but in this case without alternate compression of the chest—was commenced 70 secs. after the removal of the tube from the water and was practised for some time, there was no ultimate recovery. (Tracing not reproduced.)

Post-mortem (¾ hour after death).—The trachea having been tied, the thorax was opened. The ventral parts of the lungs show normal appearance and crepitation, but the dorsal parts and base are much congested. In the heart the left ventricle is contracted and empty; the right cavities are engorged with clotted blood. All the abdominal organs are greatly congested, especially the liver and kidneys. There is no blood in the peritoneal cavity. The lungs were removed as a whole, and the trachea tied at its division and then cut away; it contains a quantity of frothy mucus. The volume of the lungs filled with air is

440 c.c., their weight 237 grms., which gives a specific gravity of 0·538. On cutting open the lungs a quantity of frothy mucus exudes from the bronchi of the basal parts, but from the ventral parts and apices this is not the case, their bronchi being clear. The specific gravity of a piece of lung taken from the base is 0·769, whilst that of a piece from the apex is only 0·366.

Experiment XVI (Plate VIII).

Retriever, male, weight 19 kilos., girth of chest 550 mm. Position supine; tube in trachea, cannula in femoral, and stethograph on chest. Anæsthetised with ether and chloroform. End of tracheal tube immersed in water during 2 mins. 30 secs. (Plate VIII, lower tracing). In this time 620 c.c. water was taken in, and after removal of the tube 120 c.c. was returned from lungs, leaving the total amount of water absorbed 500 c.c. After removal of tube from water and tilting up of animal, as usual, to allow excess of fluid to escape, 10 c.c. of 1 in 20,000 adrenalin chloride solution was injected through the chest wall into one of the lungs. Following this injection (artificial respiration by traction method being meanwhile practised) the blood-pressure rose (see tracing), and there were also some voluntary efforts at respiration. These effects were, however, only transient, and although artificial respiration was continued for some time there was no ultimate recovery.

Post-mortem ($\frac{1}{2}$ hour after death).—The trachea was not tied; on opening it by longitudinal incision it is seen to contain a quantity of frothy mucus, which also exudes from all the bronchial tubes on cutting into the lungs. All the cavities of the heart are greatly distended, and there is also extensive congestion of all the abdominal organs, especially the liver and kidneys. No blood in peritoneum. The base of each lung is greatly congested, and gives little crepitation; the specific gravity of a piece from the base is found to be 0·8. The apex, which is lighter in colour, is found to have a specific gravity of 0·49, and to crepitate freely.

Experiment XVII (Plate IX).

Retriever, male, weight 21·816 kilos. Anæsthetic, ether and chloroform. Cannula in femoral as usual; tube in trachea; prone position.

End of tracheal tube immersed during 4 mins. 30 secs., at which time both pulse and respiration ceased almost simultaneously. There is marked cardiac inhibition throughout. About 100 c.c. water taken in, of which about 25 c.c. escaped from tube after removal. Altogether, therefore, about 75 c.c. was absorbed.

The blood-pressure fell gradually to zero, and artificial respiration was unable to effect recovery, although the heart appeared to respond for a time to each compression.

Post-mortem (1¼ hours after death).—On opening the thorax the lungs are shrunk, of a natural pink colour, and show marked crepitation. On cutting them open no water comes out of them, nor any froth out of the bronchial tubes, but the bottom of the trachea and the large bronchi contain thick plugs of mucus, the rest of the trachea being clear. The dorsal parts of the lungs are somewhat deeper in colour than the ventral, due, probably, to the fact that *after death* the animal was allowed to lie for a time in the supine position and rather on its left side. The following are the specific gravities of pieces of lung taken from different parts:—Left lower lobe, 0·837; right lower lobe, 0·48; left upper lobe, 0·59; right upper lobe, 0·456.

Heart shows all cavities distended with blood, the right auricle being especially engorged. The liver and other abdominal organs are also greatly congested.

Experiment XVIII (Plate X).

Pomeranian, female, weight 6 kilos. Anæsthetic, ether; tube in trachea, and other arrangements as usual; supine position.

End of tracheal tube immersed in water during 4 mins. Amount of water taken in, 270 c.c.; returned, 5 c.c.; total absorbed, 265 c.c.

In this case the cardiac inhibition, although soon apparent, did not become marked until the respirations were greatly slowed. The respirations are throughout deep, quick, and regular, but gradually slowing. The heart and respiration having completely stopped, the latter 40 secs. before the heart, the animal was first inverted for a few seconds after removal of the tracheal tube from the water, and artificial respiration by traction on fore-limbs and gentle compression of chest was practised. Besides this, 10 c.c. of 1 in 5000 adrenalin chloride was injected into the thorax. This caused, after a short interval, a marked rise of blood-pressure with increase of heart-beats, but the improvement was quite transient, lasting only about 25 secs., and there was no ultimate recovery.

Post-mortem (1 hour 20 mins. after death).—There is some blood in the peritoneal cavity, derived from a rupture in the liver, which is enormously congested. On opening the thorax the lungs have a normal appearance at their apices, but are congested at the base and back. The upper part of the trachea contains some thick mucus, but no froth was noticed in the bronchial tubes. The total volume of the lungs (collapsed) was 190 c.c., their weight 89 grms., giving a specific gravity of 0·468. A piece from the apex had a specific gravity of 0·421; a piece from the most congested part of the base a specific gravity of 0·812. All the cavities of the heart are full of blood, the right side being especially distended.

Experiment XIX (Plate XI).

Collie, female, weight 16·59 kilos. Anæsthetic, ether and chloroform; prone position. Arrangements as before, but with no tube in trachea.

(*a*) (Plate XI, upper tracing.) Snout immersed during 2 mins. 10 secs. in measured amount of water, of which

260 c.c. was taken in by the respirations, and 60 c.c. was returned from mouth and nose after removal from the water, leaving a total amount absorbed of 200 c.c. The respirations were at first inhibited during 20 secs., and afterwards irregular and convulsive. Although the heart is markedly inhibited, blood-pressure is maintained until the end of the period of submersion, when inhibition becomes complete.

Recovery occurred naturally without the employment of artificial respiration.

(*b*) Some minutes later the snout was again immersed for 4 mins. 10 secs. (tracing not reproduced). During this second immersion 260 c.c. was again taken in, of which, however, 160 c.c. was discharged again after removal from water, leaving a total of 100 c.c. absorbed. Before removal from the water both heart and respiration had stopped, and artificial respiration by traction and compression was unable to effect recovery. The subsequent injection of 10 c.c. 1 in 5000 adrenalin chloride into the thorax produced no effect.

Post-mortem (1 hour after death).—Throat, mouth, trachea, and larynx free of mucus. Lungs shrink on opening thorax, have a normal appearance and crepitation. The bronchi, both large and small, are filled with frothy mucus, which is less apparent in the ventral lobes. There is no apparent water in the lungs. All the cavities of the heart, especially those of the right side, are distended with clotted blood. All the abdominal organs are considerably congested, but there is no blood in the peritoneal cavity.

The following were the specific gravities of different parts of the lungs :—Base of left lung, 0·542 ; base of right lung, 0·400 ; apex of left lung, 0·444 ; apex of right lung, 0·410.

Experiment XX (Plate XI).

Young fox terrier, female, weight 6·360 kilos. Anæsthetic, ether. Cannula in femoral and stethograph to chest; no tube in trachea.

The animal being placed in the prone position with head hanging over edge of table, the snout was immersed in a measured quantity of water during 2 mins. 10 secs. (Plate XI, lower tracing). About 140 c.c. of water was taken in and 30 c.c. returned from air-passages, leaving 110 c.c. absorbed. The most marked phenomenon observed during the immersion was the complete inhibition of the heart, which occurred four times at intervals of about 20 to 30 secs., and lasted 10 to 25 secs. Respirations ceased at 1 min. 40 secs. At the end of the period of immersion, the animal's head being removed from the water, partial recovery occurred spontaneously, but it was evident from the appearance of the blood in the arterial cannula that the respirations, although deep and fairly frequent, were not effective in aërating the blood, and the respiration and heart gradually failed, the animal eventually dying, in spite of assistance given by artificial respiration, 30 mins. after the immersion. Injections of adrenalin and atropine into the thorax were given during the failure of heart and respiration, but produced no advantageous result.

Post-mortem (½ hour after death).—On opening the thorax, after ligaturing the trachea, the lungs appear normal and show no obvious congestion, but there is a large ecchymosed patch at the base of the right lung, produced doubtless by the needle of the injecting syringe. The trachea is clear. The volume of the lungs filled with air was 180 c.c., their weight 86 grms., giving a specific gravity of 0·477. The condition of the bronchial tubes is not recorded; they probably therefore had a normal appearance without frothy mucus. All cavities of the heart contain blood, that on the left side being fluid, while the right side is greatly distended by loose clot. All the abdominal organs except the spleen are much congested; there is no blood in the peritoneal cavity.

Samples of blood taken before and after the immersion gave the following results:

	Before immersion.	After immersion.
Red corpuscles per c.mm.	5,400,000	5,333,000
Percentage of hæmoglobin	84	83

Experiment XXI (Plate XII).

Fox terrier, male, weight 8·635 kilos. Anæsthetic, ether and chloroform (2 to 1); $\frac{1}{4}$ gr. morphia also given subcutaneously. Cannula in femoral and fine trocar in jugular. No tube in trachea. Animal in supine position. In this animal both vagi were cut before the immersion, the animal having been used for another experiment and having previously received three several intra-venous injections of adrenalin (4 c.c. of 1 in 5000 each time).

The animal's head having been allowed to depend over the edge of the table, the snout was immersed during $3\frac{1}{2}$ mins. in water, of which 510 c.c. was taken in and 80 c.c. returned after removal from the water, leaving 430 c.c. absorbed. At the end of the $3\frac{1}{2}$ mins. the respirations, which were irregular and convulsive throughout, had stopped entirely, and the blood-pressure, which remained throughout at a much higher average level than in animals with the vagi intact, was rapidly sinking. Artificial respiration by traction and compression was, therefore, begun (1 min. after the stoppage of natural respiration), and continued for a long time, the heart at first responding to each compression, and the respiratory movements being so far resumed as to produce several deep, gasping inspirations. In spite, however, of these signs of commencing recovery, the animal ultimately succumbed. It appeared evident from the colour of the blood in the artery, not only in this case, but in others in which artificial and even a certain amount of natural respiration failed to effect restoration, that the blood was not becoming aërated; in other words, that the air drawn into the chest was not reaching the pulmonary alveoli. In this animal, during the process of attempted resuscitation, an extract of pituitary body and also a solution of peroxide of hydrogen were successively injected through the chest wall into the heart, but without producing any obvious result. Blood (about 60 c.c.) was further drawn from the arterial cannula, and also a quantity (not measured) from the jugular vein, but without effect. Samples of blood taken immediately before and immediately after the immersion gave the following results :

	Before immersion.	After immersion.
Red corpuscles per c.mm.	6,600,000	5,950,000
Hæmoglobin per cent.	102	94

Post-mortem (made immediately after death).—The trachea not being tied, the lungs collapse on opening the thorax; they have a normal appearance and crepitation. The larger bronchi are full of froth, which is absent from the smaller ones, and is more apparent in the left than in the right lung. Pieces of the lungs show the following specific gravities :—Lowermost lobe of left lung, 0·643; uppermost lobe of left lung, 0·428 ; lowermost lobe of right lung, 0·614 ; uppermost lobe of right lung, 0·555.

The heart contains comparatively little blood, but the right cavities have some frothy clot of bright colour, doubtless due to the peroxide of hydrogen which had been injected during the attempts at resuscitation. The abdominal organs are all congested. There is no blood in the peritoneal cavity.

Experiment XXII (Plate XIII).

Fox terrier, male, weight 9·544 kilos. Anæsthetic, ether and chloroform. Cannula in femoral and stethograph round chest ; no tube in trachea.

(*a*) The animal, being in a condition of only light anæsthesia, was immersed in a bath of warm water during 1 min. 40 secs. The immersion was accompanied by convulsive movements, followed, as asphyxia supervened, by gradual quiescence with ultimate cessation of respiration and heart-beat, and fall of blood-pressure nearly to zero. During the first part of the immersion the heart was strongly and entirely inhibited during periods of short duration. After removal from the bath at the end of the time stated the animal recovered spontaneously, the blood-pressure rapidly rising to a point much higher than before the immersion. (Tracing not reproduced.)

(*b*) After a few minutes' interval the immersion was repeated (Plate XIII, upper tracing), the animal having been in the meantime placed more deeply under the anæsthetic. After about 2 mins. immersion, the respiration (which was irregular and convulsive in character) having stopped, and the blood-pressure being very low, although the heart was still beating slowly, the animal was taken out of the water and inverted for a few seconds to allow the excess of water to drain from the air-passages, and laid upon the table in the supine position a little on the right side. Since no spontaneous respirations appeared, artificial respiration was commenced (1 min. 30 secs. after removal from the water) with an ordinary bellows, to the nozzle of which a piece of india-rubber tube about 18 inches long had been attached. The free end of this tube was held over, but not within, one nostril, and air was forced by a sharp closure of the bellows into the respiratory passages at intervals of about 3 or 4 secs. The mouth in the meantime was kept closed and its floor pressed upwards, but the second nostril was not occluded. With each injection of air the lungs were obviously distended, and after artificial respiration had been kept up in this way for 4 mins. the animal began to respire naturally, and recovery became complete (Plate XIII, lower tracing). The aërating effect of this method of artificial respiration was very obvious upon the blood in the arterial cannula, which, at first nearly black, soon became less dark, and eventually of a bright colour.

The animal was allowed to live a little more than an hour after recovery, being meanwhile kept lightly anæsthetised, and was eventually killed by intra-abdominal injection of prussic acid.

Samples of blood taken (α) before the first immersion, (β) after the first immersion, and (γ) about ¾ hour after the second immersion, gave the following results:

	α	β	γ
Red corpuscles .	5,866,600 .	5,650,000 .	5,400,000
Hæmoglobin per cent.	96 .	92 .	90

Post-mortem (3½ hours after death).—Mouth, larynx, and trachea full of froth; some fluid and air in œsophagus. On opening the thorax the lungs collapse; their ventral lobes crepitate, their dorsal lobes appear much congested. The colour is deep red. The total volume of the lungs is 316 c.c., their weight 262·5 grms., giving a specific gravity of 0·83. On opening up the bronchi frothy fluid exudes; this is seen even in the small bronchi. The dorsal and basal parts of the lungs contain a considerable amount of bloody fluid and little or no air.

Pieces from different parts give the following specific gravities:—Uppermost lobe of right lung, 0·725; lowermost lobe of right lung, 0·928; uppermost lobe of left lung, 0·631; lowermost lobe of left lung, 0·889. The comparatively high specific gravity in this case is partly accounted for by the fact that the blood had clotted in the pulmonary vessels and did not exude from them on cutting the heart away from the lungs, as was the case with most of the observations recorded in this series of experiments.

The heart contains comparatively little blood. The stomach is distended by air, and contains some prussic acid. The kidneys and liver are somewhat congested; there is no blood in the peritoneal cavity.

The preceding experiments were all made with fresh water; in the next six recorded sea water was employed.

Experiment XXIII (Plate XIV).

Fox terrier, male, weight 7·214 kilos. Anæsthetic, chloroform; supine position. Cannula in femoral and tambour applied to epigastrium.

The animal being under light anæsthesia, the snout was immersed in a measured amount of sea water during 1 min. 50 secs. (Plate XIV, upper tracing). There was at first inhibition of respiration followed by rapid and convulsive respirations, but these soon became slower (16 per minute, having been 24 previous to the immersion). The blood-pressure rose from 90 mm. to 114 mm., and the pulse-rate from 96 to 112. But after 1½ minutes' immersion the heart became greatly inhibited, and the blood-pressure fell nearly to zero. After 1 min. 50 secs. both heart and respiration had stopped, but they recovered spontaneously, the first heart-beat occurring 12 secs. after removal from the water, and the first respiration 35 secs. after removal. During about one minute the heart continued to beat very slowly, but then resumed a rate about equal to that before immersion. The blood-pressure gradually rose, and 6 mins. after removal from water it was 146 mm., the respirations being 34 per minute; but during the succeeding 5 minutes it slowly fell to about 128 mm., the heart's beats being now 100, and the respirations irregular and shallow.

The amount of sea water inspired in this experiment was 225 c.c. After removal of the snout from the vessel about 125 c.c. of frothy fluid was returned, leaving 100 c.c. permanently absorbed.

Neither this animal nor the next one was killed immediately after the completion of the experiment (see Experiments XXIX, XXX, pp. 46, 47).

Experiment XXIV (Plate XIV).

Fox terrier, male, weight 10 kilos. Anæsthetic, chloroform. Supine position.

The snout was placed in a measured amount of sea water and kept in during 4½ mins. The immediate effect of the immersion was to produce violent and convulsive respirations, with, after 30 secs., marked cardiac inhibition, the pulse-rate falling from 78 to 12; this slow rate being maintained not only during the whole period of immersion, but for several minutes after removal from the water (Plate XIV, lower tracing). The respirations were at first rapid, but after 1½ minutes became slow and deep, gradually lessening, until at the end of the immersion they were scarcely perceptible. Three minutes after removal of the head from the water artificial respiration was begun with bellows. After continuing it during 2 mins. the natural respirations were resumed, and the pulse-rate and blood-pressure recovered rapidly (see tracing).

	Before immersion.	After recovery.
Pulse-rate	78	108
Mean blood-pressure	146 mm.	114 mm.
Rate of respiration	30	36
Red corpuscles per c.mm.	8,210,000	7,130,000
Hæmoglobin per cent.	110	106

During the period of immersion 130 c.c. of sea water were taken into the lungs and air-passages. Of this amount 100 c.c. were returned after removal, leaving 30 c.c. absorbed.

Experiment XXV (Plates XV and XVI).

Fox terrier, male, weight 9·523 kilos. Anæsthetic, chloroform. Supine position, partly on left side. Cannula in femoral, tambour over lower part of chest.

(*a*) The snout was immersed in a measured amount of sea water and kept under during nearly 6 mins. At first the respirations became gradually deeper with convulsive expiratory efforts (Plate XV, upper tracing). After 4 mins. they somewhat suddenly ceased, but there was now and then a gasping inspiration. Half a minute after removal of head from water they were resumed and became gradually more frequent and deeper, and 6 mins. after removal they were rapid and regular (Plate XV, lower tracing).

During nearly half the period of immersion the blood-pressure was maintained at about the same level as prior to the immersion, but during the last 2 mins., when there were hardly any respiratory movements, the pulse-rate slowed down to 18, and the blood-pressure fell gently. This rate of 18 was maintained for 6 mins. after removal from the water, but when the respirations resumed their normal activity the blood-pressure and heart-rate rapidly recovered.

The dog took in 180 c.c. of fluid during immersion, and subsequently gave out 120 c.c., leaving 60 c.c. absorbed. The water given out was very frothy.

	Before immersion.	After recovery.
Average blood-pressure	100	126
Pulse-rate	69	84
Respiration rate	44	36

(*b*) (Plate XVI.) About a quarter of an hour after complete recovery from the first immersion the snout was again immersed in sea water and kept in during 10 mins. At the end of this time the heart had not completely ceased to beat, although the respirations (which were at first very rapid, deep, and convulsive, but soon became shallow and slow) had already stopped for 3 mins. The pulse-rate was very slow during the whole period, but became quicker towards the end; the blood-pressure fell gradually. Artificial respiration (compression) failed to effect recovery.

During the immersion 170 c.c. water was taken in, and after removal from the water the same amount was given out, so that in this second experiment none was permanently absorbed. The water given out was mixed with much froth.

Post-mortem (1 hour after death).—Apex and ventral aspect of lungs normal in appearance; base greatly congested; trachea full of froth; also bronchial tubes. Total volume of lungs (collapsed) 250 c.c.; weight 178 grms.; therefore sp. gr. 0·71. All cavities of heart greatly dilated with blood.

The lung substance was found to be composed of 88·2 per cent. of water and 11·8 per cent. solids. The percentage of chlorides was 2·816 in the dry lung substance.

Experiment XXVI (Plate XVII).

Fox terrier, male, weight 6·8 kilos. Anæsthetic, chloroform; tube in trachea. Position supine, but slightly on right side.

End of tracheal tube immersed in sea water (Plate XVII, upper tracing). The immediate effect was to produce slowing of respiration and heart with fall of blood-pressure (followed by a slight rise). After an immersion of 1 min. the respirations became convulsive, this phase lasting 1½ mins., when they gradually ceased—a long pause now occurring of 3 minutes' duration, broken only by two shallow inspirations during the first minute. At the end of this pause—although the drowning was continued—twelve quiet respirations, gradually increasing and then gradually decreasing in height, made their appearance at regular intervals, after which respiration ceased altogether. The heart continued to beat to the end of the experiment with—after the first 2 mins.—a regular slow rhythm of about 36; but the beats gradually decreased in extent, and ceased altogether about 3 mins. after removal of the tube from the water (the proper respiratory movements having already ceased for 2 mins. 50 secs.).

The amount of water taken in during the experiment was only 35 c.c.

Post-mortem (immediately after death).—Trachea full of frothy fluid; lungs pit on pressure; look normal anteriorly, but much congested posteriorly. Volume of lungs filled with air 425 c.c., weight 265 grms., giving a specific gravity of 0·609. Eighty cubic centimetres of fluid escaped from the cut lung. The lung substance contained 93 per cent. water and 7 per cent. solids, and there was 4·928 per cent. of chlorides in the dry lung substance.

Experiment XXVII (Plate XVII).

Lurcher, male, weight 14·7 kilos. Anæsthetic, chloroform. Tube in trachea. Position supine.

End of tracheal tube immersed in sea water, of which the animal rapidly inhaled nearly half a litre, but expelled almost all again strongly tinged with blood. The actual amount found to have been taken in at the end of the experiment was 50 c.c., but after removal of the tube from the water, and during subsequent tilting and artificial respiration, 175 c.c. was returned, so that 125 c.c. more fluid was lost from the respiratory passages than was taken in. The fluid which was given out was found to contain blood, about 22·5 c.c. of which was lost from the lungs.

The immersion lasted during 3½ mins. At first there was slowing of pulse and fall of blood-pressure, which after 2 mins. rose again; but one minute later there was marked inhibition of heart, and the blood-pressure was again very low (Plate XVII, lower tracing).

The heart-rate was maintained during the rest of the experiment at a rhythm of from 18 to 36 per minute, but gradually declined in force, the blood-pressure falling to zero about 7½ mins. after the immersion was begun.

Respirations ceased just before removal of the tube from the water, and did not recommence. Artificial respiration was begun 2½ mins. after removal of the tube, but failed to effect recovery, although the heart was still beating slowly.

	Before experiment.	Towards end of experiment.
Red blood-corpuscles per c.mm.	6,600,000	5,950,000
Hæmoglobin per cent.	98	92

Post-mortem (¾ hour after death).—Lungs pit on pressure, and are covered with ecchymoses; are much congested dorsally, but not ventrally. Very little froth in trachea. Volume of lungs (with trachea tied) 570 c.c.;

weight 300 grms.; their specific gravity therefore 0·526. Percentage of solids 15, of chlorides in the dried lung 1·848.

The heart and abdominal organs show the normal appearance of asphyxia, *i. e.* great fulness of all the cardiac cavities and congestion of the viscera, especially of the liver.

Experiment XXVIII.

Spaniel, young male, weight 7·15 kilos. Anæsthetic, chloroform; tube in femoral. Supine position.

Snout immersed during nearly 3 mins. in sea water, of which 210 c.c. was taken in during that time, and 120 c.c. was given out subsequently, leaving 90 c.c. retained in lungs. (The tracings of this experiment are not reproduced.)

Respirations at first convulsive; after 2½ mins. ceased, but about 20 secs. after removal of head from water recommenced, and in 2 mins. again became fairly regular.

Heart was strongly inhibited during and for half a minute after the immersion, the blood-pressure coming gradually down. Both rapidly recovered on resumption of respiration. The animal was allowed to completely recover from the "drowning," and was then killed by chloroform.

Post-mortem (½ hour after death).—Lungs have a normal appearance. Trachea full of frothy fluid. Volume of lungs (full of air) 230 c.c.; weight 159 grms., their specific gravity therefore 0·69. Percentage of solid in lungs, 11; of chlorides, 3·344 in the dry lung substance.

Heart.—A good deal of fluid in pericardium. All cavities full of blood.

Experiment XXIX.

This is a continuation of Experiment XXIII (which was a submersion of nearly 2 mins. in sea water). Instead of killing the animal before recovery, the dog in this case was allowed to recover from the anæsthetic after the cannula had been removed from the artery (which was tied up, and the wound closed and dressed antiseptically). After about half an hour, *i.e.* as soon as the effects of the anæsthetic had passed off, the dog walked and ran about the room in a normal manner. There was some wheeziness and tendency to cough for a few hours, but this had disappeared by the following morning, and no further ill-effects of the immersion were noticeable. The animal was kept a week, and killed on the eighth day with chloroform. Neither the lungs nor any other organs showed any unusual congestion or abnormality.

Experiment XXX.

This is a continuation in like manner of Experiment XXIV, in which the animal was submersed during as long a period as 4½ mins. in sea water, and had been recovered from drowning by artificial respiration applied with the aid of bellows. As in the last case, the dog was allowed to come out of the anæsthetic after the arterial cannula had been removed and the wound sewn up and dressed antiseptically. In this case, in spite of the prolonged immersion, the dog had completely recovered in an hour's time, and showed no adverse symptoms whatever during the week it was kept alive, nor did the lungs after death exhibit any sign of congestion or other abnormality. These two experiments were performed in order to determine whether immersion in sea water, even when much of that fluid is taken into the lungs, is likely to be followed by pneumonia. Although too few in number to be conclusive, they appear to show that at least in dogs (animals which may suffer from pneumonia) such a contingency is not probable, even after a prolonged immersion.

Experiment XXXI.

Small mongrel terrier, male, weight 6·34 kilos. This animal was drowned by being held under fresh water. No anæsthetic was used. The commencement of submersion was attended by violent struggling and by convulsive movements of the muscles of respiration, but in about a minute these movements had ceased and the animal had become completely unconscious (quiescent period). This period lasted during 4 mins., at the end of which time the respirations and pulse ceased almost simultaneously. No attempt at recovery was made. About 200 c.c. of water was permanently absorbed during the submersion. The animal was removed from the water immediately after death.

Post-mortem (15 mins. after death).—No froth in mouth or nostrils. On clamping the trachea and opening the thorax the lungs present externally a normal appearance—they show no ecchymoses,—have a pink colour, and crepitate naturally. On opening up the air-passages the lower part of the trachea is seen to contain some froth, and the larger bronchial tubes the same, besides some plugs of mucus not churned into froth. No water flows from the lungs on cutting into them, except a small amount from the smaller bronchial tubes. The volume of the lung still filled with air was 180 c.c., and its weight 122 grms., giving a specific gravity of 0·677. After cutting it open and allowing air and fluid to escape from it the volume was reduced to 160 c.c. and the weight to 116 grms., giving a specific gravity of 0·72. After being dried completely the weight of the lungs was 11·25 grms. (= 9·69 per cent. solids, containing 1·96 per cent. chlorides). The heart and other organs present the same appearances as in animals drowned under anæsthesia.

Experiment XXXII.

Moderate-sized mongrel terrier, male, weight 9 kilos. In this case also, as in the last, no anæsthetic was administered. The animal was drowned by immersing its snout in a measured amount of fresh water. The immersion was accompanied, as before, by convulsive movements. The quiescent period, with complete unconsciousness, came on in a little over 1 min. and lasted for 3½ mins., during which time the heart continued to beat slowly. The respirations, however, in this case ceased near the commencement of the quiescent period, but, as in several of the experiments with anæsthesia, after a long period of cessation—in this instance 2½ mins.—a group of a few deep respirations made its appearance. After the submersion had been continued during 5 mins., the heart having ceased to beat half a minute previously, the snout was removed from the water, which was tinged with blood and contained also some discharged mucus. Altogether 125 c.c. of water was permanently taken in during the submersion. No attempt was made to recover the animal.

Post-mortem (5 mins. after death).—The trachea was first clamped. On opening the thorax the lungs present a normal appearance on the surface except for the presence of a few small ecchymoses; they crepitate freely and pit on pressure. Their volume full of air is 435 c.c., and their weight 164 grms., giving a specific gravity of 0·377. On cutting them open the trachea is seen to contain a little watery mucus, but no froth. The larger bronchial tubes also contain some mucus, but no water or froth, and no water issues from the cut lung. The volume of the lungs, after allowing the air to escape, was reduced to 350 c.c. and their weight to 161 grms., giving a specific gravity of 0·46. After drying, the weight of the lungs was 26 grms. (= 16 per cent. solids, containing 1·96 per cent. chlorides). The heart, liver, and other organs showed appearances similar to those already abundantly described in drowned anæsthetised animals.

The purpose of these two experiments of drowning without anæsthesia was to determine whether the anæsthetic produces any material influence upon the main physiological phenomena or on the post-mortem appearances attendant on drowning. Apart from the large fluctuations of pressure in the respiratory and circulatory systems which must necessarily accompany the convulsive struggling, there was no greater difference apparent than is to be found in the records from different anæsthetised animals. There was the same marked slowing of the pulse in the later (quiescent) period, and the length of time occupied before complete cessation of the heart-beat was not less than with many of the anæsthetised cases. Other points in common are also exemplified in these two cases, such as the variation which obtains in the time at which heart and respirations respectively cease—*i.e.* sometimes simultaneously, sometimes respirations long anterior to heart,—and also the remarkable occurrence of a group of respiratory movements near the end of the period of quiescence, and long after respiration had to all appearances completely ended.

Experiment XXXIII (Plate XVIII).

Irish terrier, male, weight 8·16 kilos. Anæsthetic, chloroform only; no morphia.

The animal was placed in the supine position and slightly on its right side. A tube was tied into the trachea and a cannula into the femoral artery, and respirations were recorded by a stethograph.

(*a*) The end of the tracheal tube was immersed in a measured amount of (fresh) water during nearly 2 mins. (Plate XVIII, upper tracing). The immersion immediately caused marked failure of heart and slowing of respiration, the blood-pressure falling almost to zero, followed by slight recovery after the first half-minute. The respirations are then deep, but regular. On removing the tube from the water there is rapid spontaneous recovery of both heart and respiration, and the blood-pressure shows complete recovery a little more than a minute after the removal. During the immersion of the tube 155 c.c. of water was drawn in, and after its removal 12 c.c. dropped from the end, so that 143 c.c. was absorbed in the lungs. No blood, mucus, or froth passed out.

(*b*) A few minutes after recovery from experiment *a* the tube was again immersed (Plate XVIII, lower tracing), this time during $3\frac{1}{2}$ mins. Again there was marked slowing of heart, with fall of blood-pressure, but this time to a less extent, and the inhibition continued during the whole period of submersion, the blood-pressure remaining at a moderate height. The respirations, at first very deep, irregular, and convulsive, became in a little more than half a minute slow and expiratory, and in another minute ceased altogether, except for three quiet inspirations at 20-sec. intervals. About a minute and a half after complete stoppage of respiration the tube was removed from the water, and artificial respiration by chest compression was begun. This immediately caused the heart to beat fast and the blood-pressure rapidly to rise very high. It fell rapidly again, however, in spite of the continuance of artificial respiration, but the heart-beats remained fast until artificial respiration was intermitted, when the cardiac inhibition again showed itself. During this period of intermittence there were two or three efforts at natural respiration. On resuming artificial respiration the heart again beat fast and the blood-pressure again rose, and on desisting both again fell off. The natural respirations were now resumed at a slow rate, but gradually became faster, and in a few minutes more both the respiration and blood-pressure showed complete recovery.

During this second immersion 170 c.c. of water was taken in, and 12 c.c., frothy and tinged with blood, dropped from the tube after its removal, leaving 158 c.c. absorbed.

As soon as recovery appeared complete, the dog was killed by injection of prussic acid into the peritoneal cavity.

Post-mortem (1 hour after death).—The lungs are congested in the more dependent parts, and show in places small ecchymoses. Their volume full of air (trachea tied) is 350 c.c., their weight 233 grms., giving a specific gravity of 0·66. Cut open, the trachea is found to contain a quantity of froth and mucus, and the bronchial tubes are full of watery froth, except in the parts which were lying uppermost. About 25 c.c. of this fluid, mingled with blood, exuded on cutting up the lungs. The volume of the lungs, after being opened up, was 270 c.c., and their weight 204 grms., giving a specific gravity of 0·75. After drying, the total weight of the lungs was 25 grms. (=12·25 per cent. solids, containing 2·9 per cent. chlorides). The heart shows the left ventricle contracted, but not quite empty; the auricles and right ventricle moderately full of clotted blood.

Experiment XXXIV (Plate XIX).

Fox terrier, male, weight 10·88 kilos. Tracheal tube and arterial cannula as usual. Anæsthetic, chloroform; no morphia. Position supine.

(*a*) Tracheal tube immersed in measured amount of fresh water, of which 100 c.c. was rapidly absorbed. Owing to a defect in registering the blood-pressure this experiment was, however, stopped almost at once.

(*b*) Ten minutes later the tube was again immersed (Plate XIX, upper tracing), this time for five minutes, during which period 430 c.c. of water was permanently absorbed—not more than 5 c.c. of fluid dropping from the end after removal. No blood, froth, or mucus. During the immersion the blood-pressure at first fell somewhat, then rose gradually in spite of increasing cardiac inhibition, and remained fairly high until the heart ceased. During the latter half of the period of submersion the cardiac inhibition was profound, but disappeared for a brief period near the end. The respirations, at first shallower, soon became deeper and slower, and maintained a regular slow rate with inspiratory type for about 2½ mins. longer, when they ceased altogether. The heart-beats lasted 2 mins. longer than the respiration and 1 min. longer than the submersion, *i. e.* for 6 mins. from the commencement of drowning. After the heart had ceased to beat there appeared a "staircase" of respiratory movements, sixteen in number, succeeding one another with great regularity during rather more than a minute. No attempt was made to recover the animal.

Post-mortem (immediately after death).—The lungs present a healthy appearance, without ecchymoses, but the back part is somewhat congested (hypostatic ?). Their volume (trachea tied) is 430 c.c., their weight 230 grms., giving a specific gravity of 0·53. On opening up the air-passages the trachea is seen to contain some froth, and the bronchi are full of frothy fluid. About 20 c.c. of this, mingled with blood from the pulmonary vessels, exudes on cutting up the tubes. The volume of the lungs after opening the air tubes is 325 c.c., and their weight 196 grms., giving a specific gravity under these conditions of 0·6. Their weight after drying was 19 grms. (= 9·7 per cent. solids, containing 2·46 per cent. chlorides).

The heart is throughout distended with blood, and the liver and other organs present the usual congested appearance characteristic of asphyxia.

Experiment XXXV (Plate XIX).

Mongrel terrier, male, weight 6·3 kilos. Anæsthetic, chloroform only. Position supine. Tube in trachea; cannula in left femoral artery; respirations recorded by stethograph. Both vagi exposed, and threads passed round them, but not tied.

End of tracheal tube immersed during 3 mins. in measured amount of fresh water, of which 160 c.c. was permanently absorbed. In less than half a minute the immersion was followed by a rapid fall of blood-pressure, due to cardiac inhibition, the respirations also becoming greatly slowed (Plate XIX, lower tracing). Both vagi were now cut (1 min. after the commencement of the immersion), and the effect produced was a rapid rise of blood-pressure to a point far above the original normal, the effects of the slow respirations being very apparent upon the curve. The height of this was maintained as long as the respirations lasted, viz. for nearly 3 mins. from the beginning of the immersion, after which it gradually fell, although the rapid rate of pulse was maintained until nearly the end. When the submersion was ended the heart had not ceased to beat, although its beats had become very feeble. On applying artificial respiration by chest compression the heart responded to each compression, and the blood-pressure was raised a few millimetres and maintained at this level as long as the intermittent compression was continued, *i. e.* during rather more than 2 mins. This was now desisted from, and the heart immediately ceased to beat and the blood-pressure sank to zero. Further resuscitation was not attempted.

The tracing shows that although the section of the vagi had a markedly beneficial effect upon the heart, it had no apparent effect upon the already slow respirations.

Post-mortem (immediately after death).—Lungs normal in appearance, except a few small scattered ecchymoses. Their volume (trachea tied) 250 c.c.; weight 104 grms., which gives a specific gravity of 0·41. On cutting them open the trachea is seen to contain a little froth. The bronchial tubes are full of watery froth, but hardly any fluid drains away from them. After cutting up the bronchial tubes the lung volume is 205 c.c. and weight 100·5 grms., giving a specific gravity of 0·49. After drying, the weight of the lungs is 10·5 grms. (= 10·45 per cent. solids, containing 2·28 per cent. chlorides). The heart does not respond to artificial excitation, although exposed immediately. Its cavities are all distended with blood, the right most so. The inferior vena cava—which was cut across in removing the heart and lungs a few minutes only after death—already contains a firm clot. The liver is, as usual, enormously swollen and congested,[1] and all the other abdominal organs are also greatly congested.

Experiment XXXVI[2] (Plate XX).

Mongrel terrier, weight 12·7 kilos. Anæsthetic, chloro-

[1] To observe this extreme congestion and swelling of the liver, which is so characteristic of drowning, it is necessary to open the abdomen and examine its contents before the thoracic organs are interfered with.

[2] This experiment was shown to the Physiological Society.

form. Supine position. Tube in trachea; cannula in artery; respiration recorded by stethograph.

The end of the tracheal tube was immersed in fresh water and kept there until every sign of life had disappeared—a period of 9 mins. (Plate XX). The immersion was at first followed by a slight rise in the blood-pressure, in spite of the heart being inhibited. This rise lasted about half a minute, after which there was a gradual fall to about half the original blood-pressure. After 1½ mins. immersion the inhibition became rather suddenly more pronounced, and during the remaining 7½ mins. the heart was very gradually becoming slower, although beating with great regularity except when affected by the very slow respirations. The average blood-pressure was maintained at about one half of the original normal until near the end of the experiment. Just before the heart ceased altogether its rate became, during about 20 secs., increased from 12 per minute to about 40 per minute; in other words, as death ensued the inhibition disappeared. The respirations in this animal, which was deeply under chloroform at the commencement of the immersion, were at first but little affected, being somewhat shallower and more expiratory in character than before immersion, but at about the same rate. They gradually, however, became deeper and slower up to 1½ mins., when, simultaneously with the marked cardiac inhibition, they assumed the very slow rate of about 6 per minute, becoming still slower near their point of cessation, 4½ mins. after the drowning was begun. (This was about 4½ mins. before the heart ceased to beat.) There then ensued a long period (nearly 3 mins.) without any respiratory movement, when a group of fifteen mostly very deep respirations made their appearance, at intervals of at first about 5 secs., but becoming lengthened to 10 secs. or more. This series does not show the usual "staircase," but begins by the deepest possible respiration, then sinks gradually, then rises again gradually, and finally falls more rapidly. The last respiration of this series, which is a very feeble one, preceded the last heart-beat by 50 secs.

This experiment is of great interest as showing the length of time (nearly ten minutes) during which the heart will continue to act in some cases of drowning, while in other cases it very speedily is brought to a standstill. The differences appear to be largely due to individual idiosyncrasy—at least there appears to be no obvious cause for the variations. Similarly great differences in the time of immersion followed by recovery have been frequently recorded in drowning cases in the human subject. It has been often suggested that a condition of unconsciousness such as that caused by fainting may account for the delay of the fatal result in some cases, and this may be so, although we have no evidence that fainting would have that effect; that there are other unknown causes appears clear from these results in dogs. It seems very probable that one of these causes is closely related to differences in excitability of the inhibitory cardiac mechanism (see also p. 62).

Remarks on the Results obtained in these Experiments.

Results with fresh water.—One of the most striking results shown in this series of experiments is that of the disappearance of most of the water which is taken into the lungs, even in cases not followed by recovery. The actual amounts which were absorbed varied greatly (from 75 c.c. to 690 c.c.). This may have depended somewhat upon the size of the dog used, but it probably depended more upon the depth of the anæsthesia. Without an anæsthetic, or if the anæsthesia is light, the respirations are at first inhibited, and during this time no water is getting into the lungs; but this inhibition rarely lasts more than half a minute. Later the respirations take on a markedly expiratory character, and last comes a period of quiet, deep, and slow respiration. According to P. Bert and Brouardel and Loye, it is during this third period that most water is inspired.

It might be supposed that a part of the water taken in would be swallowed, but there was no evidence of this in any of our experiments, and the contingency was eliminated when the water was inspired through a tracheal tube. The amount of water absorbed appeared to bear no proportion to the result—a fatal result occurring quite as readily with absorption of a small as of a large quantity. That the water is partly absorbed into the blood there can be no doubt. It is not found in the pleura, or in any of the other serous cavities, and there is distinct evidence, from the effect on the number of corpuscles and on the percentage of hæmoglobin, that the proportion of plasma to corpuscles is increased.[1] In only one instance was any decided increase of the general specific gravity of the lung found; this may have been partly due to retention of water in the alveoli, for in this case (XXII) the mode of artificial respiration employed—that, namely, by a bellows—was probably less well adapted for the absorption of water from the alveoli than the chest movements which were usually practised. But even when the animals were completely drowned by submersion, and no attempts were made at resuscitation (IX, XXXI, XXXII), little or no water exuded from the lungs on cutting into them, although in one case they were firm in consistence and showed little crepitus. It is clear, then, from these experiments that the exudation of water from the cut lung after death is not only not a constant phenomenon in fresh-water drowning, but is not even necessarily to be expected. Probably, however, if

[1] Brouardel and Vibert ('Étude sur la submersion,' 1880) obtained similar results with the hæmacytometer; and Brouardel and Loye ('Arch. de physiol.,' 1889, p. 455) directly determined a dilution of the blood of drowned animals. Cf. also on this point Paltauf, 'Berl. klin. Wochenschr.,' 1892, p. 298. It is stated that the osmotic pressure of the blood is diminished in cases of drowning in fresh water, but increased in cases of drowning in sea water (Revenstorf, 'Münchener med. Wochenschr.,' No. 45, p. 1880; C. Carrara, 'Vierteljahresschr. f. gericht. Med.,' 24, p. 236).

the subject lay submerged for some time after death and were then examined, water would be found in all the air-passages and even in the alveoli, since there would be no likelihood of its absorption proceeding to any appreciable extent except during life or immediately after death; and hence it is that we find record of water exuding from the cut lungs in such cases of drowning. In many instances, however, the fluid which exudes from the cut lung is doubtless bloody serum, which comes from the enormously congested pulmonary vessels. That some water is retained in the lung substance is shown by the fact that in four dogs drowned in fresh water without attempt at resuscitation there was an average of 88·54 per cent. water and 11·46 per cent. solids, whereas three normal dogs killed with chloroform gave an average of 81 per cent. water and 19 per cent. solids.[1]

The records of specific gravity show it to be *below* the average specific gravity of normal dog's lung. The methods adopted were of three kinds. Thus in some cases the total specific gravity of both lungs together in the ordinary collapsed condition was taken. The average of eleven observations gives a specific gravity of 0·634 (maximum, 0·830; minimum, 0·460). In other cases the trachea was tied before the thorax was opened, and again at its lower end before cutting it away, so as to retain all the air in the lungs. The specific gravity of the lung thus naturally filled was found to be 0·523 as the average of ten observations (maximum, 0·677; minimum, 0·377).[2] Lastly, the specific gravity of large pieces taken from different parts of the lungs, generally after opening up the bronchial tubes, was found to be 0·589 as the average of twenty-eight observations (maximum, 0·889; minimum, 0·336).[3]

[1] Cf. on this subject P. Bert, 'Leçons sur la respiration,' 1870, p. 530; and A. Paltauf, 'Ueber d. Tod durch Ertrinken,' Wien, 1888. The older literature as to retention of water in the lungs is given by Kay, 'The Physiology, Pathology, and Treatment of Asphyxia,' London, 1834.

[2] Similar observations by Dr. Herring on three normal dogs gave specific gravities of 0·645, 0·380, and 0·340 respectively—or an average of 0·455.

[3] In order to compare these results with those obtained from normal

Another striking fact which comes out in these experiments is the great length of time during which immersion may last, and yet be followed—with efficient artificial respiration—by complete recovery. Several of the experiments illustrate this point. In some cases the immersion lasted several minutes (nearly eight minutes in one case, Experiment III)—without a fatal result—provided the artificial respiration proved efficient. In other instances a much shorter immersion was followed by death, in spite of artificial respiration, and even in two instances in spite of the fact that the natural respirations were recovered. The reason for the failure of recovery—when it was not due, as seemed to be the case in certain instances, to early complete failure of the heart—appears to have been deficient aëration of the blood by the respiratory movements. This deficient aëration may have been sometimes caused by inefficiency of the artificial respiration, but in many it seems to have been the result of failure of the air which was taken into the chest to diffuse into the alveoli. For it must be borne in mind that the tidal air is not much more than sufficient to fill the air-passages, and the penetration of its oxygen to the recesses of the alveoli is effected by diffusion. Now it was found in many of the cases which we record as having terminated fatally—in spite of artificial, and in some instances even in spite of natural respiration—that the bronchial tubes in considerable parts of the lung were occupied by frothy mucus, which must form a very serious barrier to gaseous diffusion, and thus to aëration of the blood. Hence, in those cases of drowning where this froth is extensively formed, a fatal

dogs, Dr. H. J. Scharlieb has made a number of observations for us upon the specific gravity of the lungs of dogs killed rapidly by an overdose of chloroform. He has found in these the specific gravity of the lung tissue (collapsed, and with the bronchial tubes cut open) to be 0·745 as the mean of thirty-two observations (maximum 0·957, minimum 0·55), which is considerably greater than that of the specific gravity of the lung under the same conditions in drowned animals. The less specific gravity in these is no doubt due to the retention of air in the alveoli owing to the obstruction of the bronchial tubes by frothy mucus.

result is probable; while in other cases in which immersion may have been much longer, and in which much more water may have been taken in, but in which little or no froth is formed, recovery is more likely to occur. What the exact conditions are which determine in some cases and not in others the formation of a froth is not clear; but it appears probable that it is due to excessive secretion of mucus, combined with convulsive respiration of a type which would tend to churn the mucus up into such a froth. Doubtless, also, the dilution of the mucus by water might assist this result; but that it is not wholly the water is abundantly evident from its absence in some cases in all parts, and in others in considerable parts of the lung. If such a froth is formed in the smaller tubes it could not readily drain out from them, being too coherent to be affected by gravity within such small passages. It is possible that in such cases the bellows method might prove effective when others were ineffective, for by the sharp action of the bellows a certain amount of air might be forced through the partially blocked bronchi into the alveoli.[1]

It must not, however, be assumed that the inefficiency of artificial respiration is in every case due to the presence of frothy mucus in the air-passages; for an analysis of our cases[2] shows that although in the majority of instances

[1] Bergeron and Montano ('Ann. d'hyg. publ.,' xlviii, 1877) found froth constantly present in (eight) drowned dogs, whether the animals had been anæsthetised or not. It should be stated that the formation of froth in the bronchial tubes is not peculiar to drowning; it may occur whenever there is increased secretion of mucus in the tubes, and is certainly sometimes formed in merely etherised dogs to a sufficient extent to interfere with the proper aëration of the blood. It appears more abundant when the drowning has been caused by sea water, but seems then of a less tenacious character.

[2] Thus out of twenty of our cases, in which resuscitation by artificial respiration was resorted to, fourteen showed excess of mucus or frothy mucus in the air-passages. In these fourteen cases the attempts which were made to effect recovery by artificial respiration were without success in nine, with success in five. In the remaining six cases out of the

in which no recovery was obtained by artificial respiration there was froth in the air-passages, in a certain number of such instances this was absent, while in other cases in which it was conspicuously present recovery resulted. In these last-named instances we might assume that certain of the air-passages were left free, some only being blocked by froth; but in those cases in which no excess of mucus and no froth was found the fatal result was in all probability due to failure of the cardiac muscle to recover from the paralysis produced by asphyxia.

Results with sea water.—The results with sea water are, on the whole, similar in character to those with fresh water, but there are certain points of difference. In the first place, so far as these experiments go, it would seem that there is, as a rule, less absorption of water from the lungs. This is to be expected, seeing that the osmotic force of sea water is higher than that of blood. In one case (Experiment XXVII) a larger amount of fluid was returned from the air-passages than had been taken in, and the excess must have come either from the blood or from other fluids of the animal body.[1] Secondly, the amount of froth found was always very great in the sea water experiments, but it appeared to be more fluid in consistence than that which occurred with fresh-water drowning; cer-

twenty no excess of mucus or froth was observed; of these recovery was effected in three, while in two artificial respiration failed to effect recovery. In one of these (V) the heart failed before the respiration, and in the other (X) there was found post mortem an extensive rupture of the liver. In the remaining case (XX) natural respiration was resumed spontaneously, but was ineffective.

[1] That the inspired water, when sea water is used, is partly retained in the lungs is shown by the high percentage of water in the lungs of animals so drowned (88·8 per cent. as the mean of four observations—XXV, XXVI, XXVII, and XXVIII: 93 per cent. in XXVI, where there was no attempt at recovery), and also by the large percentage of chlorides in the dried lung substance (an average of 3·234 as against 2·310 after fresh-water drowning). XXVI had nearly 5 per cent. Three normal dogs killed by chloroform averaged 1·525 per cent. (Herring). No doubt there was also less blood in these, as compared with the lungs of the drowned animals.

tainly it flowed much more freely and abundantly from the air-passages. Thirdly, the rapidity and certainty of a fatal issue to the immersion was not in these experiments greater, but rather less, than in most of the experiments in which fresh water was used; certainly there was not a greater difficulty in effecting recovery by artificial respiration, and even natural respiration seemed to be more readily resumed. Whether these differences are constant will need a larger number of experiments to determine with certainty, but they undoubtedly come out in the experiments here detailed. Finally, attention may be drawn to the two experiments (XXIX and XXX) in which "drowning" in sea water followed by recovery—in one case without, in the other with, the aid of artificial respiration—was attended by no subsequent adverse symptom, except in the case of one of the two animals, which had a slight cough for a few hours.

From a study of the tracings taken during drowning it is obvious that there is in different cases a considerable amount of difference in the effects upon circulation and respiration. Thus the blood-pressure may rise at first—as is usual in asphyxia, although this is greatly modified by the anæsthesia,—but usually it immediately and markedly falls, the fall being due to cardiac inhibition. Hence it is delayed or temporarily abolished with cut vagi (XXI and XXXV). Sometimes the inhibition is so great that the heart actually stops altogether for a short time, and this may recur again and again during the immersion. Nevertheless the fall of blood-pressure is not in proportion to the inhibition, for at the same time the arterioles are contracting. Towards the end of the asphyxia, however, the vessels become paralysed, and at the same time the heart fails, becoming very weak as well as slow, so that the blood-pressure falls nearly or quite to zero; unless the pressure recover the animal would soon die, even if the heart did not cease altogether to beat. Prior to this state the respirations, which are usually at first—after a preliminary inhibition—deep and convulsive, becoming afterwards gradually quieter and shallower, cease, so that the heart- and blood-pressure are maintained longer than the respiration. If artificial respiration is now begun such cases often rapidly recover. In other cases the heart ceases along with the respiration, and in yet others the heart stops first and respirations proceed for a time after the heart has ceased and the blood-pressure is at zero. The heart failure is probably the result of the paralytic action of the blood surcharged with CO_2 upon the rhythmic function of the heart-muscle.[1] The differences of result observed may have to do with the character and amount of the anæsthetic used, or they may depend on individual idiosyncrasies, or upon the physiological condition of the nerve-centres and of the heart at the moment of immersion. In any case they would be likely also to show themselves in cases of drowning in the human subject—at least, in so far as they are independent of anæsthetics.

Since one of the most marked ultimates ymptoms of death by asphyxia from drowning—as by other forms of asphyxia—is the extreme lowering of blood-pressure owing to paralysis of the vaso-motor system, it was hoped that such a drug as supra-renal extract might, by antagonising this symptom, produce, in association with artificial respiration, rapid recovery; the more so because this drug is known also to increase the force and rate of the heart's action. But it is obvious that it would only act if there were some sort of circulation going on to promote its absorption and to carry it to the peripheral vessels; and even then it could only produce permanent benefit if the artificial respirations were efficiently promoting the aëration of the blood, since as long as the venous condition of the blood continues the paralysis of the vessels and heart could not be more than quite temporarily relieved. This is, in fact, what is found to occur, for in cases in which, owing to froth in the bronchi, the diffusion of the

[1] Richet ('Arch. de physiol.,' 1894) infers that a specific cardiac poison is produced in asphyxia.

oxygen of the inspired air into the alveoli is interfered with, or in which, from any other cause, the artificial respiration is inefficient, the result of intra-pulmonary or even of intra-cardiac injection of adrenalin has only a quite temporary effect—the blood-pressure rising and the pulse improving for a short time,—to give place again to paralysis of vessels and heart, and at the best only deferring the fatal result for a brief period (see Experiments XIII, XIV, XV, XVI, XVIII).

APPENDIX.[1]

Since the above Report was read the experiments relating to artificial respiration in man have been continued and extended by Prof. Schäfer with the view of determining the exchange of air *per minute* which can be effected by the employment of the methods principally in use. In the numbers given in the table on p. 11 of this Report the factor of time was not taken at all into consideration; its importance was in point of fact overlooked by us, as it had been by all previous investigators in the subject. It is obviously, however, of much more importance to determine whether by any method which is adopted it is possible to obtain an amount of air exchange per minute equal to the natural exchange per minute of the individual, than to merely determine whether it is possible by any given method to obtain in one movement or series of movements, *irrespective of the time occupied*, an amount equal to the so-called tidal air.

In continuing these experiments it was found necessary, in order to obtain accurate measurements, to discard the apparatus which had been used in the earlier experiments, and which is figured on p. 4 of this Report. For there are two objections which render the readings yielded by that apparatus only approximately correct. The one

[1] Added December, 1903.

is the fact that it is difficult to obtain a glass bell-jar which is truly cylindrical, so that the readings must vary somewhat with the immersion of the bell-jar. The other objection is more serious, and arises from the swing which is imparted to such a balanced bell-jar by the entrance and exit of air—a swing which, if the movements are to be as rapid as the normal rate of respiration, would materially detract from the accuracy of the measurements, and even at slower rates serve to introduce a considerable but unknown error. In place of the balanced bell-jar a spirometer has been employed in the later experiments (Fig. 2). This spirometer, which is graduated in litres and tenths of a litre, is fitted with the excentric devised by Marcet for keeping the inverted cylinder exactly balanced at all positions of immersion. The air of respiration is passed from the mouth-piece or mask into the spirometer through a water-valve, whilst another similar valve serves to admit air to the mouth-piece. The amount of air which is pumped by any given method of artificial respiration through the lungs and into the bell-jar in the space of a minute is read off upon the graduated scale, or can be recorded upon a slowly moving cylinder. The rate of artificial respiration is that which has been previously determined to be the normal rate of the individual who is to be the subject of the experiment, and who is first instructed to breathe naturally into the spirometer through the valves for a sufficient number of minutes to ensure a fairly accurate average of rate. In this way also the normal amount of air exchange per minute for the individual can be determined at the same time, and may serve for comparison with the amount of air exchange per minute obtained by the methods investigated.

For exact comparison of the several methods it is important that both the operator and the subject of the experiment should be the same in all the experiments. It is also important to make use of a subject who, by practice, has acquired the faculty of remaining absolutely passive during the performance of the experiment. Persons who are not thus habituated are liable involuntarily either to obstruct the passage of air by closure of the

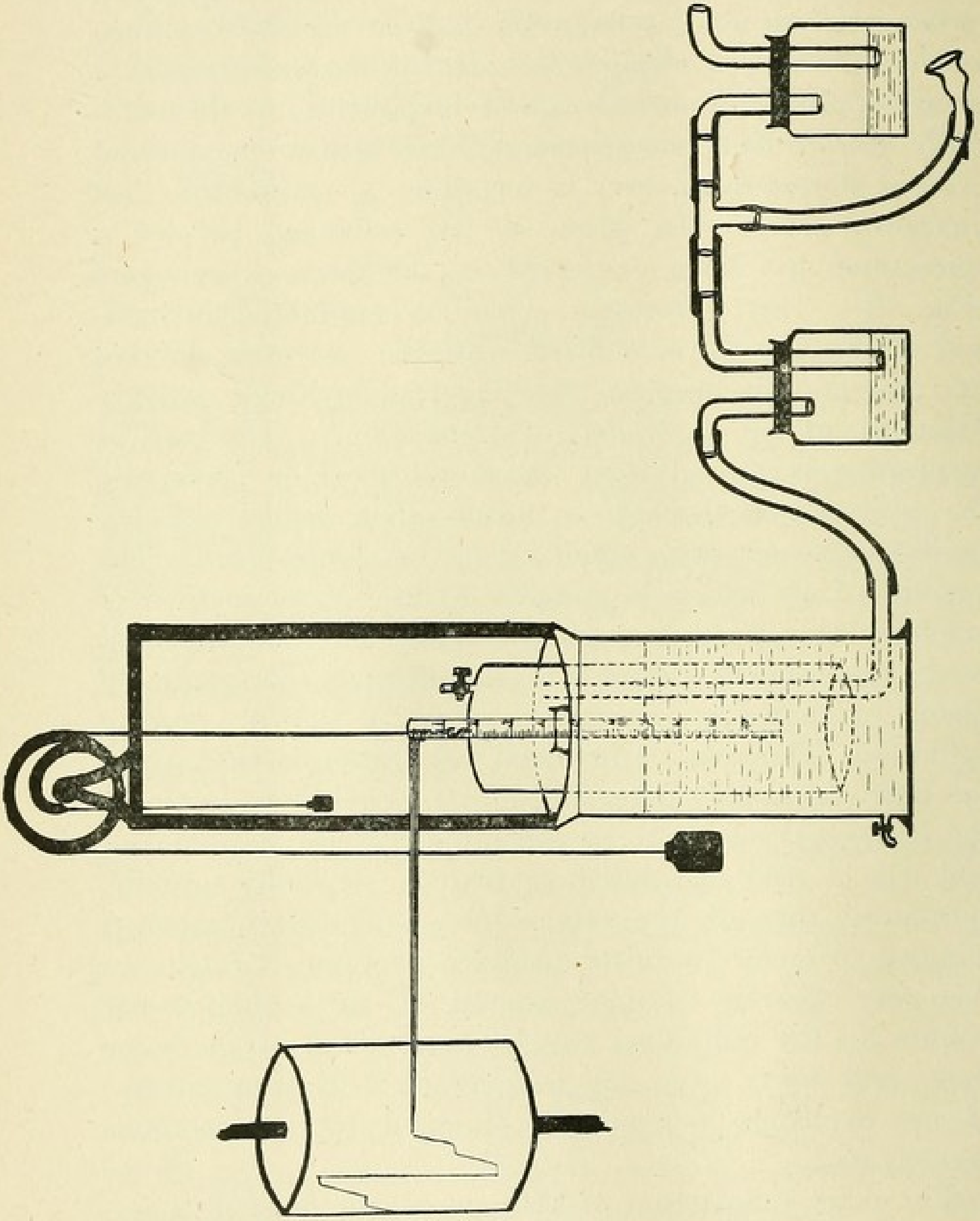

Fig. 2.—Apparatus used to determine the air exchange per minute by different methods of artificial respiration.

glottis or to assist the respiratory movements (which should be entirely passive) by an occasional active movement of their respiratory muscles.

The subject of the experiments was a young man aged 23, one of the attendants in the laboratory. His height is 1·71 metres (5 feet 7¼ inches); chest measurement at the mammary line and in full inspiration, 0·978 metre (38½ inches); weight, 64 kilos. (10 st. 1½ lbs.); and vital capacity, 4450 c.c.

The natural rate of respiration was 13 per minute. The normal amount of air exchanged per minute was determined to be 5850 c.c., the average amount per respiration 455 c.c. The following comparative experiments were all made at the same time. In each case the method of artificial respiration was employed during 5 separate minutes, at the rate of about 13 per minute. The number of movements and the total amount of air pumped into the spirometer were recorded, and the average amount of air pumped per minute, as well as the average amount per respiration, calculated from the results.[1]

Method.	Amount per minute.	Amount per respiration.
Silvester	2280 c.c.	178 c.c.
Marshall Hall	3300 c.c.[2]	254 c.c.
Intermittent pressure over lower ribs in supine position (Howard)	4020 c.c.	295 c.c.
Intermittent pressure over lower ribs in prone position[3]	6760 c.c.	520 c.c.
Natural respiration . . .	5850 c.c.	455 c.c.

It is obvious from this table that the only method which, under the conditions of the experiment, produced an amount of air exchange per minute which could be regarded

[1] For further details see E. A. Schäfer, "The Relative Efficiency of Certain Methods of performing Artificial Respiration in Man," 'Proc. Roy. Soc. Edin.,' Dec., 1903.

[2] Average of three minutes.

[3] This method is described in a paper (by Prof. Schäfer) read before the Royal Medical and Chirurgical Society, Dec. 8th, 1903, which will be found in the 'Transactions.'

as adequate, was the method of intermittent pressure upon the lower ribs with the subject in the prone position. This gave an exchange per minute of 6760 c.c., which compares favourably with the natural exchange of 5850 c.c. Next to this, but a long way behind it, came the Howard method of intermittent pressure upon the lower ribs with the subject in the supine position. This was so far adequate that the subject had no desire during the minute that each pumping lasted to respire naturally, but it is doubtful if it would be adequate for an indefinite time. On the other hand, both the Silvester and the Marshall Hall methods gave, under the conditions of the experiment, an entirely inadequate exchange per minute—so much so that the subject of experiment suffered distress, and could with difficulty abstain from breathing, even during the minute that each experiment lasted. The operator in these experiments was a person of slight build, fifty-three years of age, and weighing about 60 kilos. The maximum amount of pressure exerted when the weight of the forepart of his body was thrown on to the hands, placed over the lower ribs of the subject of the experiment, was ascertained to be about 27 kilos. (60 lbs.). It is, of course, obvious that a more muscular and heavier individual could obtain larger numbers than those given in the above table, but this in no way affects its testimony as a comparative estimate of the value of the several methods investigated.

DESCRIPTION OF THE PLATES [1]

In all the plates (I to XX) illustrating this Report, the uppermost line is the curve of blood-pressure obtained by means of a mercurial manometer connected with the femoral artery; the second

[1] It has been judged important to reproduce a considerable number of tracings on account of the striking individual variations which they exhibit, and also because the literature of the subject contains very few graphic records of the phenomena which attend drowning.

the respiratory record obtained by means of a tambour connected with a stethograph applied to the chest or abdomen; and the other two lines show a 10-secs. time tracing and a signal marking the period of submersion (thick black line). The abscissa of the blood-pressure curve is not given, but can be seen in those tracings in which the blood-pressure ultimately falls to zero. The compression of the chest, and other actions which were employed in attempts to resuscitate by means of artificial respiration, naturally affected the stethograph, and are therefore recorded upon the respiratory line. The several tracings are sufficiently described in the accounts of the individual experiments, and the salient features are also indicated upon the plates themselves. The records of some of the experiments are not reproduced as tracings, but their main results are stated in the text. In a few of the tracings which are continued on a second or third level small portions are omitted between the levels, in order to adapt the tracings to the size of the plate.

The tracings clearly show that the physiological phenomena of drowning naturally range themselves under three periods,—one of exaggerated and often convulsive respiration (which may or may not be accompanied by a rise of blood-pressure, according to the greater or less degree of cardiac inhibition caused by the submersion); one of slow, deep, and quiet respiration, accompanied by marked cardiac inhibition; and a last phase with no respiratory movements, but with a continuance of cardiac action. Towards the end of this last phase there may be a few isolated respiratory movements, generally in the form of a "staircase" (see Experiments IX, XXVI, XXXIV, and XXXVI).[1] Of these three periods 1 and 2 merge, as a rule, more or less gradually into one another, but are sometimes more sharply differentiated, and 3 may be absent altogether, the heart ceasing almost simultaneously with the respirations (Experiments I, XXIII, XXVII); indeed, in one instance (Experiment V) the heart became suddenly inhibited, and ceased even before the respirations. This extreme inhibition in the first period is also exemplified in Experiment XX. During Period 3 the inhibition of the heart is generally very marked[2] (Experiments III, VII, IX, XIII, etc.), but quite towards the end it may pass off, and the cardiac beats may become more rapid (Experi-

[1] Similar "late" respirations are described by other authors—*e. g.* Falk, 'Virch. Arch.' 1869, xlvii, p. 44, and Brouardel and Loye, 'Arch. de physiol.,' 1889, p. 408—as a constant phenomenon in asphyxia.

[2] It may be observed that the larger excursions of the mercury produced by the slowly beating heart do not necessarily imply, as is sometimes assumed, a greater force of contraction.

ments XXV and XXXVI). In the tracings where the phenomena of recovery are recorded, one of the most striking features is the rapid recovery of heart- and blood-pressure as soon as the natural respirations are resumed (Experiments III, VI, XII, XXIV, etc.). Artificial respiration by itself rarely produced so marked a result, which is, of course, a sign of the recovery of all the centres in the medulla oblongata from the effects of asphyxia.

DISCUSSION.

The PRESIDENT, before calling upon Professor Schäfer to read his paper, said: The Society is honoured by many distinguished visitors this evening, and as the subject of Professor Schäfer's paper is somewhat ancient history in this Society, it will perhaps not be inappropriate if I briefly recall some of the points of this question. For many years during the middle of the last century the *Ready method* of the late Dr. Marshall Hall had become universally adopted, not only in this country, but by all civilised communities, mainly because of its adoption by the Royal Humane Society; but in 1858 a new method, devised by Dr. Silvester and called after him, was brought prominently before the profession as a more efficacious means. With the object of investigating the whole subject in a scientific manner, a committee of the Society was appointed. In 1862 it reported in favour of the Silvester method, and as a consequence the Silvester method was adopted by the Royal Humane Society, and is in favour to-day. Even in this Society, and to a larger extent outside it, the conclusions of the 1862 Committee were challenged, and this was done by none more forcibly than by Dr. Bowles, who in 1889 read a paper here. In 1890 a fresh committee was appointed to revise and supplement the Report of 1862, and it is the substance of the Report of this Committee, prepared by Professor Schäfer, the Chairman, which is before us to-night.

Dr. SILVESTER thanked the Council for kindly inviting him to be present, and for allowing him to take part in the discussion. He had had the honour of being invited to be present at some of the experiments undertaken by the Resuscitation Committee of this Society in 1862. The present Committee of Inquiry had divided the subject under consideration into two parts, the first having for its object "The determination of the most efficient and most convenient mode of carrying on artificial respiration in the human subject;" the second, "The investigation of the physiological phenomena which attend asphyxia." He desired to confine his observations to the first of these subjects. Dr. Silvester thought it was to be regretted that in their experiments the present Committee, instead of connecting the lungs of the subject of experiment with the so-called spirometer and apparatus by means of a tube passed into the trachea in the dead body, as was the practice of the Committee of 1862, had instead employed a "face mask," and had experimented on the living subject. The course pursued seemed open to much more serious objections than the former plan was liable to. Dr. Silvester then detailed some of these objections. He stated that it was well known that when attempts were made to inflate the lungs by bellows placed in the mouth, and the nostrils closed, the air forced in took the course of least resistance, and unless the pharynx was closed by some mechanical means the air failed to raise the costal parietes and enter the lungs; it distended the cheeks and upper air-passages, and then passed down into the pharynx and stomach. The same thing happened during the experiments on the chest; if there should be the least difficulty in the free exit of air from the mouth, the air, as before, taking the path of least resistance, passed into the said air-passages and stomach, etc., instead of into the so-called bell-glass spirometer, of course making a false record as to the amount of air expelled from the lungs. These dilatable air-passages being in communication with the lungs, the stomach, and the spirometer—as must necessarily be the case when a "face mask" was used, instead of a tube in the trachea,—it was as impossible to estimate correctly the exact amount of air from the lungs, as it would be if the lungs were connected with an elastic air-bag with a hole in it. It did not appear from the Report whether the Committee had sufficiently safeguarded this obvious source of error. There was another serious objection to the employment of the "face mask" on the living subject, and it was that flatulence from the stomach was liable to pass with the air from the lungs into the spirometer, and this was especially the case when the body was in the prone position and pressure was made on the back. This of course would give rise to a false registration on the spirometer as to the amount of air exclusively from the lungs. It also gave a fictitious and unfair advantage to the prone position as a means of treatment in competition with other methods of treatment. He might mention, in passing, that in attempts to restore the apparently dead one of the objections to the prone position, and also to the rolling plan, was that the contents of the stomach were commonly ejected, and were apt to pass into the windpipe and become a source of danger to the unconscious patient. The foregoing observations had a direct bearing on the "Table of columns of figures," and would probably explain some of their inconsistencies. The only columns which need concern them were Column IX and Column XVII, as it was on these figures the Committee based their recommendations for their treatment of the apparently drowned. A moment's consideration of these two columns would be sufficient to show their inaccuracy as records of the amount of air alternately inspired and expired from the lungs in the Silvester method. If the figures in Column IX were added up and compared with the amount in Column XVII, it would be seen that Column IX, "traction, etc.," = 2290; Column XVII, "rolling," = 2540, making a balance of 250 in favour of Column XVII; that was to say, it merely showed that more air was introduced into the lungs by "rolling and pressure" in the prone position than by the "traction and pressure" plan of treatment of the Committee. The method of treatment in Column IX described as "traction and pressure," as practised by the Committee, was not designated "the Silvester method," although it was founded upon it. Dr. Silvester then proceeded to show that it did not follow out his instructions in an important particular, and that consequently his method was unaffected by the above conclusions. If his method had been duly carried out the conclusions arrived at would have supported the views of the strong Committee of this Society of 1862, for they had been verified both in this country and abroad by himself and others, and these experiments could be repeated at any time by competent persons experimenting on the human subject before it had cooled down and rigor mortis had set in. By these experiments it could always be proved that the amount of air introduced into the lungs by mechanical muscular expansion of the chest by the muscles of respiration, and again expelled by mechanical pressure and collapse of the thoracic parietes in the supine position, invariably and in all subjects exceeded that effected by rolling and pressure in the prone position, and that for the simple reason that when the capacity of the chest was enlarged it admitted more air than when that was not the case, rendering it impossible for the Committee to negative the conclusions of the Committee of 1862. Dr. Silvester pointed out that according to the Report his published directions had not been duly carried out. The Report of the Committee stated: "The traction on the arms was insufficient to move the subject, who was in every instance reclined upon the (carpeted) floor; the pressure on the chest was exerted slowly and gradually, and was of such a force as not to cause pain or even inconvenience." He stated that his directions were as follows:—"Place the patient on his back on a flat surface inclined a little from the feet upwards. Raise and support the head and shoulders on a small firm cushion or folded article of dress placed under the shoulder-blades. Remove all tight clothing from about the neck and chest," etc., etc. This direction, which seemed so unimportant, was really essential to success; for it was, in fact, the inertia of the body, by its pressure against the inclined plane during traction, which was necessary to the due elevation of the ribs and the consequent inflation of the lungs. Traction on the arms insufficient to move the subject reclined on a carpeted floor would, as far as his experience went, be quite insufficient to inflate the lungs with much air, and he had usually secured the patient's feet before commencing operations. Consequently it was not to be wondered at that the figures in Column IX were unsatisfactory, and did not compete favourably with those of the "rolling and pressure" column. Dr. Silvester thought that something might be attributed to a defect in the construction of the apparatus employed for registering the amount of air respired. The Report did not state what amount of air the bell-glass jar contained as residual air. The Committee of 1862 found when experimenting on his method that "in a body which had been dead three days, and rigor mortis was at first strongly marked, a volume of air was inspired amounting to forty-four inches, and on sternal pressure fifty-two cubic inches were expelled." (In ordinary breathing adults usually inspired and expired on an average about twenty cubic inches.) For the success of experiments with the bell-glass it should be charged by the forcible expiration into it of not less than fifty cubic inches for the distension of the chest of the subject of experiment. There were reasons for looking with suspicion on experiments on living animals in a state of consciousness. One source of error was from a sort of muscular antagonism, the muscles of the chest being opposed by those of the abdomen; and another source of error was the unconscious and involuntary aid or opposition rendered by the subject of experiment. The prone treatment which had been recommended had been practised from the earliest times. The body was placed on a table with the head hanging over the edge, and pressure occasionally made upon the back. Rolling the body on the ground before a fire, or on casks, and holding it up by the heels, was usually resorted to to eject the water from it. The prone position was perhaps the least desirable position, for it was that in which the capacity of the chest for air was smallest and the ribs least movable. The thorax was easily injured by being pressed on a stony beach, and the face and clothing in women unnecessarily damaged. This position had been supposed to offer special facilities, combined with latero-supine movements, for the escape of fluid and mucus from the mouth and air-passages; and Dr. Silvester had carried out many experiments to elucidate that part of the subject. He had injected with a forcing syringe various amounts of fluid into the lungs, and had noted the result of placing the subject in various positions—such as depending with the head downwards, the body rolled from the latero-supine to the prone position, etc., etc.,—in order to facilitate the escape of water and mucus from the air-passages. It was found that this plan of treatment was inefficacious, and did not remove the fluid once injected. As the cause of drowning was now known to be due rather to the absence of air than to the presence of fluid, and as the access of air was of the most urgent necessity, these means for removing fluid from the air-passages had been discontinued, and especially since it had been observed that the bronchial mucus was brought up by forced artificial expiration and readily escaped by the side of the mouth. Fluids were freely discharged from the stomach by latero-supine and prone movements with pressure on the back.

With regard to the tongue, Dr. Silvester did not regard the tongue as a source of obstruction in the supine position when the chest was being forcibly expanded in the case of the apparently dead, but only in the actually dead. He had observed that in the merely unconscious person the air found its way through the nostrils to the chest without any apparent obstruction. As to the facility with which various modes of treatment could be practised, Dr. Silvester considered that rolling the body was very arduous to the operator, dangerous to the subject when in the hands of the public, and in many situations impossible; and in comparison his method was extremely easy of prolonged performance as directed by the Committee of 1862. It was as follows:—

"After the arms had been elevated above the head they were at once to be lowered and replaced by the side; this should be immediately followed by moderate pressure with both hands on the lower part of the sternum." Not a very arduous undertaking! In rules and regulations such as those of the Royal Humane Society, which he had published to guide the public, the pressure on the patient's chest by means of his own arms had been introduced as a precautionary measure to protect the thoracic parietes. The Committee did not appear to have suggested any new or unknown mode of treatment for the apparently dead. Very similar recommendations to those of the present Committee had been for about the last forty years, and still were, published by the Royal National Lifeboat Institution; but its example had not been followed by many other large life-saving societies, either in this country or abroad, nor by the public services, such as the Army and Navy, Board of Trade, nor by the Colonial humane societies. Probably it was not considered advisable for the public to have to select between various modes of treatment when in the presence of a sudden emergency.

"The Silvester method" had been exclusively adopted by the Royal Humane Society, which had awarded the author the Fothergill Gold Medallion, and this Society had by means of its publication and dissemination saved from apparent death in all parts of the civilised world large numbers of valuable lives.

Dr. Bowles offered his best thanks to the Committee for the time, patience, and ability they had bestowed on the very interesting and important matter before them. Only those, perhaps, who had worked at the subject could fully appreciate the difficulties that such an inquiry entailed. Some of those difficulties had just been explained to them, and Dr. Bowles felt sure, from a very long experience, that those difficulties had not been exaggerated. Moreover it was satisfactory to feel that precisely similar difficulties had been encountered by all who had experimented on this subject. Like those who first worked at the subject in 1855 and 1856 for the late Dr. Marshall Hall, the first steps taken by the Committee were to ascertain the amount of air which could be introduced into the lung by manipulation of the chest walls. The present Report practically confirmed the experiments of Marshall Hall, of Silvester, and of the 1862 Committee, and showed that sufficient air for the maintenance of life could be introduced by alternate compression and relaxation of the chest walls and by means of arm-movements in healthy subjects, always provided that the lungs were clear of all obstruction and uninfluenced by the presence of rigor mortis. From this last trouble Dr. Bowles, and those who were working with him for the late Dr. Marshall Hall, were driven almost to distraction. They, however, in some measure succeeded in overcoming the difficulty of rigor mortis by moving and working well the muscles of the trunk, by bending all the limbs, and doing everything they could think of to render the subject supple and the chest more or less elastic before beginning their experiments. It was in this way that they, Dr. Bowles believed, obtained better results on the dead body than any other experimenters could show. Moreover it was during these apparently "rough and tumble" movements that they first encountered all those difficulties arising from the falling back of the tongue, the gravitation of fluids which had been pressed up from the stomach by the movements they had been using, from mucus already in the lungs, and so forth; which difficulties caused them to cast away all methods of artificial respiration in which the supine position of the body was implied or employed. They knew that the public, untrained in physiological problems, would not be able to discriminate, and ought not to be burdened in mind by any alternative instructions. It was stated in the Report then before them that in only four of the subjects experimented on by the 1862 Committee was it able to obtain any marked effect upon the capacity of the thorax, and *that* only by one method (Silvester's combined with pressure on the thorax). By other methods hardly any appreciable result was in most cases obtained; but, on referring to the 1862 Report, Dr. Bowles found it stated that in the Marshall Hall method the amount of air introduced "varied much, according as the subject was favourable or the contrary, sometimes only a few cubic inches, but never exceeding fifteen cubic inches." In the Silvester method it was stated in the 1862 Report that "the volume of air inspired varied from nine to forty-four cubic inches." And again, the Report of 1862 went on to say, "Without expressing an opinion as to the efficiency of the method of Dr. Silvester as a means of restoring suspended animation in cases of drowning, its claims to be considered as an effectual means of producing an *exchange of air* similar to that effected by the respiratory movements appears to us to be satisfactorily established." In the Marshall Hall experiments they certainly obtained better results than the 1862 Committee, sometimes as much as thirty cubic inches being respired, for in a rough way they had measured the amount. The present Committee had found in its experiments on living human beings that under favourable conditions both these systems were essentially equal as a mode of introducing air into the thorax, and that was in effect also the finding of the 1862 Committee appointed by this Society. This information was of the utmost value, and although some allowance had to be made for possible error, they might, Dr. Bowles felt sure, rest satisfied that they had now dependable measures for the employment of artificial respiration, and that it only wanted the cordial co-operation of those most instructed in the question to arrange a system which would be suitable for the use of the public. Dr. Bowles then drew attention to a foot-note in the Report under discussion, referring to the experiments on living human beings, which stated: "The employment of the living subject for these experiments is disadvantageous from one point of view, seeing that there is not the same tendency as in the dead or apparently dead subject for the tongue to fall back and block the pharynx when the subject is in the supine position. But it is the *universal practice* in such cases to draw the tongue forward and fix it there, and the conditions are then fairly similar in the two cases. In the prone position of the dead subject the tongue naturally falls forward, and this difference does not manifest itself." Dr. Bowles begged those present to particularly notice the second part of that foot-note, in which it was stated that "it is the universal practice to pull forward and fix the tongue," etc. This he considered must be an oversight, for it certainly was not his practice nor of those who thought with him, nor was it the universal practice of anæsthetists, who could, and did in many other ways, avoid the dangers of gravitation by pushing the lower jaw forward, by throwing the head back, by hooking up the tongue from the base, by turning the face downwards to empty or sponge out the mucus, and so forth; but the public was not so armed with knowledge or with instruments, nor even with elastic bands or whipcord, which were erroneously thought to be so useful. What was sought and what must be supplied, if the public was to be of use in drowning cases, was a simple, ready method in which the public could be drilled, and in which no alternative methods were allowed to be introduced. The Silvester method, in consequence of the way it had been published and the illustrations which accompanied it, always implied the supine position of the body, and yet the above note in effect practically advised the supine position as at least being of equal value to the prone position under the circumstances therein mentioned. Such an ambiguous statement could not be too emphatically condemned. The Silvester method was contrary to the teaching of the Committee's own experiments; it admitted in one breath that the tongue, fluids, and foreign bodies might gravitate to the back of the throat and cause obstruction, and yet it spoke favourably of a method in which the supine position was employed, and in which all these obstructions might occur. Dr. Bowles urged that the Committee, if this point were not cleared up and definitely settled, would have left them where it found them, or even in a worse difficulty, for it would be in the position of having confirmed an error. Dr. Bowles had shown by dissections on man and on animals, by direct experiment on himself and others, and by the strongest evidences in the treatment of cases of drowning, that the difficulties above referred to did exist in the supine position, and that they were sources of real danger. He had shown, too, in numerous cases of apoplexy, in hæmoptysis, in suffocation or drowning from small quantities of fluid finding their way into the larynx in diphtheritic paralysis, in suffocative bronchitis, and in all cases of unconsciousness, how easily death might ensue in the supine position of the body. Notwithstanding all these evidences, which had for many years been carefully recorded, the Committee, without a single dissection so far as Dr. Bowles could see to support it, implied, by advocating the Silvester method, the harmlessness of the supine position. In practice Dr. Bowles held that it was quite impossible in the supine posture to draw forward and fix the tongue, because dragging on the tip, as a rule, only acted on the upper and anterior portion, the upper fibres, *i. e.*, of the fan-shaped genio-hyoglossus; for several reasons: first, the opening of the mouth dropped the chin, to which the tongue is loosely attached, into close relation with the posterior wall of the pharynx; and secondly, because the frænum strictly limited the movements of the tongue. The air-way could only with certainty be kept clear in the unconscious supine by hooking up the tongue from its base, and then the difficulty would be how to keep it there. Dr. Bowles was particular in drawing attention to this note, as it underlay an important principle, and would induce the public to adopt the supine position, *apparently* the most natural and easy for treating such cases, but in reality the most dangerous, on account, amongst other things, of the gravitation of fluids into the larynx.

The experiments on animals determining the physiological phenomena which occurred during asphyxia by drowning were also full of interest and importance, but obviously they could only be superficially noticed on the present occasion; that they had been carefully undertaken and recorded was certain, and as far as the facts went their teaching must be accepted and reflected upon. Dr. Bowles begged those present, however, to remember that the experiments were on animals, and on animals *not* under the same conditions as drowned human beings, that their lymphatics and tissues generally might not be influenced in the same way, that they moved on horizontal planes, and that the supine position might not be the same to them as to human beings; and finally, that they were under the influence of anæsthetics and morphia. The anxiety of mind, the violent struggles, the forcible inspirations were all evaded, and important differences between animals drowned whilst under anæsthesia and without it were experimentally demonstrated by the Committee of 1862. It was then found that the anæsthesia, by diminishing the violent struggles of drowning, considerably lessened the formation of froth in the air-tubes; and, as that Committee said, the state of the blood and blood-pressure "may depend upon the character and amount of the anæsthetic used, or they may depend on individual idiosyncrasies, or upon the physiological condition of the nerve-centres and of the heart at the moment of immersion." In some of the present experiments the rapid death might have been caused by the anæsthetic, and from the same cause the absence of foam and fluids from the bronchial tubes might be accounted for; in other cases death may have arisen from the anæsthesia preventing the inspiratory efforts, or, in the supine position of the animal, from the tongue blocking the air-way, as had been demonstrated to be the case in "cast sheep." In the dog they had to remember, too, that violent pantings largely took the place of skin action, and that the dog very quickly expelled and dissipated water from its lungs when those organs were freed from other obstructions. Another point to be taken into consideration was the statement that larger quantities of water entered the lungs than could be found in the bronchial tubes after death, and that very little or none at all was found in the stomach. Possibly animals absorbed water into their blood-vessels more readily than human beings did. It was clear from the experiments that water had entered the tubes, and that the blood-vessels were full, a state of hydræmia was established; and, moreover, a very important additional fact was discovered, viz. that the liver was enormously distended. Dr. Bowles wondered if the more rapid transference of water from the stomach of animals to the liver was the cause of the empty stomach so commonly found by the Committee. On this important point the present Report said, "Out of twenty of our cases fourteen showed excess of mucus or frothy mucus in the air-passages," and it suggested that the dilution of the mucus with water assisted in the formation of that froth. The Report further drew attention to a very serious danger, viz. that of rupture of the liver from the pressure method. It showed that this accident had happened in practice on the human being, and it certainly was shown to have happened in dogs under experiment. Dr. Bowles had always, he said, but for another reason, used great gentleness in the application of pressure. It was obvious that contracting the chest by pressure necessarily reduced in size all its contents; at the same time it tended to expel froth from the bronchial tubes, to move the blood onwards to the left side of the heart, and still further onwards from the left ventricle. On the other hand, it impeded the blood arriving from the large veins, and obviated in some measure the terrible engorgement of the right side of the heart. The combination, therefore, of chest pressure and arm movements might be made to aid the circulation as well as the respiration; but, as it was certain that the lungs of the apparently drowned were usually loaded with froth and fluid, the employment of the forcible inspiratory movements of the Silvester method before the lungs were somewhat cleared would inevitably drive the contents further in and increase the respiratory difficulties. On the other hand, the elasticity of the chest walls and of their contents was very decidedly lessened in the apparently drowned, and so some advantage might be derived from the judicious application of arm movements after the expulsion of the fluids contained in the tubes. Dr. Bowles said that there were even yet many questions remaining for consideration and solution which could only be adequately discussed in committee; but in conclusion he would venture again to assert that the methods of introducing air into the lungs, called respectively the Marshall Hall and Silvester, had completely established their claims as efficient methods, but that the supine position of the body should under no circumstances whatever be recognised in any scheme of artificial respiration to be submitted to the public for its practical use.

Inspector-General H. D. Woods, R.N., said that in attempting to resuscitate the apparently drowned a certain amount of water must be got rid of from the air-passages. The St. John Ambulance Association, which he represented, did this by turning the body in the prone position and exerting pressure on the chest, afterwards employing the Silvester method. With a heavy person the Marshall Hall rolling method had advantages, but the Silvester method was more readily carried out. The employment of the Silvester method was often imperfect in practice because too little pressure was exerted in expelling air from the chest.

Dr. F. W. Hewitt referred to the analogy between death from drowning and death from intercurrent asphyxia during anæsthesia. He reminded the Society that he had on a previous occasion attempted to define the numerous ways in which intercurrent asphyxia might arise at all stages of general anæsthesia. During the induction and recovery stages spasmodic states of the respiratory apparatus were common causes of this intercurrent asphyxia, and he would like to know whether, in the case of drowning, respiratory spasm was a common event. When arising under anæsthetics, spasm of the jaws and respiratory apparatus might be so great that even though laryngotomy were performed air could not be made to enter and leave the chest by

Silvester's method; and it seemed to him that if some simple and readily available means could be devised for inflating the lungs of drowned persons, the chance of recovery might be greatly increased.

Dr. M. S. Pembrey did not think that whether an extra 100 c.cm. of air could be forced into the lungs or not with each movement of artificial respiration was of such great importance as previous speakers maintained. A few extra movements made up for any deficiency in the amount of air drawn into the chest with each artificial respiration; for Professor Schäfer's figures showed that in each of the various methods of artificial respiration as much air as the ordinary "tidal air" passed into the lungs. The influence of the nervous system was of the utmost significance, and this had not had its full influence in these experiments, because of the anæsthetic, and because dogs were accustomed to water. As to the amount of water in the lungs, it was obvious that absorption would be very rapid if the animal were alive, and in this respect the results obtained by Professor Schäfer were much more reliable than the inferences drawn from the post-mortem examinations of people who had been drowned. If the water in which the animals were plunged were coloured by carmine or Indian ink, its course could be followed. The method of inflation was of great use and wide applicability.

Professor Schäfer pointed out that most of the objections raised by Dr. Silvester were met in the Report. It was quite certain that in these experiments no air passed into or out of the stomach, and clear that all the methods employed produced a sufficient passage of air into and out of the thorax. He thought the method of rolling the body over less laborious than the Silvester method, and intermittent pressure on the back with the patient lying prone still less so. The Committee had not made any recommendation; it had observed facts and drawn inferences. Personally he would prefer to adopt the prone or semi-prone position, and exert intermittent pressure. Much greater pressure could be applied to the back than to the front of the chest without injuring the patient. The relative amount of air that could be got into the chest by the various methods was of minor importance; other considerations were of greater significance, such as the furtherance of escape of water and mucus from the mouth and air-passages. The Howard method was, he thought, dangerous from the amount of pressure applied to the lower part of the chest, tending to injure the greatly congested liver.

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PLATE I.

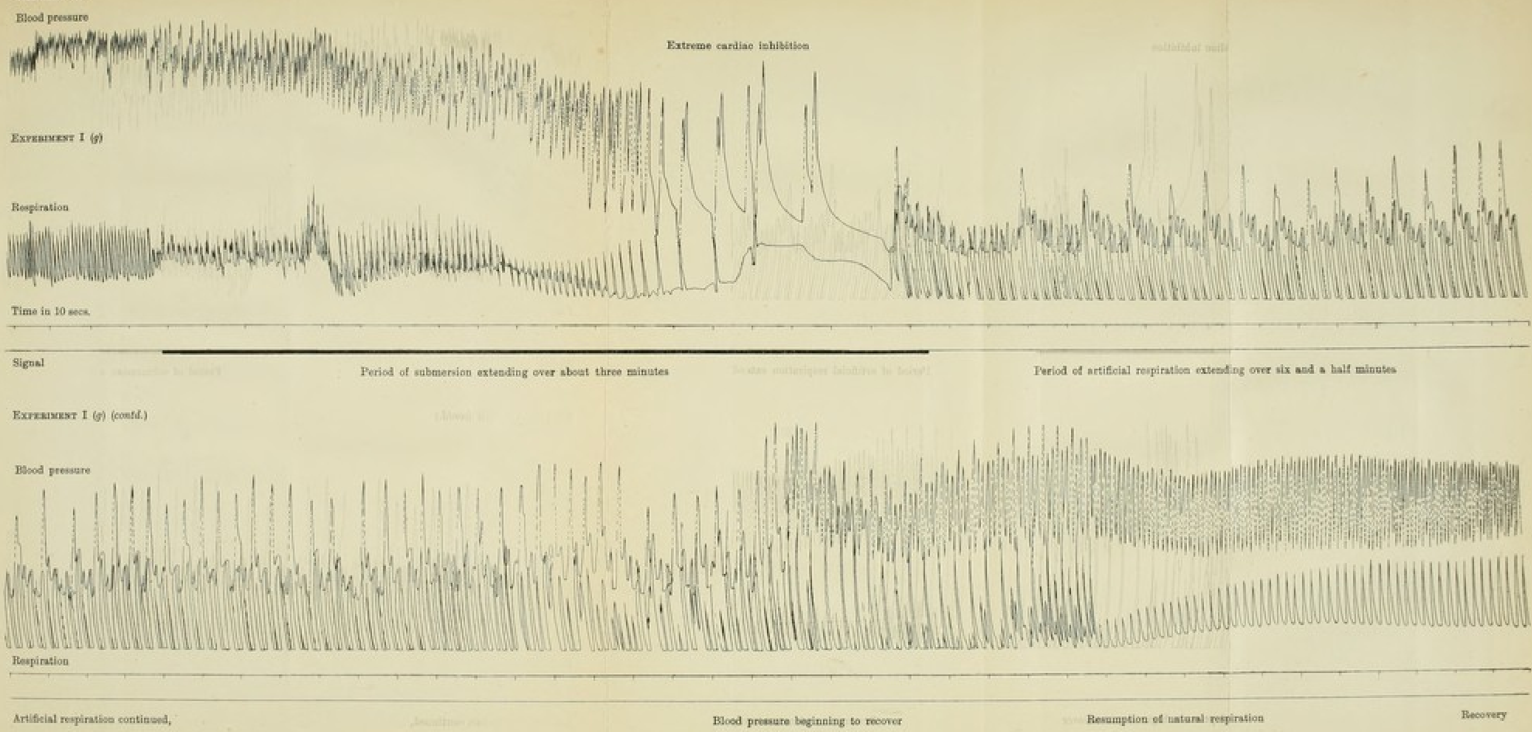

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PLATE II.

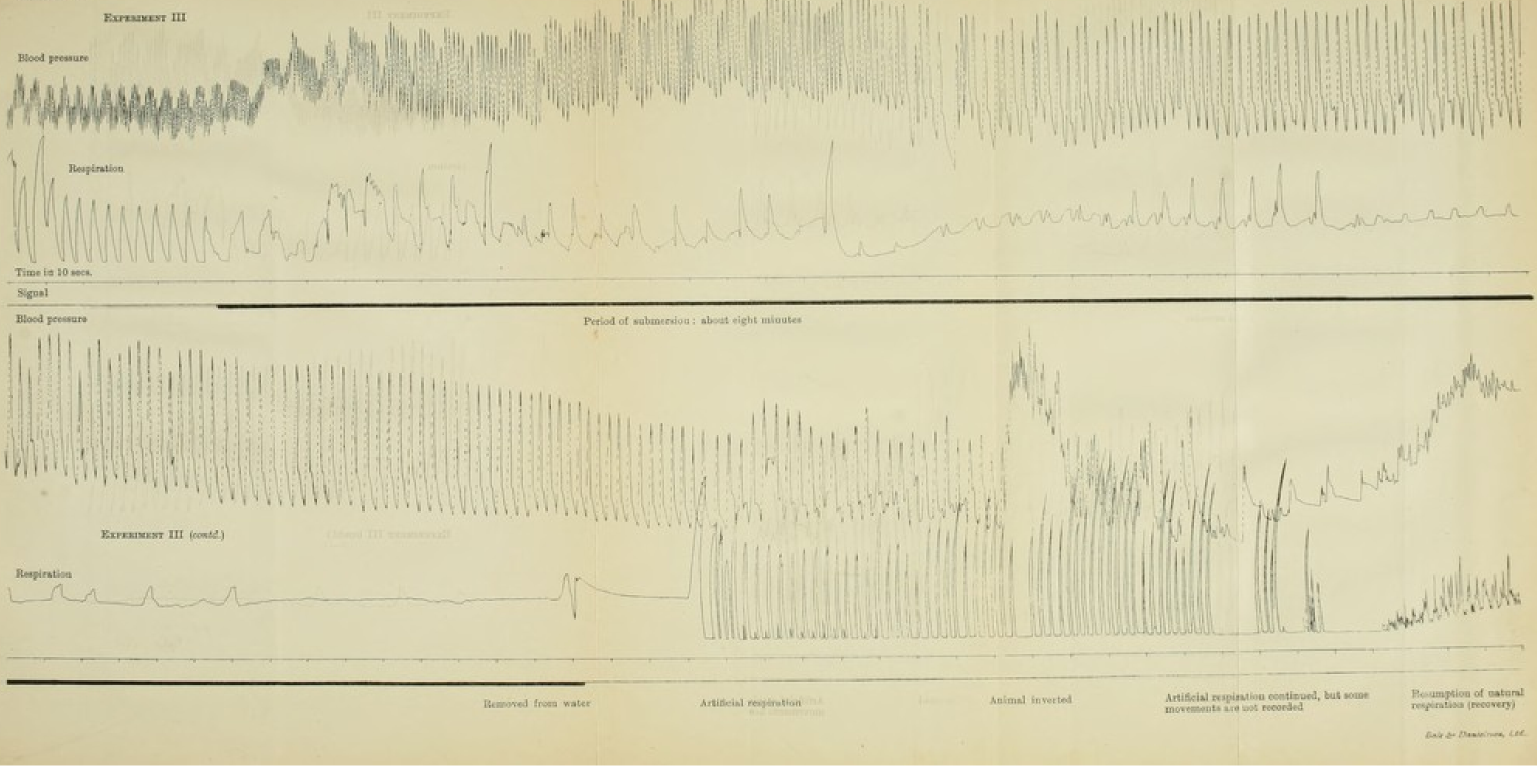
EXPERIMENT III
Blood pressure
Respiration
Time in 10 secs.
Signal
Blood pressure
Period of submersion : about eight minutes
EXPERIMENT III (contd.)
Respiration
Removed from water
Artificial respiration
Animal inverted
Artificial respiration continued, but some movements are not recorded
Resumption of natural respirations (recovery)

PLATE III.

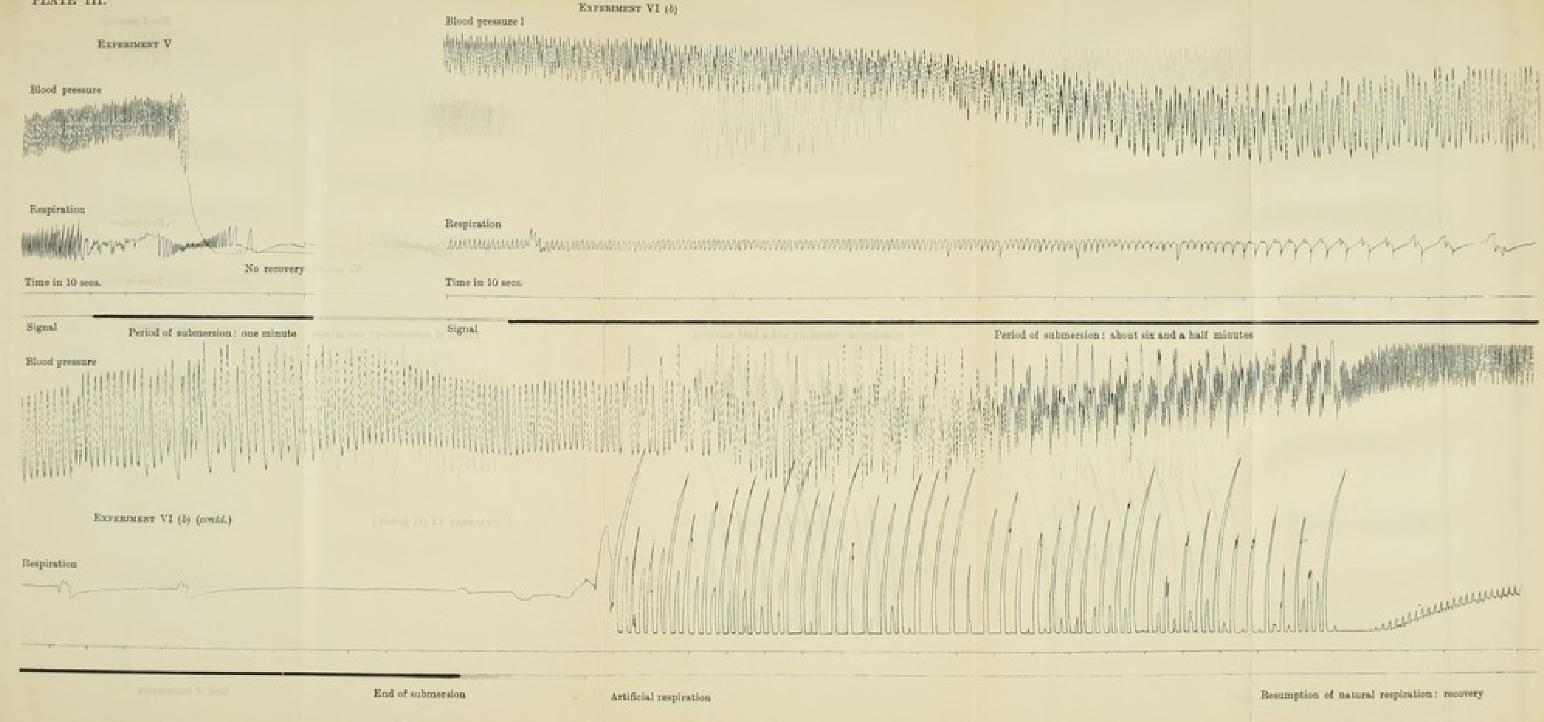

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PLATE IV.

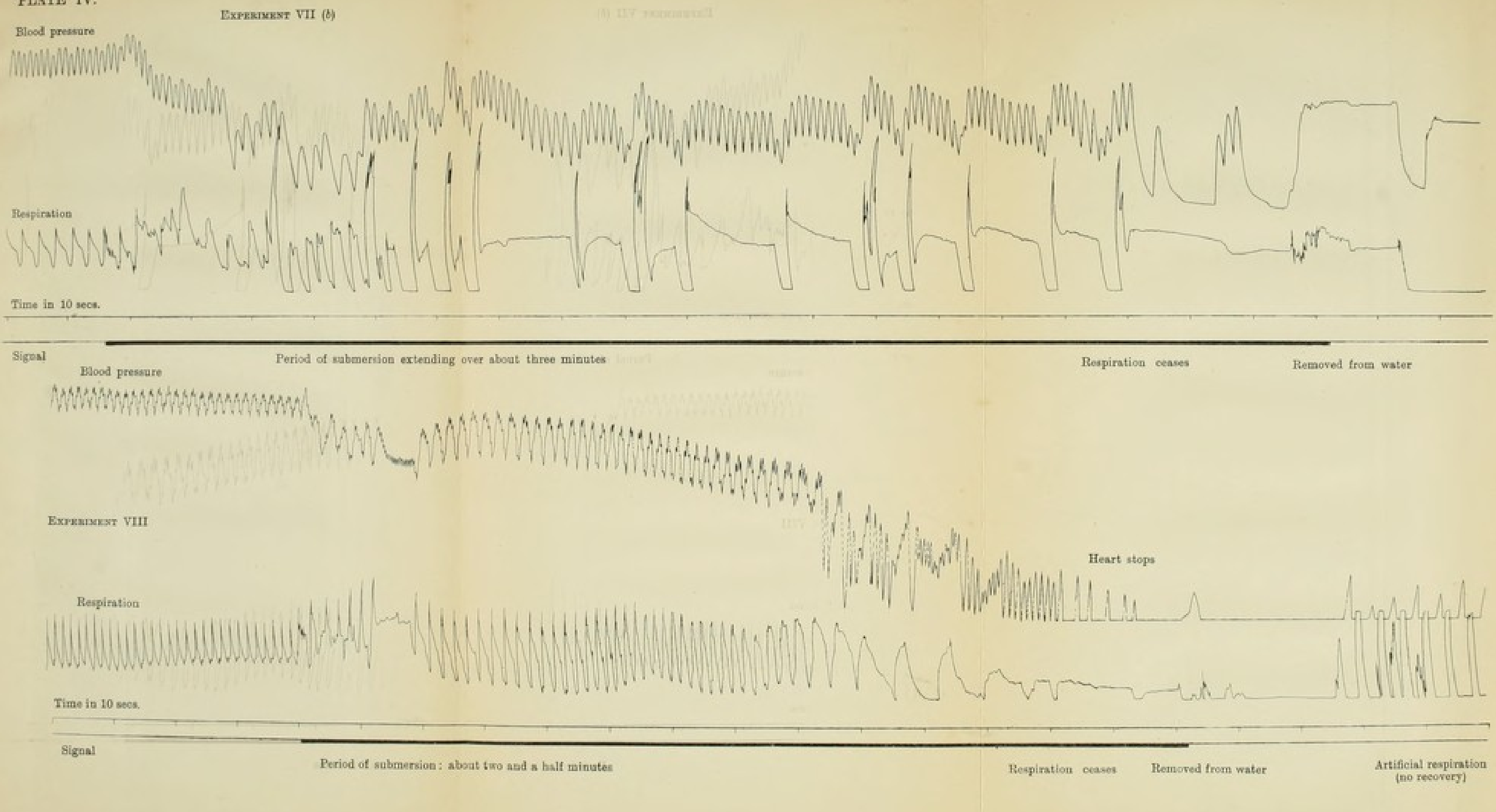

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PLATE V.

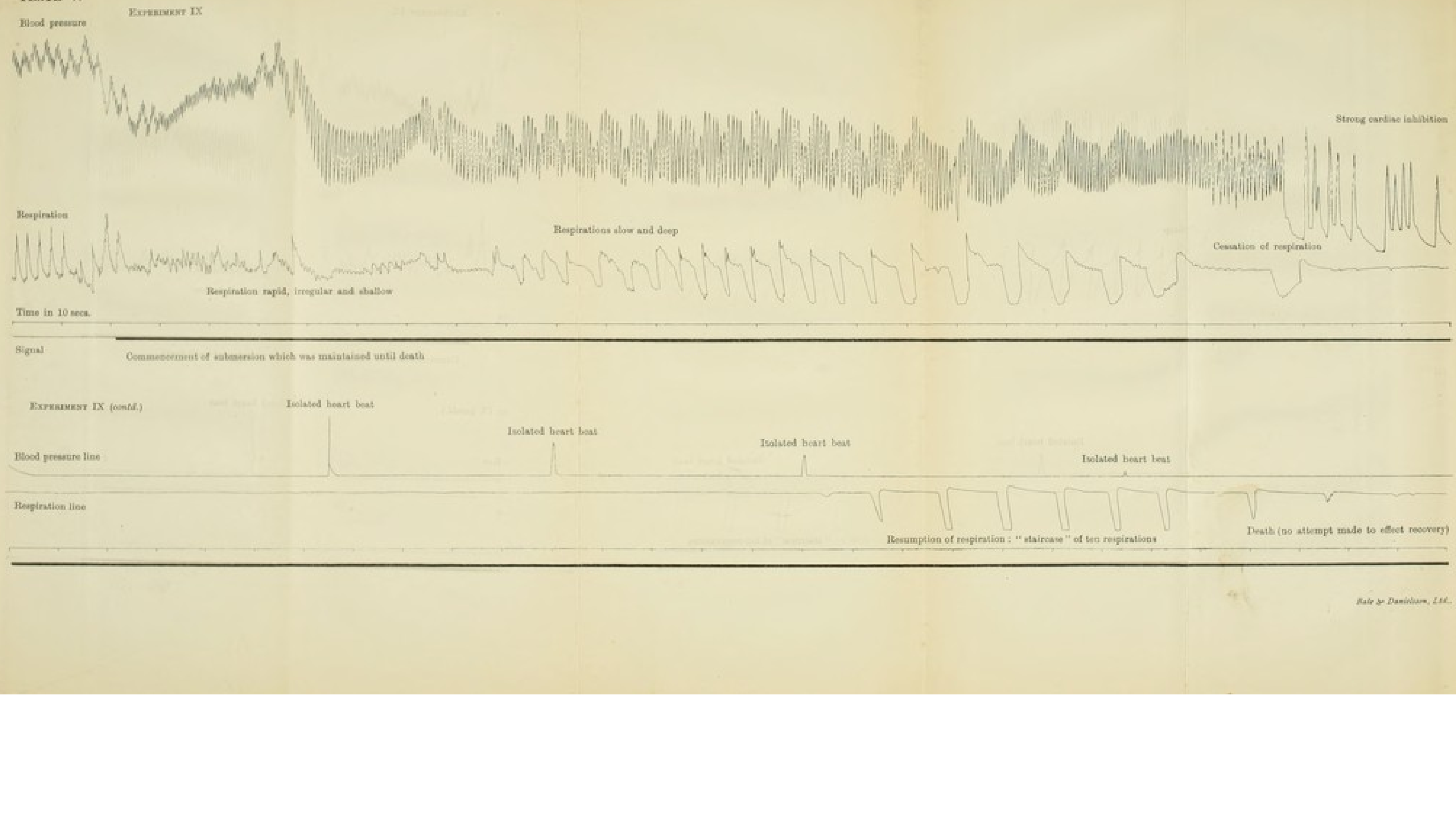

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PLATE VI.

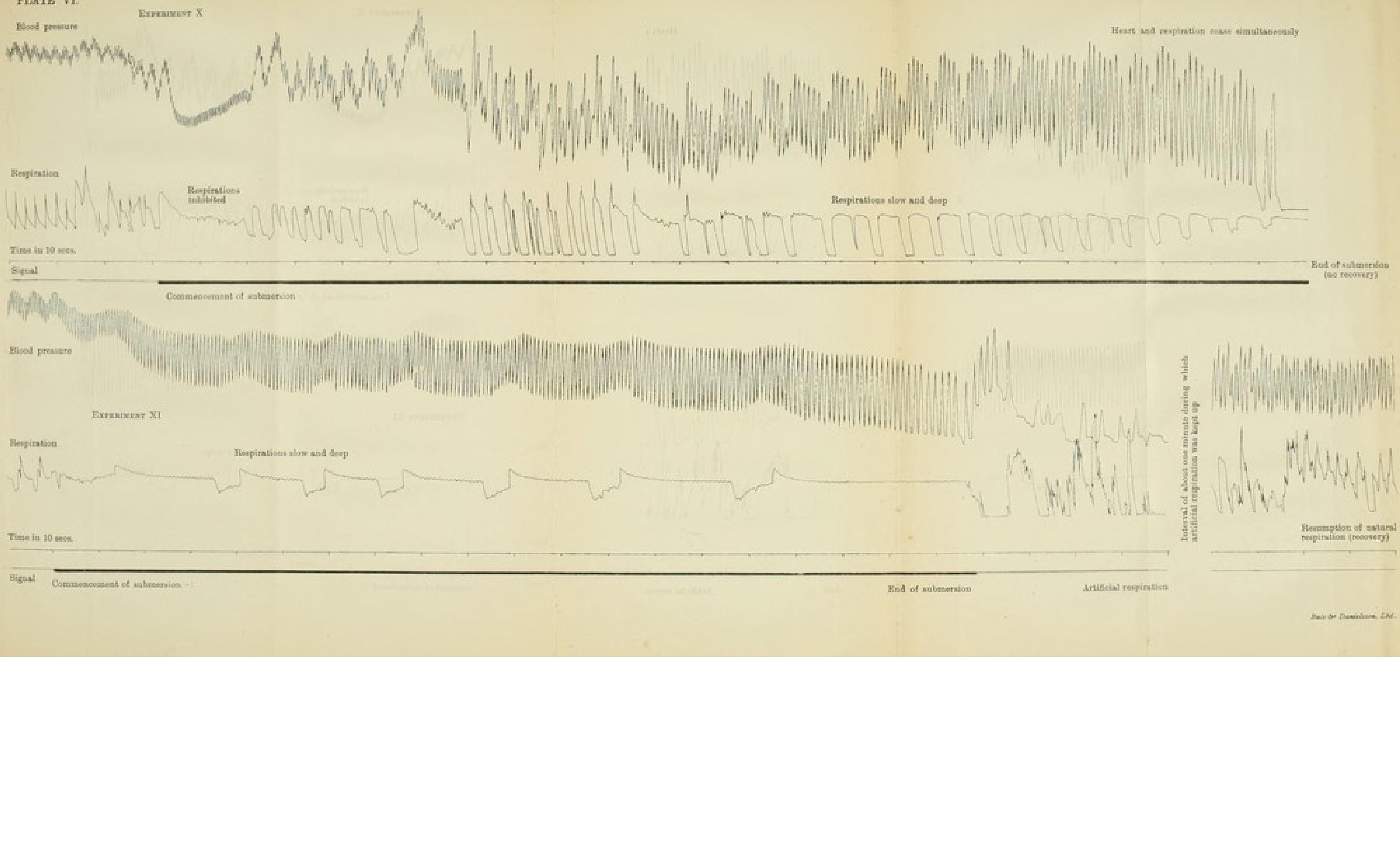

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PLATE VII.

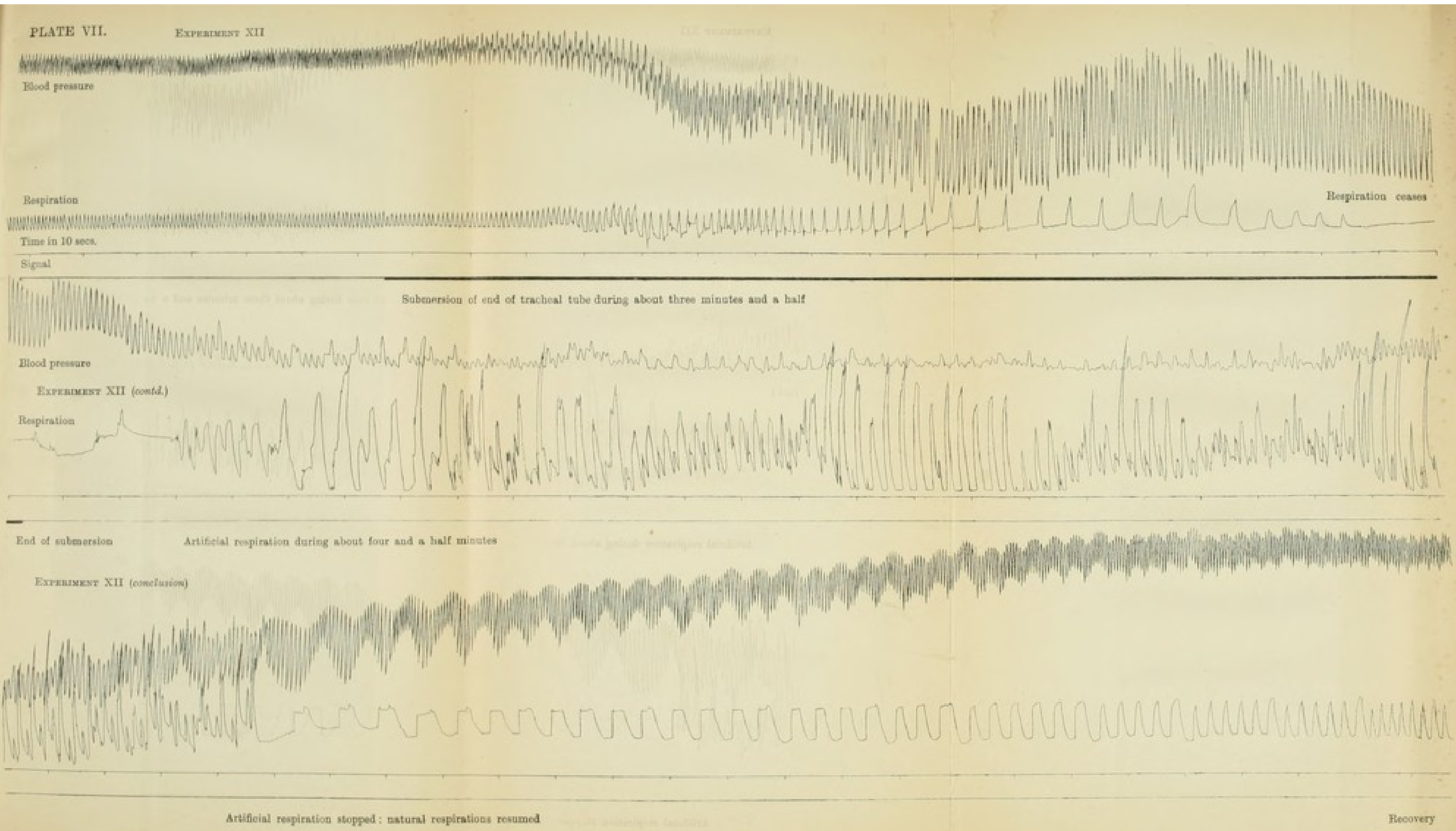

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PLATE VIII.

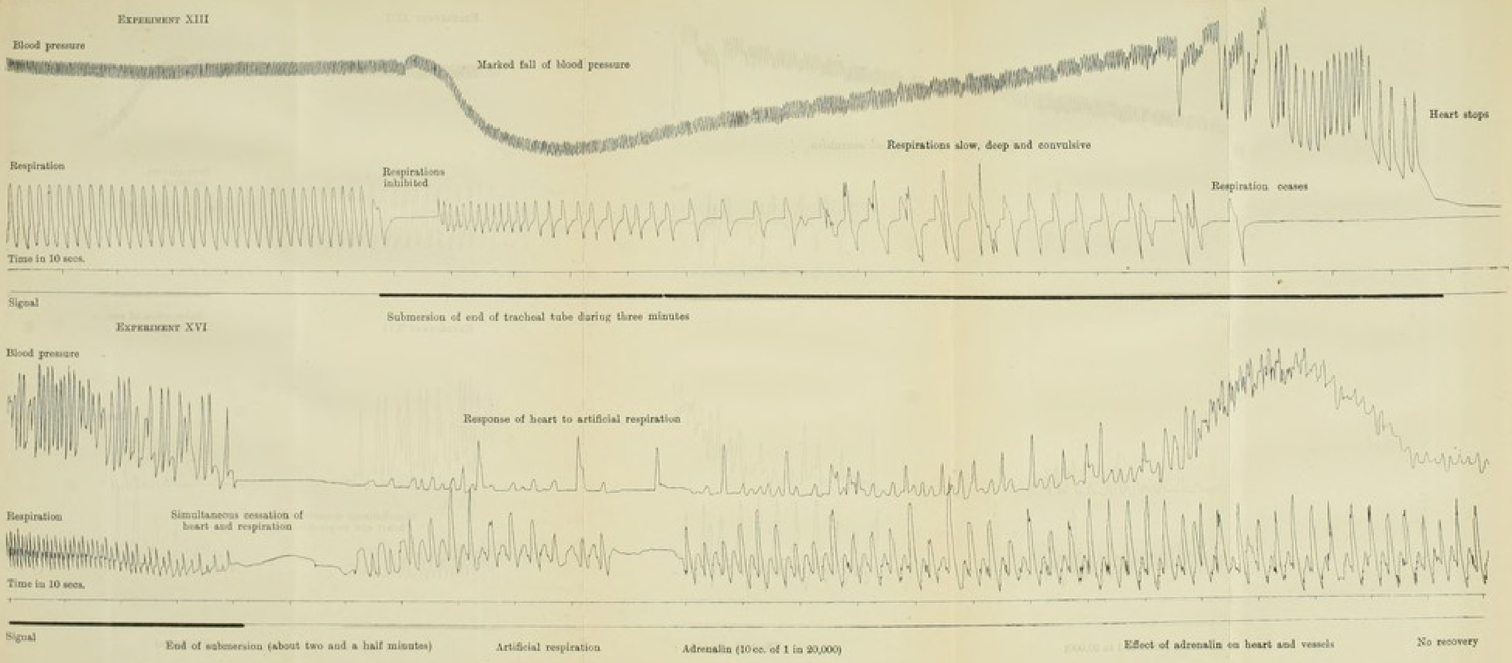

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PLATE IX.

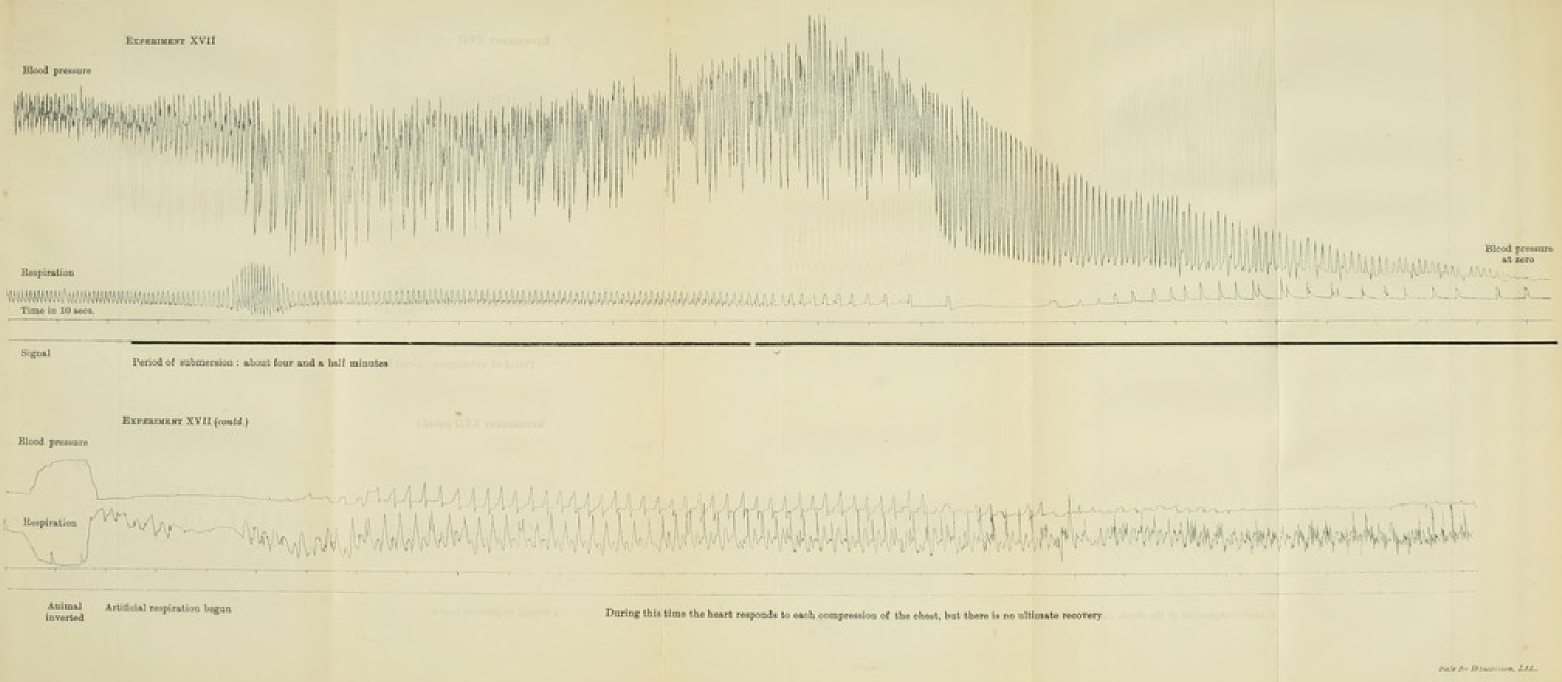
Experiment XVII
Blood pressure
Respiration
Time in 10 secs.
Signal
Period of submersion : about four and a half minutes
Blood pressure
at zero
Experiment XVII (contd.)
Blood pressure
Respiration
Animal
inverted
Artificial respiration begun
During this time the heart responds to each compression of the chest, but there is no ultimate recovery

PLATE X.

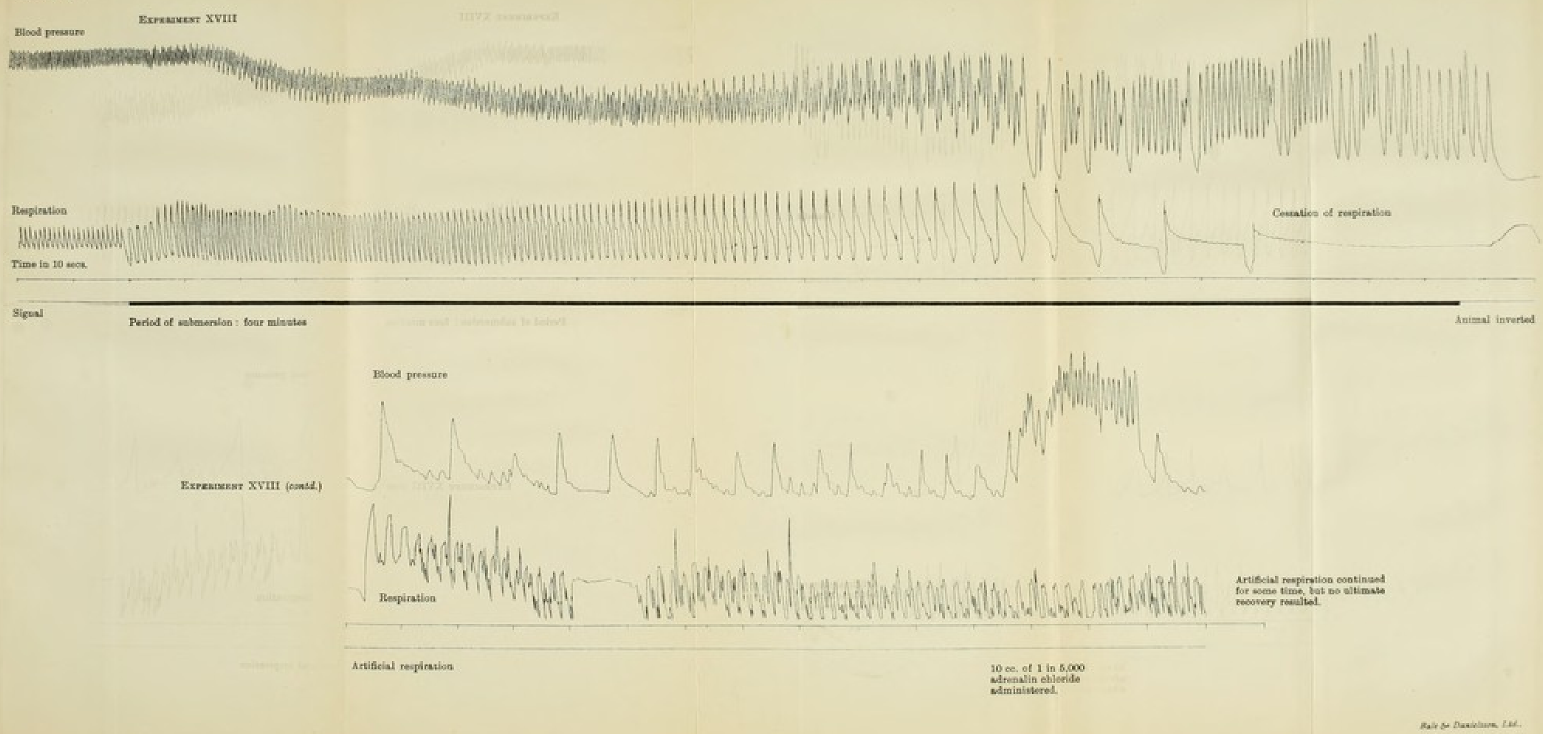

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PLATE XI.

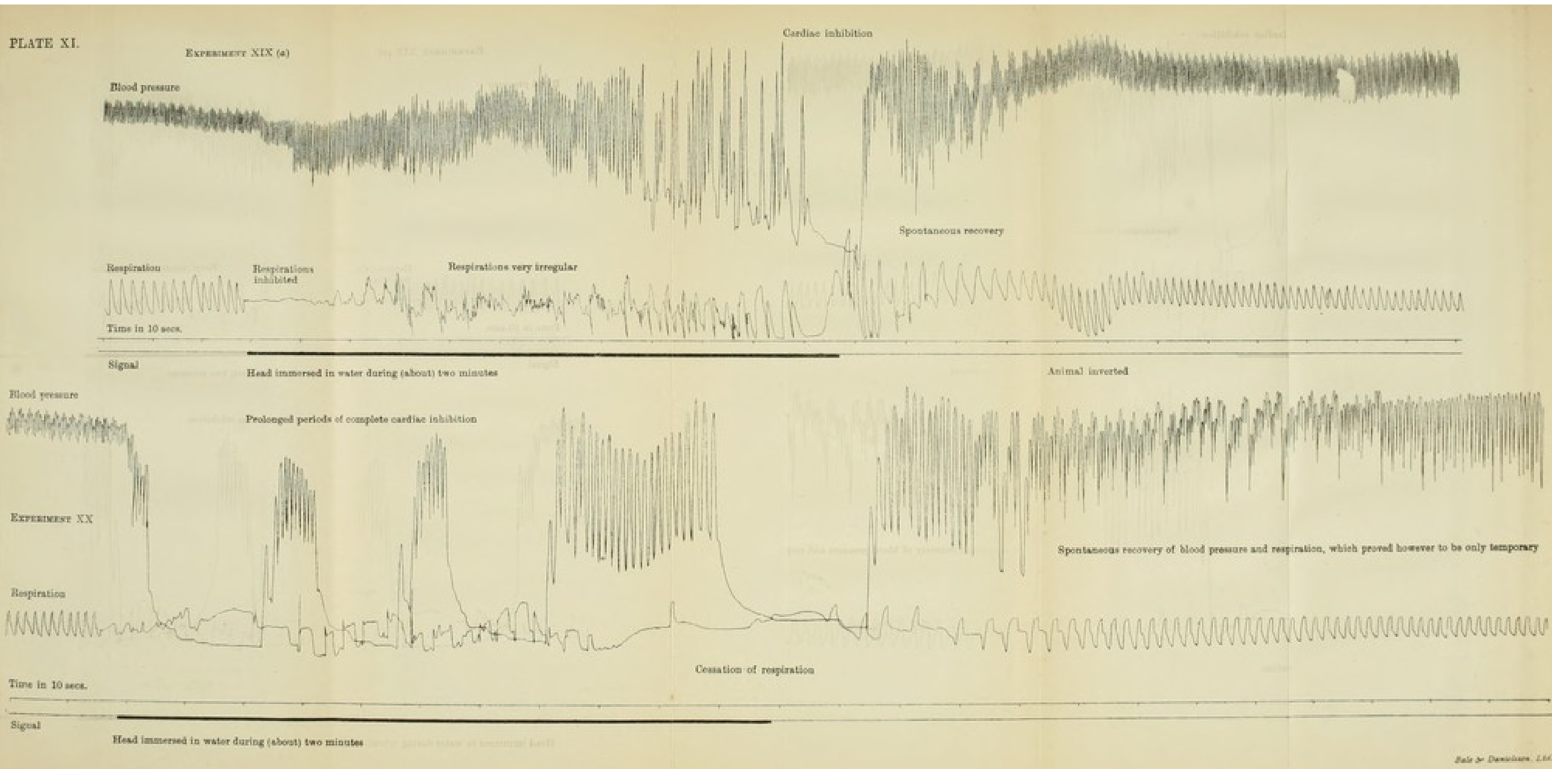

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PLATE XII.

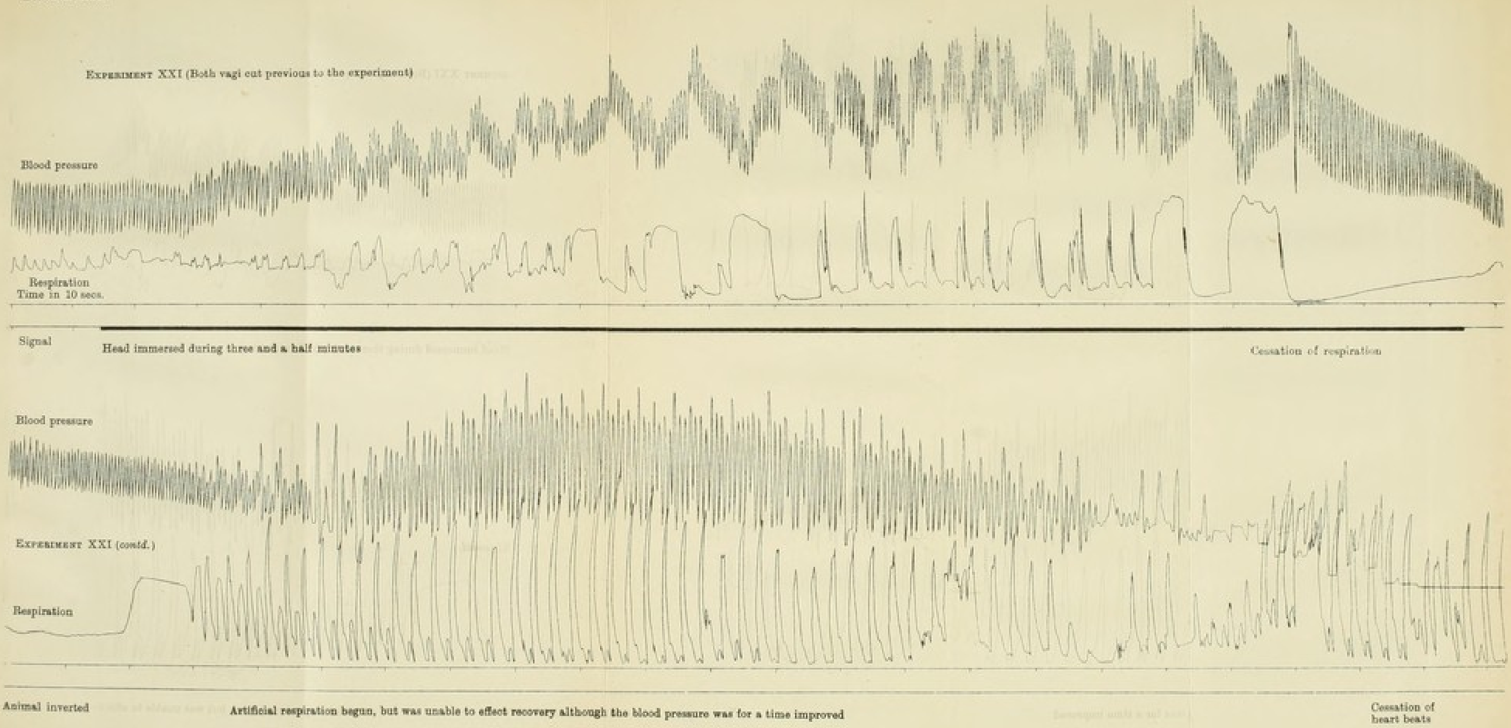

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PLATE XIII.

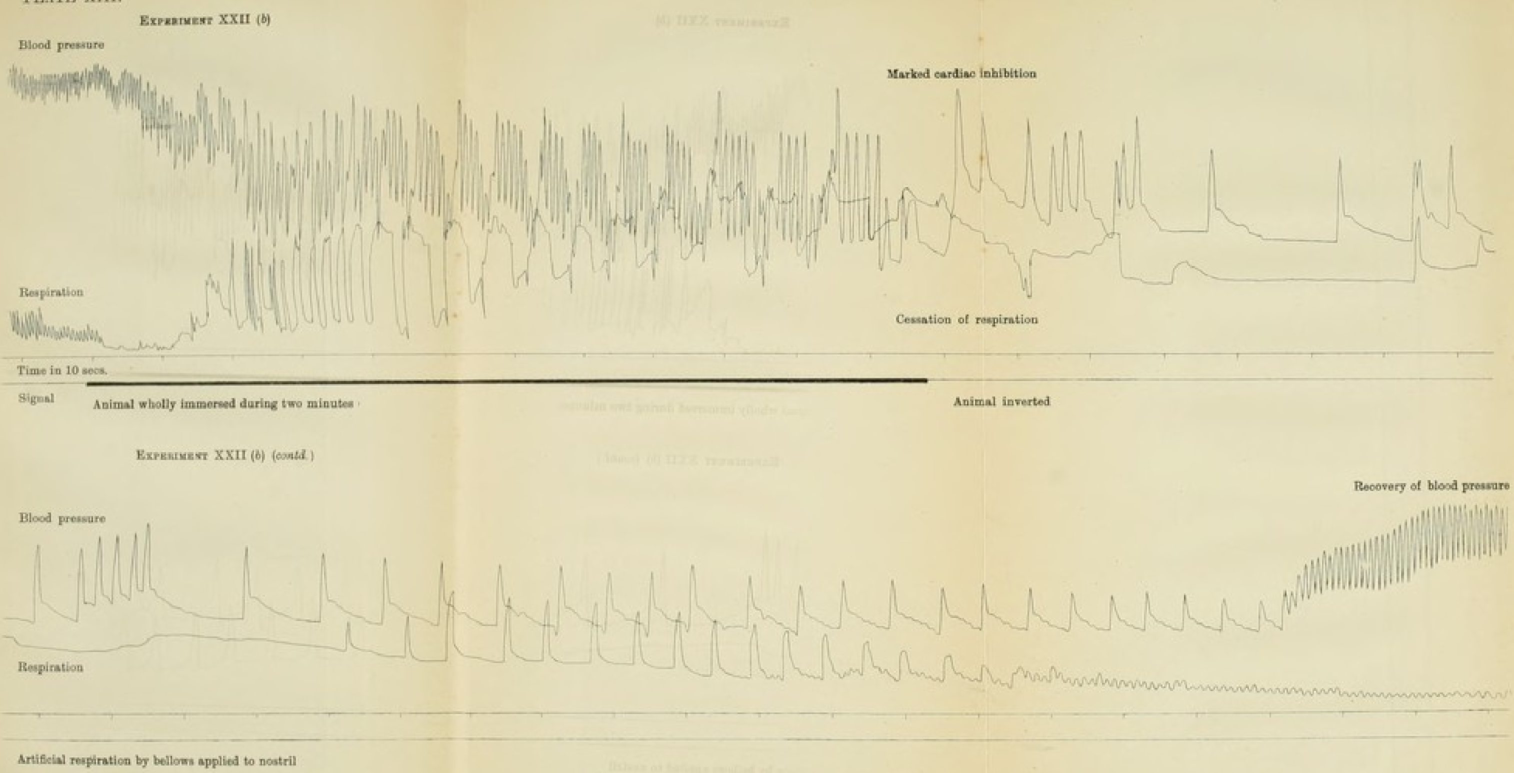

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PLATE XIV.

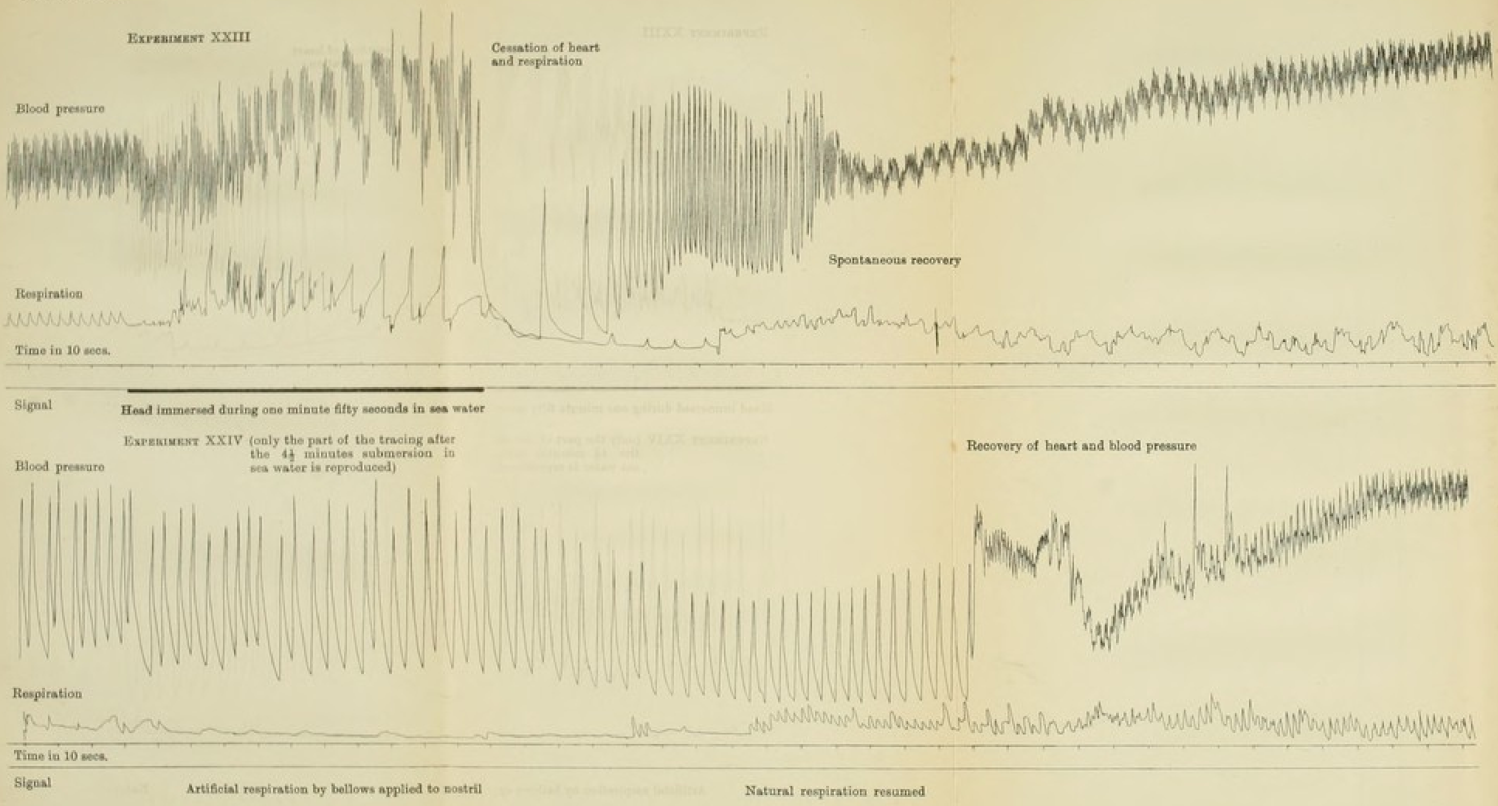

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PLATE XV.

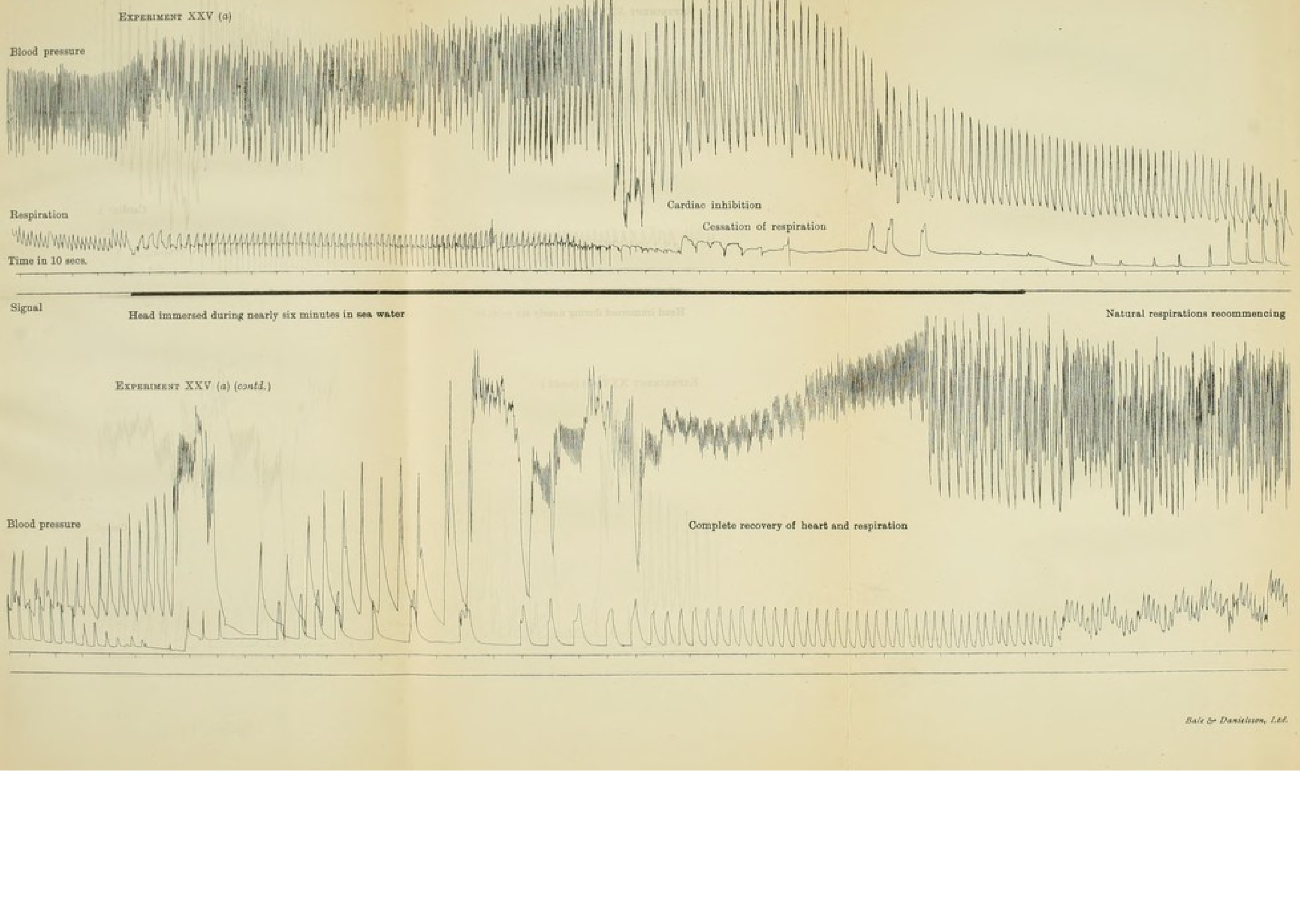

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PLATE XVI.

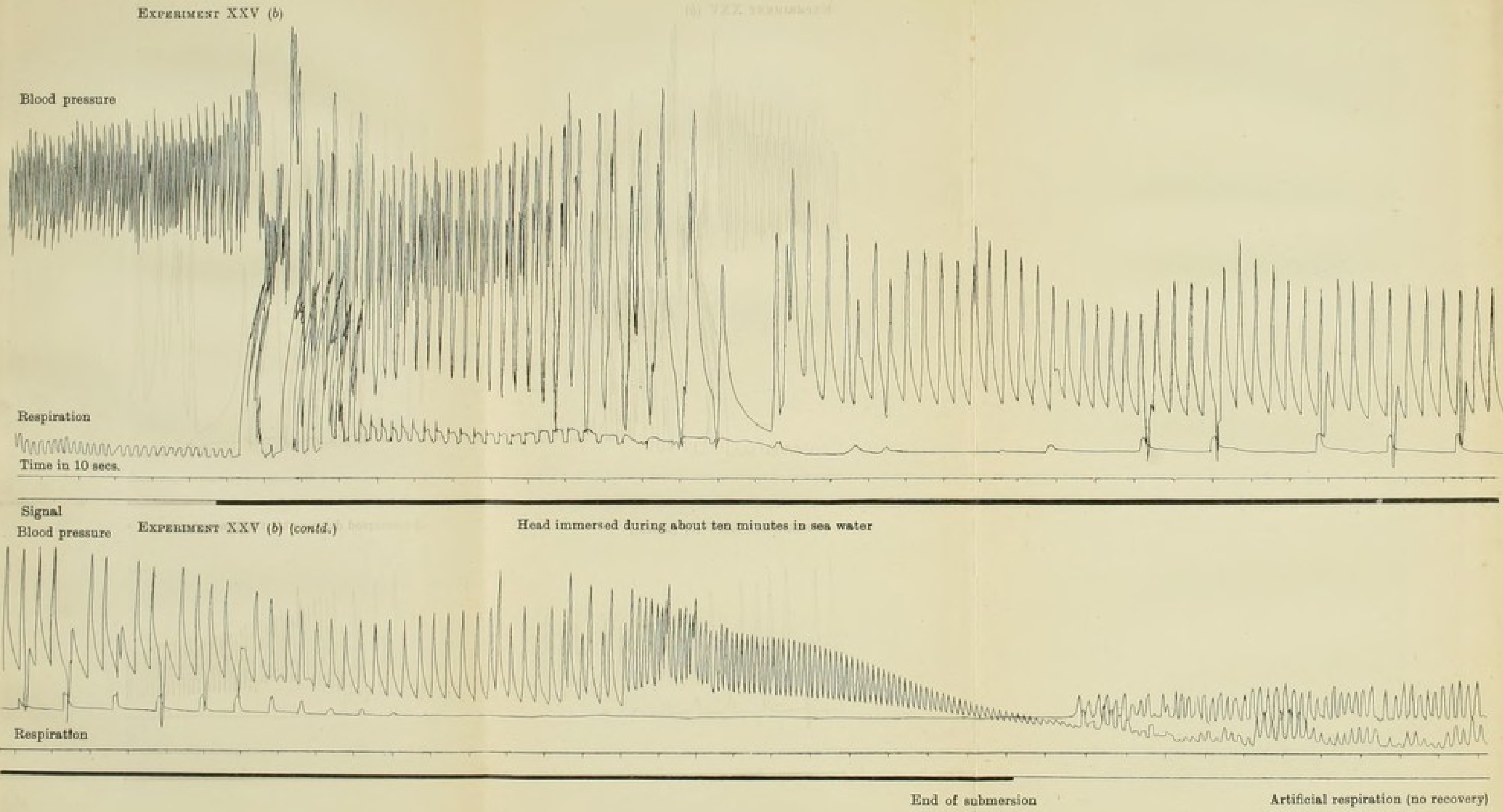

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PLATE XVII.

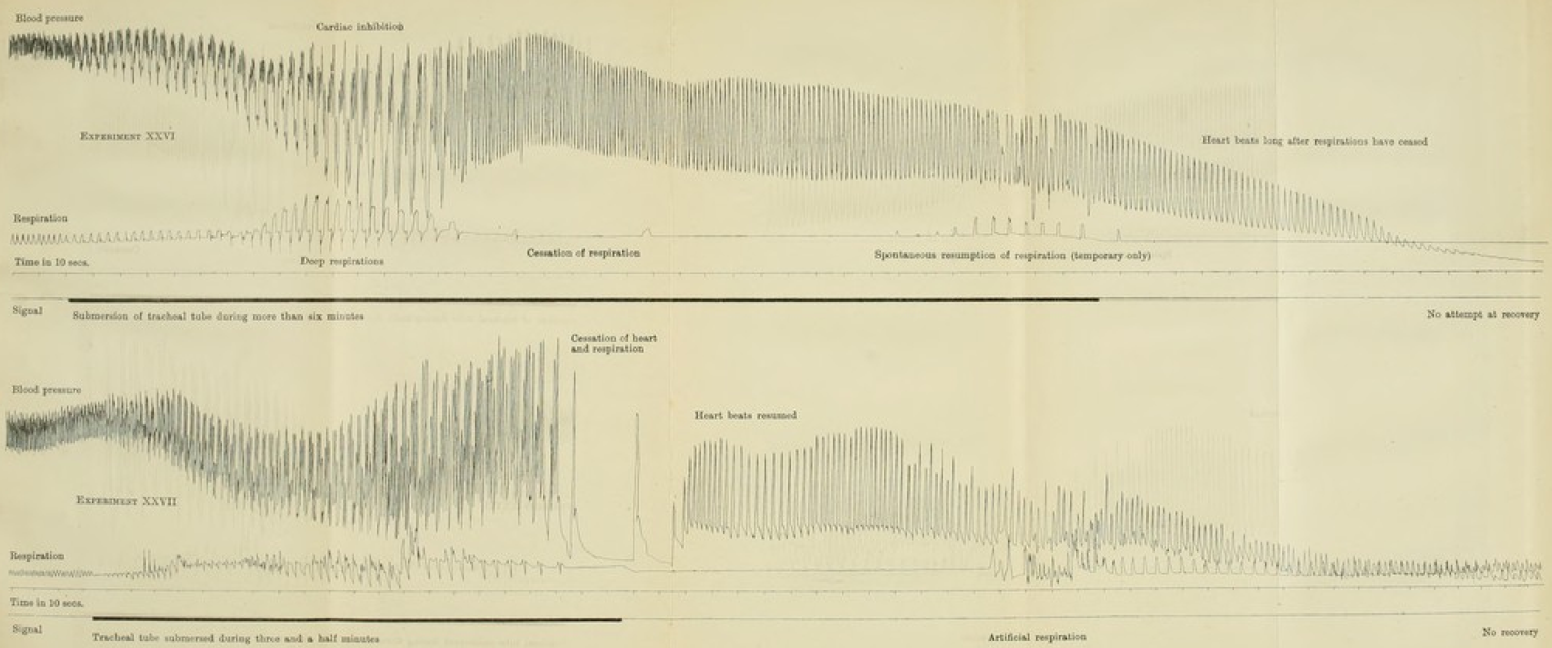

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PLATE XVIII.

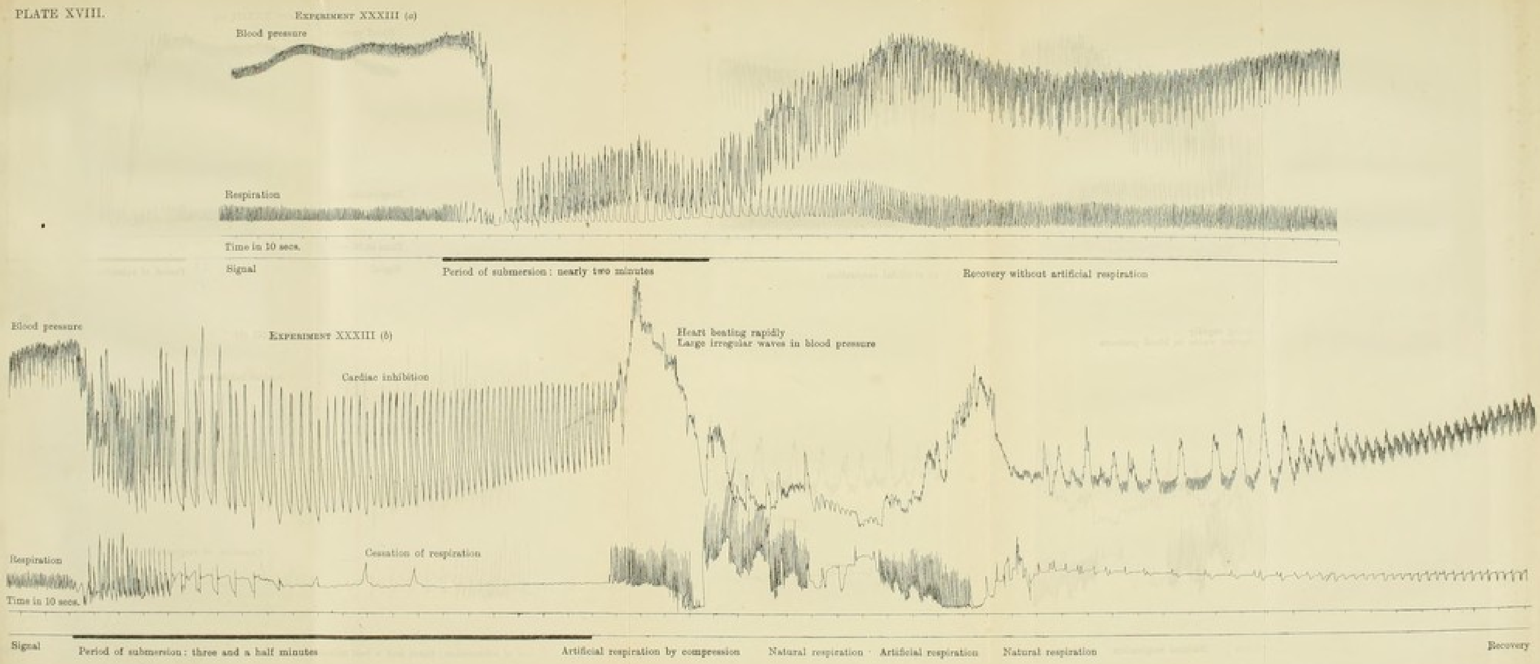

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PLATE XIX.

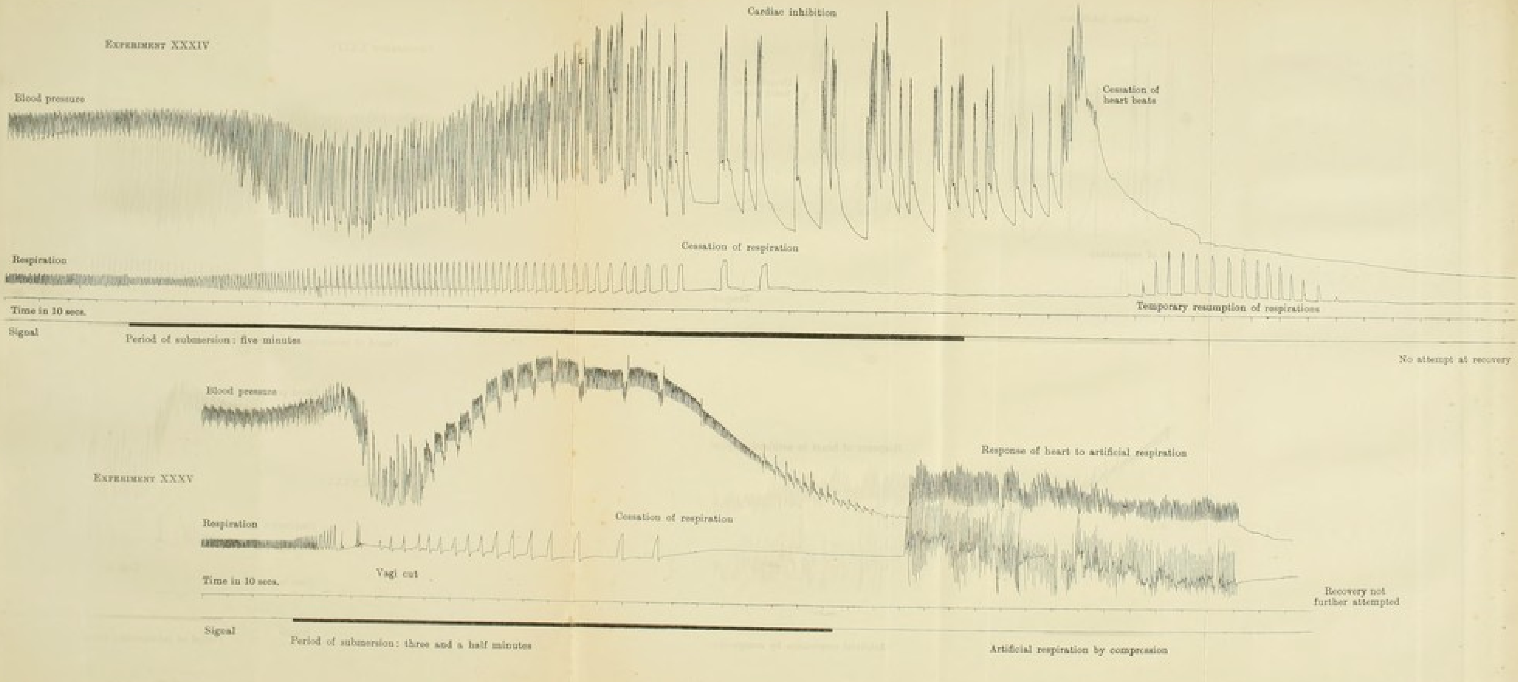

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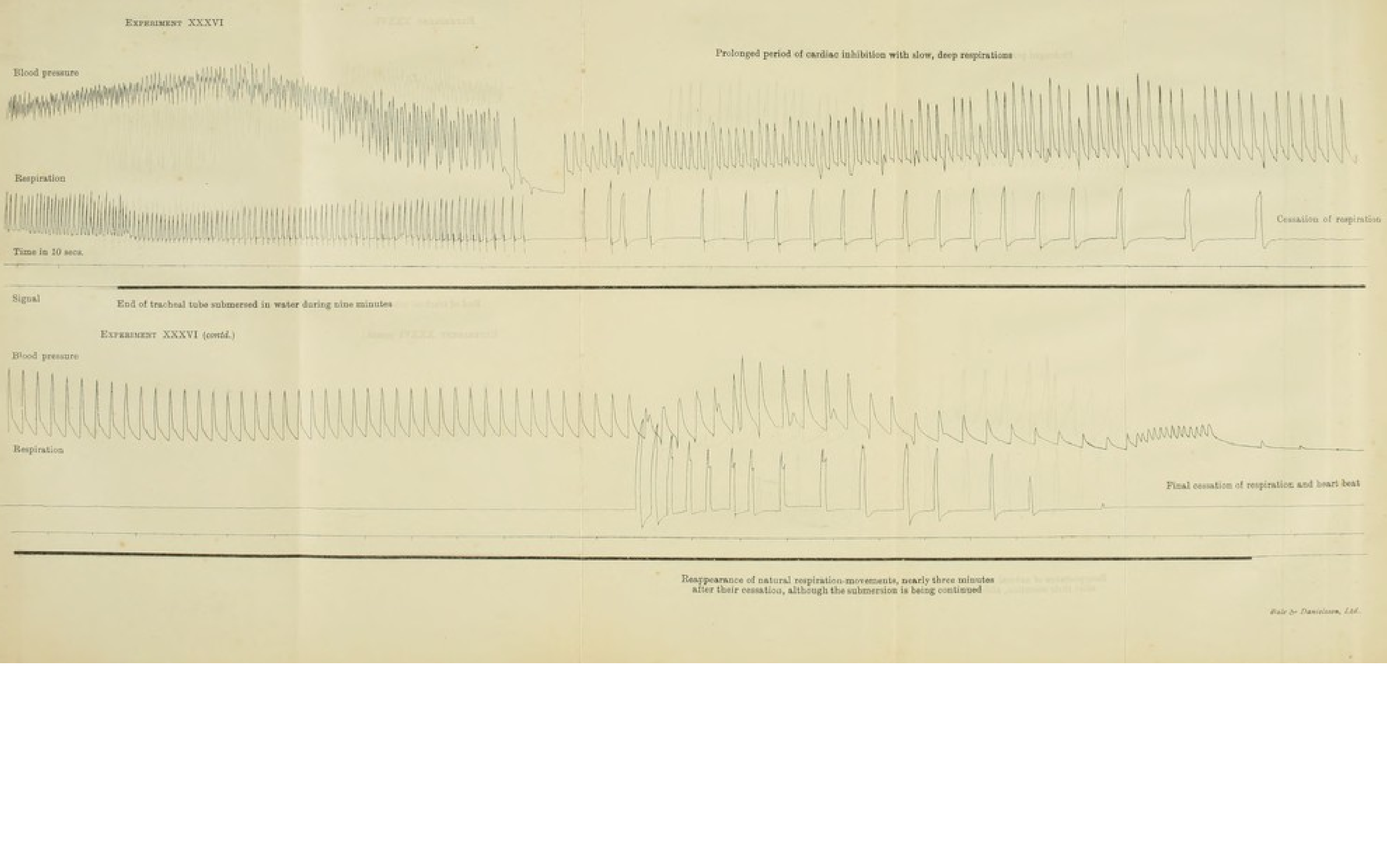
PLATE XX.



Experiment XXXVI
Prolonged period of cardiac inhibition with slow, deep respirations
Blood pressure
Respiration
Cessation of respiration
Time in 10 secs.
Signal
End of tracheal tube submersed in water during nine minutes
Experiment XXXVI (contd.)
Blood pressure
Respiration
Final cessation of respiration and heart beat
Reappearance of natural respiration-movements, nearly three minutes after their cessation, although the submersion is being continued
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