AN ESSAY ON THE LAW OF MUSCULAR ACTION

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THE LAW OF MUSCULAR ACTION,

By LOUIS MACKALL, M. D.

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PREFACE.

The subject of muscular action is one of the first magnitude in the Science of Physiology, and as such has been laboriously investigated for many years past by the Scientists of Europe. It is at this time exciting among them more than usual interest.

Since the discovery of electricity—from observing the effect of this agent on the muscles of recently killed animals—the impression has very generally prevailed that this difficult subject was destined to be fully elucidated by means of electrical experiments. Accordingly, all the investigations referred to above have been directed to this end.

The anticipations resulting from this general impression have not been realized; nor is this suprising, when it is considered that it has been attempted to establish, or to reason out a law of nature that belongs to one department of science, by making use of instances or phenomena which belong to another and very distinct department.

For the last thirty-odd years I have been engaged in investigating this subject of muscular action, but have reasoned solely from instances derived from vital phenomena, or such as are observable in the living body. The following is a succinct account of my proceedings in this investigation:

From often observing, in the practice of medicine, the inadequacy of remedial means made use of, and from frequently experiencing disappointment in my anticipation of the results of the operation of such means, I became convinced that there was something wrong—some great error in the theory, or in the principles of medicine in which I had been taught.

This conviction was brought forcibly home to my mind by the death of my wife from uterine hemorrhage, notwithstanding the use of all the remedial means known to myself and a very skilful medical friend who was present.

Under the influence of grief consequent on this bereavement, I resolved that I would devote the residue of my life to the task of endeavoring to discover, if possible, the error in the theory of medicine that I had before suspected, and in which suspicion I was confirmed by my late experience.

While studying this theory in the books for the above purpose, a case of whitlow (*paronychia*) was presented for treatment. Prompted by the resolve mentioned, I carefully noted the prominent facts of the case. I particularly noticed the pulsation of the arteries at the diseased point and at the wrist; and my attention was forcibly arrested by observing the remarkable difference in that pulsation at the two points. That in the finger was full and strong, while the pulsation of the artery at the wrist was comparatively calm.

Reflecting on the above fact, I arrived at the conclusion that there must be some agency in the arteries of the finger, that were throbbing so violently, to produce this result, that was independent of that in the general circulation; and, in casting about in my mind for some suggestion as to what that agency could be, it occurred to me that the throbbing or distension of the arteries was occasioned by the *action* of their muscular fibres. The correctness of this explanation of the phenomenon in question, was confirmed by running over in

my mind, as I did at the moment, a number of instances wherein irritation was attended with the distension or dilatation of the tubes or hollow organs, when such organs were supplied with muscular fibres—as in the esophagus, in the stomach, intestines, in the uterus in pregnancy, &c.

I had now arrived at a definite proposition; and in the year 1834, in November, I wrote down that proposition in the following words: "All the tubes of the animal body, which are supplied with muscular fibres, have their calibres increased by the *action* of those fibres." This was shown and explained to four medical gentlemen at the time mentioned, and signed by them, witnessing that it was so shown. Three of these gentlemen, namely: Drs. J. H. Skinner, B. B. Hodges, and William Ghiselin are now (1865) living. One of them, the late Dr. Henry Brooke, died a few years since.

In 1836 I forwarded a paper, setting forth the above idea by an application of it to a number of vital phenomena, to the Professor of Anatomy in the University of Maryland, requesting him to advise me as to the best mode of bringing the subject to the notice of the medical profession. My communication was treated with contempt, as were also several papers written on the same subject, and shown to members of the medical profession.

Although I was fully convinced, from the period mentioned above, that the calibres of the tubes and hollow organs were increased by the action of their muscular fibres, I did not fully comprehend how this occurred until the spring of 1842. At that time, being in conversation with a gentleman who was fond of gesticulating, he, in derision of something that was said, thrust out his tongue over his under lip. This sudden elongation of the tongue instantly suggested that which I had been in search of for eight years—a rational explanation of the action of the fibres about the tubes. The truth flashed on my mind, *that the fibres of muscles are actively elongated by innervation.*

In 1843—February 24—I wrote an Essay on Muscular Action, embracing the idea just mentioned, applying it to the action of all the muscles in the animal body, and showing its application by a number of experiments on living domestic animals and on my own person. This essay is certified by me, under oath before a magistrate, as having been written at the time at which it bears date.

In 1844 I wrote another essay on the same subject, and illustrated my views by a reference to a large number of instances taken from natural history. This essay is included in the same pamphlet with the last, that was published in 1860.

In 1848 I published a small pamphlet, entitled "Outlines of a New System of Physiology," and at the same time a circular to be enclosed with it, referring to instances in natural history in corroboration of the correctness of my view of muscular action. This pamphlet and circular were gratuitously distributed the same year to all the most distinguished physiologists and physicians in Europe and in this country of whom I had any account.

In 1850, having carefully reflected on and retraced the mental process by which I had been enabled to arrive at and to apprehend the law of muscular action, I wrote and published an essay, entitled "An Account of the Reasoning Process," and instanced this process in the discovery of this law.

In 1852 was published my "Notes on Carpenter's Human Physiology;" and, In 1857, the first forty pages of "Principles of General Physiology"—merely as a record of conclusions at which I had arrived, but which I had not time to arrange in any order.

In 1859—in May or June—my essay on the Law of Muscular Action was printed; and in 1862 "The Action of the Voluntary Muscles," embraced in the present essay.

Most of the above publications have been distributed freely and gratuitously, wherever it was thought probable they might awaken an interest.

GEORGETOWN HEIGHTS, *October*, 1865.

AN ESSAY

ON

THE LAW OF MUSCULAR ACTION.

BY LOUIS MACKALL, M. D.

A LEADING object of science is "the endowment of man's estate" in nature, by the aiding of human Invention. This object is best attained by the exercise of human reason, in tracing out the true laws of nature, that are the real potentials, and the only proximate causes in natural phenomena. This essay is intended to set forth a law of nature relating to the movements of the muscles in the living body, that we have traced out, and that has hitherto been overlooked by Physiologists. A knowledge of this law must lead to a more intelligible and rational explanation of the animal functions, and at the same time will suggest more efficient and certain means of attaining ends in the practice of the medical Art.

In the investigation of the laws of nature, it is essential that the facts or phenomena from which we start, and which we make use of in our reasoning, should be taken from the particular department of science to which such laws will belong. When investigating the laws of nature that relate to physiology, is it not unphilosophical, to say the least, to reason from facts taken from the department of physics? This, however, is what is being done by Physiologists in their investigation of the subject before us. Their reasoning on this subject is, for the most part, confined to facts connected with electricity, which is a branch of physics; and, indeed, it is proposed as a most desirable object, *that we should have a* PHYSICAL THEORY *of physiology.*

The experiments that have been made with electricity,

with a view to elucidate the action of muscles, have served rather to retard than to advance the progress of physiological science, for the very plain reason, that the phenomena presented in these experiments were misunderstood and misconstrued.

Electricity cannot be substituted for the nerve fluid; it cannot be made to subserve the same purposes in the living economy. These two forms of matter are totally different in their natures. Electricity pertains to the earth and to inanimate matter, while the nerve fluid pertains to animants, or living beings. Electricians, as well as physiologists, have been in error in assuming that the *contraction* of the muscles was their *state of action*, and in supposing that when a current of electricity is passed through the living body a cause of action is *determined to* the muscles, when, in fact, the nerve fluid is *abstracted from* the nerves of the muscles.

When a strong current of electricity (as what is called a stroke of lightning) passes through, or near to, a living body, the nerve-fluid of the body, by virtue of a law of nature that we have elsewhere pointed out, *passes into and along with this Life-current;* and this fluid being lost to the body, death ensues; as happens to animals, trees, &c., that are struck with lightning. When a stronger or more concentrated current of electricity is produced by means of the large galvanic battery, all natural forms of matter may be decomposed by this current, and resolved into more simple forms, or into the most simple form—*the element of matter;* but when the current is more feeble, (as that from an electric machine, or from a voltaic pile,) and is made to pass through the body of a living or recently killed animal, a portion of the nerve-fluid is abstracted from the nerves of the muscles, to pass along with this feeble current, that is sufficient to induce their *state of contraction*, which is not their *state of action*, as will be presently explained.

We deem it proper to state fairly, at the outset, some of the conclusions at which we have arrived, in order that the reader may form some notion of the views we are about to offer to his consideration, and that he may thus be enabled the more readily to follow or apprehend our meaning as we proceed.

There are four separate states, or conditions of a muscle, in the living body. 1st, *its static condition*, or the state of rest or repose; 2d, *its state of action;* 3d, *its state of contraction;* and 4th, *its state of relaxation.*

In the first of the above states—the static condition—there

is a partial or moderate determination of the nerve-fluid to the fibres of the muscle, and there is also a moderate action or suction in its corresponding nerve-centre, withdrawing the nerve-fluid partially from the muscle, and thus giving it tone or a certain degree of tension. In the second state—the state of action—there is a full determination of the nerve-fluid to the fibres of the muscle, attended with *the erection and active elongation of these fibres.* In the third state, the state of contraction, *the action is in the nerve-centre of the muscle contracted;* the nerve-fluid is thus withdrawn from the fibres of the muscle, and its contraction thereby induced; and the fourth state, that of relaxation, is dependent on a want or absence of a proper action in the corresponding *nerve-centre;* when the nerve-fluid is suffered to flow passively, as it were, to the fibres, and thus to induce their partial elongation, and their loss of tone or atony.

That my views on this particular point may be fully understood, let me repeat: When a muscle is in its normal state of rest in the living animal body, there is a partial determination *to* it, and a partial withdrawal *from* it, of the nerve-fluid, so that it is always, to use a sporting phrase, "held well in hand." When the nerve-fluid is determined fully to a muscle, it is thrown into *a state of action,* and its fibres become *erected* and *actively elongated.* When this state passes off, the muscle returns to its *static condition* or state of rest. When a muscle is thrown into a state of contraction, it is in a very different condition from that of its state of action, for here the nerve-fluid is *withdrawn* from its fibres towards its corresponding *nerve-centre.* As the contraction ceases or passes off, the contracted muscle also returns to its static condition, and is at rest. When the fibres of a muscle are relaxed, or are in a state of relaxation, this proceeds from a *loss* of power or of action in the corresponding *nerve-centre,* arising either from exhaustion from previous inordinate action of the centre, or from some deleterious influence, as of a sedative, or of some virus, exerted either on the parenchyma of the centre, or the nerve-fluid, producing some change in its normal constitution. The peculiar state of the muscles in the animal recently deceased, called "*rigor mortis,*" has a like origin with the state of relaxation, and should be referred to this state. When death occurs, there being no agency by which any part of the nerve-fluid can be retained in the nerve-centres, the *whole* of this fluid flows to the muscles, and superinduces the condition of the muscles spoken of, resembling in some

respects their state of action. As the nerve fluid evaporates or passes from the dead body, this condition of the muscles passes away.

The three following general conclusions will also be found of use in comprehending what we shall afterwards have to say on the subject before us:

1. When an impression is made, or an irritation produced on any point in the living body, such impression or irritation may be followed either by an action or *elongation* of the fibres at the point of irritation, caused by a determination of the nerve-fluid to such fibres; or, it may be followed by a *contraction* of the fibres of the part, induced by the *action* of the *centre* and the consequent withdrawal of the nerve fluid from such fibres—a number of circumstances, which it is not necessary to stop here to consider, determining which of these effects shall be produced.

2. Where there is a concatenation or a series of acts combined or linked together in one or more functions, if one of such series is brought into play, others of the same series take place until the whole series is performed. This is seen in suspended animation, as in drowning, when a mechanical movement of the chest will sometimes set in motion the series of acts constituting respiration, and also those of the circulation of the blood. The same thing is seen in retained placenta and in some cases of slow parturition, when the introduction of the hand will start a series of acts that result in the expulsion of the placenta or in the birth of the child.

3. There is a condition of the human body that is commonly referred to, among physicians, as *a state of nervous excitement*, but would be more properly called *a state of exalted action in the nerve-centres*. When an unusually strong or striking impression is made on the mind, whether physically or morally—that is to say, whether intermediately through the bodily organs or directly on the mind, the individual instinctively determines an extra quantity of nerve-fluid *to the centres*, and this fluid is accumulated there at the expense of the secretory and muscular systems of the body. All the emotions tend to produce this state of exalted action in the *nerve-centres*, and especially in the large centres, as the brain, the cerebro-spinal axis, the solar plexus, the semilunar ganglion, &c. The condition of the system to which this paragraph relates is one of the most important practical points in pathology, as it presents a remarkable instance of *the action of the nerve-centres*—a knowledge of which is in-