XIII. "An Inquiry into the possibility of restoring the life of Warm-blooded Animals in certain cases where the Respiration, the Circulation, and the ordinary manifestations of Organic Motion are exhausted or have ceased." By Benjamin Ward Richardson, M.A., M.D. Communicated by Dr. Sharpey. Received June 14, 1865.

The present memoir presented to the Royal Society is preliminary; it does not profess to do more than to open the way to new work, and to show the reasons why the restoration of action, in cases where life is suspended, is at present so doubtful and difficult.

In the course of my inquiries I have not confined myself to the mere question of treatment as applied when there are still faint indications of spontaneous animal action, or when such action has ceased only for the moment. It is true that many of the experiments related in this Paper have reference, incidentally, to treatment under the circumstances named; but I have had actually in view a much wider research. I have asked, When an animal body that has undergone no structural injury (that is to say, no destruction of organ or tissue) has ceased to exhibit those actions which indicate what is commonly called life, why may it not be restored at a period previous to the coagulation of the blood in its vessels, if not previously to the period when the new chemical changes, developed under the form of putrefaction, are established?

To render the memoir concise, I have divided it into two parts. One of these parts contains nothing more than the details of experiments, the experiments being classified in groups according to the object for which they were performed. It is my desire that this record should be preserved for reference in the Archives of the Society. The other part, which is here published, consists of an analysis of the experimental evidence, with the conclusions to which I have been led by the evidence.

Analysis of the Experimental Evidence.

In the experimental inquiry all the animals operated upon had been subjected to such means for suspending their animation as produced the least possible amount of change in the structure of organs. The animals were all healthy while living. To suspend the spontaneous action which they presented, and which marked their life, chloroform was employed in the large majority of cases; but in some instances carbonic acid was used, and in others the process of drowning.

The readiness with which chloroform can be employed, and the painlessness to the subject which is implied in its use, recommended this agent specially at first. As the inquiry has proceeded I have seen no reason, so far, to introduce any modification, inasmuch as the continuance of experiment and repeated observation have simply tended to indicate that the process called "death" is unity; and that if animal action, brought to a stand by chloroform, could be reproduced by any process, the same restorative

process would be applicable after every other kind of suspension that was unattended by mechanical injury of structure.

Throughout the inquiry I have kept steadily in view a process for restoring the development of force which is constantly and successfully being performed. A simple process enough! I mean the relighting of a taper. I see in the taper as it is burning the analogue of living action. The combustible substance having the force stored up in it circulating through the wick as through so many vessels, becoming distributed in the presence of incandescent heat so as to combine with oxygen; then itself liberating force, burning, and in the process showing spontaneous action, the analogue of living action.

From this analogy I gather, further, that if I could set the blood burning as it burns in life, after its natural combustion has been suspended, I should relight the animal lamp, and that the redevelopment of force in the form of animal motion, which is life, would be reestablished.

But how in the case of the animal body is the light to be applied? That is the difficulty.

Suppose that the taper or the fire were known only to us from their spontaneous manifestations, would the task to restore their burning if that had gone out be less difficult? What philosophical process should we adopt? We should first most naturally take fire from fire when that were possible. But how, when that were not possible, should we proceed to obtain the spark for kindling that which we might well know would burn spontaneously after kindling, the proper conditions being supplied? In such case we should most naturally look for the process by which fire is spontaneously exhibited, and we should discover it in the friction of one body with another; in the friction of stone, for example, with iron. Straightway we should imitate this and produce fire, and know how to renew and perpetuate it.

Again, in our observation of burning bodies we should see often that a point of flame well-nigh extinguished would rekindle under a little additional friction of air, or an additional communication of matter that would burn, and we should acquire an art of sustaining fire by these measures.

Lastly, as we went on observing we should discover that the force elicited in the combustion could be so applied as to set in motion almost endless mechanism; and we should learn, as we have learned, that however complicate the mechanism, however numerous its parts, it takes all its motion from the fire.

The physiologist who would distinguish himself by learning the art of resuscitation must, I have thought, place himself precisely in the same condition as the primitive man who, in the matter of ordinary combustion, would pass to the civilized man through the phases I have described; and it seems to me that, so far as we have progressed we have become acquainted with three natural steps in the inquiry at least. We have discovered that when the animal fire is declining from want of air, it may be fanned into

existence again by gentle friction of air. We have learned by an experiment, first thoroughly demonstrated before the Royal Society in the early days of its remarkable history, that when the animal fire is waning, owing to deficiency of fuel, that is to say, of blood, it may be revivified by the direct introduction of new blood. Lastly, we have learned that the natural or spontaneous combustion of blood is due to the affinity of the oxygen of the air for combustible substance in the blood, when such substance is presented to the air over a sufficient extent of surface.

These observations may be received as demonstrable truths; and to them may be added an inference which amounts nearly to a demonstration, though all its elements have not yet been estimated—that the motion of the animal (the action of its mechanical parts) is produced by the force evolved in the process of combustion.

The experiments submitted in this paper have reference to the best means to be adopted for fanning into active life the animal fire that is expiring but is not suspended. But they extend also to the deeper questions, whether animal combustion cannot be reestablished when it appears to have been extinguished? and whether so-called vital acts would not be spontaneously manifested upon such reestablishment of animal combustion?

In the part of this paper which contains the details of experimental research, the experiments are classified in three series.

The first series of experiments has reference to attempts made to produce combustion of blood in the lungs by the introduction of air—*Artificial Respiration.*

The second series embraces experiments in which attempts were made to induce circulation of the blood by physical operations—*Artificial Circulation.*

The third series supplies the records of experiments in which the effects of *an increased temperature* upon the body were observed.

First Series of Experiments.—*Artificial Respiration.*

Effects of simple inflation of the lungs with air.—The first series of experiments, those in which artificial respiration was employed, exhibits, I believe faithfully, the precise value of artificial respiration. In the preliminary inquiries, the animals, having ceased to breathe, were immediately subjected to artificial inflation by means of double-acting bellows. The result in every case was, that whenever the action of the heart had come to rest, the temperature of the air employed being at various degrees, from 40° to even 120° Fahr., no reaction followed the inflation.

In opening the bodies of animals thus treated, the lungs were invariably found empty of blood, and in a large number of cases emphysematous, while the right side of the heart was filled with fluid blood.

The heart continues to beat when artificial respiration restores.—In one striking experiment, where respiration had entirely ceased and no action of the heart could be detected from pulsation, a recovery took place in a dog.

Narcotism was again carried on to the same extremity, with recovery on inflation; and this was repeated once more with the same result. But in this experiment, although, to appearance, animal action was entirely suspended, a minute examination of the heart, through an opening in the skin sufficiently large to allow the mouth of the stethoscope to rest on the ribs, but not to injure either them or the intercostal muscles, proved that there was still sufficient action of the heart to produce a faint first or systolic sound.

Cessation of the heart during artificial respiration. Order of cessation.—These experiments by inflation were modified. So soon as the animal ceased to exhibit evidence of life, the artificial respiration was set up, the chest-wall was removed, and the effects of the artificial respiration on the heart were observed. In every case where the operation was performed within five minutes the heart was discovered pulsating. The action was uniformly best marked in the right auricle, next in the right ventricle, next in the left auricle, and next in the left ventricle. Contraction remained longest also in the same order. But it was observed uniformly that the contraction of the right ventricle never sufficed to fill the pulmonary artery with blood so as to reestablish the pulmonic circuit.

Effect of inverting the body.—In one case the animal was suspended with the head downwards while the right ventricle was contracting vigorously. In this case blood passed into the pulmonary artery and faintly coloured the surface of the lung, which was previously pale; but the pulmonic circuit was not reestablished, and after death the capillaries were found to be obstructed mechanically from coalescence of the blood-corpuscles.

Effects of artificial inflation with air raised in temperature.—These experiments with the chest laid open were varied by the employment of air at different temperatures. The evidence was clear that when the contractions of the heart were failing, an increase in the temperature of the air to 140° Fahr. caused a more vigorous action, which often lasted from five to ten minutes.

Effect of exposure to the air in exciting cardiac action.—To determine whether the act of insufflation of air at a mean temperature of 60° was sufficient of itself to set up contraction of the heart, two animals were destroyed with chloroform and allowed to rest fifteen minutes. Then in one animal artificial respiration with air at 60° was employed for five minutes, and the hearts of both animals were immediately exposed to view. There was no action in either case at first; but after exposure to the air for a few minutes the right auricle in both hearts commenced to contract, and the ventricles followed. But the action was in no way more determinate in the animal that was receiving air by inflation than in the other animal. I notice this point particularly, because some experimentalists, who have made but one or two observations, on seeing the heart pulsate during artificial respiration, have conceived that the phenomenon was due solely to the in-

flation. I believe it myself to be due to the action of the external air, which at a moderate temperature gives up a little oxygen to the blood in the walls of the heart, by which some heat is evolved and therewith motion is exhibited. My reasons for this view rest on the facts that a current of air at 35° Fahr., brought to bear on the heart, at once stops the action, while another current above 60° restores it, and that a little vapour of chloroform or of ammonia blown upon the heart—both of which agents stop oxidation—immediately arrests the action, which returns, at a sufficient temperature, when these agents are lost by diffusion. I believe also that the right auricle is last to die, because its thin walls allow the passage of oxygen to venous blood on their interior, since on washing out the auricle thoroughly with water, or on applying to it a substance which prevents oxidation, the auricular motion at once declines.

These remarks on the effect of artificial respiration in relation to the motion of the heart, do not apply with the same force when the air employed for inflation is heated to 120° Fahr.; then even fifteen minutes after death, if the inflation be sustained, the heart is found contracting as the chest is laid open, the action really being sustained by the diffusion of heat from the lungs to the heart; but the action excited is insufficient to produce a pulmonic current.

Effects of other gases used in artificial respiration.—The experiments were further modified by using for insufflation other gases in place of common air. Oxygen was thus used, oxyhydrogen, ozone, and air containing 0·20 per cent. of chlorine. With two exceptions, the same observations are applicable to these experiments as were made in reference to those with common air. As a rule, the gases possessed no action on the heart to restore the pulmonic current when the natural action had been arrested. The exceptions were, that when the action of the heart was still feebly proceeding, respiration not being suspended, the air containing chlorine or ozone produced a quicker restoration, the ozone being much the less objectionable in regard to its after-effects.

Artificial respiration by electro-galvanic action.—The experiments on artificial respiration were finally modified by using the electro-galvanic current to excite the muscles of respiration so soon as natural respiration and circulation had ceased. By inserting a fine needle, insulated except at the point, into the larynx of an animal, and the other needle into the diaphragm, and by regulating the shock by means of a metronome, so that a given number of shocks representing the respirations of the animal are administered, the most perfect appearance of natural respiration may be sustained for so long, in some cases, as seven minutes; and the phenomena are often remarkable, and to the inexperienced deceptive. Thus, owing to the action on the vocal apparatus, a rabbit will scream as loudly as in life; and, lying breathing and screaming, might well be considered to be alive. But all the while the heart is at rest, if it have once rested, and on opening the chest the lungs are found bloodless.

Résumé.—Value of Artificial Respiration.

Reviewing the whole series of experiments, I am led to the conclusion, and I think it admits of direct demonstration, that artificial respiration, in whatever way performed, is quite useless from the moment when the right side of the heart fails in propelling a current of blood over the pulmonic circuit, and when the auriculo-ventricular valve loses its tension on contraction of the ventricle.

Break of blood-column.—At this point the blood-column is broken: the resistance to the passage of blood is of itself almost overwhelming, while the muscular action is decreasing in power in proportion as the difficulty of propulsion is increasing.

Obstacle from coalescence of blood-corpuscles.—Another obstacle is in the blood itself. It consists in the rapid coalescence of the blood-corpuscles as the motion of the blood ceases. This is so determinate, that within three minutes after its complete cessation, the blood, though still fluid, often fails to be carried, even by a moderately strong stroke, over the lungs. In one experiment the chest of a strong dog was laid open while the animal was under chloroform, and artificial respiration was sustained. Both sides of the heart were acting vigorously, and there was a good arterial current. In the midst of this action, which could easily have been sustained for an hour, the pulmonary artery was suppressed for the space of two minutes and fifty seconds. Then it was liberated, and the ventricle, which was still beating vigorously and gave out a valvular sound, carried the pent-up column into the pulmonary vessel; but there was no circuit. The lung was somewhat congested, and the capillaries were blocked up so as to resist an impulse which, increased by galvanism, was more active for some minutes after the liberation of the artery than it had been previously.

Obstruction from coagulation of blood.—The last obstruction is the coagulation of the blood; but as this does not, as a general rule, occur (in cases where the blood-vessels are not opened) within twenty minutes, and often not within an hour, it may be considered a secondary difficulty, though naturally fatal to success, according to our present knowledge, when it has taken place.

Modes of applying Artificial Respiration.

Regarding the modes of applying artificial respiration, and the time, the facts are briefly as follows:—

1. It is unnecessary and even injurious to employ it so long as there is any attempt at natural respiration*.

2. Before employing it, the patient should be placed with the head slightly lowered, a position which will largely assist the right ventricle in any feeble effort it may be making to propel a current of blood into the pulmonic circuit.

3. It is of the greatest importance that the air conveyed into the lungs

* On this point see observations 20 and 21 in the Experimental Part.

should be at a temperature above 60°; air below that temperature should never be used.

4. All violent attempts to introduce large quantities of air are injurious; for whenever the pressure of the blood from the right side of the heart is reduced, the danger of rupturing the air-vesicles by pressure of air is increased. In a word, the practitioner should remember that he is doing the same act, virtually, in artificial respiration, as he is when attempting to relight an expiring taper. Any violence will only disarrange the mechanism, and turn the last chance of success into certain failure.

5. So long as care be taken to sustain a gentle action of respiration, it signifies little, in my opinion, what means be employed. I have found a double-acting bellows, described in the experimental part of this paper, answer every purpose fairly. If any philosophical-instrument maker could invent a good and portable electro-magnetic machine with my metronome principle applied to it, so that from fifteen to twenty shocks per minute could be passed from the larynx to the diaphragm directly, the most perfect attainable artificial respiration would be secured so long as any muscular irritability remained; and I should suggest the value of such an instrument in cases where it could be brought into operation immediately after natural respiration has ceased. In combination with air heated from 120° to 140° for inhalation, every possible advantage that could accrue from artificial respiration, or rather from respiration artificially excited, would be secured, the persistence of muscular irritability being at the same time a sure index that the effort should not cease.

Note on Receiving-houses for the Drowned.

The observations I have made in respect to the influence of heated air lead me to suggest that, in all receiving-houses for those who are apparently dead, a room should be set apart the air of which should be at 140° in summer, and 130° in winter. If bodies taken out of the water showed any indications of breathing, it would be sufficient, in my opinion, to place them in such an atmosphere, simply providing by the position of the body for the escape of water from the lungs. There would be under such conditions quick evaporation of water adhering to the bronchial surface, while the warm air would quicken the respiration, encourage the action of the heart, and prevent radiation of heat from the body. If artificial respiration were considered necessary, its performance in such an atmosphere would render the possibility of recovery far greater than if a low temperature and a moist state of atmosphere prevailed.

Second Series of Experiments.—*Artificial Circulation.*

In the second series of experiments an attempt was made by various physical means to restore the circulation; these attempts may be called attempts at *artificial circulation.* Various processes were adopted. In one class of inquiry oxygen was gently infused into the circulation, either in the form of gas, or in solution as peroxide of hydrogen, in order to see

if by this means the heart could be stimulated to active contraction. In other instances water heated to a given temperature was injected, or the vapour of water. Again, electricity was brought into play; and, lastly, various mechanical contrivances were introduced, either for forcing the blood over the system or for drawing it over.

Injection of oxygen.—In respect to the effect of oxygen gas, I found that when the gas freshly made from chlorate of potassa, but well washed, was driven into the venous current towards the heart by the vena cava superior, the auricle and ventricle of the right side at once exhibited active contraction, which could be prolonged for an hour without difficulty by simply continuing the introduction of the gas at intervals; but the contraction of the ventricle was never sufficient to produce a pulmonic current. When the gas was injected into the arteries, the current being directed towards the heart, so as to charge the structure of the heart itself with the gas through the coronary arteries, the heart in one instance made active movements which could be distinctly felt through the chest wall; but the effect was only momentary; and after it was over, the organ was found distended with gas and devoid of irritability. In another case, on making a *post-mortem* examination of an infant that had been dead twelve hours, oxygen gas at a temperature of 96° was injected into the heart. The organ became gradually distended; and on the left side, both in the auricle and in the ventricle, tremulous muscular action, like very feeble contraction, was distinctly seen. Whether this was due to the mechanical entrance of the gas or to true muscular contraction excited by the presence of the gas, is perhaps open to question, but I could make no distinction between this contraction and ordinary contraction as it is elicited immediately after death. The subject of this experiment was fourteen days old. Previous to the injection there had been no cadaveric rigidity, but after the injection this phenomenon was well marked.

Injection of peroxide of hydrogen.—The experiments with the peroxide of hydrogen were varied by passing the solution very slowly into the lung through the trachea, so that the oxygen that would be liberated might come into contact, together with the air afterwards introduced by the bellows, with any blood remaining in the pulmonic circuit. A little fluid during this process found its way into the left auricle through the pulmonary veins, and the auricle thereupon contracted. On injecting the peroxide, in another experiment, over the arterial system, the blood on the venous side was pushed forwards into the heart and it was made red in colour from absorption of the oxygen. As the fluid found its way round the systemic circuit, vigorous muscular contraction of the pectorals, of the muscles of the neck, and of the diaphragm followed, but there was no reaction of the heart.

Oxygen excites muscular action.—I gather from these researches that oxygen, introduced into the circulation directly, possesses the power of calling forth muscular contraction. This power seems to be due to the combination of the oxygen with a little blood remaining in the circulatory

channels, and to the evolution of force from that combination. The effect of the oxygen, therefore, is extremely limited; and when introduced in the gaseous form, the distention it produces leads to a certain degree of disorganization of structure. I do not at this moment see therefore that oxygen admits of being applied as a direct excitant of the heart; but it is worthy of remembrance that the element produces temporary excitability when diffused through muscular structure recently rendered inactive.

Heat as a restorer of the circulatory power.—A large number of attempts were made to restore the circulation by means of heat conveyed into the vessels by heated fluids. The phenomena produced were very remarkable, and they have engaged my attention for more than five years. I first observed that when vapour of water (steam) at a temperature of 130° was driven into the arteries, there was at once rapid and general muscular action, the heart participating in the movement, but less actively than the voluntary muscles.

Injection of heated water.—I afterwards used simple water for injection heated to various degrees, from 96° to 130°. When water is thus injected, the animal being only a few minutes dead, and the water not being below 115° Fahr., the extent and activity of the muscular contractions are even more marked than when galvanism is brought into action, but in the greater number of cases the effect of the warm water ceases in from fifteen to twenty minutes. When the temperature of the air in which the animal lies is below 40°, the water will act for so long a period as three hours after death. The water ceases to exert its influence when it infiltrates the cellular tissue. The admixture of salt with the water, so as to raise the specific gravity to the natural specific gravity of the blood, unquestionably diminishes the effect of the heated water; the muscular contractions are less rapid and less prolonged, although the infiltration into the cellular tissue is prevented for a much more lengthened period of time. I attribute the action produced on the muscles entirely to the heat evolved by the water.

*Injection of blood**.—Injection of blood held fluid by alkali, oxidized and heated to 96°, was employed. The blood was injected into the carotid in the direction of the heart, the object being to fill the coronary arteries with the fluid. This intention was fully carried out; but although the animal had been only a few minutes dead, there was no response on the part of the heart.

In another experiment, blood from the sheep, defibrinated, thoroughly oxidized, and warmed to 115° Fahr., was injected into the arterial system immediately after the death of an animal (a rabbit that had been destroyed by chloroform). The right auricle having been opened to allow of the escape of venous blood, no difficulty was experienced in forcing over the oxidized blood, and it returned freely by the veins; but it did not excite the least contraction. When this transfusion had been carried on some minutes, the blood was replaced by water at 125° Fahr. Immediately as the water found its way round the body, vigorous action of the body was

* See note, p. 369.

manifested, with facial movements extremely like life; and these movements, by repeating the injection, were sustained for an hour. This experiment shows that heat alone was the restorer of the muscular irritability.

Electricity as an excitant of the circulation.—Electricity, in the form of electro-galvanism, was employed in several experiments and in various ways to excite the heart. The little battery of Legendre and Morin, with the addition of the metronome so as to regulate the stroke, was the instrument used, and artificial respiration was combined with the electric process. In one experiment the negative pole from the battery was passed along the inferior cava into the right side of the heart, and the opposite pole, armed with sponge at its extremity, was placed over the heart externally. Sufficient action was excited to produce a pulmonic current by the contraction of the right ventricle. The left side of the heart also contracted on receiving blood, an arterial circuit was made, and the animal exhibited for the moment all the signs of reanimation. In another case the insulated pole from the battery was passed into the left side of the heart of a dog, the opposite pole being placed on the divided chest-wall. There was immediate action of all the muscles of the chest, but the heart was uninfluenced. In a third case a current was passed from the brain along the whole length of the spinal column, and artificial respiration was sustained for half an hour. On opening the body, the heart was found full of blood on both sides and was contracting, but not with sufficient force to produce a circuit.

In a fourth case, a dog being the subject of experiment, electric communication between the right side of the heart and the external part of the organ was set up with artificial respiration, as in the first experiment of this kind, only that the poles were reversed, and at the beginning of the experiment the pole applied ultimately to the heart externally was placed for a few minutes previously over the intercostal muscles. In this experiment the heart did not respond at all, although the thoracic muscles made vigorous contractions.

The inference which I draw from these experiments with electricity on the heart is, that by rapidly establishing a direct circuit between the blood in the right side of the heart and the external surface of the organ, using a moist conductor from the positive pole for the external surface, a sufficient contraction may (I had almost said, by a fortunate accident) be induced in the right ventricle to drive over the pulmonic current of blood, and to allow of its oxygenation by artificial inflation of the lungs. This fact at first sight looks small; but I value it beyond measure, because it has demonstrated that, when the action of the heart has ceased, the chest of the animal being open and all the conditions for reanimation being most unfavourable, the mere passage of blood from the right to the left side of the heart is sufficient to reestablish the action of the left side; that the left side thus reacting can throw a blood-current into the arteries; and that upon the reception of blood by the system, general muscular action and rhythmical action of the muscles of the chest are reproduced.

Advantages and dangers of galvanism.—In considering the advantages that may be derived from galvanism, certain dangers of it must not be forgotten. My experiments clearly showed that the natural muscular irritability, while it is for a short time made more active by galvanism, is shortened in duration. This is natural. The irritability of muscle is in proportion to the degree of force which remains in it after the blood is withdrawn, which force is evolved in proportion as it is called forth. It is well, therefore, in applying galvanism for any purpose to the subject in whom the action of life is suspended, to use the agent for one definite object, and to remember that, in proportion as it is used, its power for good diminishes.

Mechanical methods for restoring the circulation.—In the last division of the physical series of experiments, the object held in view was to set the blood mechanically in motion through its own vessels. The attempts were made (*a*) by forcing blood towards the right side of the heart and into the lungs by the action of a syringe fixed in a vein, (*b*) by trying to draw over a current of blood into the arteries from the veins and over the lungs, (*c*) by trying to inject the heart of one animal with blood derived from another animal.

Forcing-action by the veins.—*A priori* it seems an easy task to take an animal so soon as it is dead, to fix a tube from a syringe in the external jugular vein, to fill the syringe with blood, and by a downward stroke to push on the blood in the course of the circulation. From a mechanical point of view, the operation is perfect in theory; and when we remember that the auriculo-ventricular valve of the right side becomes in fact a natural valve for the piston, it is difficult to see how an artificial circulation can fail to be established by this simple means. When we further remember how easy it is to combine artificial respiration with the propelling process, one must feel that, prior to a point of time when the blood has coagulated, the process ought to succeed. Indeed, when the suggestion first occurred to me, I was so struck by it, that I rose from bed in the middle of the night to carry it out. Without for a moment losing faith in it, it has not as yet, however, been successful in my hands. The practical difficulty lies in the adjustment of the force employed. If too much force be used, the vein gives way; if too little, the obstruction in the pulmonary artery and lungs is not overcome. In further researches I shall employ larger animals than I have done up to the present time.

Suction-action by the arteries.—While conducting this forcing-process for artificial circulation, another idea suggested itself, viz., that perhaps it would be possible to *draw* a current of blood over the lungs into the arteries, oxidizing the current as it passed by artificial respiration. With this object in view, a syringe, connected with an air-pump, was fixed in a large artery, and the barrel of the syringe was then exhausted. When the syringe was thus filled with blood, the motion of its own piston downwards pushed the blood back into the arteries in the direction of the heart. The

difficulties in this experiment were connected with the rapid coagulation of blood; but here, as in a previous experiment, sufficient was indicated to prove that reanimation is a possible fact. In one case the syringe was filled with blood, brought over the lungs and oxidized; and when this blood was driven again over the arterial circuit into the muscles, it reestablished, wherever it found its way, muscular action, and, for a brief period, all the external phenomena of life.

Transference of motion from living to dead hearts.—Equally interesting with the results just named were those in which it was attempted to stimulate to contraction the dead heart of one animal with the force derived from the blood issuing from the heart of a living animal. In the experiment related as bearing on this point, although the force could not be readily conveyed by the pulsating stroke of the living heart, it was shown that twenty-eight minutes after the dead heart had ceased to pulsate, its contractions were revived by the transference of the blood derived from the heart of the animal that lived.

Artificial blood for injection.—It remains to be seen whether a fluid resembling arterial blood, and capable either of being readily compounded when required, or of being kept ready for use, and capable also, when heated to 98°, of restoring the muscular power of the heart, may not be invented. If it can, then the operation of injecting the heart by a carotid or brachial artery will be the most important practical step yet made towards the process of resuscitation when the motion of the heart has been arrested.

Value of the heart-stroke.—Granting, however, that such a fluid could be discovered, it would be necessary, in using it, to feed the heart, not in one continuous stream, but stroke by stroke, as in life; for it seems to me that the stroke supplements or, more correctly speaking, represents a certain measure and regulation of the force derived from the combustion of the blood. After many failures, I believe I have at last contrived an injecting-apparatus which will supply the stroke at any tension and at any speed that may be required; but the instrument is not yet out of the maker's hands.

Bearing on this subject, it is certain that blood at 98° in the living heart will excite spontaneous action of involuntary muscle; that blood which has been drawn, oxidized, and heated even to 115° will not excite spontaneous muscular action when injected in a continuous stream, but that water or blood at 125° injected with a continuous stroke will excite. It is essential, therefore, to determine whether the addition of mechanical force by stroke will supplement the necessity of a higher temperature*.

* Since this paper was laid before the Society, I have determined by a direct experiment that rhythmic stroke is of the first importance in restoring muscular contraction. By means of a machine which can either be worked by the hand or by electro-magnetism, I was enabled, assisted by my friends Drs. Wood and Sedgewick, to introduce blood heated to 90° Fahr. into the coronary arteries of a dog by rhythmic stroke, and at the

THIRD SERIES OF EXPERIMENTS.—*Application of External Heat.*

The last series of experiments were conducted to ascertain the effects of external heat applied to the body that has ceased to show evidence of life. I was led to the inquiry by the fact that a kitten that had been under water, to my direct knowledge, for two hours, became reanimated in my pocket, and lived again perfectly. To see what further could be done in this direction, I placed three young rabbits, which had been drowned, in a sand-bath at temperatures respectively of 100°–110° and 120°. Afterwards other rabbits that were destroyed by carbonic acid and chloroform were placed in the same manner and exposed to the raised temperature for an hour. In no case was there any restoration of vitality; but it was observed that those parts of the body that had been more directly exposed to the heat showed the earliest indications of cadaveric rigidity. In the experiments where the death took place from chloroform, and where the animals had been exposed to a temperature of 100°, the heart at the end of an hour was found still excitable, and on the right side was contracting well without the application of stimulus. This did not occur in the cases of death from drowning and carbonic acid, nor yet in cases where the warmth was carried above the natural temperature. These observations are of moment as indicating two facts,—viz., that chloroform is less fatal as a destroyer of muscular irritability than either carbonic acid or the process of drowning; and that in the application of temperature to the external surface of the body by the bath, it is not advisable to raise the temperature many degrees above the natural standard.

It is worthy of remark that in one of the rabbits which had been destroyed by chloroform and exposed to a temperature of 100°, the muscular irritability in the intercostal muscles was present thirteen hours after death. In all the cases the right side of the heart was found free of engorgement, while the left side and the arteries contained blood—thus indicating that a pulmonic current had been produced.

GENERAL CONCLUSIONS AND INDICATIONS.

I have already shown that artificial respiration is of service only when blood from the heart is being still distributed over the capillary surface of the lungs—or, to return to the simile with which I set out, that the process is simply one of fanning an expiring flame, which once expired will not, in spite of any amount of fanning, relight. The further conclusion to which I am at this moment led, goes, however, beyond the process of artificial respiration; returning again to the simile, I venture to report that, even

same rate as the stroke of the heart of the animal previously to its death. The result was, that one hour and five minutes after the complete death of the animal, its heart, perfectly still, cold, and partly rigid, relaxed, and exhibited for twenty minutes active muscular motion, auricular and ventricular. The action, which continued for a short time after the rhythmic injection was withheld, was renewed several times by simply reestablishing the injection.

when the heart has ceased to supply blood to the pulmonic capillaries, during the period previous to coagulation, the blood may be driven or drawn over the pulmonic circuit, may be oxidized in its course, may reach the left side of the heart, may be distributed over the arteries, and that, thus distributed, it possesses the power of restoring general muscular irritability and the external manifestations of life. Hence I infer that resuscitation, under the limitations named, is a possible process, and that it demands only the elements of time, experiment, and patience for its development into a demonstrable fact of modern science.

Various modifications of the experiments to which I have had the honour to draw the attention of the Society are in hand; and if I am allowed the privilege, they will form the subject of another communication.

XIV. "On the Anatomy and Physiology of the Nematoids, parasitic and free; with observations on their Zoological Position and Affinities to the Echinoderms." By Henry Charlton Bastian, M.A., M.B. (Lond.), F.L.S. Communicated by Dr. Sharpey. Received June 13, 1865.

(Abstract.)

After commenting upon the many conflicting statements which have been made concerning the anatomy of these animals, and more especially with regard to the presence or absence of a nervous system, and of real organs of circulation, the author alludes to the increased interest which has lately been thrown over this order by the discovery of so many new species of the non-parasitic forms, marine, land, and freshwater.

He has entered fully into the description of the tegumentary organs, and has recognized a distinct cellulo-granular layer intervening between the great longitudinal muscles and the external chitinous portion of the integument. This layer is one of great importance in the economy of these animals; the author looks upon it as the deep formative portion of the integument from which the chitinous lamellæ are successively excreted. It is bounded internally by a fibrous membrane, which serves as an aponeurosis for the attachment of the four great longitudinal muscles; and the well-known lateral and median lines which have so long been a puzzle to anatomists are, he says, in reality nothing more than inter-muscular developments of this layer. In some species each of the lateral lines contains an axial vessel, though in very many others nothing of this kind is to be met with. A periodical ecdysis of the chitinous portion of the integument takes place in all Nematoids during the period of their growth.

The author agrees with Dr. Schneider as to the nature of the transverse fibres attached to the median lines. They are contractile prolongations from the longitudinal muscles, and may be considered extrinsic muscles for the propulsion of the intestinal contents, since the intestine itself has no muscular tissue in its walls.