## VII. *Additional Note on the Contraction of Voluntary Muscle in the Living Body.*

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In my paper of June last, published in the Philosophical Transactions*, I showed, by observations on the *Rigor Mortis*, that contraction, in voluntary muscle, essentially consists of an approximation and change of form of the minute particles composing its structure; the phenomena of contraction in living Monoculi and Arguli were also briefly adverted to, but it remained undecided in what manner these minute movements are employed in the higher animals, in the production of motion *during life*. The almost insurmountable difficulty of submitting the living muscle of the Vertebrata to high powers of the microscope, so much enhances the value of any facts bearing on this obscure point, that I am induced to lay before the Society a short account of some recent examinations of human tetanic muscle, which, with the considerations accompanying them, appear to me to afford conclusive evidence on the subject.

Two opportunities have lately occurred to me of carefully observing the conditions of the muscular system, in cases of fatal tetanus, and the following has been the result:

1. Many muscles appear healthy in all respects.

2. Parts of certain muscles present a remarkably pale gray aspect, arising, doubtless, from their blood having been pressed out by the contraction, a state of which the appearance has been aptly compared by my friend Professor Budd, to that of the flesh of fishes.

3. In other situations, the muscles have lost in a great measure their fine fibrous character, and present a soft mottled surface, which readily tears, or receives an impression from the contact of the finger, a condition with which may be associated,

4. Extensive ecchymoses, often contrasting strangely with the pallor of contiguous portions.

On microscopic examination, while the other affected muscles appear natural, the primitive fasciculi of those which have lost their texture or are ecchymosed (3. 4.), are by no means so, but present at certain points characteristic marks of a high degree of contraction; they are swollen into a fusiform shape, and have their transverse striæ very much closer together than usual (Plate II. (*a*)). Elsewhere these primitive fasciculi are, on the contrary, diminished in diameter, and their

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transverse striæ either greatly widened and deranged (*b*), or altogether obliterated (*c, c, c*), in consequence of the whole texture of the organ being broken up into those primitive elements, of which the discs are constructed; and here the primitive fasciculi are frequently broken across, with or without a corresponding rupture of the sarcolemma (*d, e*). The extent of the swollen or contracted parts seems liable to great variety; the one selected for delineation (Pl. II.) contains upwards of sixty striæ, but others on contiguous primitive fasciculi were more extensive. Some primitive fasciculi in the neighbourhood, which at the point examined presented no rupture, had a very unusual diversity in the proximity of their striæ at different points, but everywhere preserved, like the rest, that proportion which I have shown to obtain between the diameter of the primitive fasciculi and the closeness of their transverse striæ. These I conclude to have been ruptured at a point further on.

Although the bare detail of these appearances may seem to warrant the conclusion that contractions have taken place in the situation of the fusiform or belly-like swellings, the effect of which has been to stretch and even to disorganize the remaining parts of the primitive fasciculi, yet I shall endeavour to confirm and illustrate it by the following considerations.

1. *The Contraction of a Muscle is the essential cause of its own rupture.*

This is best exemplified in a fragment of a primitive fasciculus of a reptile or fish removed from the body, and contracting between plates of glass. The contraction commences at its extremities, which, becoming swollen, receive the pressure of the upper plate, and may be fixed by it. If so, the intermediate part is stretched and torn as contraction proceeds; and if an isolated contraction occurs in the centre, the parts between it and the two extremities are similarly affected*, the conditions of the rupture being, 1. a partial contraction of the ruptured muscle, and, 2. a force superior to the tenacity of the uncontracted part, holding the ends of the fragment asunder.

The same conditions apply in the healthy living subject, where it is impossible, in consequence of the admirable adaptation of mechanical arrangements to the extensibility of muscles, that any rupture can take place solely from the action of antagonists. For example, no force of the flexors of the knee can by itself rupture the extensors, because the structure of the joint prevents flexion being carried beyond a point which the extensors, if relaxed, readily allow. And yet antagonist muscles may and do play a conspicuous part in most muscular ruptures; but it is only by affording a resistance to the approximation of the ends of the ruptured muscle, greater than the tenacity of its uncontracted parts,—such a resistance, in fact, as might be offered by any power mechanically adapted to produce the same effect. I say *uncontracted* parts, and the propriety of supposing them in the living subject appears from the examination of the tetanic muscle; for putting aside the impossibility of any rupture happening in a muscle of which no part was physically weaker than another,

* *Loc. cit.*, p. 490.

by a contraction consisting of an *absolutely simultaneous and uniform approximation* of all its elementary parts to one another, and supposing for a moment that though the contraction was everywhere present, yet some feebleness of structure, or trifling diminution of the contractile force at one part, determined a rupture to take place there, the resulting appearances would necessarily be altogether different from those that have been detailed. The rupture would be definite and abrupt, without extensive stretching and consequent disorganization, and the whole retracting fibre would bear traces of an uniform and universal contraction, instead of an unequal and partial one, very limited in extent, and similar in every essential character to that which I have delineated in dying muscle*.

2. *There is no Repellent Force between the Contractile Elements of Muscular Fibre.*

When muscle is taken from the body after all irritability has subsided, and when no stimulant has been previously applied capable of disordering its action during the rigor mortis, the distance between the transverse striæ will usually be found nearly uniform at every part; but when partial contractions occur in a fragment that has been removed prior to the cessation of its irritability, the contracted parts remain permanently distinguished from the rest of the primitive fasciculus, by the closeness of their transverse striæ. In the former case, every primitive fasciculus having its extremities held apart by its proper antagonists, the contractile efforts constituting the rigor mortis are uniformly and gradually expended, and no inordinate amount of contraction can leave its vestiges in any part; but, in the latter, no such antagonizing power being exerted, the contractions remain wherever and to whatever degree they may have been present.

This explanation involves and rests upon the above principle, and it follows, that whatever prevents a muscular fibre from being elongated, when its contractile energy subsides, must cause it to retain that arrangement of its parts which was assumed during contraction. Now, in the examples under consideration, the *rupture* prevented such an elongation, and the result is, that *the organ has been, as it were, surprised in the very act of contraction, and retains in its structure the permanent impression of that act*,—a view strongly corroborated by the uniformity of the distance between the transverse striæ in those muscles, which had been likewise convulsed, but had escaped rupture.

It may be further remarked, that the occurrence of ecchymoses entirely accords with the idea of partial contractions, while it is inconsistent with that of an universal one, for how could the vessels be torn in tetanic spasm if this were merely a strong and enduring, but uniform approximation of all the elements of the primitive fasciculi to one another? They would be compressed indeed, but not dragged asunder; whereas, such would be the natural effect of excessive partial contractions, oscillating from place to place, and continually drawing in opposite directions, and in an irregular manner, the uncontracted portions; for the capillaries take a longitudinal course be-

* *Loc. cit.*, Plate XIX. figs. 83. 88., No. 3. &c.

tween the primitive fasciculi, and inosculate with one another by very frequent transverse branches, which complete the vascular web, and serve to attach its several parts to the primitive fasciculi which occupy its interstices.

Lastly, all the specimens of bloodless tetanic muscle which I have seen, have presented this striking peculiarity:—that the pallor has not occupied the whole muscle, but patches of it, comprehending a portion of many primitive fasciculi, but not the entire length of any,—a fact tending to the same conclusion.

What has now been advanced, seems to render it—as it appears to me—certain, that the tetanic spasm has consisted in contractions engaging only parts of each primitive fasciculus at a time, and if so, of course changing their place, in order to bring every portion into use in its turn. Whether the primitive fasciculi alternate with one another in their contractions, is an obscure question, on which these observations shed no light.

It may be urged, however, that, even granting this conclusion true, it is unsafe to argue concerning the healthy and moderate actions of an organ from the phenomena it presents when in a morbid state. But the weight of this objection is more apparent than real, for in a physiological point of view, the contractions of tetanus differ from those properly termed voluntary, only in being uncontrollable by the will and excessive in amount and duration. In violent tetanic spasm, I have myself ascertained that the peculiar sound of voluntary contraction is audible in the part, and identical with the normal sound; and the appearance and feel of a muscle thus rigidly convulsed, can be perfectly simulated for a short period by an act of volition*.

I therefore conclude, from the whole of the preceding remarks, combined with the facts and arguments advanced in my former paper, that *the contraction of voluntary muscle is not a sustained act of the whole congeries of contractile elements composing it; but a rapid series of partial acts, in which all duly share, becoming by turns contracted and relaxed.*

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The figure represents a portion of a primitive fasciculus, taken from among many others, from the complexus muscle, where it was ecchymosed and had lost in a great measure its fibrous appearance. At (*a*) a fusiform contracted portion, with the striæ remarkably close. On either hand the sarcous elements are much stretched (*b*), or even entirely disarranged (*c*, *c*, *c*), while at (*d*) there is a transverse rupture within the sarcolemma, and at (*e*) this sheath itself has given way.

* I yesterday, in company with my friend, Professor Todd, discovered the same appearances of *partial* contractions in the recti muscles of the abdomen, ruptured by violent straining in diarrhœa. The voluntary muscles of the whole body were infested with the *Trichina Spiralis*, and were enfeebled.—*August* 2, 1841.