which fuse at a gentle heat, and then take fire, with the characteristic lead flame.

Oxide of diplumbic triethyl may be obtained by heating any of the corresponding salts with strong potash, or by acting on a solution of the chloride with oxide of silver. It is a crystalline body, which fuses into an oil-like liquid, at a gentle heat.

Sulphuric acid forms an abundant crop of asbestos-like needles when mixed with a warm solution of the chloride of diplumbic triethyl. It may also be obtained by neutralizing a solution of the oxide, and also by the action of sulphate of silver on the chloride.

Analysis furnished numbers which pointed to the formula

$$Pb_2\,C_{12}\,H_{15}\,SO_4 \text{ or } Pb_2\,(C_4\,H_5)_3\,SO_4.$$

All the salts of this sesqui-ethylated base are volatile, and their vapours attack the eyes and mucous membrane of the throat. In this respect they imitate their homologues in the stannic series.

In concluding this short abstract, I will only express my belief that a wide field of research is still open for inquiry, and that some promising experiments are at present in hand, from the right understanding of which we may hope to throw additional light on these interesting substances.

IV. "On Muscular Action from an electrical point of view." By Charles Bland Radcliffe, M.D., F.R.C.P., Physician to the Westminster Hospital, &c. Communicated by James Paget, Esq. Received February 6, 1859.

This Paper was read in part.

March 17, 1859.

Sir BENJAMIN C. BRODIE, Bart., President, in the Chair.

The reading of Dr. Radcliffe's Paper, "On Muscular Action from an electrical point of view," was resumed and concluded.

(Abstract.)

The author begins by observing, that the signs of electrical action in living muscle die out *pari passu* with the signs of irritability; and, as with these latter signs, *their last trace has disappeared before the occurrence of rigor mortis.*

It would appear, also, (in so far as electrical action is concerned) that there is a close agreement between *ordinary muscular contraction* and *rigor mortis*, for *in ordinary muscular contraction, as Prof. Du Bois Reymond has so well shown, there is a partial disappearance of electrical action.* Professor Matteucci, however, is doubtful as to this, and he maintains, on the contrary, that at this time the "muscular current" is sometimes reversed, and sometimes increased in intensity without being reversed.

In his recent experiments Prof. Matteucci uses a galvanometer of which the ends are so arranged as to get rid of the disturbing influences of secondary polarity. Instead of being of platinum immersed in a saturated solution of common salt, as in Prof. Du Bois Reymond's arrangement, these ends are of amalgamated zinc immersed in saturated solution of neutral sulphate of zinc. This arrangement, originally proposed by Dr. Jules Regnault, the author agrees with Prof. Matteucci in regarding as a great improvement upon that used by Prof. Du Bois Reymond; for, says he, "not only is the disturbing influence of secondary polarity got rid of, but the entrance of currents into the coil of the galvanometer is greatly facilitated. Of this I am satisfied after many comparative trials *."

In the experiment in which Prof. Matteucci finds what he considers to be the proof of the reversal of the muscular current during contraction, he takes a prepared frog's thigh with a long portion of nerve attached, and watches the changes of the muscular current

* The galvanometer used by Dr. Radcliffe was made by Mr. Becker, then of Newman Court, after the pattern of the one used by Prof. Du Bois Reymond. The gauge of the wire forming the coil is No. 38, or as nearly as possible that of the pattern coil; the weight of the wire entering into the coil 1lb. 11oz., the layers of the coil 154, the number of coilings 20,020, and upwards of three English miles. The needles are cylindrical, with each end sharpened out into a long point, and the connecting piece, instead of being made of tortoiseshell, as in Du Bois Reymond's instrument, is made of aluminium—a difference by which the astatic system becomes a little lighter, namely, 4·5 grains instead of 4·9 grains. In the first instance, Dr. Radcliffe used electrodes consisting of a pair of platinum plates immersed in a saturated solution of common salt (an arrangement recommended by Du Bois Reymond); afterwards he used the electrodes recommended by Dr. Jules Regnault, and adopted by Prof. Matteucci—electrodes consisting of a pair of amalgamated zinc plates immersed in a saturated solution of neutral sulphate of zinc.

which is derived from two points of the uncut surface. On laying the thigh upon the cushions which form the electrodes of the galvanometer, the needle diverges under the current of the relaxed muscle; on producing contraction by irritating the nerve with a feeble interrupted current, the needle immediately travels back and passes to the other side of zero. The fact is undeniable, but, according to the author, the backward movement of the needle does not indicate, as Prof. Matteucci supposes, a reversal of the muscular current during contraction. There is, it is true, no secondary polarity in the galvanometer to drive the needle back, as in the case where platinum electrodes are used; but there may be a tendency to oscillate backwards, and the question is whether the mere movement of oscillation may not be sufficient to account for the phenomena. What must be done, then, is to compare the rate at which the needle moves backward during contraction with the rate at which the needle falls backward in simple oscillation; and when this is done, the author finds that the needle moves backward *more slowly* during contraction than it does when it is simply left to oscillate in the same direction. It is found, indeed, that there is no reverse current during contraction, for if there were, the impulse of this current would be added to the impulse of oscillation, and (as is the case where the platinum ends are used) the needle would go backwards *more quickly* during contraction than it does when left to fall backwards from the same point under the influence of simple oscillation. There is also another way of showing the non-existence of a reverse current during muscular contraction, namely, by modifying the experiment in the way which Prof. Du Bois Reymond employs to get rid of the secondary polarity of the platinum ends. The only difference between the experiment as modified and the original experiment is this—that the wire of one of the electrodes is broken, and the broken ends are connected by being dipped into a small cup of mercury. An arrangement is thus made by which the circuit may be easily broken and closed again. In performing the modified experiment, the degree and direction of the current of the relaxed muscle is first observed. Then the circuit is broken by removing the end of the divided electrode out of the cup of mercury, and the needle is allowed to return to zero. In the next place, the muscle is tetanized, *and while in this state*, it is included in the circuit of the galvanometer by replacing the end

of the divided electrode in the mercury. The result is simply this, that the needle moves in the same direction as that in which it moved under the current of the relaxed muscle, but not to the same distance from zero. In other words, the muscular current is weakened but not changed in direction when the muscle passes into the state of contraction.

In the experiment in which Prof. Matteucci sees an intensification of the muscular current during contraction without any change in direction, he takes a prepared frog, and after preserving a sufficiently long portion of the sciatic nerve, he amputates the thigh above the middle joint. Then, taking the lower portion of the amputated thigh with the nerve attached to it, and placing the cut surface against an electrode of the galvanometer and the uncut surface against the other electrode, he watches the needle as it diverges under the current of the relaxed muscle. After this, he brings about a state of contraction in the muscle, by irritating the nerve with a feeble interrupted current, and, looking at the needle, *he sees it move in the same direction as that in which it had already moved under the current of the relaxed muscle.* That is to say, the needle shows, not weakening or change of direction, but actual intensification. On repeating this experiment, the author finds that it is most difficult to draw any safe conclusion from it; for in a thigh prepared in this manner it is almost impossible to keep the same point of the cut transverse surface in steady opposition to the electrode. Indeed, the necessary effect of contraction is to draw away the cut end from the electrode, and in this way to interrupt the entrance of the current of the contracted muscle into the circuit of the galvanometer. The effect of contraction, moreover, is often to bring upon the electrode portions of muscle which have not entered into the state of contraction, and in this way the only current which finds admission into the galvanometer may be that which is derived from *relaxed muscle.* This is often the case, and hence the apparent intensification of the muscular current during contraction, which is now and then witnessed in this experiment (it is not always witnessed), *may,* after all, be due to the irruption of additional quantities of the current of the relaxed muscle into the galvanometer. At any rate, the experiment is one from which it is most difficult to draw any certain conclusions.

In ordinary muscular contraction, then, there is good reason to believe that the muscular current is *enfeebled*—enfeebled to a degree approaching very closely to extinction ; and in *rigor mortis* all traces of muscular current have disappeared. It appears, indeed, as if muscular contraction were antagonized by the muscular current.

In tracing out the history of muscular action from an electrical point of view, the author proceeds, in the next place, to consider the mode in which the muscular current is affected by the nerve-current. In doing this, after describing the peculiarities of the nerve-current, and relating a beautiful experiment of Prof. Du Bois Reymond, in which it is seen that the nerve-current agrees with the muscular current in exhibiting a positive loss of force during muscular contraction ; he interprets the reactions which must take place between the nerve-current and the muscular current by appealing to the history of the electrical organ of the torpedo and its congeners. The interpretation is that the reactions during muscular contraction are, not between the *primary* nerve-current and the muscular curtent, but between the muscular current and the *secondary or induced currents* which may be supposed to spring into existence when the primary or inducing nerve-current is suspended or renewed. The fact that the nerve-current sinks during contraction, is appealed to as an argument that the primary nerve-current is actually suspended and renewed during muscular contraction, and that in this manner the occasions for the appearance of the secondary or induced currents are thus properly provided for. It is pointed out that the reactions between the uninterrupted nerve-current and the muscular current, and between the muscular current and the induced or secondary currents which come into play when the primary or inducing nerve-current is interrupted or renewed, must be altogether different. With respect to the reactions which take place between the uninterrupted nerve-current and the muscular current, there is reason to believe that these must result in mutual intensification, for the nerve-current and the muscular current pass in the same direction. At any rate this is the case in the hind-limbs of the frog, or the fore-limbs of the same animal, and in the hind-limbs of the rabbit, dog, cat, and mouse. With respect to the reactions which take place between the muscular current and the secondary currents which come into play when the primary or inducing nerve-current is suspended or renewed,

there is every reason to believe that the result is altogether different. In this case, it appears as if the secondary or induced current must involve, not the intensification, but the *discharge* of the muscular current in all the muscle which enters into the circuit of the secondary current. For what is the peculiarity of the secondary current? It is a current of momentary duration, disappearing almost in the very instant of its appearing, and carrying along with it in its discharge any electricity it may meet with in its circuit. Hence there is no difficulty in understanding why the galvanometer should afford evidence of abatement of the muscular current at the moment when the nerves are concerned in producing muscular contraction. Nor is there any difficulty in understanding how contraction should be brought about by this action of the nerves, if, as there has seemed some reason to believe, muscular contraction is antagonized by the presence of the muscular and nerve-currents.

The author proceeds, in the next place, to consider the phenomena which attend upon the action of the ordinary galvanic current upon the muscular current. In this part it is pointed out that there is the same broad line to be drawn between the effects of the primary galvanic current and of the secondary currents which spring into existence when the inducing or primary current is suspended or renewed, and by keeping this distinction in mind it is shown that an intelligible physical reason may be obtained for the differences of the "direct" and "inverse" currents for "voltaic alternatives," and so on. The argument is complicated and not easily reducible to a few words; it requires, moreover, certain diagrams which cannot be used in this abstract, and therefore we will only say that the conclusion to which it leads, is that there must be a distinct annihilation of the muscular current during muscular contraction when the muscle contracts under the galvanic current, and that the contraction is seen to be most marked when this annihilation is most complete.

"Reflecting upon these facts and considerations," the author continues, "there appears to be nothing in the history of ordinary muscular contraction which does not harmonize with the electrical history of *rigor mortis*. If the muscular current be present, *rigor mortis* is absent, and in this case it seems as if the state of muscular contraction is antagonized by the muscular current. In ordinary muscular

contraction, to all appearance, it is the same, and when the muscle is relaxed the muscular or the artificial current is present, and when the muscle is contracted the muscular current is weakened or annihilated. It seems, indeed, as if the direct effect of the uninterrupted current, whether natural or artificial, is to antagonize contraction; and that this is really the case may be argued finally from the fact (recently discovered by Dr. Eckhard) *that the state of tetanus is put an end to by the passage of a constant galvanic current through the tetanized parts.*

"Nor is there any reason to suppose that the contraction is produced by a kind of correlative transmutation of electricity into contractile force. In *rigor mortis* such an idea is scarcely tenable, for here the muscular current has died out *slowly*, and the contraction has not supervened until the last traces have disappeared. In ordinary contraction, it might be supposed that there had been some transmutation of the muscular current into contractile force, or that an electric discharge had served as a stimulus to some vital property of contractility. But this idea is contradicted (this among other ways) by the recent investigations of Dr. Harley upon the *modus operandi* of strychnia. These investigations prove conclusively that this poison acts by making the blood less able to appropriate oxygen, and by impairing the irritability of the muscles. They prove, that is to say, that strychnia produces contraction, by reducing the amount of stimulus supplied in the blood, and by rendering the muscles less capable of responding to any stimulus. I find also that strychnia exercises a directly depressing influence upon the nervous and muscular currents. I place the two hind limbs of the same frog, properly prepared, one in a weak solution of strychnia, the other in plain water, and, leaving them to themselves, I find that the nerve and muscular currents have died out much sooner in the limb which has been acted upon by the strychnia. Now, in this case, the limbs have been left to themselves, and it cannot be said therefore that the nerve and muscular currents have been changed into contractile force by any kind of correlative transmutation. Indeed, the facts would only seem to be intelligible on the supposition that, electrically considered, the strychnia has brought about contraction according to the mode which has been set forth in the preceding pages. Nor on this view is the fact less intelligible, that

the respiration of muscle is carried on more energetically in muscles which are made to contract than in muscles which are allowed to rest. Prof. Matteucci, who has recently ratified this fact by some very elaborate investigations, holds that the chemical actions of muscular respiration are transformed into electricity, and the electrical into contractile force; but there is just as good reason for supposing that the increased chemical action may be required to keep up the muscular current, which current is being continually annihilated by the actions which bring about contraction. And thus, after all, the increased respiration of muscles which are made to contract, may refer, not to the contraction, but to the renewal of the state of relaxation. At any rate, it is scarcely possible to refer to this fact as an objection to the view which is set forth in this paper.

"Regarded in an electrical point of view then, there appears to be good reason for concluding that the history of muscular action is in harmony with the theory which I have endeavoured to set forth at various times, and more recently in the second edition of a work having for its title, 'Epilepsy and other Convulsive Affections, their Pathology and Treatment:'—a theory, according to which, in every case, pathological as well as physiological, muscular contraction is produced, *not* by the stimulation of any vital property of contractility belonging to muscle, but by the simple cessation of the action of certain agents—electricity, nervous influence, and others, which had previously kept the muscle in a state of relaxation or expansion."

The following communications were also read:—

I. "On the Action of Carbonic Oxide on Sodium-alcohol." By J. A. Wanklyn, Esq. Communicated by Professor E. Frankland. Received February 15, 1859.

Dr. Geuther* found that sodium-alcohol $\left(\begin{matrix}C_4 H_5 \\ Na\end{matrix}\right\} \Big) O_2$ when gently warmed in a stream of carbonic oxide, yielded not pre-

* Annalen der Chem. und Pharm. Jan. 1859.