Three Hunterian lectures on the mechanism underlying the various methods of artificial respiration practised since the foundation of the Royal Humane Society in 1774 : delivered in the Theatre of the Royal College of Surgeons of England on March 1st, 3rd, and 5th, 1909 / by Arthur Keith.

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Three Hunterian Lectures

ON

THE MECHANISM UNDERLYING THE VARIOUS METHODS OF ARTIFICIAL RESPIRATION

PRACTISED SINCE THE FOUNDATION OF THE ROYAL HUMANE SOCIETY IN 1774

Delivered in the Theatre of the Royal College of Surgeons of England on March 1st, 3rd, and 5th, 1909

BY

ARTHUR KEITH, M.D. ABERD., F.R.C.S. ENG.

HUNTERIAN PROFESSOR AND CONSERVATOR OF MUSEUM, ROYAL COLLEGE OF SURGEONS OF ENGLAND.

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PRACTISED SINCE THE FOUNDATION OF THE ROYAL HUMANE SOCIETY IN 1774.

LECTURE I.

Delivered on March 1st.

MR. PRESIDENT AND GENTLEMEN,—In order to make clear to you the circumstances which led to the foundation of the Royal Humane Society I wish to carry you, in imagination, back to London of the year 1774. John Hunter was then in his forty-sixth year, a surgeon at St. George's Hospital, with a house in Jermyn-street, where he was collecting, teaching, and experimenting on an income of less than £1000 a year. Close by, in Windmill-street, his elder and successful brother William, with Cruickshank as his assistant, lectured brilliantly to large classes. William Hewson, whose experimental ability equalled that of John Hunter, was established as a teacher and surgeon in Craven-street, Strand, having quarrelled with, and separated from, William Hunter some three years previously, in spite of the friendly negotiations of their mutual friend Benjamin Franklin. Anywhere between the Temple and Leicester-square (then Leicester Fields) one might have encountered Johnson, Reynolds, Goldsmith, or Garrick. The founder of the Humane Society, although known to these four celebrities as well as to the Hunters, was plain Dr. William Hawes, practising in Thames-street and physician to the London and Surrey Dispensaries. In the year of which I speak he was in his thirty-eighth year. He is known to literary men as the friend and medical attendant

of Oliver Goldsmith. By natural constitution he was an enthusiast. A booklet translated by Dr. T. Cogan [1] in 1773 fired him with the purpose of introducing in London the methods practised by a society established in Amsterdam in 1767 for the recovery of the apparently drowned, or dead. He offered rewards, paid out of his own pocket, to all boatmen between Westminster and London Bridges who would rescue and bring ashore the bodies of the drowned so that he might apply to them the methods of the Dutch society. Thus the resuscitation movement which had spread over the continent from Amsterdam reached England in 1773 in the persons of Dr. Cogan and Dr. Hawes. In the London Coffee House on the 18th of April, 1774, these two men brought together 32 of their friends and founded the Humane Society—soon afterwards to have the title "Royal" prefixed. Oliver Goldsmith had died a fortnight previously, over £2000 in debt, but his name appears in the list of founders and subscribers. David Garrick was one of the earliest and most liberal subscribers. In 1776 John Hunter's name appears in the list of directors. Hawes was the leading and moving spirit of the society and continued so until his death in 1812. All the arts of the modern begging philanthropist were already his. He lectured on resuscitation wherever he could find a platform; he petitioned Parliament to erect receiving houses for the drowned or suffocated in every parish in England and to establish schools where medical students might be taught the methods for their recovery.

Methods of Resuscitation Advised by the Society.

In the first report of the Humane Society—and here I must acknowledge my indebtedness to its present secretary, Major F. A. C. Claughton, for giving me free access to the records of the society—we see that the methods first employed were those of the Dutch society. The means were:—1. Warmth. 2. Artificial respiration carried out in the following manner. The operator closed the patient's nostrils and applied his mouth to his and thus inflated the lungs and expanded the belly and chest. By compressing these parts with his free hand the operator brought about an expiratory movement. 3. Fumigation, counted equally as important as the two last measures. By this means the great bowel was filled with tobacco smoke; sometimes all the passengers on a Dutch canal boat might be summoned to assist the operator in administering this means if the special instrument, the fumigator, was not at hand. 4. Rubbing the body—friction. 5. Stimulants applied to the nose or skin. 6. Bleeding from a vein—

[1] See Transactions of the Royal Humane Society, vol. i., pp. 635, 1793, by W. Hawes.

"particularly necessary as life returns." 7. Vomiting, sneezing, and internal stimulants are recommended as accessory and useful means. In little more than 50 years all of these methods were discarded by the Royal Humane Society with the exception of warmth and rubbing.

Methods Previously in Use in England and on the Continent.

It has been said that resuscitation of the apparently dead was a discovery of the latter part of the eighteenth century. To speak more truly, it was only then realised by the medical profession in general and by Dr. Hawes in particular that the resuscitation of the apparently dead was a duty of the medical profession. The laity had practised methods of resuscitation from time immemorial. The earlier reports of the Royal Humane Society throw much light on the means then employed by the laity throughout England.

A surgeon practising in the City of London reports an instructive case in 1775. On riding post-haste along the City Road to assist in the recovery of a boy rescued in an apparently drowned condition from the New River, the surgeon found a crowd collected in front of the "Coach and Horses" witnessing the endeavours of two men who had laid the boy across a barrel, face downwards, still covered by his wet clothes, "and were rolling him with some vigour to get the water out of him." The surgeon carried the boy indoors to apply the methods of the Humane Society. The means he actually used were: he laid the boy on his back, stripped him, applied warmth, rubbing and fumigation, and lastly bleeding, and thus restored, or, as the society claimed, saved, the boy's life. What may be called the "barrel method" had long been prevalent in England; sailors practised it; the method is not yet extinct, for in the most recent records returned to the Royal Humane Society there are instances where the person has been restored by being laid across a wall or fence if a barrel was not at hand. An injunction against this method has been issued every year by the Royal Humane Society since 1774, and it was also forbidden to carry a rescued person across the shoulder or in any position where the head was suspended or the neck flexed. Yet when the method of rolling on a barrel is examined it will be found, as we shall see later, that in principle it has much in common with the method most recently advised—that of Professor E. A. Schäfer.

Another case which throws light both on the methods used by the people and by the medical profession is reported in 1774. A surgeon on being called to a man who had been rescued from the river near the south end of London Bridge, found the patient on the table of a public-house, apparently dead,

his face downwards and hanging over the edge of the table; his body was stripped and being vigorously rubbed with salt, a favourite and prevalent method. The surgeon set him up and drew blood from his arm and then rubbed his head and neck with ammonia. This method of resuscitating by rubbing the body with salt was forbidden at an early date by the society. So was rolling the body on the ground, yet much the same effect is produced on the body by rolling as is obtained by the method which was advised by Marshall Hall in 1856. Inversion of the body or suspension by the heels was then, and still is, a popular method; it, too, was forbidden by the society. The effects of inversion I propose to examine when speaking of postural methods. How far such methods are still practised may be seen from the following extract from a recent report of the Royal Humane Society: "We adopted the usual style of resuscitation, practised at the waterside, Wandsworth—viz., rolling, rubbing, and standing on the head, &c.—very primitive, and unless the person has been long immersed, very effective."

The application of warmth for the restoration of the apparently drowned was also a method used by the people. Shakespeare represents the Queen of Pericles as being restored thus:

> . . . "Make fire within,
> Fetch hither all my boxes in my closet;
> . . . the fire and cloths. . .
> I pray you give her air."
>
> —*Pericles*, Act III., Scene 2.

Although mouth-to-mouth inflation of the lungs had been practised for time out of mind throughout Europe as a means of restoring the apparently dead or drowned, yet the method was not one often employed by the the common people prior to the foundation of the Humane Society. William Hunter spoke of mouth-to-mouth inflation as the method practised by the vulgar to restore stillborn children. That the method was not widely known to medical men in the first half of the eighteenth century one may infer from a paper in the Philosophical Transactions for 1744 by Dr. John Fothergill,[2] practising in the City of London, on its efficacy. The article was occasioned by the report of a successful case in which Dr. Wm. Tossack of Alloa had by mouth-to-mouth inflation recovered a miner who was apparently dead from suffocation. Dr. Fothergill mentions the use of the bellows as an alternative means but prefers mouth-to-mouth inflation. The use of the bellows had long been known to anatomists as a means of restoring and keeping animals alive during experiment, and bellows were apparently occasionally used by the laity in restoring animation. It will be thus seen that the societies which were established throughout Europe in

[2] Philosophical Transactions, 1744, vol. xliv., p. 275.

the latter half of the eighteenth century merely systematised and made accessible the ordinary means already in use; no new methods were introduced.

Experiments and Recommendations of John Hunter.

Dr. Hawes, the founder of the Humane Society, had a profound admiration for John Hunter and he appealed to him in 1776 to advise the society as to the best means for the restoration of the apparently dead. Hunter[3] turned to the records kept by him of experiments and founded his reply to Dr. Hawes on certain investigations which had been carried out while he was assistant to his brother in 1755—the year in which he made a passing visit to Oxford as a student. These investigations dealt with the influence of the lungs on the heart. He exposed the contents of the thorax of dogs by removing the sternum and then performed artificial respiration by a double-chambered bellows—his own invention—one chamber being used for filling, the other for exhausting the lungs. "When I stopped the motion of the bellows," he writes, "the heart became gradually weaker and less frequent in its contractions, till it entirely ceased to move. By renewing the action of the bellows the heart again began to move, at first very faintly, and with long intermission; but by continuing the artificial breathing its motion became as frequent and as strong as at first. This process I repeated upon the same dog ten times, sometimes stopping five, eight, or ten minutes, and observed that every time I left off working the bellows the heart became extremely turgid with blood, the blood in the left side becoming as dark as that in the right. These situations of the animal appeared to me exactly similar to drowning." He inferred "that restoration must therefore depend immediately on the application of air to the lungs." He further inferred from his experience that the restoration of the circulation did not take place because the nervous system was again supplied with arterial blood but because air thrown into the lungs exerted a reflex effect on the heart; restoration in his opinion was not due to the heart being again supplied with arterial blood but to a "reflex effect." On that belief he founded the principles of his treatment. He recommended: 1. That air be thrown into the lungs by properly constructed bellows, suggesting at the same time that oxygen—discovered two years previously (1774) by Priestly—might prove more efficacious than common air. 2. The gradual application of warmth. An incident which he relates in this connexion (the gradual application of warmth) I cannot forbear quoting because it throws some light on his boyhood days at Long Calderwood.

[3] Collected Works, Palmer's edition, vol. iii., p. 79.

"I observed many years ago," he writes, "in some of the colder parts of this island, that when intense cold has forced blackbirds or thrushes to take shelter in outhouses, such of them as had been caught, and were, from an ill-judged compassion, exposed to a considerable degree of warmth, died very soon. The reason of this I did not then understand; but I am now satisfied that it was owing, as in other instances, to the degree of heat being increased too suddenly for the proportion of life remaining in the animal." 3. He recommended also the application of stimulants to the nose, to the skin, and to the lungs, and also to the stomach through an œsophageal tube, and to the bowels by steam and enemata administered per anum. As auxiliary measures he regarded forced movements and electricity as worthy of trial, but condemned blood-letting and emetics and fumigations of tobacco.

The closing paragraph of his reply to Dr. Hawes has a close bearing on these lectures and I quote it at length: "I shall therefore conclude this account by proposing that all who are employed in this practice be particularly required to keep an accurate journal of the means used and the degree of success attending them, whence we may be furnished with facts sufficient to enable us to draw conclusions on which a certain practice may hereafter be established." During the 133 years that have elapsed since Hunter penned this wise suggestion no one, so far as I know, has consulted the records accumulated by the Royal Humane Society. Major Claughton, the present secretary of the society, has placed these records most freely at my disposal and although, especially as regards the earlier periods of the society, their scientific value has been lost sight of, yet there remains a great body of most valuable material, especially in the more recent records, which will assist us to determine the relative value of the various methods of resuscitation.

Cullen's Recommendations.

In 1776 Dr. Hawes also consulted Dr. W. Cullen, then professor of physic in the University of Edinburgh and at the zenith of his fame, but Cullen's recommendations are addressed not to Dr. Hawes but to Lord Cathcart, then President of the Board of Police in Scotland.[4] His recommendations, almost a copy of the Dutch methods, are in the following order: (1) the application of warmth; (2) stimulants per anum, preferably tobacco smoke per anum; (3) inflation of the lungs by bellows after the manner discovered by Monro (secundus), then professor of anatomy; (4) blood-letting—from the jugular for preference—a procedure recommended 60 years afterwards by my old teacher Pro-

[4] A Letter to Lord Cathcart, Edinburgh, 1776.

fessor Struthers; (5) application of stimulants; and (6) the French method of giving emetics may also prove useful Every church door and market place throughout Scotland was placarded with Cullen's letter. A case of instruments, a pair of bellows, nozzles, tubes and fumigator were recommended—price £1 9*s*. 6*d*. Thus while Hunter, "the inductive philosopher," gave artificial respiration first place, Cullen, the deductive philosopher, assigned the first to warmth.

Experiments and Recommendations of De Haen, Fothergill, Goodwyn, and Kite.

Amongst the investigations which placed the means of resuscitation on a secure basis, those of A. de Haen[5] must take a foremost place. He was professor of medicine at Vienna. In 1772, two years before the Royal Humane Society was established and four years before the recommendations of Hunter and of Cullen appeared, he published the results of a prolonged experimental inquiry into the phenomena of drowning and resuscitation as seen in dogs. Contrary to the belief of his time, indeed, I may say contrary to the belief which persisted for nearly a century after his publication, he found that water did enter the lungs in the act of drowning and he therefore commended the inversion of the body and other means of expressing the water from the lungs—means which we have seen were condemned by the Dutch and English societies. The other means he recommended were the usual ones: warmth; inflation either with bellows or by the mouth-to-mouth method; friction of the body; stimulants to the nose, skin, and feet; and fumigation. Two other remarks of this same observer are worthy of note: (1) the crowd always over-estimates the time of submersion; and (2) the uninitiated are over-impressed by the success of a single instance. The history of resuscitation illustrates very frequently the truth of these two statements.

By 1782 the Royal Humane Society recommended inflation by bellows in preference to the mouth-to-mouth method. Much ingenuity was spent on the improvement of the technique of inflation. I am able to show from the College Museum two outfits for the resuscitation of the apparently drowned, and others may be seen in the Museum of the Royal Humane Society at the Receiving House on the Serpentine. The two outfits belonging to our Museum were in use more than a century ago and are but little modified from the pattern designed in 1786 by Charles Kite, a surgeon at Gravesend, and adopted by the Royal Humane Society. Each outfit contained a pair of bellows with a capacity of 500 cubic centimetres

[5] Abhandlung ueber die Art des Todes der Ertrunkenen, Wien, 1772.

(those recommended by Monro of Edinburgh had a capacity of 1500 cubic centimetres) and so fitted with valves that they could be used to exhaust as well as to inflate the lungs. That it was not usual to employ them for emptying the lungs is shown by the operator being instructed to employ an assistant to compress the epigastrium when the chest was seen to heave after each inflation. Several tubes and nozzles were supplied, inflation being made by placing a nozzle in one nostril and closing the other as well as the mouth by the help of a second assistant. The first assistant not only attended to the expiratory compression of the thorax but also kept the cricoid lightly pressed backwards to prevent the inflated air passing down the œsophagus. E. Goodwyn,[6] who carried out a series of experiments on drowning and resuscitation and also observed that a small amount of water did enter the respiratory system in drowning, discovered that the tongue might fall back and the opening of the larynx be thus occluded. Monro had overcome such obstructions by passing a catheter into the larynx by way of the mouth—a process of inhalation commended for another purpose by Sir William Macewen in 1880. With the outfit there was also supplied a stomach-tube—such as was commended by Hunter—and a modification of the elaborate fumigator designed by Dr. Cogan in 1775, with a bowl which took one and a half ounces of tobacco and the necessary tubes and bellows for inflating the rectum. Flint, steel, and a tinder-box were also part of the outfit; there is still some tinder in one of the museum boxes. It is worthy of note that Dr. A. Fothergill[7] between 1781 and 1783 carried out some experiments showing the efficacy of oxygen as compared with air in the resuscitation of animals and pressed the adoption of this method on the Royal Humane Society—Achard of Berlin had also found its use advantageous. Lately the experiments of Dr. Leonard E. Hill have roused interest in oxygen as a means of relieving dyspnœa; I find that it has been recommended time after time since the foundation of the Royal Humane Society as a means of restoring the asphyxiated.

Artificial Respiration by the Use of Bellows.

From 1782 onwards bellows are recommended by the Royal Humane Society as the best means of carrying on artificial respiration, but in many of the cases recorded no mention is made by the resuscitator of having used them. For 40 years no one had a word to say against them; they were used in every country. In 1829, however, a memoir, published in France by Leroy,[8] relegated the bellows to

[6] The Connexion of Life with Respiration, London, 1788.

[7] Report of the Royal Humane Society, 1783.

[8] See Magendie's Journal de Physiologie, 1829, tome ix., p. 187.

their former place by the fireside. Leroy found (1) that it was possible to kill an animal by suddenly inflating its lungs; and (2) that it was possible to produce emphysema of the lungs and pneumothorax in dead animals; no mention of the force used is made, but Champneys in experiments carried out on dead infants and published in 1887 found that he had to use a pressure of from 20 to 80 millimetres of mercury to produce such effects, whereas the lungs can be distended while still inclosed in the thorax to the extent of 500 cubic centimetres and more at a pressure under 10 millimetres of mercury. But the fact which damned the use of the bellows was Leroy's statement that the lungs of those on whom inflation had been unsuccessfully performed were frequently emphysematous. He was unaware that emphysema is commonly seen in the lungs of drowned beings who have had no artificial respiration performed on them. It was not until the publication of Paltauf's memoir[9] in 1888 that emphysema was recognised as a consequence of drowning. A pair of bellows of the capacity recommended by Monro and in the hands of a vigorous operator could easily produce the effects pictured by Leroy. Leroy himself did not lose faith in the bellows; he supplied a form in which the capacity of the instrument could be regulated according to the age of the individual operated on. Leroy's experiments alarmed the Royal Humane Society; Mr. John Dalrymple, afterwards a member of the Council of this College, drew up a report of Leroy's paper for the society; the bellows fell into disgrace and in 1837 disappeared from the list of methods recommended by the society.

Experiments and Recommendations of Sir Benjamin Brodie.

The relegation of the bellows was not altogether the result of Leroy's memoir; their disuse is rather to be ascribed to a past President of this College, Sir Benjamin Brodie.[10] In 1821, then in his thirty-eighth year and rising to the top of his fame as a surgeon, he gave in this theatre as Hunterian professor three lectures on asphyxia. His lectures were founded on experiments carried out ten years before when he was a lecturer at the Windmill-street School—the medical school established by William Hunter. In these lectures he stated dogmatically that there were few cases of drowning in which artificial respiration would prove of any service. His reason for this statement was that in from two to three minutes after respiration ceased the heart stopped and when that occurred artificial respiration was powerless to restart

[9] Ueber den Tod durch Entrinken, Wien und Leipzig, 1888.

[10] Brodie's Collected Works, by C. Hawkins, vol. i., p. 407; also Philosophical Transactions, 1811, vol. ci., p. 178.

it. Artificial respiration was only of use, in his opinion, when it could be applied before the heart had stopped and such cases would generally recover without any assistance. On the lay mind of his day Brodie wielded a most potent influence, and this was particularly the case with the Royal Humane Society in which he took great interest. Even in 1862, when mortally ill, he maintained, when the merits of the Marshall Hall and Silvester methods were being discussed by the society, that artificial respiration was of secondary importance, but if required he advised the inflation method rather than that of Marshall Hall or of Silvester. Indeed, from 1830 to 1855 artificial respiration was regarded as an altogether secondary measure in the restoration of the drowned. We shall see that the results during this period show no increase in the number of unsuccessful cases of resuscitation. "It is a singular fact," writes Dalrymple in a report to the Royal Humane Society in 1835, "that one of our most active and useful medical assistants, Mr. Woolley, residing near the Serpentine, in all the cases in which he has been successful in restoring suspended animation, has never performed the operation of inflation of the lungs, and in all these cases where he did use the bellows his exertions were of none avail." During the period in which artificial respiration was in abeyance the chief treatment lay in the application of warmth—treatment commencing with the immersion of a patient in a bath at about 100° F.

The Experiments and Recommendations of Erichsen.

If the relegation of the bellows was the work of one past President of this College, their restoration, or rather partial restoration, was the work of another. In 1845 Mr. John Erichsen was awarded the Fothergillian medal by the Royal Humane Society for his essay on An Experimental Enquiry into the Pathology and Treatment of Asphyxia.[11] The chief conclusion of his inquiry was that, if artificial respiration failed to restore animation, then warmth applied in any form whatsoever would also fail; in his opinion if it were possible to resuscitate at all, then artificial respiration was the only certain means and ought always to be applied. He considered the inflation of hot air was superior to the use of cold air and that the addition of oxygen had enabled him to resuscitate a greater proportion of asphyxiated animals. He invented a machine for administering a warm oxygen-laden air to the apparently drowned. F. Sibson[12] in 1848 modified a chloroform mask in such a way that when it was applied to the patient's face with a tube attached to it the surgeon could inflate the lungs by blowing into the tube and

[11] Edinburgh Medical and Surgical Journal, January, 1845.
[12] Collected Works, edited by Wm. Ord, 1881, vol. iv., p. 369.

at the same time be able to compress the chest to produce expiration. In spite of all the improvements and modifications of the technique and the method of inflation by bellows the instrument never again came into favour and was speedily forgotten when the various means of compressing and expanding the chest were introduced towards the end of the sixth decade of the nineteenth century.

The Application of Tobacco Fumes.

The history of fumigation as a means of restoring the apparently drowned illustrates how quickly and how unreasonably a method at one time extensively used may fall into disrepute. When the Royal Humane Society was founded the distension of the rectum and colon with tobacco smoke was very extensively used for the purposes of resuscitation. The record of case after case bears witness to the success ascribed to this method. It is true that John Hunter and afterwards Coleman criticised its efficacy on theoretical grounds. Three experiments by Brodie in 1811 (he was then in his twenty-eighth year) brought the practice to an abrupt close. He found that four ounces of a strong infusion of tobacco, administered per rectum, could kill a dog, and one ounce a cat. Nicotine was a cardiac poison. The Royal Humane Society became alarmed and relegated fumigation to the list of forbidden methods. During the previous 40 years the method had been found to succeed in hundreds of cases and had been warmly commended by the society; three crude experiments by a young surgeon were sufficient to overturn 40 years' of experience.

The Condition of the Lungs in the Asphyxiated.

Before proceeding to discuss the best means of artificial respiration for restoring animation to the apparently drowned, it is very important that we should have a clear picture of the condition of their lungs. We have seen that there was much debate as to whether or not they contain water; throughout the whole of the period with which I am at present dealing (1774–1860) it was generally believed that they did not; de Haen and Goodwyn found that they did. The first Resuscitation Committee of the Royal Medical and Chirurgical Society, which reported the results of its investigations in 1862,[13] placed our knowledge of this matter on a sure basis; it found that water was drawn freely into the lungs during the act of drowning. Paltauf added very considerably to our knowledge by showing that not only did

[13] Report of First Resuscitation Committee, Transactions of the Royal Medical and Chirurgical Society, 1862, p. 449.

water pass freely into the lungs but also that it was rapidly absorbed by them. When the animal was drowned in a coloured fluid medium the lymph tracks in the lungs became quickly stained. It is, however, to the fourth Resuscitation Committee (1889–1903), or, to state the matter accurately, to Professor Schäfer, that we owe our most accurate knowledge of the absorption of water by the lungs in the act of drowning. He found that the amount taken into the lungs of dogs varied greatly. The sixth dog of his experimental series took 780 cubic centimetres of water into its lungs during an immersion of five minutes and recovered spontaneously. He found that the air expired in the act of drowning was equal to only a fraction of the water taken into the lungs. A specimen from the collection in the Museum of the Royal College of Surgeons of England of the lungs of a cat drowned in water containing plaster-of-Paris shows that the air-passages from the trachea to the terminal bronchioles are filled with plaster; near the roots and along the dorsal parts the plaster has even reached the infundibula and air cells. The lungs of drowned persons are large and do not collapse: (1) because their capillaries are overladen with blood; (2) because the air passages and spaces of the dorsal and deeper parts of the lung are filled with water; and (3) because the anterior (ventral) and diaphragmatic parts of the lung are distended with air. The appearance of the lungs gave rise to the ancient belief that the drowned and hanged died in the act of inspiration. The parts of the lungs which become emphysematous in the act of drowning are those which are most liable to this condition in common respiratory diseases. I do not propose to discuss now the cause of emphysema, but those interested will find this condition very thoroughly analysed by N. Ph. Tendeloo.[14] The capillary system of the lung is often seriously damaged. How often the froth that exudes from the respiratory passage is blood-stained I cannot discover; in the records—often very brief—of the Royal Humane Society it is occasionally noted. I had an opportunity of examining the lungs of the walrus which was accidentally drowned in the Zoological Gardens during the present winter. Mr. William Pearson, prosector of the College, poured a solution of plaster-of-Paris into the trachea; we were surprised to note that in several of the deeper parts of the lungs it had also passed into the smaller veins; we were able to trace these veins to infundibula full of plaster-of-Paris. On microscopic examination large areas of the lungs were found to be full of blood from rupture of the smaller vessels. At these points of rupture the plaster entered the vessels. I infer that air would also have entered into the veins if artificial resuscita-

[14] Studien ueber die Ursachen der Lungen-Krankheiten, Wiesbaden, 1902, pp. 470.

tion had been applied. Is it not possible—nay, probable—that some of the cases which died suddenly after being partially restored are killed by air embolism? Out of six cases of asphyxia in young children Dr. Ivy McKenzie[15] found large pulmonary extravasation of blood in one, and minute extravasations in four. Whichever form of resuscitation be adopted it is important that the condition of the lung be kept in mind.

Inflation of the Lungs contrasted with Natural Breathing.

Inflation of the lung does not produce a pulmonary movement similar to that which takes place either in a natural inspiration or in an inspiration produced by an artificial expansion of the chest. When air is blown into the lungs those parts expand—as J. Hutchinson[16] demonstrated in 1852—which are situated against the most yielding parts of the thoracic cavity. The most yielding wall is (1) the diaphragmatic and (2) the anterior sterno-chondral wall. Hence when the lungs are inflated the chief movement seen is one at the epigastrium. The water-logged parts of the lungs lying against the rigid apical and dorsal walls are expanded to a much less extent. The resistance offered by the thoracic wall to the expansion of the lungs was found by Hutchinson to be very considerable. In two men, just dead, he found that a pressure of 30 millimetres of mercury was necessary to introduce 1000 cubic centimetres (twice the amount necessary for resuscitation), whereas when he removed the lung from the thorax he could introduce 1500 cubic centimetres at a pressure of 10 millimetres of mercury. In one case in which he inflated the lungs while *in situ* he found that they ruptured when 1460 cubic centimetres had been introduced at a pressure of 37·5 millimetres of mercury. Inflation differs also from natural inspiration in its action on the blood-content of the lung; whereas inflation diminishes the amount of blood and lymph in the lung by forcing on the blood and lymph along their courses natural inspiration serves to increase the volume of blood and lymph within the lung. The expiratory movement caused by compressing the epigastrium and anterior wall of the sternum does not differ materially from the effect of a natural expiration. Compression applied to the anterior wall of the chest acts chiefly on the anterior part of the lung—the dorsal and apical parts are but slightly affected. The pressure applied serves to empty the lung of air and blood.

[15] Journal of Anatomy and Physiology, 1906, vol. xl., p. 120.

[16] Todd's Cyclopædia of Anatomy and Physiology, 1852, vol. iv., article "Thorax."

LECTURE II.

The Period of Mechanical Expansion and Compression of the Chest Wall (1856-1909).

Delivered on March 3rd.

Methods of Compression employed prior to 1856.

Mr. President and Gentlemen,—Although I have dated the commencement of this period with the introduction of Marshall Hall's method in 1856,[2] it must not be thought that artificial movements of the chest wall had not been intentionally practised before this date. In the report of the Humane Society for 1812 it is recommended, if bellows are not at hand, that the surgeon should practise alternate compression and relaxation of the abdomen rather than resort to the method of mouth-to-mouth inflation, because the exhaled breath was regarded then as poisonous. Astley Cooper recommended intermittent pressure of the chest and belly as the best means of resuscitation, a method he had seen (in his boyhood days, I suppose) employed by a surgeon in Yarmouth with great success. The first, however, to give his mind to the perfecting of this method was Leroy of Paris. In 1829 he saw that the bellows in the hands of ignorant operators might become a lethal weapon, and to replace them he proposed artificial respiration by a method similar to that introduced by Howard 42 years later. Leroy's method consisted in laying the patient face upwards and compressing the anterior wall of the abdomen and thorax, thus producing expiration, inspiration resulting from the elastic rebound of the chest wall. Semple, a surgeon of Islington, also practised this method—independently of Leroy. Dalrymple, on reviewing Leroy's method in the report of the Royal Humane Society of 1831, suggested, in place of Leroy's front-to-back compression of the thorax, a side to side compression either by the direct application of the hands or, better, by a wide (18 inches) many-tailed bandage

[2] Marshall Hall: Prone and Postural Respiration in Drowning London, 1857 (edited by his son).

placed round the patient's body. The drowned person was laid on his back and the bandage was passed beneath him, its ends being crossed in front of the chest. An operator on each side of the body constricted the thorax by pulling on the crossed ends, then relaxing their hold allowed a recoil and inspiration to occur. Dalrymple's bandage continued to be figured and recommended by the Royal Humane Society from 1833 until Silvester's method was introduced, but its use is seldom recorded.

Marshall Hall's Method.

Mechanical movements of the chest wall as a means of producing artificial respiration were never seriously considered until they were advocated by Dr. Marshall Hall. In 1855, being then in his 65th year, he came across, on his return from a long holiday on the continent, the instructions issued by the Royal Humane Society for the resuscitation of the apparently drowned. He observed that all mention was omitted of artificial respiration, and he probably was well aware that the omission was owing to Sir Benjamin Brodie's influence. Impressed with the dangers of inflation by the bellows, a fear founded on the experiments of Leroy, he carried out a series of most ingenious experiments from which he concluded that the condition of drowning was one of anæsthesia and poisoning by a surcharge of carbon-dioxide. While experimenting on the dead human subjects at St. George's Hospital, assisted by Dr. Robert L. Bowles, Marshall Hall found—as Goodwyn had discovered 70 years before—when the patient was supine, that the tongue and larynx were apt to fall back and occlude the air passage. When the patient was placed in the prone position this difficulty was avoided. The ancient process of rolling the body as a method of resuscitation was well known to him. His reason for commencing with the body in the prone position was the result of experiments on the dead body. Compression of the chest which failed to produce artificial respiration when the body was in the supine position succeeded when it was turned face downwards. (Figs. 1 and 2.) He named his method the "ready" or "postural" method; he produced expiration by (1) turning the patient in the prone (face down) position; and (2) by applying pressure to the back—over the thorax and abdomen. Inspiration commenced the moment this pressure was withdrawn and was completed by rolling the patient on to his side. The manner in which the body is turned over is important; the operator placed one hand *under the shoulder* and another under the hip. When the shoulder is thus lifted every muscle passing to the sternal and lateral aspect of the chest becomes taut and tends to expand the thorax. The two most essential features of

Marshall Hall's method are often forgotten [3]—the expiratory compression of the thorax and the inspiratory traction of the shoulder muscles. The gaseous exchange effected by this method in the dead body was determined by the first Resuscitation Committee of the Royal Medical and Chirurgical Society in 1862 and was found to vary from 70 to 240 cubic centimetres. Within a year from the date of the publication of his method—that is, in 1857, the year in which he died—Marshall Hall was able to announce 23 cases of successful

FIG. 1.

Marshall Hall's method. Inspiratory phase.

FIG. 2.

Marshall Hall's method. Expiratory phase.
(From the "Instructions" issued by the National Lifeboat Institution.)

recovery from drowning by the employment of his method and one fatal case in which his method was not applied, besides three recoveries from chloroform syncope. It is worthy of note that everyone in the long train of inventors which followed in Marshall Hall's footsteps was also speedily in a position to show a long and impressive list of successes.

[3] In the official instructions issued by the National Lifeboat Institution instructions are confined merely to turning the patient over.

The Mechanism of Respiration in Dr. Marshall Hall's Method.

Since the principles underlying the Marshall Hall method are those involved in the greater number of methods of artificial respiration it is important to examine them now somewhat closely. The possibility of carrying on artificial respiration by a process of compression depends on the resiliency of the thoracic walls—on their tendency to resume their natural position when pressure is withdrawn. This property depends on: (1) the tension of the ligaments which bind the ribs to the vertebral column and limit the extent of the costal movement—when the ribs are depressed beyond their functional extent (under 45° to the spinal column) a strain is thrown on these ligaments; (2) the bending of the ribs and especially of their cartilages; (3) the stretching of all the muscles which are attached to ribs; and (4) the compression of the liver, the heart, the lungs, the spleen, and intestines, which in asphyxiated persons may be regarded as sacs filled with semi-fluid contents. When the compressing force is withdrawn the strain on all these parts is *gradually* undone by their return to a state of rest. During the rebound the lungs are more or less distended.

I carried out observations on a series of dead and living bodies to discover how far the resiliency of the thorax was altered by turning the body on its face.[4] Five bodies were employed, varying in age from 40 to 70 years; they were subjects from which rigor mortis had passed off. On turning the bodies from the supine to the prone position I found the back-to-front diameter of the chest to diminish 21·4 millimetres, while the side-to-side diameter increased 13·5 millimetres, the capacity of the chest, as shown by the escape of air, amounting to a little over 60 cubic centimetres. When a weight equal to 28 pounds was placed on the chest of the supine body the front-to-back diameter decreased 29·6 millimetres; when placed on the prone body the decrease was only 4·6 millimetres. Further, the recoil is slower in the prone position than in the supine; after applying pressure to a body in the prone position five minutes elapsed before the front-to-back diameter attained to within 5 millimetres of its original measurement, whereas in the supine position it reached within 2 millimetres of its original extent in one-third of a minute. Intermittent pressure applied at the rate of 15 times per minute quickly diminished the capacity of the chest in the dead, for each subsequent pressure is applied at an earlier stage of the rebound. It was undoubtedly to avoid this effect that Marshall Hall proposed to alternate pressure in the prone position with a lateral turning movement. In the prone posture the

[4] London Hospital Gazette, June, 1908, p. 206.

capacity of the chest and both the extent and rapidity of its resiliency are diminished. The essential acts in the Marshall Hall method are: (1) the expiratory pressure applied to the back when the body is prone; and (2) the inspiratory traction exercised on chest wall on turning the body over by lifting the shoulder.

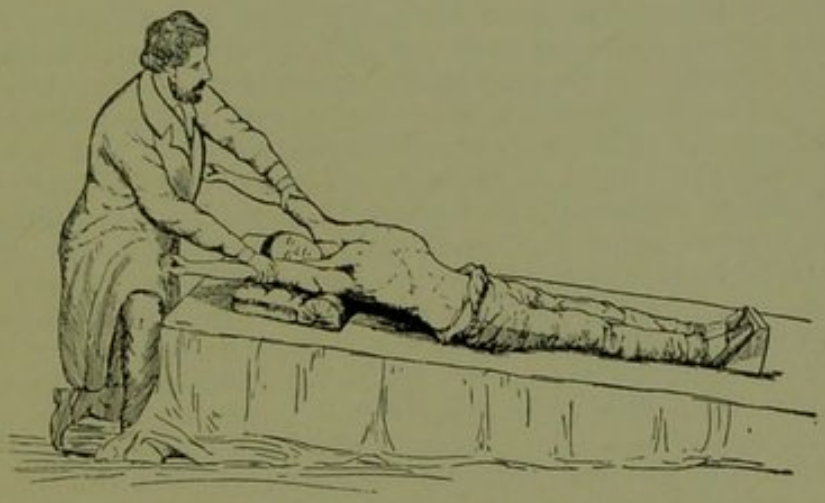
The Mechanism Underlying Silvester's Method.

When the merits of Marshall Hall's method were being discussed by the Royal Humane Society, Silvester, a young practitioner in South London, introduced to its notice a method he had worked out on quite a new principle. The method was adopted by the society in 1861 and still remains its official method. The work of Silvester is of special interest to all connected with this College. He was one of the last of the student assistants paid and taught by the Council of this College to assist in the Museum when Owen was conservator. They were engaged by the College in the hope that when they went out into the world the Museum and its needs would be kept in mind. I have here the note-book in which Silvester kept a record of his original dissections. Soon after leaving the service of the College he published an account of his method of artificial respiration.[5] His aim was to imitate the natural respiratory movements. (Figs. 3 and 4.) He selected the supine posture, producing inspiration by expanding the chest wall and expiration by compressing it. His inspiratory movement is an example of applied anatomy. Traction was exercised on the anterior wall of the thorax through the great and small pectoral muscles. The operator stands at the patient's head and seizing the arms above the elbows lifts them towards the patient's chin, thus making the pectoral muscles taut. The tautness is much increased, as Champneys pointed out in 1887, if the arms be everted or rotated outwards as they are lifted. The arms are then carried back towards the patient's ears; the humerus and shoulder are thus used as levers and the anterior wall of the chest is raised upwards and forwards. The part of the lung expanded is chiefly that which lies under the sterno-chondral wall—the part which in drowning already contains the greatest amount of air. Expiration is produced by pressing the patient's arms firmly against the anterior wall of the chest. All experimenters are agreed that Silvester's is the most effective method of producing an ample ventilation of the lungs. The first Resuscitation Committee of the Royal Medical and Chirurgical Society (1862) commended it as the best method. In most dead sub-

[5] The True Physiological Method of Restoring Persons Apparently Drowned or Dead. London, first edition, 1858; third edition, 1863.

jects—*but there is a considerable proportion in which every method fails*—a respiratory tide, varying from 300 to 500 cubic centimetres, can be produced by Silvester's method. Unfortunately, it is a laborious and exhausting method and one which is only effective when applied expertly. It differs

FIG. 3.



Silvester's method. Inspiratory phase.

FIG. 4.

Silvester's method. Expiratory phase.

in one very important point from nearly all other methods; the movements affect chiefly the upper part of the thorax; it is a thoracic form of artificial respiration, whereas nearly all the other methods give a movement of the abdominal type.

Experiments of Benjamin Ward Richardson.

Although Ward Richardson[6] introduced no new method of artificial respiration, yet his inquiries (1865) into resuscitation of the apparently dead deserve our attention, for they are amongst the most important carried out in the nineteenth century. He found, as Benjamin Brodie and Erichsen had observed, that artificial respiration was powerless to resuscitate the heart if once its movements had ceased. He observed that inversion of the animal caused the surface of the lung to become again suffused with blood, but the pulmonary pressure thus raised was not sufficient to force blood through the lungs. He found that warm air or air laden with oxygen was more potent to resuscitate suspended animation than air at the ordinary temperature or of the usual composition. He was able to resuscitate the heart of a child which had been 12 hours dead by injecting its arteries with a fluid saturated with oxygen. He wished to convey such a solution to the heart of animals apparently dead by injecting it into the jugular vein with sufficient force to send it through the pulmonary circulation, but he found that the necessary force led to rupture of the pulmonary vessels. He then attempted to reach the heart through the arterial system and found that an oxygen-laden solution forced into the arteries with rhythmic strokes might reawaken the heart. In 1906 Crile and Dolley,[7] unaware of Richardson's researches, published a series of experiments showing that the heart could be resuscitated ten minutes after circulation had ceased by means similar to those proposed by Richardson. Two inferences drawn by Richardson from his experiments may be accepted as representing our present knowledge of the principles of resuscitation: (1) Resuscitation is possible by artificial respiration so long as there is a pulmonary circulation; and (2) it is also possible after circulation has ceased and before coagulation has commenced if the blood can be drawn or forced through the lung with sufficient pressure to enter the arteries of the heart.

Methods of Pacini and Bain.

In 1867 Pacini[8] of Florence introduced a method which, as regards the principle on which it is founded, is a modification of Silvester's. The supine posture is adopted and the patient's feet are fixed to the table so that the body may not

[6] Proceedings of the Royal Society, June 15th, 1865, p. 358.

[7] Journal of Experimental Medicine, 1906, vol. viii., p. 713.

[8] Bain, W. P.: Transactions of the Royal Medical and Chirurgical Society, Dec. 8th, 1868.

move when the operator standing at the patient's head applies his strength. The manipulation carried out by the operator may be described as a "passive shrugging of the shoulder"; the shoulders are seized with the thumb in front of, and the fingers behind, the head of the humerus; as the operator pulls and lifts the shoulders towards the patient's ears the pectoral muscles passing to the front of the chest and the latissimus dorsi passing to its side become stretched and cause an inspiratory movement of the ribs—chiefly the upper. Expiration is caused by the recoil which follows relaxation of the shoulders. The Pacini method is also laborious and the passive expiratory recoil requires to be aided by active pressure to be really effective.

In the following year (1868) Dr. W. P. Bain on returning from Italy made Pacini's method known in England. He modified the manner in which Pacini grasped the shoulders so that the movements of the clavicle might be made more effective. He also introduced a method which is deserving of attention because it represents the effective part of one of the most ancient methods of resuscitation and one which I find from the records of the Royal Humane Society is still much in use—viz., that known as "agitation of the body." From 1774 onwards the Royal Humane Society had condemned agitation or manipulation of the body by the limbs. Bain observed that when he seized the hands of a dead subject—which lay on its back on the floor—and attempted to lift it by drawing the arms towards him an inspiratory movement occurred varying in amount from 80 to 300 cubic centimetres. He found that most effect was produced by standing at the head of the passive subject and then pulling and lifting the body by the hands towards him. The feet of the subject require to be held or fixed. The method is laborious and needs the application of pressure to the chest to make expiration effective. The second Resuscitation Committee was instituted to inquire into the merits of the Pacini-Bain method but it never really proceeded to work.

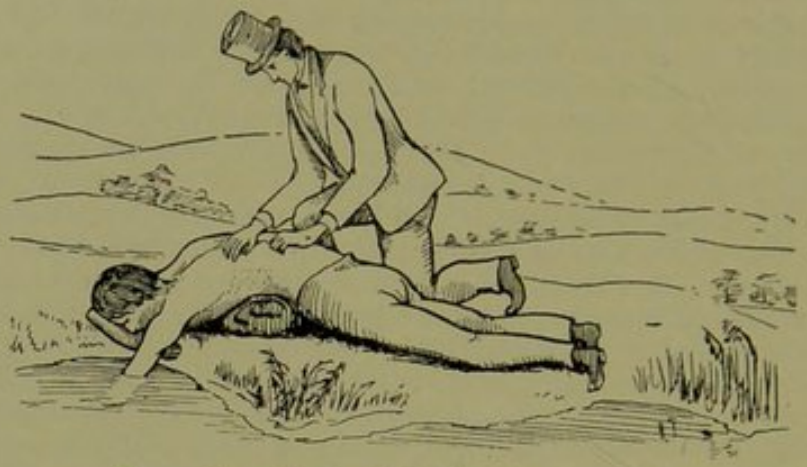
Howard's Method.

In 1871 Dr. Benjamin Howard[9] of New York introduced another method of artificial respiration. In teaching the police of New York he found that the methods of Marshall Hall and of Silvester were too complicated to be clearly understood and readily applied by non-professional assistants. His aim was to discover a method which was at once simple and effective; as a preliminary measure the body of the patient is turned face downwards and is compressed to expel

[9] The Direct Method of Artificial Respiration (Prize Essay), Transactions of the American Medical Association, 1871; The Lancet, August 11th, 1877, p. 194.

the water. The patient is then turned face up and artificial respiration applied. The principles underlying Howard's method are the same as were utilised by Leroy, Dalrymple, and Marshall Hall—viz., expiration by compression and inspiration by the recoil of the chest wall. (Figs. 5 and 6.) In order to secure as great a degree of recoil as possible, he

FIG. 5.



Howard's method. Preliminary compression.

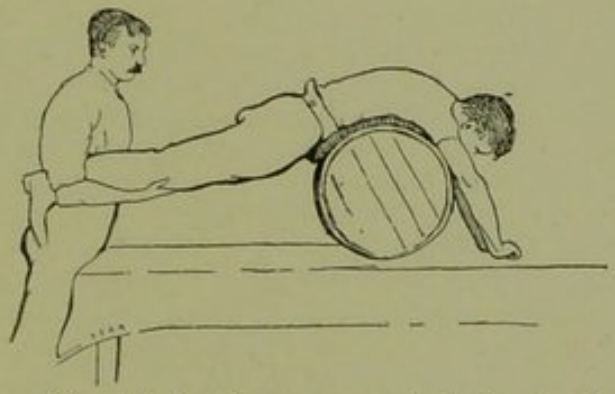
FIG. 6.

Howard's method. Posture of patient and of operators.
(From Howard's original paper.)

produced over-extension of the spine by placing a pillow or any convenient support under the patient so as to make the subcostal margin prominent. The operator faces and kneels astride, or at the side of, the patient, placing a hand over each prominent subcostal margin so that the fingers occupy the furrows between the ribs above the margins and the palm below them. When pressure is applied by the operator

placing his weight over his hands, expiration is produced by a triple movement: (1) the lower six, or diaphragmatic ribs are depressed; (2) the abdominal contents, especially the liver and spleen, engorged and distended with blood, are compressed so as to force upwards the diaphragm and empty the lungs; and (3) the extension of the spine is partly undone. The spinal movement is an important one. Whenever the pressure is withdrawn the spine again becomes

FIG. 7.



The "barrel" method. Commencement of the inspiratory phase. (To illustrate the ancient method mentioned in Lecture I.)

FIG. 8.

The "barrel" method. Expiratory phase.

over-extended and produces an inspiratory movement. The lower ribs again become prominent and the viscera slowly return to a position of rest. Inspiration is effected by the rebound.

Whereas Silvester's methods and all its modifications produce movements resembling the thoracic type of respiration, Howard's method gives one which is abdominal in type. It is alleged that rupture of the liver is apt to follow a too vigorous use of the Howard method. I have been unable to

discover in post-mortem records any real ground for such rumours, but unfortunately our post-mortem records of cases of asphyxia are very deficient in both number and quality. Howard's method differs from Silvester's in its effect on the circulation. In cases of drowning, when the circulation has begun to fail, the right heart is distended; within the great engorged venous cistern formed by the great veins of the abdomen and the thorax the blood is locked in by valves situated above the clavicle and below Poupart's ligaments. The liver and spleen are distended with blood. Pressure applied as in the Howard method will force the blood through the pulmonary circulation. The late Mr. Harold Barnard informed me that in a case of death from chloroform he had been able, by performing Howard's method after death, almost to empty the great veins and right side of the heart, and to distend the left side of the heart and the arteries. But what is the effect of the application of such pressure on the right side of the heart? Will the increased distension of the right auricle and ventricle which follows from compression of the body favour an increased action of the heart already weakened from over-distension? This is a point which requires further experimental elucidation. In 1878, the third Resuscitation Committee reported that Howard's method had no advantage over Silvester's.

Resuscitation of Stillborn Children.

The Royal Humane Society has always taken a close interest in the resuscitation of stillborn children. In 1802 it presented its medal to Mrs. Ann Newby, matron of the City of London Lying-in Hospital, for 500 cases of successful resuscitation. Unfortunately, no mention is made of the method employed, but I have reason to believe that mouth-to-mouth inflation was part of the means. In 1816 her successor, Mrs. Widgeon, had a similar honour conferred on her, and in 1857 Mrs. Mary Widgeon also received a medal. She employed the same means "as her late mother"—chiefly warmth and friction. In 1871, the same year as Howard introduced his method, Schultze[10] made known a very ingenious manner of performing artificial respiration on children. In principle the method is a modification of Pacini's. The operator stands up and suspends the child between his legs by a finger in each armpit. The legs hang down and the head is supported between the operator's hands. The child's body is thus suspended by the muscles passing from the shoulder to the thorax, the ribs pulled upwards and outwards and air drawn into the chest. An additional effect is produced: the abdominal viscera sink downwards, drawing with them the diaphragm and thus

[10] Der Scheintod Neugeborener, p. 162, Jena, 1871.

assisting to expand the lungs. Champneys found that the movement of the diaphragm was not of great consequence. The weak point of Schultze's method is the expiratory movement. The operator, standing with the child suspended between his legs, swings it forwards and upwards until the lower part of the child's body doubles upwards on to its chest; such a movement is not well designed to give an effective expiration.

Schroeder's Method.

We are now dealing with that part of the nineteenth century when a rapid procession of new methods of artificial respiration appeared. In 1874 Schroeder[11] published a method for resuscitation of the newly born. Although the method is ineffective, the principle underlying it is interesting. The operator supports the child horizontally by placing one hand under its back; the spine is thus over-extended, the head, arms, and legs hang downwards, thus producing expansion of the chest. The inspiratory movement is rendered ineffective by the fact that in the over-extended position the abdominal viscera are pressed upwards against the lungs by the stretched abdominal musculature. Schroeder produced expiration by raising and flexing the suspended arms and legs against the body of the child. The method proposed by Mr. J. A. Francis[12] in 1886 for the resuscitation of adults is similar in principle to Schroeder's. The patient is laid on the ground, face upwards. By slipping a pole or other convenient means under the back the patient is raised or prized upwards until only the heels and head and hands are in contact with the ground. The over-extension of the spine and the weight of the arms and head, dependent from the thorax, produce an inspiratory movement; replacing the patient on the ground an expiratory one.

Shücking's Method.

Adrian Shücking[13] of Halle, in 1877, proposed a method for stillborn children which is really a modification of Silvester's. The arms, instead of being raised and drawn towards the side of the head, as in Silvester's method, are abducted or drawn outwards from the side of the body, thus giving a lateral expansion of the thorax; expiration is produced by pressing the arms firmly against the sides of the chest and belly.

[11] Lehrbuch der Geburtshülfe, p. 673, Bonn, 1874.
[12] Brit. Med. Jour., vol. i., 1886, p. 540.
[13] Berliner Klinische Wochenschrift, Jan. 8th, 1877, p. 20.

Schüller's Method.

The method designed by Max Schüller [14] of Greifswald in 1879 was more especially designed for the resuscitation of cases of chloroform asphyxia. He made the usual claim that his method was "simpler, more practical, and more effective" than the methods then in use. Schüller reversed the movements used by Howard. He stood or knelt at the patient's head and bent over it to grasp the subcostal margins which are made prominent by placing a support under the patient's back; the operator inserts his fingers under the subcostal margins and then draws the ribs upwards and outwards in the direction of the patient's shoulders, thus producing inspiration. Schüller was of opinion that this movement flattened and depressed the diaphragm, thus helping to distend the lungs. Expiration is produced by pressing the lower ribs downwards and inwards to force the abdominal viscera and diaphragm upwards. He supported the efficacy of his method by experiments on the dead body and on the living.

The "Experimental Researches on Artificial Respiration on Still-born Children," published by Dr. F. H. Champneys [15] in 1887, remains the most authoritative statement of our knowledge on this subject. In a series of 21 bedies of children he was able, by inflating the lungs, to produce emphysema of the mediastinum in seven of them, the rupture occurring near the root of the lung, and pneumothorax in five. Rupture of the lung occurred at various degrees of intra-tracheal pressure ranging from 20 to 80 millimetres of mercury. As regards artificial respiration his final advice is: "Inflate by the mouth and then by Silvester's method. If air enters the lungs, well and good; if not, try Schultze's method." He modified Schultze's method by suspending the child by the hands instead of supporting it from the axillæ. This modification, which should be known as Champney's method, is not recommended by its author.

Recommendations of Dr. R. L. Bowles.

Since 1856, when he assisted to carry out experiments for Marshall Hall, until the present day Dr. Bowles [16] has championed the claims of the prone or postural method. In his opinion it is a matter of the utmost importance that the water, as far as is possible, should be emptied from the

[14] Ibid., June 2nd, 1879, p. 319.

[15] London, Lewis, 1887.

[16] The Lancet, June 22nd, 1901, p. 1743 et seq.; Brit. Med. Jour., vol. i., 1864, p. 149; Transactions of the Royal Medical and Chirurgical Society, May 28th, 1889. "A Method for the Treatment of the Apparently Drowned": London, 1904.

lungs by placing the patient in the prone position. In performing Marshall Hall's method he secures a greater inspiratory expansion of the chest by abducting the free arm when the patient is in the lateral position. He also advocates maintaining the patient, when spontaneous respiration has returned, on one side, so that the upper, which is necessarily the active lung, may clear up by draining into the lower. He has proved by clinical means that the lung thus set free clears up first.

LECTURE III.

The Period of Mechanical Movements of the Chest Wall.—(*Continued.*)

Delivered on March 5th.

Doe's Method.

Mr. President and Gentlemen,—Having set out to examine the principle underlying the various methods of resuscitation it is necessary for me to notice the method introduced by Dr. O. W. Doe [2] in 1889, because the application of the principle involved is new. Doe's method is designed for the resuscitation of stillborn children. An air-tight box is employed into which the child is placed and with only its mouth exposed. By exhausting the box inspiration is produced; and expiration by forcing warm air into it. The author records the successful treatment of 50 cases.

Tongue Traction.

Although the method of resuscitation introduced by Laborde [3] of Paris in 1892 cannot be regarded as a process of artificial respiration, yet for those who wish to arrive at a just opinion of the relative value of artificial respiration as a means of resuscitation Laborde's methods and results are of the greatest interest. Rhythmical traction of the tongue has been employed by anæsthetists as an incentive to produce inspiration in cases of deep narcosis for some considerable time, but Laborde was the first to practise it on the apparently drowned. He applied the method to a case where artificial respiration had been unsuccessfully employed for an hour. On opening the mouth with a spoon and pulling out the tongue with some degree of force a violent inspiratory movement was set up followed by vomiting. After applying rhythmical traction of the tongue for some time, the patient regained consciousness.

[2] Boston Medical and Surgical Journal, 1889, vol. cxx., pp. 9.

[3] Bulletin de l'Académie de Médecine, Paris, 1892, vol. xxviii., pp. 30, 155, 728.

Laborde found in his experiments with anæsthetised dogs that tongue traction was the quickest and most certain means of bringing the animals round; he found that section of the ninth pair of cranial nerves delayed the appearance of animation and concluded that the effect was a reflex manifested through the respiratory centre. Soon after the publication of his method a considerable number of cases were recorded from various parts of France in which the method had been successfully applied. Some of the cases reported in the recent records of the Royal Humane Society were treated by Laborde's method. Here, then, is a reputably successful method of resuscitation which its author supports with experimental data and practical application and yet cannot be called a method of artificial respiration. Examples like this make one look critically at all methods whatsoever.

In 1896 Sir A. E. Wright[4] made a suggestion, founded on his experience in the resuscitation of dogs, which, so far as I can learn, had never been applied to cases of suspended animation in man. Before commencing artificial respiration he opened a major artery to relieve the pressure in the enfeebled left ventricle and found that he could recover a much greater proportion of cases. The arteries he would prefer to open in man are the temporal. The experiments of Crile and Dolley have been already mentioned; by injecting two cubic centimetres of a saline solution of adrenalin (1 in 1000) into the femoral arteries of dogs five minutes after circulation had ceased and then performing artificial respiration they were able to resuscitate a great number of apparently dead animals. If the circulation had ceased for ten minutes they found it possible to restore the heart and respiration but not consciousness. The brain appears to die first.

In 1889 the Royal Medical and Chirurgical Society instituted its fourth committee to consider the best means of recovery of the apparently drowned. Professor E. A. Schäfer was a member, but ultimately became the committee, and his report[5] read in 1903 is one of the most important contributions ever made to the literature of resuscitation. In his experiments he employed a more exact technique than had been used by those who had formerly investigated the means of resuscitation. To him we owe an accurate knowledge (1) of the large amount of water which may pass into, and be absorbed by, the lungs; (2) the small amount of the air expired in the act of drowning; (3) a standard method of estimating efficiency by stating the amount of air exchanged, not with each movement but in a given time—the five minutes' standard; (4) the employment of the living

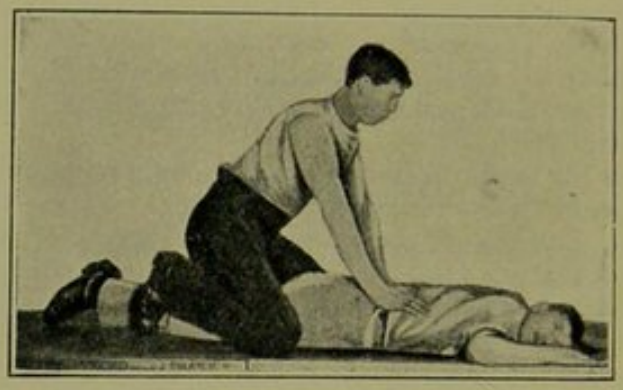
[4] Brit. Med. Jour., 1896, vol. i., p. 203.

[5] Transactions of the Royal Medical and Chirurgical Society, 1904, p. 609; Proceedings of the Royal Society of Edinburgh, vol. xxv., part 1.

instead of the dead human body as the subject of experiment; and (5) a new process of artificial respiration—now well known as Schäfer's method.

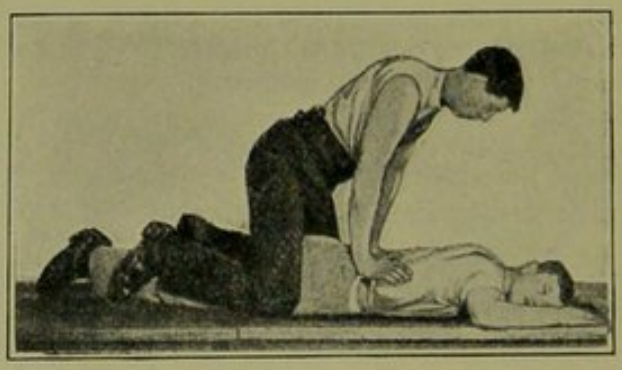
It is possible that there are others besides myself who formed, in their first acquaintance with this method, a totally erroneous opinion of the mechanism underlying it. Schäfer's method is not a simple compression and expansion

FIG. 9.



Schäfer's method. Inspiratory phase.

FIG. 10.



Schäfer's method. Expiratory phase.

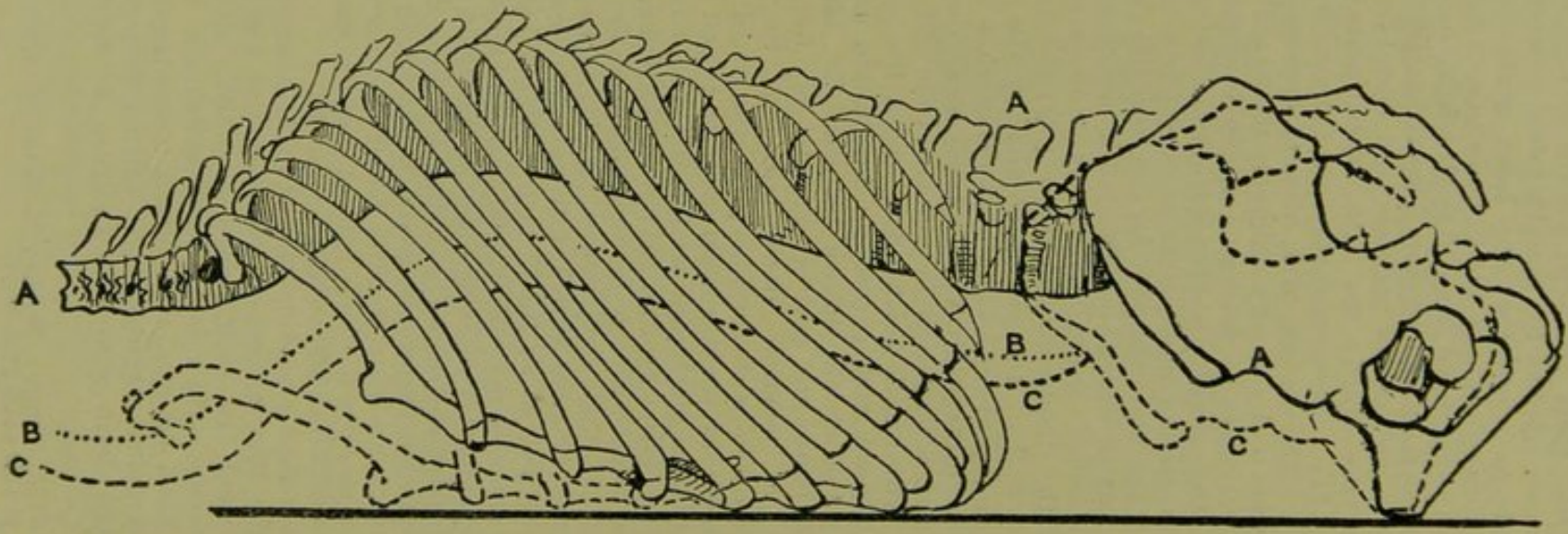
of the chest. The subject is placed face downwards (see Fig. 9), his chest resting directly on the table or floor. The operator kneels by the side or better astride the prone subject and places his hands over the lower ribs (tenth, eleventh, and twelfth) on each side of the spine (Fig. 9). To produce the expiratory movement the operator keeping his arms outstretched brings the weight of his body to bear on the lower dorsal region of the patient (Fig. 10).

A weight varying from 50 to 90 pounds is thus applied. When the operator applies his weight to the subject's back and thus produces expiration, the head and chest are seen to move forwards along the floor or table, away from the operator to the extent of from 10 to 20 millimetres. The forward movement is due to the fact that the subject's body rests on the lower part of the sternum and costal cartilages of the longest ribs—chiefly the fifth, sixth, seventh, and eighth (see Fig. 11). These parts form the fulcrum on which the body moves. The longest ribs, already depressed to expiratory position and set very obliquely to the axis of the spine (see figure), serve as levers on which the trunk rides forwards when the operator applies his weight to the spine. In Schäfer's expiratory manipulations the lungs are compressed: (1) by the abdominal viscera—especially the liver, spleen, and stomach, which are situated immediately under the operator's hands—being powerfully compressed and forced against the diaphragm and lungs; (2) the flattening of the anterior wall of the thorax formed by the yielding costal cartilages; and (3) by the ribs being thus brought into a position of ultra expiration and the chest compressed from back to front although it is widened from side to side (see Fig. 13). The recoil which occurs when the operator's weight is withdrawn and causes an inspiration to occur is due to (1) the strain thrown on the ribs and their costo-vertebral ligaments and ligaments of the spine, for there is a bending downwards of the spinal column in the dorso-lumbar region; (2) the recoil of the abdominal viscera to their normal position; and (3) the gradual unbending of the costal cartilages. There is also a rotation of the pelvis (see Fig. 11) and a flattening of the sternum; when the pressure is removed both of these parts instantly recoil to their inspiratory position. Inspiration results from the rebound which follows over-compression. In Howard's method, so in this, which is Howard's method with the body reversed in position, the respiratory movement is of the abdominal type. The abdominal viscera are exposed to a greater degree of pressure than in Howard's method. A powerful impetus is given to the blood content of the abdomen. Professor Schäfer found that each movement, tested on an apnœic living subject, gave a respiratory exchange of from 300 to 400 cubic centimetres.

At the present time a modification of the Silvester method—known as the Brosch-Silvester—is attracting much attention in Germany.[6] In 1897 Brosch modified the Silvester method as follows. He raised and extended the arms by the patient's head exactly as Silvester recommended, but in place of stopping the movement after the first degree of traction has been exercised he uses a considerable

[6] G. Meyer and A. Loewy: Berliner Medicinische Wochenschrift, June 15th, 1908, p. 1134; also 1909, No. 5.

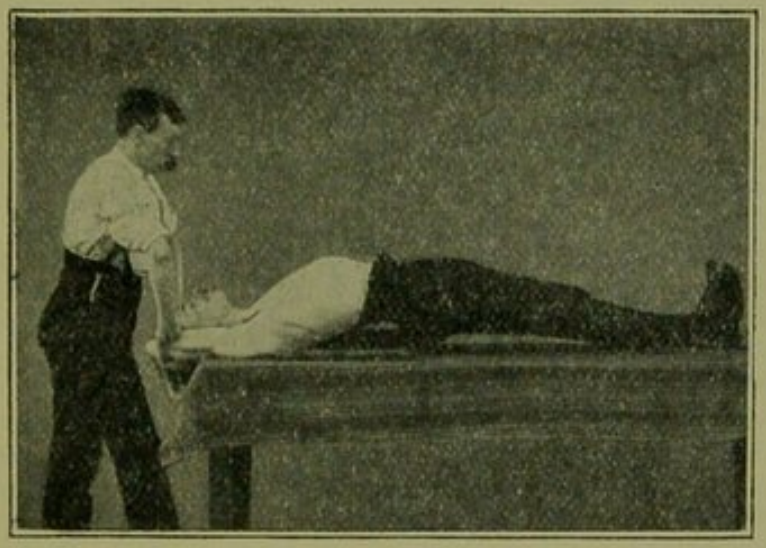
FIG. 11.



Skeleton from which the muscles were removed but ligaments retained. Three positions are shown: A, The specimen laid prone with the parts just touching the table. B, Position when the weight of the spine rests on the ribs. C, Position when a weight of 14 pounds is laid on the thorax. The rotation of the pelvis and flattening of the sternum are shown, but the movement of only one rib—viz., the first.

degree of force to continue the movement until the arms actually touch the table or ground on which the supine patient is placed. At the end of this movement the body is arched upwards so that it rests on the ground only at the shoulders and at the heels. The spine is over-extended. With the withdrawal of the operator's force the body recoils on the ground and the chest at the same time begins to collapse. The expiratory movement is completed by forcing the patient's arms against the chest, not towards the lateral aspect as advised by Silvester but directly over the sternum and yielding costal cartilages which are forced inwards so as to compress the lungs and heart.

FIG. 12.



The inspiratory phase of Brosch's modification of the Silvester method. (From photograph by H. George.)

Meyer and Loewy have recently (1908) carried out experiments on the efficiency of the Brosch-Silvester method. They followed Schäfer's example—as did Ploman the Swede—and tested it on the thorax of individuals rendered apnœic by a short period of deep breathing. They found that they could fill the lungs with from 1000 to 3000 cubic centimetres of air with each movement and effect a respiratory exchange varying from 7000 to 16,000 cubic centimetres per minute. Schäfer finds that he can produce a respiratory exchange of 5850 cubic centimetres with his method, an amount which he regards as amply sufficient for the purposes of resuscitation.

Professor Schäfer, as we have seen, in carrying out his investigations experimented on the living in place of the dead human subject. The men on whom he applied his

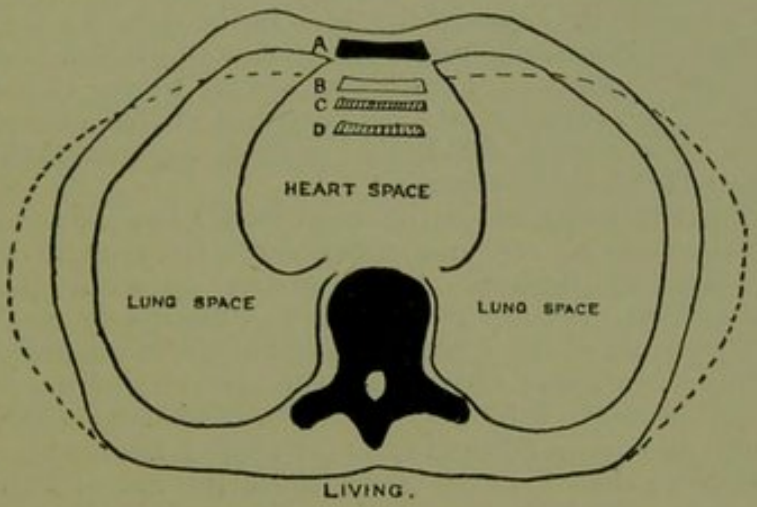
method prepared themselves by a series of deep breaths so that, during the period of the experiment, they were able to submit themselves as passive apnœic subjects. Is the living subject a reliable substitute for an apparently drowned individual? May one, with security, expect to obtain the same respiratory exchange in the one as in the other? There is a marked difference in their conditions. The apparently drowned subject is in a state of profound anæsthesia; the muscles are relaxed and destitute of tone. In the living subject, the muscles, in spite of any voluntary effort to the contrary, control the movements of the ribs and the viscera. The muscles of an apparently drowned subject are, as regards their action on the ribs and respiratory organs, comparable to those of the dead. Certain it is that the resiliency of the thorax in the dead differs in degree and in kind from that found in the living body, a difference which I regard as due to muscular tone. In Figs. 13 and 14 I give in a diagrammatic form the results of experiments carried out on ten living and five dead subjects.[7] When the living subjects were turned from the supine to the prone position their chests were flattened to a much less degree than in the dead; when in the prone position with a weight of 28 pounds placed on the thorax to represent the pressure applied in Professor Schäfer's method, the thorax of the living was flattened to a still greater degree, while in the dead the further flattening was comparatively slight. The living body loses its resiliency to a much less degree than the dead when it is turned prone, and since resiliency is the property which makes inspiration possible in the performance of artificial respiration the difference is an important one. The difference is due to the fact that in the living body the tone of the muscles which act on the ribs prevents the chest from flattening to the same extent as in the dead or anæsthetised.

Thus, in my opinion it is very improbable that Professor Schäfer's method will give a respiratory exchange in the apparently drowned at all equal to that which he obtained in living subjects; yet I think a sufficient exchange may be effected, and the method deserves to be tried because of its simplicity. In order that there may be no reasonable ground for scepticism left, I would strongly urge that those who are employed in the resuscitation of the apparently drowned at fixed stations where apparatus can be kept and applied should keep accurate records of the respiratory exchange effected in all cases. Such measurements can be taken by Zuntz's air meter without in any way interrupting the proper application of the means of recovery.

In 1908 the chief surgeon of the Metropolitan Police, Mr. Clinton T. Dent, requested the Royal Society of Medicine to advise him as to the best method of artificial respiration for the resuscitation of the apparently drowned. The Royal

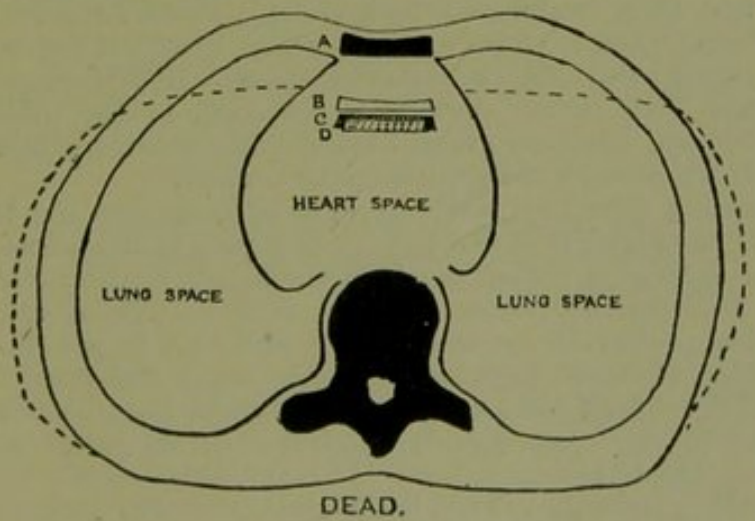
[7] See London Hospital Gazette, June, 1908.

FIG. 13.



Transverse section of the thorax on which is represented the results of compression of the thorax in ten living subjects. A, The position of the sternum in the supine position. B, The position of the sternum in the prone position. C, The position of the sternum when a weight of 28 pounds is placed over the sternum in the supine position. D, The position of the sternum when a weight of 28 pounds is placed over the thorax in the prone position. The stippled line shows the increase in the transverse diameter of the thorax on turning the body from the supine to the prone position.

FIG. 14.



Similar diagram showing the results of corresponding measures applied to the thorax of five dead subjects. The figures also show the marked compression of the "heart space."

Life-Saving Society had by then boldly adopted the Schäfer method, the Royal Humane Society retained Silvester's, while the National Lifeboat Institution continued to recommend Marshall Hall's and Silvester's in the order named. A fifth Resuscitation Committee was constituted with Sir William Church as chairman. I had the honour to be elected a member. The result of the deliberations of that committee was to recommend Schäfer's method as preferable to Marshall Hall's or Silvester's.[8]

During the inquiries of the committee I became aware of the great mass of evidence contained in the records of the Royal Humane Society. I had grown up as a student believing that artificial respiration was absolutely essential for the recovery of the apparently drowned, and was therefore surprised when Major Claughton, the secretary of the Royal Humane Society, informed me that numerous cases of recovery had been effected after periods of immersion lasting for more than four minutes without the aid of artificial respiration. My inclination to investigate these records was stimulated by the fact that Hunter had been instrumental in causing them to be kept. I wished also to see what results had followed the practice followed in the various periods of the society's history. Major Claughton very kindly extracted for me 504 cases of resuscitation from the records of the last four years. With each case he gave me the age, sex, estimated time of submersion, condition on rescue, process employed in resuscitation, length of time artificial respiration was performed, the result, and remarks. In a considerable number of cases the time of submersion could not be estimated.

In these 504 cases there were 63 in which artificial respiration had been unsuccessfully applied. From 1903 to 1907 there were thus 12·5 per cent. of cases in which the means applied failed to bring the patient round. How these results compare with former periods is set forth in the table on page 39, the numbers given having been obtained from the annual reports of the Royal Humane Society.

Glancing over that table it will be seen that the latter part of the eighteenth and the opening part of the nineteenth centuries form a period in which the means for resuscitation were the least successful. In that period artificial respiration was performed by the bellows and over 50 per cent. of the cases were not recovered. In the period just previous to that (1774–1793), when artificial respiration, if applied at all, took the form of mouth-to-mouth inflation, the percentage of failures was 10 per cent. less. With the omission of artificial respiration from the official list of instructions issued by the society the failures drop from 50 to 10 per cent. ; with the introduction of the mechanical methods of respiration the

[8] Report of Fifth Resuscitation Committee, Pro ceedings of the Royal Society of Medicine, 1908, vol. ii., p. 1.

failures amount to only 8 per cent. ; during the last four years (1903–1907) the percentage has risen to 12 per cent. These percentages to have any value whatsoever must be drawn from groups of drowned people which are directly comparable. There are strong reasons for believing that the cases included in the earlier reports are not comparable to the latter groups. The Royal Humane Society took cognisance of only those cases which occurred in or near London in the earlier period of its existence, but it gradually extended

Period.	Chief means employed.	Successful cases.	Unsuccessful cases.
1774–1793	Warmth. Fumigation. Inflation.	959	747 = 43·7%
1773–1778 (in France).	Inflation.	813	121 = 11%
1795–1811	Warmth. Inflation (bellows.)	2470	3018 = 54·8%
1821–1826 (in France).	Inflation. Warmth.	283	85 = 34%
1832–1851*	Warmth. Friction.	2152	217 = 10%
1865–1876†	Artificial respiration. Warmth.	2487	202 = 8·1%
1848–1860‡	Warmth. Friction.	165	97 = 37%
1856–1860‡	Artificial respiration.	38	34 = 47·2%
1903–1907	Artificial respiration. Warmth. Friction.	441	63 = 12·5

* Thirteen years taken at random between 1832 and 1851.
† Eight years taken at random between these dates.
‡ Figures given by Dr. Christian for cases in Hyde Park.

the scope of its labours, and I suspect that the cases of rescue and of resuscitation reported from a distance in the later periods were chiefly those which were successfully resuscitated. The statement made by its medical officer, Dr. Christian, in 1860, gives one grounds for such an inference. While the percentage of failures of all cases reported to the society amounted to about 10, Dr. Christian's failures amounted to 37 per cent. At the opening period of resuscitation in France 11 per cent. of cases were unsuccessful ; a later period, when the bellows were more

freely used, the failures rose to 34 per cent. Magendie attributed the increase to the use of the bellows. The inference, however, which may be justly drawn from the above figures—allowing for a considerable discrepancy in the material compared—is that the value of artificial respiration as a means of recovering apparently dead people is overestimated, for during a period in which artificial respiration was very little employed, the percentage of failures was smaller than it is now, when it is regarded as the essential—almost the only—means. Laborde claims success for his method in which artificial respiration is not used.

In order to ascertain the present-day practice in the recovery of the apparently drowned I tabulated the means applied in the 504 cases given to me by Major Claughton. In some cases two or even three methods were tried; I have added all the methods used in such cases, so that the number of methods in the following list is really greater than the number of cases on which they were tried.

Methods used.	Number of cases in which applied.	Methods used.	Number of cases in which applied.
Silvester's method ...	237	Tongue traction	5
Artificial respiration (method not stated)...	180	Movements and traction of the arms and legs	48
Marshall Hall's method	3	Friction of the body	30
Howard's method ...	3	Slapping the body ...	2
Silvester - Howard method	5	Injection of strychnine...	2
Schäfer's method ...	5	Emetics	3
Rolling the body... ...	9	Warmth	7
Compression of the body	9	Stimulation of nose ...	5
Inversion of the body	26	Laying on belly across wall or fence	2

Thus it will be seen that there still exist throughout the country certain ancient methods of resuscitation which have been condemned for a century and more by the Royal Humane Society—viz., rolling, moving the body by the arms and legs, laying the body across a support (the barrel method), emetics, and holding up by the heels or inversion. Not one of these cases where forbidden methods were applied resulted in failure.

It is of interest to observe the means employed in the 63 unsuccessful cases. In every one of them artificial respiration was performed; in 18 Silvester's method; in four Silvester's combined with another; and in 41 "artificial respiration" is said to have been applied. Now in the whole group of cases Silvester's method was applied to 237 and "artificial respiration" to only 180, therefore the

number of failures with the Silvester method ought to have been considerably greater in the cases on which it was performed than in the smaller group where "artificial respiration" was employed, but the reverse is the case; almost twice the number of failures fall amongst the cases in which "artificial respiration" was used. The operator who employs the term artificial respiration probably does not know the name of the method he employed and more than likely does not know how to apply any method properly. It is indeed highly probable that more cases are lost by artificial respiration being wrongly applied than by no artificial respiration being applied at all.

The length of the period of submersion does not explain all the failures to resuscitate, as the following table shows:—

	Periods of submersion.			
	1 to 5 minutes.	6 to 10 minutes.	11 to 15 minutes.	over 15 minutes.
Successful cases	234	89	14	4
Unsuccessful cases... ...	13 (5·2%)	21 (19%)	12 (46·1%)	16 (80%)

With the increase in the period of submersion the proportion of failures becomes greater, but the period of submersion does not account for a considerable number of cases. There are clearly some lost which ought to be saved, but we cannot save until we know how and why they are lost. The aged are not recovered with the same success as younger people. We need, above all things, more accurate observations when means are being applied to the apparently drowned, and are urgently in need of pathological observations when the means applied have failed.

The researches of Haldane and Priestey and of Hill and Flack[9] assist us to understand why recovery may occur after a prolonged submersion. Their observations seem to me capable of being utilised by those in imminent risk of drowning. Vernon[10] has recently observed that he could hold his breath for the long period of 8 minutes 13 seconds if he previously renewed the air-content of his lung by a vigorous series of respirations. In the state of apnœa thus acquired he ought to be successfully resuscitated after an immersion of 12 minutes. It is usually believed that cases are seldom, if ever, recovered after an immersion of five minutes.[11]

[9] Journal of Physiology, 1908, vol. xxxvii., p. 77.

[10] Nature, Feb. 18th, 1909, p. 458.

[11] During the delivery of these lectures Mr. William Henry, chief secretary of the Royal Life Saving Society, sent me the following valuable observations: "The experience I have had leads me to believe that the length of time one may stay under water depends upon several conditions. For instance, a stout person would probably be dead long before the expiration of three minutes. A thin person can nearly always stay under water for a longer period than a stout one. I know of a properly

With the pulmonary system well ventilated one may yet recover after a longer period and it is probable that those cases which are recovered after an immersion, alleged to be over ten minutes, are individuals who were in a condition of apnœa at the time of drowning. The practical lesson to be drawn from these facts is that those in imminent risk of drowning should prepare for a possible rescue in filling or emptying their lungs with vigor just before immersion, so that the state of apnœa thus produced may tide life over a period of from 10 to 12 minutes in place of the usual limited space of 4 or 5 minutes.

If in a few words I may sum up the chief conclusions which my inquiries into the past and present practice of artificial respiration have led me to form I would set them down thus. It is really only 1 case in 20 or 30 which is recovered by the aid of artificial respiration but that twentieth case cannot be recognised at sight, therefore it is necessary to perform respiration in every one; if properly performed it can do no harm; if improperly, it may destroy the possibility of recovery. If you ask me: Would I, if asked, advise the Royal Humane Society to abandon the Silvester method and adopt the Schäfer? I would answer, No; but with a condition—viz., that the Silvester method must be properly carried out. If that condition cannot be guaranteed then I would recommend the Schäfer method, for although it is less effective it is also simpler, and in one sense, that of obstruction from falling back of the tongue, less dangerous than the Silvester method. In every case of drowning I would follow the custom of first turning the patient prone and compressing the thorax to empty the main respiratory passage. It must not be supposed that the Schäfer method is free from danger. It is said, but I have been unable to find a sure foundation for the statement, that the engorged liver has been ruptured in

recorded case, when I personally timed the test of a young female who remained under water 4 minutes 42⅘ seconds; she regularly stayed for 3 minutes 30 seconds. There are also many recorded cases of men and women staying regularly under water for 3 to 4 minutes; the best case of a man is 4 minutes 29⅕ seconds, but in each case these people for some time prior to taking the test remained quite calm. On the other hand a person who may be in danger of drowning may struggle and the greater the struggling the quicker they will, in my opinion, become insensible. The reason for this is obvious, but in the case of a stout person, as compared with a thin one, some other reasons may be advanced. I know people who only inhale 150 to 160 cubic centimetres of air and others who register 370 cubic centimetres, yet the former have stayed under water much longer and with less inconvenience than the latter. I have a case in point where one person weighing about 8 stones inhaled 155 cubic centimetres of air and stayed under water 3 minutes 30 seconds; the other weighed 14 stones and inhaling 373 cubic centimetres was nearly insensible after 1 minute 10 seconds. The latter was not twice the weight of the former but was able to register more than twice the amount of air, yet could only stay under water one-third of the time. These are interesting points which may have some bearing on the subject of drowning."

performing the Howard method; if that is so then the danger is as great or even greater in the Schäfer method, for to the weight of the operator is added that of the patient's own body. My mind is also open to the conviction that the ancient method of mouth-to-mouth insufflation with expiratory compression of the chest may not prove more effective than either; at least, if it should happen that I may be found in an apparently drowned condition I sincerely hope that my rescuer will apply this prompt method to me as my first aid. It is air that my lungs and blood then will stand urgently in need of, not pressure, for if the pulmonary circulation has ceased such pressure is, upon the evidence at present at our disposal, more likely to weaken than to strengthen the heart. With the patient in the prone position the operator will have great difficulty in knowing whether or not air is entering and leaving the lungs freely; with direct inflation one knows the effect immediately by placing the hand on the epigastrium; the hand is also needed there to produce expiration.

I want to leave the impression on your minds that the quest for the best means of artificial respiration is by no means ended; we need more experimental evidence, more exact data as to the results of methods now in general application, more clinical observation on the lungs and hearts of people being resuscitated, and more exact data on the condition of the body, and more particularly of the lungs, heart, and liver in those cases where all means have failed or where secondary failure has occurred (seven cases out of 504 died after regaining consciousness—cause of death unknown). Especially would I beg of those who are frequently engaged at fixed stations in the work of recovery to measure accurately by a meter the air exchange effected by the methods which they apply, so that instead of having to trust to experiments carried out on perfectly healthy apnœic individuals we may have the actual effect of these methods in producing a ventilation in the lungs of the apparently drowned.