bewegungen anzuwendende Methode, erläutert am Gelenkmechanismus des Vorderarms beim Menschen. Abhandl. der mat.-physisch. Classe der Königl. Sächs. Gesellschaft der Wissenschaften, vol. iii., 315–336.

ELECAMPANE.—INULA. The root of *Inula Helenium* L. (fam. *Compositæ*).

This is a large, rank, perennial herb, with a thick fleshy rootstock and root, and an upright, branched, hairy or rough stem, from one to two yards high. The lower leaves are half a yard or more long and half as broad. The yellow flower heads are several inches broad, somewhat resembling small sunflowers.

Inula grows, either indigenous or naturalized, in the temperate parts of Europe, Asia, and North America, and is also cultivated in Europe.

The root should be collected either in spring or in autumn, suitably sliced, and dried with gentle heat. It is then "in transverse, concave slices or longitudinal sections, with overlapping bark, externally wrinkled and brown; flexible in damp weather; when dry, breaking with a short fracture; internally grayish, fleshy, slightly radiate, and dotted with numerous shining, yellowish-brown resin cells; free from starch; odor peculiar, aromatic; taste bitter and pungent."

COMPOSITION.—*Inulin, helenin, alant camphor, alantol, essential oil, alantoic acid*, waxy, acrid, resinous, and bitter substances, besides ordinary vegetable principles and ash. The first of these, although of no medicinal properties, is the most interesting, and has received its name from this plant. It was discovered in it in 1804 by Valentine Rose, who also pointed out its intermediate position between starch and sugar. Since then it has been observed in the roots of nearly a hundred *Compositæ*, but in the plants of no other family excepting the *Lobeliaceæ*. It has likewise not been found in the aerial portions. The *alant camphor*, or *helenin*, is obtained by boiling the roots with alcohol, filtering, and adding cold water to the filtrate, when the helenin separates, upon standing, in fine needles; or it may be separated by distillation. It is a faintly odorous and nearly tasteless, volatile substance, insoluble in water, but soluble in ether, oils, and hot alcohol. The *oil* is a yellow liquid of mint-like odor, and contains alantol ($C_{10}H_{16}O$). Alantic acid is a crystalline substance associated with the oil.

ACTION AND USE.—Although an old remedy, it can hardly be said that elecampane has any important place in modern therapeutics. It is a stimulant, stomachic tonic, and enjoys a slight reputation in the treatment of amenorrhœa and bronchitis. Dose, from 2 to 4 gm. (gr. xxx. ad ʒ i.) in decoction or infusion. *W. P. Bolles.*

ELECTRICITY: THE DESTRUCTIVE AND LETHAL EFFECTS OF HIGH-PRESSURE* CURRENTS.—There are delivered from the high-pressure line of a big transmission plant, at night glowing blue with the energy that is streaming off into the dielectric, perhaps thousands of kilowatts to distant transformers, which may serve to light a whole city or furnish power to operate a street-railway system. The one result or the other obtains according to the conditions of the conducting circuit; but, in both instances, it is energy which is delivered at the terminals, and which by its expenditure produces the different phenomena instanced.

In the application of an electric current to the human organism, whether administered therapeutically, encountered accidentally in the pursuit of one's avocations, or whether applied with intent to kill (electrocution), energy is expended within the tissues of the body, causing physiological change, pathological lesion, or destruction of life. The phenomena produced, whether for life, disability, or death, depend not alone upon the initial pressure, but upon all the conditions of the conducting circuit, *i.e.*, resistance electrical and vital, as well as position, superficies, and nature of contacts. A recognition of the oneness of this energy, whether of low or of high pressure, whether continuous or alternating in its direction, as well as the precise and definite laws under which it acts, conduces to an intelligent appreciation of the varying phenomena produced by its expenditure. A study of the action of an expenditure of energy from a high-pressure source or from a lower pressure, but capable under suitable conditions of producing injurious or destructive effects, involves an analysis of:

(1) Experiments made upon animals with a view to determine the cause of death;

(2) Of such accidents as occur in the use of industrial currents;

(3) Of the phenomena observed in the electrocution of criminals.

There is a considerable array of experimental work to be drawn from, going back to the time of Nollet, but much of it was conducted in a crude and unscientific manner, and is of little save historical value. The most careful and scientific work has been done within the past eleven years; and the conclusions reached by the different experimenters referred to in the following analysis point in almost every instance to a uniform action and set of conditions, although only interpreted by Prévost and Battelli and Cunningham.

Under the second head the evidence is not so conclusive as in the first and third. In accidents due to electric currents—by reason of the fact that they are accidents and occur unexpectedly—the precise conditions of the conducting circuit, as well as the phenomena pertaining to the mechanism of injury or death, are rarely observed with scientific accuracy. Still, considerable data have been accumulated, which, with the data of experimental work and those secured from the electrocution of criminals, suffice to further an intelligent analysis of the subject.

Under the third division—the electrocution of criminals—every opportunity is afforded to note exactly all the conditions of the conducting circuit, the pressure, the superficies, position and nature of contacts, the precise measurement of current in amperes, the time, the resistance, the power or watts, and the work or total expenditure of energy in joules. The opportunity also exists, if it could be taken advantage of, for obtaining definite, detailed, and scientific information as to how and when death occurs; as to consciousness and sensation; and also whether resuscitation would be possible by the immediate application of some special method; and it has been suggested that if the law recognized the right of science to have present a trained observer, with the privilege of using the necessary physiological apparatus in order to record graphically the phenomena which take place both during and after the passage of the current, as well as to make a careful study of the post-mortem findings, the result would be of incalculable value in determining the mechanism of death in man.*

The conclusions arrived at as to the manner in which death takes place in man are determined by inference from experimental work, from the accidents which take place in the electrical industries, and from electrocutions; but the data would be more absolute and trustworthy if procured in the way above alluded to, and yet at the same time no harm would be done to the individual suffering the penalty of the law.

Before entering upon a detailed account of experimental work, it would be well to consider the electrical conditions necessary to the production of injurious and lethal effects:

(1) What is to be understood by high-pressure currents in relation to lethal effects—*i.e.*, what voltage is necessary to the production of fatal results?

(2) Is it a matter of pressure—*i.e.*, volts alone, or is it a matter of current—*i.e.*, amperes as well?

(3) What influences the latter, the pressure only, or do high-pressure currents from position and nature of contact act as medium- or low-pressure currents?

An analysis of the experimental work (which will be considered more in detail from the physiological side later on) shows that currents of varying pressure have been used to produce a lethal effect in the same species of animals, while varying pressures are required for different species of animals.

For example: Houston and Kennelly used pressures of from 690 to 1,250 volts alternating (experiments on dogs);* Bleile used from 50 to 100 volts alternating (experiments on dogs);† Kratter used 1,500 volts alternating (experiments on dogs, rabbits, and guinea-pigs);‡ Cunningham employed continuous currents of 115 volts pressure from lighting mains and 124 volts from a battery of accumulators (experiments upon dogs);§ while Prévost and Battelli conducted their experiments with both continuous and alternating currents and pressures varying from a low pressure of 120 volts to a medium pressure of from 240 to 600 volts, and high pressures of from 1,200 to 4,800 volts.‖ They used in their experiments dogs, guinea-pigs, rabbits, and rats. Bokenham and Jones, in their experiments made upon cats, reported the current, viz.: 0.5 ampere, but not the pressure;¶ Tatum used from 0.1 to 1.3 ampere; while Oliver and Bolam give only the physiological results obtained**—to which reference will be made later on,—but neither the pressure nor the current.

Kratter found that rabbits often survived pressures which proved fatal to dogs ten times the size, and Cunningham found it possible instantly to arrest the cardiac function in a very large dog—such as a Newfoundland—with a current of but 0.3 ampere; while the hearts of small, shaggy terriers, although considerably affected, not only withstood repeated shocks of 0.45 ampere, lasting from ten to eighty seconds, but quickly recovered from a shock of 0.7 ampere applied for two seconds and a half. In common with those of Prévost and Battelli, his experiments show that certain species of animals, frogs and turtles, do not succumb to currents of low pressure.

Prévost and Battelli established that with a pressure of 120 volts (alternating currents, contacts good—*i.e.*, one upon the head, the other upon the limbs) death resulted in certain animal species, while others (for example, rats) escaped without harm.

Kratter found that a short exposure to an alternating current of 1,500 volts did not always prove fatal to rabbits and guinea-pigs, while others succumbed presenting typical symptoms.

With currents of high pressure, Prévost and Battelli found that 1,200 volts (the contacts being good—*i.e.*, the one upon the head and the other upon the limbs) could kill all animals by inhibition of the respiratory centre; but that the pressure of the current and the duration of the contact should increase with the size of the animal in order to inhibit the respiratory centre. A rat, for example, succumbed to a pressure of 600 volts for one second, while a rabbit required 1,200 volts for two seconds. A dog of smallest size required 2,400 volts for three seconds, while a dog weighing 8 kgm. resisted a shock produced by the passage of a current of 1,200 volts prolonged for five seconds.†† Nor is the pressure fatal to animals, when acting as a high pressure, necessarily fatal to man.

Of equal importance with the pressure is the position, superficies, and nature of contacts. The latter may be of a material which is a good conductor, but by reason of imperfect contact they may act as a poor conductor, thereby increasing the resistance and diminishing the amperes; the same will be true if the contacts are dry instead of moist. With the skin well wetted with salt solution the resistance is lessened; and with diminution of resistance there is an increase in the amperes. In such a condition of the skin a greater amount of current is delivered to the tissues, producing a fatal result; whereas, if the skin had been dry and able to perform its function as an insulator, the resistance would have been so great as to have limited the flow in current below the lethal dose. A well-insulated contact also serves to increase the resistance and to minimize the current.

The superficies governs the distribution of current on the one hand, or its current density on the other. With large square-inch area of contact, the greater the current diffusion; with small superficies the greater the current density, within a localized area. These are factors of great importance and must never be lost sight of when considering physiological effect.

The position of contacts is of the greatest importance and largely influences the result. All experimental work, as well as what is observed at electrocutions, proves that fatal results ensue much more quickly when the contacts are so placed as to bring the heart, which is the vulnerable organ, on a line which unites the two electrodes—*i.e.*, directly in the conducting path; as, for example, on the head and calf of the leg. When they are placed on the head and fore legs, or in the case of man (electrocuted criminals) on the hands, a much greater pressure is necessary to destroy life. This is because the heart is not in the direct pathway of the current. When both contacts are placed upon the head, higher pressures are required to produce fatal results. Here, by reason of the skull, there is increased resistance; and, as the evidence shows that stronger currents, *i.e.*, greater amperage (see Houston and Kennelly, pressure 690 volts, R. 1,200 ohms, current 6 amperes, dog not killed), are withstood, the pressure must of necessity be proportional. As will be seen further on, the action of the current is different in a head contact than when the heart is included in the circuit. These facts all point to the chest directly over the heart, and to the dorsal region, as the better places for the contacts in electrocutions; but, as it is desirable that consciousness should be annulled at once, the posterior contact could be made to include the cervical spine, medulla oblongata, and the head.

Duration of contact, or time, is another important element. An instantaneous contact with a high-pressure current may be encountered with impunity, but a fatal result will ensue if an application of several seconds—five, ten, or more—be made; or, if a high-pressure current be applied for an instant of time and repeated, fatal results may ensue.

As to the amperage of a lethal current, it is not definitely known, but all the evidence obtained from experiments on animals and accidents with industrial currents show that it is very small—probably much under one ampere. In the application of the death penalty as practised in the State of New York, the strength of the alternating current passed through the body of the criminal is usually seven or eight amperes. In experimental work, the species, weight, and age of the animal have influenced the result, and the age of man, as well as the vital resistance in both man and animals, is a factor that must be considered in determining the lethal dose. In his experiments Cunningham found that young, well-nourished, and hardy dogs bore a stronger current than those older and ill-nourished, but that the size and weight seemed to bear no relation to the minimum current.

The nature of the pressure, whether continuous or alternating, is not without its influence. Cunningham found that alternating currents of moderate frequency, intermittent and coarsely pulsatory currents, were able to produce fibrillary contractions of the heart much more readily than a non-alternating or a continuous current. Tatum found alternating twice as fatal as continuous currents, but when the animal experimented upon was under ether the difference was much less marked. This would point to the influence of the powerful muscular contractions in the production of lethal effects; as, under the influence of anæsthesia, there would be a condition of general muscular relaxation which would tend to

* In every instance in which authorities quoted have used the word "tension" in relation to an electric current, the writer has substituted "pressure" in order that the terminology may be exact.

* Cunningham: "The Cause of Death from Industrial Currents."

* Houston and Kennelly: "Death by the Alternating Currents."
† Bleile, A. M.: "The Cause of Death by Electrical Shock."
‡ Kratter: "Lesions of Fatal Electrical Currents."
§ Cunningham: "The Cause of Death from Industrial Currents."
‖ Prévost and Battelli: "The Mechanism of Death by Electric Currents in Man."
¶ Tatum, Edward: "Death from Electrical Currents."
** Oliver and Bolam: "The Cause of Death by Electric Shock."
†† Battelli, Frederic C.: "The Mechanism of Death by Electric Currents in Man."

minimize this action. D'Arsonval believed that greater danger lay in accidental contact with a high-pressure, continuous E.M.F., because of the electrolytic phenomena which accompany the action of the current. The living body, in reality, is not a homogeneous conductor, and the polar action is produced not only at the points of entrance and departure of the current, but at the surface of each different tissue crossed by the current. This is an opinion—*i.e.*, as to the action of the current—which is shared by other physicists, although, as will be seen, Tatum concluded that there was nothing in the evidence obtained to show that any action on the blood was of the nature of electrolysis.

From the physiological action of high-frequency alternating currents of high potential as administered therapeutically, as well as from the experiments of D'Arsonval, Elihu Thomson and Tesla,* with currents of from 100,000 to 200,000 volts, with a frequency of 10,000 periods per second, it would be expected that fatal effects would occur in inverse ratio to the frequency—*i.e.*, that a low frequency, or periodicity, is more fatal to life than a high. The higher the frequency the greater the current which can be delivered to the tissues of the body without injury.

It is of interest here to note that alternating currents of high frequency, applied to the exposed heart, produce an increase in the number of beats and fibrillation does not occur; and that oscillatory currents of high potential very materially hasten the restoration of the coordinated heart beat in dogs in conjunction with the perfusion of the coronary vessels with defibrinated blood.†

The evidence clearly shows that high-pressure currents are not alone fatal—not even necessarily fatal; that low pressures—95 or 96 volts, and 115 volts, alternating current—are sufficient to cause death; and that while ordinarily pressures under 200 volts are not to be regarded as dangerous to life, and those over 500 volts as certainly dangerous, everything depends upon the conditions of the conducting circuit. In electrocution, to insure instantaneous and painless death, currents of high pressure are of necessity chosen.

Accidents in the electrical industries are not unduly frequent as compared with the accidents in other industrial fields; not because the pressures employed would not prove fatal under appropriate conditions, but because these conditions are but infrequently fulfilled.

In the electrocution of criminals, high-pressure currents varying from 1,300 to 2,000 volts—periodicity about 130—are commonly used, and an alternating current of 1,700 volts has traversed the tissues of the body (electrocution, Jaylor, 1893) without arresting the respiration even with an application of fifty seconds' duration, and second and third applications of the current were necessary in order to kill the condemned criminal. (This statement must not be construed as an implication that high-pressure currents do not kill, as used in electrocution at the present time, but is an illustration of the fact that a high-pressure current is not necessarily fatal. Other factors influence the result, as will be pointed out later on.) The case of Jaylor also illustrates the fact—brought out by the experiments of Prévost and Battelli—that when the pressure is high, even when the heart lies on the line which unites the two contacts—*i.e.*, within the conducting path,—this organ may not be affected, and that the nervous centres, continuing to be fed, are able to resist the action of the current; nor was the current traversing the tissues sufficient, in this case, to produce inhibition of the nerve centres, with definite arrest of the respiration. For the accomplishment of that result it was necessary to make a second and even a third application.

In the case of McElwaine (second electrocution), in which the points of contact were the head and arms,—the hands and forearms being immersed in jars of saline solution,—the effects were even less pronounced, and a second application, with the contacts applied to the head and calf of the leg, was found necessary in order to kill him. As in the case of Jaylor, the respiration was not affected by the first application. On the other hand, an alternating current of very much lower pressure—as low as 95 or 96 volts—has proved fatal in man; while several fatalities (four in number) occurred in a German mill* within a short space of time from an alternating current of 115 volts pressure.

In the death resulting from contact with an alternating current of from 95 to 96 volts, all the conditions of the conducting circuit were good (see No. 9 of the tabulated references to accidents from industrial currents). The subject, a workman in a potash and alcohol plant, was instantly killed by an alternating current of from 95 to 96 volts. He stood on an iron tank covered with soda lye—an excellent conductor—and his boots were wrapped with rags of twilled linen.† Here was the best of contact, for the saturation of the linen rags implied of necessity a similar condition of the leather of his boots, and no doubt conductivity was increased by the presence of nails in his boots, as is common among workingmen, although it is not so stated. The contact lasted for from four to five minutes, and the man was a drunkard. In this case, while the pressure was low, the resistance, by reason of position, superficies, and nature of the contacts, was reduced to a minimum and the current strength (or number of amperes) must necessarily have been high. In addition, the heart was in the conducting path, the duration of contact was prolonged, and the man was a drunkard. In this instance, then, everything favored a large electric energy, *i.e.*, a pressure, while low, fully effective because of low resistance, and resulting in large amperage; while long contact and diminished vital resistance, by reason of intemperate habits, contributed to the fatal result.

While there does not seem to be any direct connection between the lethal effect and the number of joules, there must be some remote effect, for the greater the energy the greater the chance of death. The conditions in the above instance favored the maximum rate of expending energy, the destructive power of which must have been increased, however, by the prolonged contact (three hundred seconds). The experiments of Prévost and Battelli show that the fatal effects are due to the energy, and that the energy required for killing a given animal increases in proportion to its weight. In a one-pound guinea-pig, 400 joules were necessary to arrest respiration; while in one weighing ten ounces, but 250 joules were necessary.‡

From experiments upon animals, accidents from industrial currents, and the electrocution of criminals, it is evident that the lethal effect is due to a sudden discharge. If the same amount of energy in joules was passed through the body slowly, the effects might be quite different. For example, 400 joules, the lethal dose for a one-pound guinea-pig, might mean a pressure of 20 volts, a current strength of 20 amperes continued for one second of time, *i.e.*, $20 \times 20 \times 1$ volt-ampere seconds $= 400$ joules; or $20 \times 0.1 \times 200$ volt-ampere seconds $= 400$ joules. The result would be very different in each instance. In the first, a sudden discharge of great power; in the second a gradual expenditure of energy, lasting for two hundred seconds, and accomplishing the same amount of electric work, but not violent nor disruptive in its action, as in the former instance.

This detailed case, as well as experimental work and the electrocutions instanced, show that the pressure necessary under one set of conditions is not required under another, and that a lethal dose does not of necessity require a current of high pressure. Prévost and Battelli found that under good electrical conditions, a dog—contacts head and hind limbs—could be killed with a current of 10 volts pressure; while 80 volts were necessary, under the same conditions, when the contacts were made to the head and fore-legs. In the former instance,

* Thomson, Elihu: "Effects of High-Frequency Electrical Discharges passed Through the Body." Tesla, Nikola: "Alternating Currents of High-Frequency and High Potential."
† Cunningham: "The Cause of Death from Industrial Currents."

* Battelli, Frederic C.: "The Mechanism of Death by Electric Currents in Man."
† Kolben: Elek. Zeit., February 15th, 1900.
‡ Prévost and Battelli: "The Mechanism of Death by Electric Currents in Man."

the heart lay in the conducting path, while in the latter it did not, and was not only reached indirectly—requiring more power—but, by reason of increased resistance, a greater pressure was required to secure the current necessary to the production of a lethal effect.

This experiment illustrates the influence of the position of the contacts, as does also the case of McElwaine (second electrocution), in whom the head and hands formed the points of contact. In this instance the contacts were good—*i.e.*, saline solution—and there was a large superficies; but, by reason of their position, they were objectionable for the purpose contemplated, in that the heart was not placed in the conducting path, and consequently death did not result until their position was changed.

It is clearly shown, therefore, by an analysis of the work of different experimenters as well as of the accidents from industrial currents, that lethal effects follow contact with pressures of widely varying E.M.F.

An accidental contact with a high-pressure line or terminal—or with any pressure for that matter—rarely involves the same set of conditions, and often the conditions existing are such as to render it ineffective as a high-pressure current. Favorable conditions are obtained only (1) in experimental work, and (2) in electrocutions. It is not then a matter of pressure alone, for death results from currents of low pressure as well as from those of high pressure, and the latter are oftentimes ineffective, while a fatal result may follow contact with a low-pressure current.

Cases 3 and 10 (see tabulated references) illustrate the inefficacy of a high-pressure current with poor contacts; while No. 9 is a striking example of the efficacy of a low-pressure current with the best position as well as nature of contacts; and it is not only a question of diminished electrical resistance, but of vital resistance (see Case 9) as well.

There can be no doubt that vital resistance must be counted as one of the conditions governing the action of a lethal dose. Kratter, in his experiments, found that a short exposure to an alternating current of 1,500 volts did not always prove fatal to rabbits and guinea-pigs, while others succumbed. With all the conditions of the conducting circuit absolutely the same, and with animals of the same species, age, and weight, this would indicate to the writer a difference in vital resistance—a factor which cannot be lost sight of in the administration of a lethal dose of electricity any more than in its therapeutic administration.

Cunningham, in his experiments, established the fact that anything acting to depress the vital forces increases susceptibility to the current. For example, after the cervical cord in an anæsthetized dog had been exposed and divided, it was found that a very brief passage of a current of 0.25 ampere caused the heart to stop immediately, although previously one of 0.65 ampere had been readily withstood. Whatever serves to depress the general condition increases the susceptibility even to weak currents.

From the action of a low-pressure current, when the effect is upon the heart (*i.e.*, causes fibrillar contraction), it is seen that such animal species as rats, frogs, and turtles recover spontaneously, whereas in the higher order of mammals, as well as man, death is absolute; but that from currents of a higher pressure death results in the former with a lower pressure and shorter contact than in the latter. This is when currents of high pressure act by reason of position and nature of contact as such.

The spontaneous recovery of such animals as rats, frogs, and turtles depends upon the phenomena connected with the heart. The action of a low-pressure current is more severe and more lasting as the animal kingdom is ascended. The cold-blooded animals recover from the action of the current on the heart, while the warmer-blooded animals succumb. The heart is paralyzed in ventricular tremulations in all animals, and the phenomenon produced varies in intensity according to the genus of the animal. Prévost and Battelli used four genera of warm-blooded animals:

(1) Dogs, in which the characteristic action in the heart (ventricular tremulations) is well defined.

(2) Guinea-pigs—adults—in which the tremulations were most often, but not always well defined.

(3) Rabbits, in which the tremulations are oftenest transitory, but in some cases well defined.

(4) Rats, in which the tremulations last only during the electrization of the heart. When this ceases the tremulations disappear and the ventricles resume their beat."*

These observations are in accord with the well-known physiological fact that while the hearts of the higher mammals very rarely recover spontaneously from a condition of fibrillar contraction, the hearts of those lower in the animal kingdom and of cold-blooded animals do; that in them a lethal effect must be produced by asphyxia, and necessitates the use of a current of higher pressure.

Results of Experimental Work, Physiological.—There is a wonderful similarity of result in retrospect of the work of different physiologists made within the past eleven years to determine the mechanism of death, although the earlier investigators did not carry their experiments to the definite conclusions of the later ones, and in some instances failed to appreciate and interpret correctly the phenomena observed. By far the most important experiments, and the only ones to which reference will be made—others having a purely historical interest—are those of (1) D'Arsonval, 1887; (2) Edward Tatum, Physiological Laboratory of the University of Pennsylvania, 1890; (3) Houston and Kennelly, Private Laboratory, Philadelphia, Pa., 1894 (undertaken not to determine the mechanism of death, but whether death did occur as the result of pressures similar to those used in electrocutions in which contacts were good, in order to refute the idea that in electrocution the current did not kill, and that the autopsy did); (4) Bokenham and Jones, Laboratory of the Royal College of Physicians and Surgeons, London, 1895; (5) A. M. Bleile, Physiological Laboratory, Ohio State University, 1895; (6) Kratter, 1895; (7) Oliver and Bolam, 1897; (8) Prévost and Battelli, Physiological Laboratory, University of Geneva, Switzerland, 1899; (9) R. H. Cunningham, Physiological Laboratory, Columbia University, 1899.

As a result of the experiments upon animals, of a study of accidents from industrial currents and from atmospheric electricity, and also of electrocutions, the generalization is obvious that death due to an expenditure of electrical energy within the tissues occurs in two ways: (1) By mechanical lesions of vital structures, or (2) by arrest of organic functions essential to life—*i.e.*, by arrest of respiration, heart's action, or nutritive exchange.

Death occurs, as a rule, in the first way, from lightning stroke, and there is an actual mechanical disintegration of vital structures. This is, however, not always the case. The deaths from lightning in this country are happily very few, being estimated at only about one per million of the population per annum. Oftentimes no trace of injury can be seen upon the subject of the accident, but in other cases various marks are found upon the body, or the clothing will be torn or scorched; and it not infrequently happens that the boots are torn off the feet, and nails driven out of the soles of the boots. The following case illustrates, in a striking manner, the disruptive action of this tremendous energy:

The accident occurred in Guilford, England, August 25th, 1897, and the inquest revealed that the man was found, one-half hour after a single flash of lightning and a clap of thunder, lying on his face. Around him, within a radius of several yards, were his clothes and boots, which had been torn and scattered about in an extraordinary manner. The lightning appeared to have struck him on the right side of the head, tearing his cap to pieces and burning his hair off. It then passed inside his collar, down the front of his body and both legs into his boots, which were torn to pieces, and then it passed into the ground, making a hole about eighteen inches in circumference and three inches deep. His collar was torn to pieces, the front of his shirt was rent into ribbons, the jacket and

* Battelli, Frederic C.