XLVII. *Obſervations and Experiments upon* animal Bodies, *digeſted in a philoſophical Analyſis, or Inquiry into the Cauſe of* voluntary muſcular Motion; *by* Charles Morton, *M. D. F. R. S.*

Read Dec. 5, 1751. THE paper proceeds in the following order:

The Problem, or queſtion propoſed.

Obſervations and *Experiments*, illuſtrating the ſtructure and uſe of the parts concerned.

Two Lemma's, with demonſtrations concerning automatic or involuntary motion.

Obſervations proving, that the ſenſations, of which we take cognizance, are merely relative.

Obſervations proving, that the will has a power over ſenſation univerſally, to render it more or leſs acute.

Solution, or anſwer to the queſtion, neceſſarily ariſing from the preceding facts.

Some ſhort ſcholia.

Problem.

A muſcle being given in its natural ſtate, in a living animal body, it is aſked how, or by what mechanical means, that muſcle contracts, and is again relaxed, at the command of the will?

Obſervations illuſtrating the ſtructure and uſe of the parts concerned.

Every muſcle of an animal body is obſerved to be an inſtrument compoſed of fibres or leſſer muſcles,

which are joined together every-where, by one common membrane or ſubſtance, called from its appearance, cellular. This ſubſtance, when it arrives at the ſurface of the muſcle, becomes uniform, and makes one intire ſheath for the whole muſcle, or bundle of fibres, and renders it diſtinct from others.

The conſtituent fibres in many muſcles are obſerved to be partly fleſhy, and partly tendinous; the one changing, or being continued, into the other, for the conveniency of inſertion and motion. But the obſervation is univerſal, that the fleſhy fibres alone contract in muſcular motion, and that this contraction is always wave-like, or in alternate curls, from one extremity to the other of a given fibre.

We conſtantly obſerve, in every muſcle, numerous arteries, veins, and nerves. Theſe are generally diſtributed together, or in the ſame courſe, by means of the connecting cellular ſubſtance, into every point of the fleſhy fibres. Injections, and the knife of the anatomiſt, have follow'd them a great way, and reaſon completes the diſtribution, ſince you can nowhere wound the fleſh of a muſcle, but it ſhall bleed, and witneſs a ſenſe of pain.

Therefore there is a circulation of blood, throughout the whole fleſhy ſubſtance of a muſcle: and further the muſcle feels in every part.

In a living animal, if you tie the artery and vein, which principally belong to a given muſcle, that muſcle is diſabled from acting at the command of the will. Steno, a Daniſh anatomiſt of the laſt century, performed this experiment upon the deſcending aorta, and thereby took away the uſe of all the lower limbs (*vide Bergerum*, p. 296) at once, and reſtored them

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at pleaſure. Late anatomiſts have tried it upon leſſer veſſels, with the ſame conſtant ſucceſs. (Vide *Albini hiſtor. muſcul.* p. 19.)

In a living animal, if you tie the nerve, that ſupplies a given muſcle, that muſcle is diſabled from acting at the command of the will. This experiment is diſtinctly mentioned by Galen in his treatiſe on the muſcles, and is approved by the trials of later anatomiſts. (*Alb.* p. 19.)

From theſe two experiments it is clear, and generally agreed upon, that, in order to the performance of voluntary muſcular motion, beſides the particular ſtructure, there is required an abſolute freedom of the blood-veſſels, and the nerves.

Muſcular motion is obſerved to be voluntary, and involuntary. Of the firſt kind are almoſt all the muſcles of an animal body; of the latter, the only complete inſtance is the heart. The firſt ſeems more complex than the latter, ſince, beſides the motion, it implies an additional act of the will. Effects, that are leſs compounded, ought naturally to precede effects, that are more; theſe receiving light from the former, where both are homogeneous. For this reaſon, I have placed here two lemma's relating to automatic, or involuntary motion.

Lemma I.

The heart, in its natural ſtate, in a living animal body, being given, its contraction proceeds ſolely from, or is mechanically cauſed by, the warm blood, flowing into and filling its fleſhy ſubſtance in every part.

If this be denied, let the body of an animal be taken quickly after death, and let a warm mild fluid of any kind be injected gently into the heart, ſo as to fill it. When this is done, we ſhall ſee the heart quicken and contract, as in the life of the animal. This experiment was firſt diſtinctly mentioned by Peyer a Switzer (ſee a ſmall treatiſe of his, printed *anno* 1682, at Amſterdam, and intituled, *Miraculum anatomicum in cordibus ſuſcitatis*) and is now known to every anatomiſt. But if this effect is thus conſtantly produced ſoon after death, how much more, when the animal is alive? And if, by the introduction of any common fluid, with the bare addition of a warmth cognizable by our ſenſes, how much more by the introduction of the living blood, an inimitable and wonderful fluid, and the immediate ſubject of the vital warmth?

If therefore it is granted, that we ought not to admit more cauſes of natural things than are real (and preſent for the occaſion) and ſufficient for explaining the appearances (*a*), and we muſt grant a rule, whoſe uſe is ſo obvious in the Newtonian, which is the philoſophy of nature; we ſhall, I ſay, alſo grant, that the contraction of the heart, in its natural ſtate, in a living animal body proceeds ſolely from, or is mechanically cauſed by, the warm blood, flowing into, and filling, its fleſhy ſubſtance in every part. Which was to be proved.

Corollary.

The ſubſequent relaxation admits no difficulty: for if the blood is the immediate mechanical cauſe of the contraction, when the blood is removed, the effect ceaſes.

Lemma

(*a*) Newton, R. 1.

Lemma II.

A muſcle of voluntary motion, in its natural ſtate, in a living animal body, being given, it will contract by the introduction of a warm mild fluid, into its fleſhy ſubſtance in every part.

If this be denied, let the body of an animal be taken quickly after death, and the crural artery be pierced, and a warm mild fluid be injected into it: we ſhall then ſee the muſcles, to which the artery belongs, quicken and contract, as if the living animal moved them. This experiment was known to Mr. Cowper, and is confirmed by Albinus (ſee *Hiſt. Muſc.* p. 21.)

But if this effect is conſtantly produced ſoon after death, how much more when the animal is alive?

Therefore a muſcle of voluntary motion, in its natural ſtate, in a living animal body, will contract, by the introduction of a warm mild fluid, into its fleſhy ſubſtance, in every part: Which was to be proved.

But here it may be objected, with ſome appearance of reaſon, that there is a warm fluid, the living blood, in every part of the fleſhy ſubſtance of all the muſcles, during the life of the animals; and yet it is a fact, that no muſcle of voluntary motion contracts, but at the command of the will, morbid caſes excepted. This objection comes cloſe to the original queſtion, and however reaſonable it may ſeem, will quickly vaniſh before ſome common obſervations concerning the objects of ſenſe in general, and their manner of operating upon the different organs, ſo far as it univerſally agrees.

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We muſt firſt beg leave to make an eaſy poſtulatum, *viz.* that the nerves are the immediate inſtruments of ſenſation, though they are differently organized for the different ſenſes.

Obſervations, proving that the ſenſations of which we take cognizance are merely relative.

It is a certain fact; that, in the ſeveral ſenſes, the proper objects being ſuppoſe preſent, the ſenſation is intirely relative; or, in other words, that the preſence of a powerful object always obliterates the preſent ſenſation of a weak object; and that the conſtant habitual preſence of any one object, in the ſame given degree, produces no ſenſation at all.

Thus we obſerve, that the light of the ſun extinguiſhes the light of the ſtars; a ſtronger taſte covers a weaker; the ſound of a drum drowns an ordinary human voice; itching is baniſhed by ſmart and pain; a weak ſcent, by one that is ſtrong; cold, or a leſs degree of warmth, by heat, or a greater degree of warmth; and univerſally, our daily experience demonſtrates to us, that every organ of ſenſe, made familiar to a given degree of its object, affords no manner of ſenſation of the object in the given degree.

Thus it fares with the warm blood, which has conſtantly flowed through the whole minute ſubſtance of every muſcle of voluntary motion in an animal body, from the time of their formation, or unfolding in the womb. And it is highly probable, that the quickening of the child in a woman is no other than the completion of that ſtate, in which the blood begins freely to flow through, and to affect the inſtruments of voluntary motion; and till it becomes

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familiar to them, produces thoſe frequent ſhudders, or general muſcular contractions in the whole frame of the fœtus, which for a fortnight or more are the conſtant ſigns, that it has now obtained an animal life.

And here ariſes an apparent difference, though it will be found the greateſt uniformity, between the muſcles of voluntary and thoſe of involuntary motion; and namely the heart; which being appointed to protrude the vital fluids during the life of an animal, has a ſhort alternate remiſſion of its contracting cauſe; and is thereby render'd capable of admitting a conſtant and neceſſary ſupply of labour and ſtimulus together, without any force, or contradiction, to the natural order of the whole.

It follows undeniably from what has been ſaid, that if we can prove, that a given muſcle of voluntary motion, does really feel an increaſe of the familiar warmth of its contained blood, or an equivalent, to riſe and fall inſtantly at the command of the will, we ſhall then duly account for the ſubſequent motion. Or, more particularly, if we can prove, that the will has a direct power of heightening, increaſing, and rendering more acute, the ſenſe of any nerve, diſtributed to a given muſcle, the ſame familiar poſitive degree of warmth in the contained blood will, to this more acute ſenſe, appear to be proportionably heightened and increaſed, and the muſcle (by lemma 2) will inſtantly contract, and continue in that ſtate during the action of the will; allowing for a ſmall feebleneſs, that will gradually ariſe from the gradual excluſion of the contracting cauſe, and from the blunting of this more acute, and, as it were, new ſenſation; which yet, as we ſee, may be

be proportionably compenſated, by the will, for a time, even to the deſtruction of the nerve, the blood-veſſels, and indeed the whole organ, by a mortification, which has been known to ſucceed a long muſcular contraction.

Obſervations, proving, that the will hath a direct power of rendering more acute the ſenſations of the nerves univerſally.

We know from daily experience, that the will hath a power over all the organs of ſenſe, to heighten, or render acute, and again to relax them, their proper objects, in a reaſonable degree, being ſuppoſed preſent. And the ſame experience teaches us, that this power is greater or leſs, according to the more or leſs frequent uſe and exerciſe that is made of it. For it is obvious to every one, that any ſound man is able to feel, to taſte, to ſmell, to hear, and to ſee, more accurately when he pleaſes. And it is equally obvious and certain, that any one of theſe five ſenſes, being exerciſed, with an uncommon degree of attention and induſtry, either from choice, or from neceſſity, arrives at an uncommon degree of accuracy, and perfection. Indeed it is intirely from uſe and exerciſe, that a child learns to diſtinguiſh at all between the ſeveral objects of a given ſenſe, or, which are the ſame, between the ſeveral degrees, or modes, of its proper object.

All theſe particulars, being demonſtrably true of every ſenſe, that we can directly examine, the inference is very fair to the ſingle ſenſe (*Lem.* 2.) that we cannot directly examine; and, in truth, the induction in this caſe, is but one ſtep below a complete experimental demonſtration.

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It appears therefore, that the will hath a direct power of heightening, increaſing, and rendering more acute, the ſenſe or feeling of a given nerve, diſperſed throughout the whole contracting ſubſtance of a given muſcle, with all its gradations of accuracy and perfection. by repeated uſe and exerciſe.

Solution, or anſwer to the problem.

It follows therefore, that, a muſcle being given, in its natural ſtate, in a living animal body, the blood, which is preſent in every part of its contracting ſubſtance, and which, in effect, to the ſenſe of the given muſcle, (which is occaſionally render'd more acute) puts on an increaſed heat, and again lays it down at the command of the will, is the immediate mechanical cauſe, by which the muſcle does inſtantly contract, and is again relaxed, at the command of the will.

Therefore, a full ſolution is given to the queſtion propoſed: which was to be done.

Corollary 1.

Hence it appears, that muſcular voluntary motion is performed merely as a ſenſation (*a*), extremely acute, and under the niceſt management of the will: which explains its velocity in a great meaſure.

(*a*) Hartley *Conjecturæ de ſenſu, &c.*

Corol. 2.

Hence it appears, that the Galenic diſtinction of nerves, into nerves of ſenſation and nerves of motion, which greatly puzzles phyſiology, has no real foundation in an animal body.

A ſhort ſcholium.

The ſolution, that is given to the problem, may be aſſumed in a philoſophical ſyntheſis, and the various appearances may thence be announced, as well in natural as in morbid caſes; which again may be ſubjected to a ſtrict examination. Some trial has been made of this, and a ſurpriſing agreement found: but the detail muſt be omitted. In the courſe of this inquiry, every foreign diſquiſition is induſtriouſly avoided, and ſuch at this time would be a further queſtion, Why blood, in a certain, or apparent, degree of heat, contracts a muſcular fibre?

The buſineſs of natural philoſophy is, to obſerve, and to note down facts, that are conſtant; and ſingling out thoſe that are ſimilar, to collect their proper univerſal, by a fair and regular induction; and to acquieſce in this, till a new collection of conſtant and ſimilar facts affords an higher univerſal, and leads nearer the firſt cauſe.

October 16, 1751.