undervest were literally torn to shreds, and the knickerbockers he was wearing were stripped from him and scattered on the ground. His stockings and gaiters were similarly torn to pieces, and on the boots the lightning had a remarkable effect. They were burst open, some of the brass eyelet holes were torn out, nails were forced out, and the soles were torn out. The skin had been torn off the chest and the right leg was torn and blackened; blood was issuing from the mouth and right ear.*

In view of the fact that the current strength of a particular stroke of lightning, from the data presented, has been estimated at at least hundreds if not thousands of amperes, it is not difficult to account for the phenomena described.†

There is no doubt that a lightning stroke acts sometimes as a high-pressure current, *i.e.*, it causes an inhibition of the respiratory centre and syncope, and it is in such cases that recovery follows either spontaneously or from artificial respiration. That death occurs sometimes in the first way from industrial currents is unquestionable, and the post-mortem findings in some of the electrocutions point to an actual mechanical disintegration of the vascular structures; at least, such seems to have been the case in the twenty-fourth electrocution (Hampton) witnessed and reported by Drs. A. E. Kennelly and Augustin Goelet.‡ In this case, upon post-mortem examination, it was observed that the blood was driven from the peripheral vessels into the organs and tissues of the chest and head and there was actual rupture of the overdistended vessels. Examination of the brain demonstrated the presence of a quantity of dark blood due to rupture of the blood-vessels. It was estimated that at least two quarts escaped from the scalp and cranium in removing the brain. Upon the removal of the dura mater the vessels on the surface were seen to be distended, while in many places there were evidences of rupture. The same condition existed in the interior of the brain and coagulated blood was found at the base of this organ.

As to the actual mechanism of death occurring in the second way, for a long time there was no uniformity of opinion among physiologists. Happily, more solid ground seems now to have been reached.

In reviewing the work of the different experimenters in sequence, it is found that D'Arsonval concluded from his observations of the phenomena which took place in animals subject to lethal doses of electricity, that death occurred in two ways:

(1) By lesion or destruction of the tissues (disruptive and electrolytic effects of the discharge).

(2) By excitement of the nerve centres, producing the arrest of respiration and syncope, but without material injuries. In the first instance death is absolute and final, but in the second he believed that the nerve centres—respiratory—were inhibited, which gave rise to a suspension of respiration and arrest of heart action. In his estimation the primary action was upon the respiratory function, and the cardiac failure followed upon exhaustion of the medulla oblongata and functional death of the ganglionic cells. The fact of cardiac action after arrest of respiration led to this theory.

(3) Tatum concluded that the essential fatal field of action lay within the substance of the heart itself; that the external inhibitory mechanism played little or no part; that electrical currents finally arrest respiration without simultaneous or still earlier arrest of the heart; and that no changes were observable in the substances or functions of the muscles and nerves or blood which could in any sense be the cause of sudden death. He offered no explanation as to the nature of the action on the heart, but, from experiments with curare and atropine, he believed that the action was a direct one upon the muscular tissue rather than one involving any nervous mechanism. He had no suggestion to offer as to why the heart muscle was more susceptible than other muscles, but hoped that a more special study of the subject would soon be possible. That hope has been fulfilled in the work of Prévost and Battelli and in that of Cunningham.

(4) The experiments of Houston and Kennelly have already been referred to as of interest, not from the physiological side, but in demonstrating that death is practically instantaneous and painless from the purposed and scientific applications of high-pressure currents. They showed, as Tatum had,—and this has been confirmed by later investigators,—the tolerance of an animal to currents of high pressure when passed through the head (contacts consisted of cotton pads well wetted with saline solution and placed in the ears of a dog; alternating current of 700 volts, 690 of which were effective; resistance 1,200 ohms; current 6 amperes; duration five seconds; loss of consciousness, but animal not killed). Their conclusions as to the instantaneity and painlessness of death will be considered later on.

(5) Bokenham and Jones confirmed the observations of Houston and Kennelly, that a much stronger current was required to kill an animal (the experiments were made upon cats) when passed through the head or when the contacts were placed on either side of the neck. The pulse tracings taken by Bokenham and Jones, and careful inspection of the respiratory movements, led them to conclude that death was caused by failure of the heart, and the negative results of shocks of equal strength passed through the head and neck strongly suggested to them that the action was upon the heart muscle directly rather than through the nervous mechanism.

(6) Bleile, after a series of very carefully conducted experiments, eliminated during their progress (1) the direct action of the current upon the heart, by artificial respiration; and (2) the influence of the pneumogastric nerve, by the hypodermic injection of atropine, thus paralyzing the nerve fibres. He also, (3) prior to the application of the current, administered nitroglycerin and nitrite of amyl to produce dilatation of the arterial system. He then concluded that death was due to the contraction of the arteries, through the influence of the nervous system, and that the constriction of the arteries furnished a greater mechanical impediment to the flow of blood than the heart was able to overcome.

(7) Kratter concluded from his experiments that the first effect consisted in a permanent arrest of the respiration and he regarded death from an electric shock as a form of suffocation.

(8) Oliver and Bolam concluded that the action was upon the heart muscle rather than upon any of its nervous mechanisms. They observed that when the current ceased to pass, the heart underwent distention and then entered into a state of *fibrillary tremor*, maintained for a variable period, while the animal would make deep, respiratory efforts—shown by forcible movements of the diaphragm. They failed, however, to interpret the value of this phenomenon, although they were the first to record it in connection with experiments made to determine the mechanism of death.

The analysis of the work of the physiologists thus far recorded points with three exceptions to a direct action on the heart as the cause of death. But it remained for Prévost and Battelli and Cunningham to show how the current acted on the heart muscle. Their experiments seem to have been conducted simultaneously and without knowledge on the part of either one as to what the other was doing—as is so often the case when scientific investigation of any sort has been carried to a certain definite conclusion—but the priority of publication belongs to Prévost and Battelli (Comptes Rendus de l'Académie des Sciences, March 13th and 27th, 1899; *Jour. de Phys. et de Pathol. Générale*, May and September, 1899—et *Revue Médic. de la Suisse Romande*, September, 1899; R. H. Cunningham, N. Y. *Med. Jour.*, October 21st, 28th, 1899.*

* The Electrical Engineer, October 21st, 1897.

† Wurtz, Alex. J.: "The Current Strength of a Lightning Stroke." The Electrical Engineer, October 27th, 1898.

‡ Kennelly and Goelet: "Does Execution by Electricity Produce Instantaneous, Painless, and Absolute Death?" Electrical World, vol. xxv., p. 195.

* Cunningham's article was completed toward the end of February, 1899, but was held back until March 31st, when it passed into the hands of one of the Prize Committees of the College of Physicians and Surgeons, New York, where it remained until published.

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The experiments of Prévost and Battelli are no more conclusive as to the action of a lethal dose, but are more complete in that they deal both with continuous and with alternating currents of varying pressures, thereby establishing very clearly the apparent discrepancies in the action of low- and high-pressure currents. The experiments of Cunningham, on the other hand, were made with continuous currents only, at pressures of 115 volts (lighting mains), and 124 volts (battery of accumulators*).

Prévost and Battelli determined from their observations that the mechanism of death from both continuous and alternating currents was the same, although the action varied in a slight degree.

From their researches they find that death by electric currents takes place in two ways entirely different the one from the other:

(1) By the action of a low-pressure current, death in man is due to the primary paralysis of the heart in *ventricular tremulation*. This is regarded as the usual cause of death in accidents of the electrical industries, because, as has been pointed out, the conditions of the conducting circuit are such that a high-pressure current acts as a low-pressure current.

(2) A high-pressure current, when the contacts are good and the heart lies upon the line which unites the electrodes—*i.e.*, in the conducting path,—does not paralyze the heart of man. In this case the respiration has been resumed, as has been noted at the earlier electrocutions in New York State.

When death takes place, under the conditions just mentioned, it is due to an inhibition of the respiratory centre. The heart continues to beat with energy and stops only after the asphyxia. It is in these cases that it is sufficient, as a rule, to practise artificial respiration.

The paralysis which occurred in animals the subject of experiment, through the action of a low-pressure current, *i.e.*, 120 volts, they found "analogous to that which is directly obtained from exciting the exposed heart with an induced current, *fibrillary tremulations* of the ventricles, while the auricles continued to beat. This is the well-known phenomenon designated by physiologists as *ventricular tremulations* or *fibrillar contraction*."

A. The following phenomena were observed by them in their experiments upon dogs, cats, guinea-pigs, rabbits, and rats:

Alternating Currents.—"1. Instantaneous paralysis of vagus and of cervical sympathetic with currents of high pressure.

"2. Non-modification of phenomena described above by previous section of vagus nerves.

"3. The repletion of the heart with blood, even in the case of currents of high pressure and short duration, which seems to prove that the vascular tone and vaso-motor centres are not paralyzed.

"4. No appreciable elevation of the temperature, if the time of the passage of the current is not prolonged.

"5. Rapid appearance of cadaveric rigidity in the case of the currents of high voltage.

"6. At autopsy, absence of constant and characteristic microscopic lesions. Notwithstanding, one finds sometimes hyperæmia of the meninges, but not intracerebral hemorrhages, if the subject of the experiment has not been subjected to elevation of the temperature.

"7. *Duration* of the contact is important; respiration, *cæteris paribus*, is more affected when contact has been longer. Convulsions and general tetanus will be more pronounced if the contact has been short. The more the voltage is raised, the shorter is the duration of the contact necessary to cause convulsions.

"8. The *points of application* of the electrodes are a matter of great importance. Their differing position can vary the appearance of this or that symptom.

"*Respiration* will be affected more easily and convulsions more easily produced if one of the electrodes is placed upon the head.

"*Heart.*—The voltage necessary to produce the *fibrillary tremor* is less if the heart is in the line between the poles. Inversely, if the heart is not in this line, it can be thrown into *fibrillary tremor* (*tremulations fibrillaires*) upon the application of currents of high pressure, which, in traversing the heart directly, would not have paralyzed it.

"9. When, after currents of high pressure, the heart of the dog or of the guinea-pig is paralyzed consecutively to the arrest of respiration, *massage* of the heart provokes the *tremulations fibrillaires*, which are wanting in a case of simple asphyxia not produced by electrocution.

B. *Continuous Currents.*—Conclusions reached:

"1. *Respiration* and *sensibility* react the same to the shocks of closure or of opening.

"2. *Convulsions*, on the other hand, are especially provoked by opening of the current.

"3. As to the *heart*, the fibrillary tremor will come on if the circuit be not closed or opened abruptly. It is a fact, analogous to that which was stated with regard to alternating currents, that a violent excitation can make the fibrillary tremor cease.

"4. Examination of the tracings of arterial pressure seems to indicate the absence of a vaso-motor excitation, which, on the other hand, is produced by the alternating currents."

The fact that in some of the earlier electrocutions in New York (McElwaine, Jaylor) respiration was not definitely arrested when the body was traversed by a pressure of 1,700 volts alternating current (contacts good, head to leg, continued for several seconds), is in a line with some of the experiments of Prévost and Battelli. For example, a large-sized dog was submitted to the action of an alternating current of 4,800 volts (contacts good, duration several seconds), and yet spontaneous recovery of the respiration took place. On the other hand, in their experiments with a much lower pressure (240 to 600 volts, as well as with those of H. and K.) death was absolute. They found in dogs that these currents of medium pressure produced not only paralysis in ventricular tremulations of the heart, but also absolute arrest of the respiration. In such cases instantaneous death would result from the inhibition of the nerve centres, seconded by the failure of the circulation. In the first instance a repetition of the shock is sufficient to produce a definite arrest of the respiration, and while physiologically death cannot be regarded as strictly instantaneous, it is practically so so far as consciousness is concerned.

In view of the unquestioned fact that currents of the same degree of pressure and applied under apparently the same conditions, both in man (electrocutions) and in animals, produce such different results,—lethal in the one case, and non-lethal in the other,—we are justified in concluding that there must be differences in vital resistance. It is very evident from all the evidence forthcoming that the human respiratory system offers a very great resistance to an electric shock, and this resistance is by no means the same in all individuals, just as experiment has shown that it is not so in all animals. The fact that the nervous system is of a higher organization in man than in animals is suggested by Prévost and Battelli as a reason why the function of the respiratory centre should be abolished in the former with but a slight increase of voltage. This is not substantiated, however, by the results of electrocution. Prévost and Battelli show by their experiments upon animals that, all other things being equal, the higher the pressure the greater certainty of the definite abolishment of the respiratory function, and they place the pressure necessary for the purpose beyond 1,700 volts.

So far as the evidence is at hand from the electrocutions which have taken place in New York—some fifty in number—it appears that the expenditure of this tremendous energy varies in its action in different individuals; that while in one a complete inhibition of the respiratory centre from a single application results, in another several successive shocks are required completely to abolish its function; and again, in other instances, there seems to be an actual mechanical disruption (twenty-fourth electro-

* Cunningham made some experiments in 1894 with currents of a higher pressure, but the detailed results are not embodied in his paper of October 21st, 28th, 1899.

cution), as the blood from every peripheral as well as from the larger vessels is forced by the powerful tetanic, muscular contractions into the chest and head, with rupture of some of the blood-vessels. It is fair to suppose that nearly all the energy liberated in the body is expended as heat; and, as a matter of fact, there is a considerable rise in the temperature, although the action of this heat does not bring about death. In this connection it is interesting to note that Prévost and Battelli found that there was no intracerebral hemorrhage when the temperature was not raised, which would seem to indicate a definite relation between the amount of energy liberated and the result.

If this energy acted to produce either inhibition of the respiratory centre or paralysis of the heart in ventricular tremulation, there might not be an appreciable rise in the temperature; but when it has acted to produce a disruptive effect, as, for example, in some accidents from industrial currents and sometimes in electrocution (*i.e.*, with excessive intracerebral hemorrhage and rupture of some of the blood-vessels), the evidence shows that the rise is considerable.*

Analysis of the accidents from industrial currents (presented farther on in tabulated form) would seem to confirm the experiments of Prévost and Battelli in reference to the action of the current on the respiratory centre.

In cases 2, 3, 8, and 10, there was contact with alternating pressures of 2,000, 4,500, 10,000, and 25,000 volts respectively, followed by recovery. From the conditions of the conducting circuit (*i.e.*, position and nature of contact) No. 2 was evidently a hand-to-hand contact; No. 3, bipolar, *i.e.*, telephone wire grasped in hand, which touched another wire; No. 8 a hand-to-hand contact; and No. 10 a hand-to-hand contact (the energy was not expended upon the respiratory centre in such a way as definitely to arrest respiration, nor was the heart in the direct conducting path). To produce inhibition of the respiratory centre, a head-to-spine contact is the most favorable, although a head-to-leg contact contributes to the same result. The latter position of contacts also favors action upon the heart primarily, although a chest to spine, or to spine and head, is better. Had the latter condition obtained in No. 10, on account of the very high resistance offered by the position and nature of the contact, the pressure, although high, might have acted as a low-pressure current to paralyze the heart in ventricular tremulations.

The data in Cases Nos. 1, 9, 11, 12, 13, 15, 16, and 20 seem corroborative of the experimental work of Prévost and Battelli, showing that high-pressure currents, by reason of high resistance, act as low-pressure currents. Although the pressure in every one of these instances was high, the inference is reached, from instantaneous death, that they acted by reason of position and nature of contact as low-pressure currents, and that death was due to paralysis of the heart in ventricular tremulation. Unfortunately there has never been any opportunity of observing this phenomenon in man, and the inference can be drawn only by the action on warm-blooded animals. By reason of the fact that in the industries the contacts are always bad, both as to position and as to nature, the resistance great and amperage small, the effect produced is that of a low-pressure current. This effect is more grave when the initial pressure is high,—less so with a diminution of voltage.

It is not believed by Prévost and Battelli that the paralysis of the heart in man is always permanent, but that it may sometimes be transitory. This conclusion is reached by them as the result of an analysis of some accidents, and from the fact that the current does not affect all animals similarly; that in some—for example, a guinea-pig—the heart rarely resumes its beats, but that in the rabbit it often resumes its rhythm. These are inexplicable facts, and we have no means of knowing that the human heart may not comport itself similarly.

From experimental evidence there is every reason to conclude that besides the influence exerted by the quality, duration, strength, and density of the current (Tatum) through the thorax, some other factor, apparently residing in the heart and probably physiological in nature, also exercises a considerable influence, as evidenced by the greater or less readiness with which the cardiac effect is produced (Cunningham).

Prévost and Battelli as a result of their very complete experimental work, arrived at the following conclusions:

Conclusions and General Considerations.—Experiments upon animals, observations made upon the electrocuted criminals in America, the accounts of accidents occurring in the electrical industry, lead us then to conclude that according to all probability:

1. The heart in man comports itself like that of animals; it is paralyzed in ventricular tremulations by a current of low pressure.

2. The death of man, in the accidents of the electrical industry, cannot be attributed to arrest of respiration considered as an immediate cause.

3. The death of man in these accidents is due to the primary paralysis of the heart in ventricular tremulations.

4. Currents of high pressure, when the contacts are good and the heart lies upon the line which unites the electrodes, do not paralyze the heart of man; in this case the respiration is resumed, as has been observed upon the electrocuted criminals in America.

5. In the electrical industry the contacts are always more or less bad; for this reason the currents of high pressure act like currents of low pressure and lead to paralysis of the heart.

6. The difference in the results (mortal or not) of the grave accidents of the electrical industry can be explained in two ways: we must assume that the duration of the contact has been too short (fractions of a second) and that the heart has not been placed in ventricular tremulations; or we must admit that the paralysis of the heart of man is not always decisive, *i.e.*, permanent.

From these conclusions it would appear that in employing a current of high pressure, for the purpose of electrocuting a man, we have secured a result quite different from that which we set before ourselves to obtain, viz., to kill the man rapidly.

The study of the ventricular tremulation of the heart, which hitherto has offered only a theoretic interest, now assumes some practical importance; for it is to the development of these tremulations that are due the mortal accidents in the electrical industry. The physician, in most of these accidents, is quite impotent, for we possess no *practical* means of re-establishing the beats of the paralyzed heart. Artificial respiration, absolutely useless in the case of well-defined paralysis of the heart, can be sometimes of some use if this paralysis is transitory, in facilitating the normal resumption of the respiration. In any case, artificial respiration is actually the only treatment which the physician has at his disposition.

Cunningham in his experiments reached practically the same conclusion, at about the same time as, and independently of, Prévost and Battelli. The evidence obtained as a result of his experiments upon a series of thirty dogs is most conclusive, and his work, after a lapse of two years, may be regarded as classic. In view of this fact, a somewhat detailed description of his technique as well as of the results which he obtained, is of sufficient importance to warrant us in publishing it in the present article.

A medium-sized dog was etherized and into the right carotid artery there was inserted a cannula which was connected with a Ludwig manometer. The latter in turn was so arranged that the pulsations should be recorded upon the paper of a Hürthle kymograph. A second cannula was introduced into the trachea; and through this the anæsthetic was administered when necessary. As a third step the hair over the chest was carefully removed by shaving, and the scalp and soft parts covering the skull and temporal fascia (on both sides) were dissected off. Then, finally, the contacts, covered with thin chamois skin and well wetted with a strong, hot saline

* D'Arsonval and Brown-Séquard regarded the rise in temperature in part as the result of the asphyxia.

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solution, were applied to the two regions thus made ready for them: to that of the heart a plate electrode, connected with the negative terminal and held securely in place by means of strips of rubber plaster; to that of the head a cup-shaped electrode connected with the positive terminal. A stethograph was attached to the chest and connected with a recording Marey tambour. A chronograph placed in shunt with the circuit that passed through the dog served to inscribe the base line of the tracings as well as to mark the closing and the opening of the circuit. A second chronograph indicated the time in two-second intervals, while a Whitney dead-beat voltmeter and a Weston dead-beat ammeter were used to measure the pressure and the strength of the currents. Normal tracings of the blood pressure and the respiration were first taken and then the circuit was suddenly closed and kept closed for seventy-six seconds. During its closure there was observed a pressure of 116 volts and an observed current of 0.4 ampere. The following effects were noted: Almost simultaneously with the closing of the circuit the blood pressure rapidly fell to zero, the tracing showing a few heart beats—auricular. At the closure a deep inspiration was produced, then there was a deep expiration, followed by cessation of respiratory movement in a state of expiration so long as the current continued to pass. On breaking the circuit a deep inspiration followed by an expiration resulted, and after a few moments a few shallow respirations were observed. Artificial respiration was then begun and was continued without avail for twenty minutes.

The occurrence of natural rhythmical respiratory movements after the opening of the circuit demonstrates that the respiratory centre in the medulla is not paralyzed nor instantly killed. Further, the tracings show that an almost total and instantaneous extinction of the arterial circulation is produced. By opening the chest previously and observing the behavior of the heart, it is readily demonstrated that this extinction of blood pressure results from a practically instantaneous cessation of the co-ordinated rhythmical movements of the heart at the instant a current of 0.9 ampere or even less is passed through a dog. Both ventricles immediately stop beating, while the auricles, especially the auricular appendages, beat with extreme rapidity. On stopping the current the auricular appendages generally resume their usual co-ordinated rhythmical contractions, which may often continue for a considerable number of minutes. Frequently the auricles will begin to beat again co-ordinately for a few seconds, but the ventricles rarely if ever exhibit the slightest sign of co-ordinated contraction. Cunningham noted ventricular contraction in only a single instance, and that only after he had introduced a tube into the jugular vein for the purpose of withdrawing venous blood from the greatly distended heart. This points to a direct action upon the ventricular portion of the heart muscle. The only difference observed, when the points of contact are the chest and fore-leg, instead of the head and chest, is the greatly exaggerated respiration shown by the resultant tracings. Upon opening the thorax immediately after the passage of the current through the heart percutaneously, a careful examination of the still quivering ventricles shows that the co-ordinated beat of the heart is absent, as a whole, while the various minute bundles of muscle fibres alternately contract and relax with considerable vigor in various parts of the ventricles. As the right cavities of the heart become more and more distended by the accumulating venous blood, the asynchronous quivering of the various little bundles of muscle fibres grows less and less until finally every trace of muscular contraction disappears from the greatly distended ventricle. The action of the current, Cunningham concludes, produces upon the heart the well-known phenomenon described by physiologists as *delirium cordis* or *fibrillar contraction*, "supposed to be caused by some change in the muscular fibres themselves," and Hedley* asks: Is this a coagulation by the heat, resulting from the tetanic muscular contractions?

* "The Pathology and Treatment of Electric Accidents." London Lancet, August 25th, 1894.

Cunningham believes that there is no question of the instantaneous death of the muscle cells of the heart nor of their paralysis, nor of profound molecular changes invisible under the microscope, resulting from the direct disruptive action of the current. This, he says, is readily proved if Porter's method, or any other method for recovering the excised dog's heart from the condition of fibrillar contraction, is employed. By the use of Porter's method (perfusion of the blood-vessels of the heart with warm, defibrinated dog's blood diluted with 0.8 per cent. saline solution) the excised hearts (still manifesting fibrillar contractions) of numerous electrocuted dogs were made to beat co-ordinately again and to continue their co-ordinate contractions for nearly an hour, only ceasing then because of the discontinuance of artificial respiration. It was often necessary to plunge the excised hearts into iced saline solutions in order to stop all movements before co-ordinate beats could be established. These facts demonstrate that the heart muscle is not paralyzed or killed by the current; for if it were paralyzed no movements would have been observed after the passage of the shock; and if the muscle had been killed no recovery could have occurred on restoring the circulation. It is probable that "the effect of the electrical stimulus has been to disturb the balance of the hypothetical intracardiac co-ordinating mechanism, the nature and location of which physiologists are still endeavoring to elucidate."

Cunningham points out, as did Prévost and Battelli, that it is well known that the action of various kinds of stimuli upon the exposed mammalian heart—for example, mechanical, chemical, electrical,* and also the stimulus of cold—produce the condition known as fibrillary contraction; consequently the effect is physiological in nature and not one that is characteristic alone of the passage of an electric current.

In view of the fact that an electric current produces this effect upon the exposed heart, it is not at all remarkable that a strong electric current, continuous or alternating of a moderate frequency, when passed percutaneously, should throw the heart into a condition of fibrillar contraction.

H. Dixon Mann concluded, from the phenomena observed as a result of percutaneous applications of the continuous current upon man, that a struggle takes place between the natural and the artificial electrotonic conditions: and that when the heart is weak and the current strong, the heart is overcome, but that when the organ is fairly strong and active it is able to bear the force of the current without experiencing any harm.†

The experiments of Cunningham, as well as those of Prévost and Battelli, are conclusive in showing that death in dogs—and without doubt also in man, in view of the evidence of autopsies—from low-pressure currents (120 volts), or from those of medium pressure (240–600 volts), or even from currents of high pressure (above 600 volts), when the conditions of the circuit are such as to cause a high-pressure to act as a low-pressure current, is due to the excitation of fibrillar contractions from which the heart of the mammalian rarely recovers. The fact that certain animals (frogs and turtles, for example) recover easily from such a condition explains why they are not easily killed by low-pressure currents, and that to cause

* Weber, Ludwig, and Hoffa, for magnetic electric currents; Einbrodt, Mayer, Herbst, and McWilliams, for continuous currents from batteries and small induction coils. All of these authorities are cited by Cunningham in his treatise.

† "Action of Electric Currents on the Heart in Living Subjects."—The phenomena have also been observed by the present writer in therapeutic administrations of a continuous current when the heart was the subject of disease—mitral insufficiency—and the dose was increased beyond the tolerance of the patient. The symptoms were anguish, præcordial distress, and threatened syncope, with an irregular and feeble pulse. In view of the action of oscillatory currents of high potential previously alluded to, it is interesting to note that relief was promptly established by a general application of the convective discharge from a large influence machine with a localization directly over the heart and to the dorsal spine.