compare the alcohols obtained from them with the secondary alcohol from mannite and from hexylene, and with the primary hexyl-alcohol which is found in fusel-oil.

XX. "Formation of Cetyl-alcohol by a singular reaction." By C. SCHORLEMMER. Communicated by Prof. STOKES, Sec. R.S. Received June 14, 1870.

On heating a mixture of sebacic acid, $C_{10} H_{18} O_4$, and caustic baryta, besides the hydrocarbon $C_8 H_{18}$, which I have described in a former communication*, other products are formed, amongst which there is a solid body, which, by several crystallizations from alcohol, was obtained in small white crystals.

On analyzing it, Mr. Dearden obtained results which led to the formula $C_{16} H_{34} O$, which is that of *cetyl-alcohol*:—

	Calculated.		Found.	
			I.	II.
C_{16}	192	79·34	79·3	78·9
H_{34}	34	14·05	13·8	13·9
O	16	6·61	——	——
	242	100·00		

This body has not only the composition but also the characteristic properties of cetyl-alcohol; it melts at 49°, and solidifies again at the same temperature.

The formation of this compound is certainly very singular, and perhaps the more so as cetyl-alcohol is so easily oxidized to sebacic acid by the action of nitric acid. I intend to obtain larger quantities of it by the above reaction and to investigate it.

XXI. "Researches in Animal Electricity." By C. B. RADCLIFFE, M.D. Communicated by CHARLES BROOKE, M.A. Received May 19, 1870.

(Abstract.)

PART I.

The subjects of the present inquiry are three in number:—1. The electrical phenomena belonging to living nerve and muscle during rest; 2. The electrical phenomena which mark the passing of nerve and muscle from the state of rest into that of action; and 3. The workings of voltaic electricity, and of electricity generally, upon nerve and muscle.

1. *The electrical phenomena belonging to living nerve and muscle during the state of rest.*

Argument.—Living nerve and muscle have an electricity of their own, which fails by degrees as life dies out, and is wanting altogether after

* Proc. Roy. Soc. vol. xvi. p. 376.

death. This electricity is made known by the electrometer, as well as by the galvanometer. Living nerve and muscle supply to the galvanometer currents, called respectively the *nerve-current* and the *muscle-current*, when the sides of the fibres are connected, through the coil, with either one of the two ends, or when certain points upon the sides or upon the ends are brought together in the same manner, the direction of these currents showing that the sides of the fibres are positive in relation to either of the two ends, or else the reverse (the instances of reversal being the exception and not the rule), and that the positive surface becomes more positive, and the negative surface more negative, as the distance from the line of junction between these surfaces increases. Living nerve and muscle are also (as is now for the first time distinctly proved by means of Thomson's New Quadrant Electrometer) capable of acting upon the electrometer, the action showing that the electrical differences upon which the nerve-current and muscle-current depend are not the same in all parts of the fibres, the differences between the sides and the ends being differences in kind, like those which belong to the two surfaces of a charged Leyden jar, the differences upon the sides singly, and upon the ends singly, being only those which indicate different degrees of tension in one kind of electricity. In accounting for these phenomena, the very imperfect conductibility of nerve and muscle, and of animal tissue generally, is taken as a starting-point. It is assumed (and in support of this assumption some new measurements of the resistance of nerve and muscle to electrical conduction are given) that in nerve and muscle the *sheaths* of the fibres may conduct electricity so imperfectly as to be capable of acting as *dielectrics*,—that a charge of one kind of electricity, developed on their outsides (by oxygenation or in some other way), may *induce* an opposite charge on their insides,—and that the electrical condition of the two ends of the fibres may be opposed to that of the sides, because the charge induced within the sheath is conducted to the ends by the contents of the sheath. It is supposed, in short, that the fibres of living nerve and muscle during rest are so many charged Leyden jars, their electrical condition at this time being statical, not current, and that the nerve-current and muscle-current are no more than accidental phenomena arising from the galvanometer being placed between two points which happen to be electrically dissimilar. And in support of this view it is pointed out that precisely parallel electrical phenomena may be obtained from a piece of wood, shaped like the piece of nerve or muscle, and coated on its sides, but not at its two ends, by a sheath formed of two layers of tinfoil separated by an intermediate layer of thin gutta-percha sheeting, if only the sides be charged as the sides of the piece of nerve or muscle are supposed to be charged, and if the electrodes of the galvanomer or electrometer be applied in the proper manner.

2. *The electrical phenomena which mark the passing of nerve and muscle from the state of rest into that of action.*

Argument.—The nerve-current and muscle-current disappear almost

entirely when nerve and muscle pass from the state of rest into that of action. The "secondary contraction" set up in a muscle by simply laying its nerve upon another muscle or nerve in which a state of action is present, points to a disturbance outside the acting nerve and muscle such as might be caused by a discharge of electricity, and suggests the idea that the sudden disappearance of nerve-current and muscle-current in action may be owing to such discharge; and this view is not a little borne out by certain close anatomical and physiological analogies which are found to exist between the muscular apparatus and the electric organs of the Torpedo. In short, the evidence seems to show that a discharge analogous to that of the Torpedo is developed, as Matteucci supposed, when nerve and muscle pass from the state of rest into that of action, and that the discharge of the Torpedo itself may be nothing more than the unmasked manifestation of a discharge which occurs in a masked form in every case of nervous and muscular action.

3. *The workings of voltaic electricity, and of electricity generally, upon nerve and muscle.*

Argument.—The behaviour of muscle under the action of the so-called "inverse" and "direct" currents is taken as the text in the present inquiry.

Contraction in this case plainly belongs, not to the time when the circuit remains closed, but to the moments of closing and opening the circuit, when the nerves and muscles are acted upon by instantaneous currents, called *extra-currents*, which currents are in very deed discharges. These extra-currents agree with ordinary induced currents in their discharge-like character; but they disagree in their direction, the extra-current at the closing of the circuit taking the same course as the constant current, the extra-current at the opening having the opposite course; and this point of difference is not to be lost sight of. At first both extra-currents cause contraction; afterwards, when the muscle and nerve have lost some of their susceptibility to impressions, only that extra-current causes contraction which happens to pass in the same direction as that in which motor impulses are transmitted along the motor nerves to the muscles. With this clue, indeed, it is not difficult to trace to its cause every variation in the order of contraction which characterizes the case in question.

Nor is it altogether unintelligible that the behaviour of the muscles as to the continuance of these contractions should, under ordinary circumstances, differ in the case where the current is inverse, and in the case where the current is direct. This difference is noticed when the voltaic circuit is insulated, but not when an earth-wire is put to either of the poles. With the voltaic circuit insulated, the contractions continue for 60′ or longer in the case where the current is inverse, and for no longer than 15′ or 20′ in the case where the current is direct: with the earth-wire at the negative pole the contractions continue for 60′ or longer in the case where the current is inverse, and in that in which the current is direct also; with the earth-

wire at the positive pole the contractions continue no longer than 15′ or 20′ in the case where the current is direct, and in that in which the current is inverse also. With the earth-wire at either pole—that is to say, the part acted upon by the inverse current and the part acted upon by the direct current are both made to contract for the same length of time, the contraction in both parts being 60′ or longer if the wire be at the negative pole, and for no longer than 15′ or 20′ if it be at the positive pole. Now the earth-wire changes the charge of free electricity associated with the inverse and direct currents, but it does not alter the course of those currents. When the voltaic circuit is insulated, the part acted upon by the inverse current is charged positively, and that acted upon by direct current negatively, the charge in each case proceeding from the voltaic pole which happens to be nearest; when the earth-wire is put to either pole, the free electricity of that particular pole runs off to earth, and the parts between the poles (the half traversed by the inverse current and the half traversed by the direct current alike) are charged with the free electricity of the other pole,—with positive electricity if the wire be at the negative pole, with negative electricity if it be at the positive pole. The whole case, indeed, is one which seems to admit of only one conclusion, namely this—that the longer or shorter continuance of the contraction must have its explanation, not in the current being inverse in the one case and direct in the other, but in the free electricity associated with one or both these currents being positive in the one case and negative in the other, the contraction continuing for the longer time when this electricity is positive, and for the shorter time when it is negative. And that this should be so is not altogether unintelligible if the natural electrical condition of the fibres of living nerve and muscle be what it has been assumed to be—a condition in which the outsides and insides of the sheaths are in opposite electrical states, the charge on the outside, usually positive, inducing the opposite charge on the inside; for on this assumption it may well be that a positive artificial charge to the outsides of the sheaths may preserve the natural activity of the fibres, and so favour the continuance of the contraction by keeping up their natural charge, the positive electricity outside the sheaths inducing negative electricity inside the sheaths; and that a negative artificial charge may have the contrary effect, the negative charge outside the sheaths inducing positive electricity within the sheaths, and so producing that reversal in the relative position of the two electricities which is only met with when the fibres are upon the point of losing their activity.

Voltaic electricity, therefore, would seem to act upon nerve and muscle, not by the constant current which passes while the circuit is closed, but by the charge of free electricity, positive or negative, associated with this current, and by the extra-currents which pass at the moments of closing and opening the circuit, which extra-currents are in very deed discharges, the charge being favourable to the continuance of activity when positive, and unfavourable when negative, the instantaneous currents or discharges

causing action. As with the natural electricity of nerve and muscle, so in this case, rest and charge, and action and discharge would seem to go together.

And so also with the action of Franklinic and Faradaic electricity upon nerve and muscle. With Franklinic electricity the state of rest in both nerve and muscle is plainly connected with the charge, and the state of action with the discharge. With Franklinic electricity, too, the positive charge is found to be favourable to the continuance of the state of action, and the negative charge unfavourable. And so likewise with Faradaic electricity, not only as regards the connexion of the state of action with the discharge, for the induced currents may be resolved into discharges, but also as regards the connexion of the state of rest with the charge, for in the interval between the two induced currents the secondary circuit is in fact occupied by a charge of electricity.

Part II.—*On Electrotonus.*

Argument.—There is reason to believe that the whole truth has not yet been elicited respecting the movements of the needle of the galvanometer and the modifications of the activity of the nerve which are characteristic of electrotonus.

The movements of the needle of the galvanometer characterizing electrotonus appear to be due, not, as is commonly supposed, to modifications of the nerve-current consequent upon the action of the voltaic current, but to the passage through the coil of the galvanometer of streams of free electricity, positive or negative, as the case may be, from the voltaic pole which happens to be nearest to the coil,—of free positive electricity from the positive pole in anelectrotonus, of free negative electricity from the negative pole in cathelectrotonus. They cannot, so it is argued, be due to modifications of the nerve-current consequent upon the action of the voltaic current, because the same movements continue when there is no nerve-current to be thus modified, as when a dead nerve is used in place of a living nerve, or even when other bodies are substituted for nerve; they may, so it is suggested, be due to streams of free electricity passing through the coil of the galvanometer from the nearest voltaic pole, because such streams do pass in this direction, and because streams of free electricity from a frictional machine so passed give rise to similar movements,—the stream of positive electricity to the movement of anelectrotonus, the stream of negative electricity to that of cathelectrotonus. This is the view taken of the movements of the needle of the galvanometer characterizing electrotonus.

A different conclusion to that commonly held is also thought to be necessary respecting the modifications of the activity of the nerve in electrotonus. Instead of this activity being suspended in anelectrotonus and exalted in cathelectrotonus, the facts, many of them new, are, when fully realized, found to show that this suspension is met with, not in anelectro-

tonus only, but in cathelectrotonus also. It would seem, indeed, that the only difference between anelectrotonus and cathelectrotonus in this respect is, that this suspension is a little less complete in cathelectrotonus than in anelectrotonus, a lesser "stimulus" serving to cause action in the former state than in the latter. It would even seem that any proper exaltation of activity is to be met with in anelectrotonus rather than in cathelectrotonus. Such are the conclusions respecting the modifications of the activity of the nerve in electrotonus which are believed to be warranted by all the facts, old and new alike.

Nor is the increase of contraction detected by the myograph in cathelectrotonus a sufficient reason for concluding that the irritability of the nerve and muscle is exalted in this state; on the contrary, this increase may be nothing more than the natural consequence of the altered electrical condition in cathelectrotonus. In ordinary muscular action, the state of elongation or relaxation is believed to be caused by the mutual attraction of the charges of opposite electricities disposed upon the two surfaces of the sheaths of the muscular fibres, this attraction compressing the sheaths at right angles to their surfaces; in ordinary muscular action the state of contraction is believed to be brought about by the discharge of the charges which caused the opposite state of elongation, this discharge leaving the fibres free to obey, as simple elastic bodies, the attractive force inherent in the physical constitution of their molecules. In cathelectrotonic muscular action, on the other hand, it is believed that the state of elongation may be greater than that which is natural to the fibres (after removal from the body, at least), because the charge communicated from the negative pole to the fibres is greater than the natural charge of the fibres, the artificial charge to the outside of the sheaths *inducing* an equivalent charge of the opposite electricity on the insides, and so causing increased elongation by increasing the compression to which the sheaths are subjected between these two charges; and that the contraction may be increased, because contraction, according to this view, is only the return of the fibres, by virtue of their elasticity, from the previous state of increased elongation. The case supposed is precisely that which may be imitated in every particular upon a narrow band of thin india-rubber sheeting, coated with gold-leaf on its two surfaces within a short distance of their edge, or else wetted to the same extent simply with water, and by charging and discharging in turn; for as the charge is communicated the band goes on elongating until the charge has reached its maximum, and when discharge is brought about there is sudden shortening, the degree of shortening being always commensurate with the previous degree of elongation. What happens is that which is supposed to happen in ordinary muscular action and in cathelectrotonic muscular action also, if only the effects of the smaller charge and discharge be made to stand for the first, and those of the fuller charge and discharge for the last form of muscular action. It is of no moment, also, whether the electricity used in charging be negative or positive. Whether

the charge be negative or positive, the results are the same, and therefore it is plain that there ought also to be increased contraction in anelectrotonus if this be the true explanation of the increased contraction which happens in cathelectrotonus. In cathelectrotonus it is assumed that the negative charge from the negative voltaic pole charges the outsides of the sheaths of the fibres negatively, and induces an equivalent charge of positive electricity on the insides; in anelectrotonus, on the other hand, it is assumed that the positive charge from the positive voltaic pole brings about a contrary state of things in the fibres, charging the outsides of the sheaths positively, and affecting the insides negatively by induction. The difference assumed to exist between the two electrotonic states is in the relative position of the two charges upon the sheaths of the fibres, nothing else. It is not a difference which can affect the elongation of the fibre if elongation be brought about by the mutual attraction of the opposite charges with which the sheaths are charged; for the attraction of either charge for the other must be the same, whether it be exercised from within the sheath or from without it. It follows, indeed, from what is supposed, not only that there should be increased contraction in anelectrotonus as well as in cathelectrotonus, but also that the state of rest in both electrotonic conditions should be characterized by increased elongation. And what there should be in theory there is in fact; for it proves on inquiry that contraction may be caused in anelectrotonus by an adequate "stimulus," that this contraction is greater than that caused by the same "stimulus" in the unelectrotonized state, and that actual increased elongation of the fibres is an effect of both cathelectrotonus and anelectrotonus. The view of muscular action here taken is that which has been always advocated by the author as regards contraction, but it is modified somewhat as regards elongation; for now, instead of looking upon elongation as arising from the mutual repulsion among the muscular molecules set up by the presence in the muscle of a single charge of electricity, this state is referred to the mutual attraction of opposite electrical charges disposed, as in a Leyden jar, upon the two surfaces of the sheaths of the muscular fibres.

Looking back, then, at the history of electrotonus there appears to be nothing contradictory to what has been already said respecting the workings of electricity upon nerve and muscle. It is still the same story of rest along with the state of charge, and of action along with the state of discharge, with this significant addition, that in electrotonus the charge is shown, not only as coincident with the state of rest, but as having an actual power of suspending action in both nerve and muscle, and of causing increased elongation of the fibres in muscle.