A new essay on muscular motion : founded on experiments, observations, and the Newtonian philosophy / By Browne Langrish.

A NEW
ESSAY
ON
MUSCULAR MOTION.

FOUNDED ON

Experiments, Observations,

AND THE

NEWTONIAN PHILOSOPHY.

By *BROWNE LANGRISH*, Surgeon,
at *Petersfield* in *Hants.*

LONDON:

Printed for A. BETTESWORTH and C. HITCH, in *Pater-Noster-Row.* M. DCC. XXXIII.

To the HONOURABLE

Sir *HANS SLOANE*, Bart.

PRESIDENT of the

College of Physicians;

And PRESIDENT of the

ROYAL SOCIETY;

THIS

ESSAY

Is, with all Respect and Humility, DEDICATED, by

His most Obliged, and

Most Obedient

Humble Servant,

Browne Langrish.

To the Honourable

Sir HANS SLOANE, Bart.

President of the

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And Treasurer of the

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ADVERTISEMENT.

IN the enſuing Diſcourſe I have endeavoured to diſcuſs ſeveral abſtruſe and knotty Points in Philoſophy; I have accounted for Muſcular Motion after a Manner intirely agreeable (at leaſt I think ſo) to the Principles of that moſt illuſtrious Philoſopher Sir ISAAC NEWTON; *and in doing of this, I have occaſionally taken Notice of the Laws of Attraction and Repulſion, from whence I have made it appear to be very probable, if not certain, that every individual Corpuſcle of Matter is endued*

endued with its determinate Poles, and does attract or repel every other ſimilar Corpuſcle, which comes within the Sphere of its Activity, by the ſame Laws, and after the ſame Manner that two Loadſtones influence each other.

FROM *theſe Principles I have alſo deduced the Cauſe and Manner of an Effervescence or Ebullition, which ariſes from the Mixture of an Acid with an Alkali, and have proved that it does not depend ſo much upon the Power of Attraction as hath been hitherto imagined, but that a repellent Force between their conſtituent Particles, is the chief Reaſon of it; and from the ſame Qualities,* viz. *from every Corpuſcle being endued with its determinate Poles, I have ſhewn the Reaſon why different Kinds of Salts always coaleſce into Cryſtals of different Shapes, Forms, and Figures from each other, and why they always preſerve their peculiar Shapes, let them be diſſolved, filtred, and cryſtallized ever ſo often.*

I HAVE

I HAVE *likewiſe demonſtrated, from the Structure of the Nerves, that neither Muſcular Motion nor Senſation could be performed diſtinctly, if they aroſe from any Vibrations in the Nerves themſelves. And laſtly, I have made it appear to be very probable, that the Uſe of the Ganglions on the Nerves, is to intercept any vibratory Motion which may happen in them; ſo that, by preventing any Communication of Motion from one Nerve to another, they are greatly inſtrumental in conveying the Ideas of Pleaſure or Pain, or the various Impreſſions made on the Nerves, diſtinctly, from the ſeveral Parts of the Body, to the* Senſorium *in the Brain.*

NOW *ſince I have undertaken ſo arduous a Task, I hope every Gentleman, endued with a Taſte for Enquiries of this Nature, will read what I have here done with Candour, and be ready to make favourable Allowances, eſpecially when he conſiders that Muſcular Motion is a Subject which has hitherto baffled the moſt curious*

Reſearches,

Researches, and by some of the greatest and most learned Philosophers has been set aside as inexplicable. But if I have advanced any Thing inconsistent with the Animal Oeconomy, or with the known Laws of Matter and Motion, I shall always be ready to relinquish my most darling Notions whenever they are made appear not grounded on the Laws of Nature.

A NEW

ESSAY

ON

MUSCULAR MOTION.

MUSCULAR MOTION is ſo intricate a Subject, that, amidſt all the Varieties of Nature, there is not one Thing wherein the Cauſe is more concealed, tho' the Effect is ſo viſible. It is a Subject which has already exerciſed the Wits of a great many learned and ingenious Men, and tho' ſo many Hypotheſes have been invented concerning it, that it would be tedious as well as uninſtructive to enumerate them; yet I don't know of one which will ſtand

the Teſt of a ſtrict Examination, without appearing to be inconſiſtent with ſome Part or other of the Animal Oeconomy; and certainly whatever is not intirely agreeable to that Simplicity, Regularity, and Harmony which we conſtantly obſerve between all the Parts of an animal Machine, is not to be received as Truth, let it be ever ſo wittily and ingeniouſly contrived.

SINCE therefore ſo many great and perplexing Difficulties attend the Explication of the Cauſe of *Muſcular Motion*, I am afraid of being accuſed of Arrogancy in preſuming to offer ſome Thoughts that have occurred to me on this Subject; but as I am fully perſuaded that *Muſcular Motion* is mechanically performed, and conſequently, that it is governed by the known Laws of Matter and Motion, I flatter myſelf that ſome proper Experiments, with an exact Obſervance to the Laws of the Animal Oeconomy, and a diligent Application of ſome noble Diſcoveries that have been lately made in Natural Philoſophy, will afford us a great deal of Light towards inveſtigating the true Cauſe of *Muſcular Motion*, however dark

and

and obſcure it may ſeem at preſent; and if I am not ſo happy as to explore all its Secrets, yet I hope, at leaſt, to excite ſome better Genius to perform the Task.

IT muſt be confeſſed indeed, that the principal Agent in *Muſcular Motion* is too ſubtile for us ever to bring its Manner of Action to a mathematical Demonſtration; but however if we can be ſo happy as to produce a Theory, every Way conſonant with the Structure and Make of the Muſcular Fibres, and with the known Laws of Matter and Motion, and it does not at the ſame Time, in the leaſt claſh with, or obſtruct any of the animal Functions, there can be no Reaſon for rejecting it, tho' it cannot be mechanically explain'd.

THE noble BOYLE ‖ ſays, " If a Matter of " Fact, or other Propoſition be proved by Argu- " ments competent in their Kind, we ought not

‖ Rules for judging of Things above Reaſon.

" to deny it meerly becauſe we cannot explain,
" or perhaps ſo much as conceive the Modus
" of it.

BUT leſt I ſhould incur the Diſpleaſure of my Reader, by finding Fault with other Men's Works, or by making a long apologetic Introduction to my own, I will proceed directly to my Subject, and endeavour, according to my poor Abilities, to inveſtigate the true and real Cauſe of *Muſcular Motion*; wherein, if I err, or if my Hypotheſis ſhould be proved to be quite falſe, I ſhall have the Satisfaction of finding myſelf in very good Company; and the Choices on the wrong Side will be fewer by one, for thoſe who ſhall hereafter undertake to explain the Cauſe of *Muſcular Motion* by mechanic Principles.

THE Method I ſhall take, in order to unlock this Cabinet of Wonders, will be,

I. *By the Help of ſome Experiments which I have made on the Nerves and Blood-Veſſels.*

II.

II. *By looking into and nicely examining the Form and Figure of a muſcular Fibre.*

III. *By accounting for its Elaſticity.*

IV. *By ſhewing the true Cauſe of its Tenſion.*

V. *By proving it to be more than probable that there is ſome ſubtile, volatile, ſpirituous Matter, or animal Spirits ſecreted from the Blood by the Glands of the Brain, and continually flying into the Nerves.*

VI. and Laſtly, *I ſhall deduce the Cauſe and Manner of Contraction and Dilatation in the muſcular Fibres from the foregoing Conſiderations.*

I. IT has been always acknowledged and taken for granted, that if a Nerve be tied up, or cut aſunder, the Muſcles which that Nerve leads to immediately loſe their Uſe, tho' all other Things continue the ſame; and from many Experiments which I have made on the Nerves, I have always found

found this to be exactly true: But that tying up the crural Artery, or any other Artery, out of the Trunk of the Body, will likewiſe deſtroy *Muſcular Motion*, I have proved to be falſe, by the following Experiments.

EXPERIMENT I.

I TIED up the right Inguinal Artery of a Dog, and cut it off juſt below the Ligature, that I might be ſure there was no Blood continued to circulate thro' it; the Dog being immediately ſet down, walked along as well as uſual, tho' as the Wound grew more ſore and ſtiff, he limped a little ſometimes; but when the Wound was healed up, I could never afterwards perceive the leaſt Difference in the Motion of his hind Legs.

EXPERIMENT II.

I TIED up the right Carotid Artery as near the Heart as I could poſſibly do it, and cut it off above the Ligature; but the Dog did not loſe the

Uſe

Uſe of any one Muſcle by it: conſidering then that there were frequent Inoſculations between the ultimate Branches of the Carotid Arteries, I ſerved the left Carotid Artery of the ſame Dog in the ſame Manner, and yet there was no Loſs of Motion; he could lap up Milk, chew Meat, ſwallow, wink, and uſe all the Muſcles of the Head, Mouth, and Face as he uſed to do.

EXPERIMENT III.

I TIED up and cut aſunder both the Inguinal and both the Carotid Arteries of a large Spaniel Dog which I now keep, and yet this Dog has not loſt the Uſe of one Muſcle, neither is he diſordered in any one Way by it, that I know of, tho' it is now above ſix Months ago that I did it.

THESE Experiments are ſufficient to ſhew, how much People have been deceiv'd, and how erroneous the common Opinion is, *viz. That if the Crural Artery was to be tied up, or cut aſunder, the Muſcles of the Leg would loſe their Uſe as certainly, as if the Crural Nerve was deſtroy'd.*

THIS

THIS Aſſertion was ſpread abroad, as I am apt to believe, without making any, or ſufficient Trials of it; for I have repeated theſe Experiments a great many Times, and I am ſure with the utmoſt Accuracy, and always with the ſame Succeſs. 'Tis true, we are not to infer from hence, that the Blood has nothing to do with *Muſcular Motion*, becauſe there are moſt certainly ſome ſmall Branches detached off from the Inguinal and Carotid Arteries nearer to the Heart, than we can poſſibly lay any Ligatures on them without deſtroying the Life of the Dog; ſo that we are not to ſuppoſe the *Muſcles* are quite deſtitute of Blood, becauſe their main or principal Artery is tied up, or cut aſunder, it being well known that when all the Blood is intercepted, *Muſcular Motion* ceaſes in a few Minutes.

THIS appears to be true by tying up the *Aorta deſcendens*, which I have often done, juſt before its Diviſion into the *Iliacæ*, and I always have obſerved, that if the Dog was ſet down immediately after the *Aorta* was tied up, (without ſtaying to replace the Inteſtines, or to ſew up the Wound) he could

could make Uſe of his lower Parts, and walk a little Way, before the Palſy ſeiz'd him, but after that no manner of Motion could be perceived in his hind-Legs, tho' he would ſometimes ſurvive the Operation ſeven, or eight Hours.

SEEING therefore that *Muſcular Motion* is ſo ſoon deſtroyed, when all the Blood is intercepted, I beg Leave to propoſe the following Queries concerning the Reaſon of it.

QUERY I.

DOES not the violent Diſtenſion of the *Aorta*, and all the neighbouring Blood-Veſſels above the Ligature preſs upon the Nerves, which go to the lower Parts, and by that Means interrupt the Paſſage of the Animal Spirits thro' them; ſince 'tis well known, that in a *Nephritis* the Thigh often loſes great Part of its Motion and Senſibility by the Stones preſſing upon the Nerves?

QUERY II.

DOES not the Pulsation or Vibration of the Arteries greatly assist the Motion of the Animal Spirits thro' the Nerves? For since the Nerves are generally placed along the Sides of the Arteries, it is humbly presumed that the Design of it was to encourage the Motion of the Animal Spirits thro' the Nerves. Now if so, it follows, that tho' some of the Nerves, which go to the lower Parts, may arise below the Place where the *Aorta* is tied up, and others escape the Pressure of the distracted Blood-Vessels above the Ligature, yet the animal Spirits may want the proper and usual *Impetus* to propel them thro' the Nerves, and consequently *Muscular Motion* may be destroyed merely for Want of the vibratory Motion of the Arteries.

QUERY III.

DO not the muscular Fibres collapse, and grow so flaccid, when all the Blood is intercepted, that the Influx of the animal Spirits may be interrupted,

rupted, tho' no other Impediment ſhould happen in the Nerves?

QUERY IV.

Is not the chief Uſe of the Blood, towards *Muſcular Motion*, to keep the Fibres warm, ſupple, diſtended, and every Way ready for the Influx of the animal Spirits into them; and by its expanſive and progreſſive Motion, to aſſiſt the Motion of the animal Spirits through the Nerves?

We are aſſured by Mr. COWPER, that by injecting warm Water only into the Artery of Muſcles concerned in voluntary Motion, after the Paſſage of the Blood had been intercepted, he cauſed them to renew their Contraction. Now warm Water cannot poſſibly have any other Effect on the muſcular Fibres, than to diſtend, ſupple, and relax them, and, by its Warmth and progreſſive Motion thro' the Arteries, it may communicate Motion to the animal Spirits; but it is abſolutely impoſſible for it to have any Share

in ſhrinking up or contracting the Fibres, after ſuch a Manner as *Muſcular Motion* is performed. That the Blood is uſeful towards *Muſcular Motion*, either by encouraging the Motion of the animal Spirits through the Nerves, or by keeping the Muſcles warm, ſupple, diſtended, and moiſt, in ſuch a Manner that the animal Spirits have a free and eaſy Influx into them, cannot be denied; but that the Blood is by any Means capable of purſing up and contracting the Fibres, does not appear from any Arguments which have been made Uſe of in its Favour. On the contrary, it has been proved, as we ſhall ſhew hereafter, that a Muſcle, during its State of Contraction, is leſſened in all its three Dimenſions, and conſequently the Blood, inſtead of ſwelling and diſtending the Fibres, is ſqueezed out of them at ſuch a Time; ſo that, Action and Re-action being always equal, it appears from hence, that the Blood acts as an Antagoniſt, againſt the contractile Power of the Fibres, by extending and diſtending them, rather than having any Share in their Contraction.

WE are told by the learned AUTHOR of the *Introduction* to COWPER *on the Muſcles*, That the Blood appears ſome Way neceſſary towards *Muſcular Motion*, ſince it has been found that, by intercepting the Paſſage of the Blood to any Muſcle, the Muſcle loſes its moving Power. But from ſome Experiments on the Heart of an Eel and Salmon, (*viz.* that being warmed, they would beat long after the Death of the Animal, nay, even when ſeparated from the Body) it may be queſtioned whether this Effect ariſes from any other Cauſe, than that by depriving the Muſcle of its Blood, the Fibres and Nerves muſt ſoon grow cold and ſtiff: for we ſee in theſe Experiments, that the Fibres of the Heart, when warm, contracted themſelves, tho' the Blood was not circulating thro' them.

THE Heart of a Frog is alſo very remarkable for continuing its Pulſation a long Time after it is taken out of the Body; and even after it has ceaſed beating, it will repeat it again by being warmed, or pricked with a Needle: But the moſt

remarkable

remarkable of all is a Viper, which will continue to twiſt and twine about for many Hours after the Head, Heart, Entrails, and Skin are taken from it.

In ſhort, theſe Phænomena give great Room to ſuſpect that *Muſcular Motion* is continued in ſome Creatures as long as the Fibres are warm, moiſt, and ſupple; and that it ariſes only from ſome ſubtil Matter, or the animal Spirits, which momentaneouſly increaſe the Force of the corpuſcular Attraction in the Fibres themſelves, ſo that their component Particles run cloſer together, and the Fibres are ſhortned as long as this additional attractive Power remains in them: But of this more hereafter. Thus much being premiſed, I go on to my

IId Head, *viz. To examine into the Form and Figure of a Muſcular Fibre.* And this is beſt done by gently boiling a Muſcle till its Fibres will eaſily ſeparate from each other, and then, if it be waſh'd and cleanſed from the Blood, *&c.* the Texture

Texture and Shape of the Fibrils become more evident and perſpicuous.

WHEN a Muſcle is prepared after this Manner, and a longitudinal Fibre divided as far as we poſſibly can do it, it always appears to me to be of a cylindrical Shape; and I am of Opinion, that if we could ſeparate the Fibres much farther, or as far as they are capable of being divided, they would ſtill be of the ſame Shape, *viz.* little hollow Cylinders; for tho' every minute Fibril is allowed to be the Continuation of a Blood-Veſſel (a capillary Branch of an Artery being loſt in it, and a capillary Branch of a Vein ariſing from it) yet it cannot properly be called either an Artery or a Vein, neither does it follow either of their Shapes.

AS to the tranſverſe or ſpiral Fibres, which are found in dividing a Muſcle, they ſeem to me to be of the ſame Make with the others, and to be chiefly uſeful in holding the longitudinal Fibres in their proper Poſitions; but by the moſt accurate Obſervations, with the beſt of Glaſſes, I could

could never perceive that either the longitudinal or tranſverſe Fibres were divided into Cells, Veſicles, or Bladders.

III. *The Elaſticity of a Muſcular Fibre* is a Power or Property of reſtoring itſelf to its former Shape, after it has been ſtretched out longer than uſual by ſome impreſſed Force.

Now, in order to underſtand the Nature of this rightly, it will be proper to conſider that there is in all Matter a peculiar Power of Attraction and Repulſion; which Properties manifeſtly diſcover themſelves in many Things, and according to their particular Diſpoſitions they are called by the Names of Magnetiſm, Electricity, or Gravity.

Magnetical Attraction, ſtrictly ſpeaking, belongs to no other Bodies but the Loadſtone, and Iron or Steel; at leaſt it has not been diſcovered in any thing elſe. Electrical Bodies attract all light Things indifferently. And Gravity equally affects all Bodies, without regard either to

to their Bulk, Figure, or Matter. But notwithſtanding theſe ſeeming Differences in the Tendency of ſome Bodies towards others, we have many Reaſons to believe that the real Cauſe of Attraction and Repulſion is the ſame in all Bodies, and that all theſe different Phænomena, as well as the various Degrees of Coheſion, Hardneſs, Elaſticity, &c. ariſe only from ſo many different Degrees of Attraction and Repulſion between the component Particles, and not from any material eſſential Difference in the Cauſe. I never could find that there was any Difference between the Force of Attraction and that of Repulſion in the ſame Pole of a Loadſtone, and if the ſame Pole both attracts and repells with the ſame Degree of Power, theſe Qualities ſeem very likely to proceed from the ſame original Cauſe.

AGAIN, if the original Cauſe of Attraction and Repulſion be the ſame in all Bodies; that is, if every Particle of Matter, which is endued with an attractive Force, is alſo endued with a repellent, in the ſame *Ratio*, 'tis very probable that theſe Qualities were equally impreſſed on all the ori-

ginal primitive Atoms of Matter at the Creation; and that all the different Degrees of Attraction and Repulſion, which we now find in ſeveral Sorts of Bodies, proceed only from the various Shapes, Aſſociations, and Combinations of their conſtituent Particles; ſo that it is entirely owing to ſuch and ſuch particular Structures and Diſpoſitions of the component Particles, that ſome Bodies are naturally receptive and retentive of Magnetiſm, others of Electricity, and others of neither of them, at leaſt not within the Reach of our Senſes.

SINCE therefore we have great Reaſon to believe that every Parcel of Matter is endued both with an attractive and repelling Force, in ſome Degree or other, and ſince theſe Vertues are more eminently conſpicuous in a Loadſtone than in any other Sort of Matter whatſoever; I think we ought to fix that as the Standard, and deduce our Theory of Attraction and Repulſion from thence.

'TIS

'TIS well known that a Loadſtone hath its determinate Poles, and that it does attract or repel every other Loadſtone, placed within the Sphere of its Activity, according as their Poles are applied to each other; that is, if the South Pole of one Magnet be placed within a proper Diſtance of the North Pole of another, they will fly together, and embrace each other with the utmoſt Affection: but if the South Pole of one Magnet is offered to the ſame Pole of another, they will then avoid and fly from each other, with as much Velocity as they came together before. The very ſame Thing will happen between two magnetic Needles, or any Pieces of Iron or Steel properly touched with a Loadſtone; nay, a magnetical Vertue may be communicated to Steel, by rubbing it between an Anvil and an Iron Bar, without ever touching a Magnet, and this as ſtrong and permanent as poſſible, as Mr. ARNOLD MARCEL † (Ne-

† Phil. Tranſact. N° 423.

phew to the late Mr. ANTHONY VAN LEEUVENHOEK) has lately diſcovered.

IF a Loadſtone be broke into ten thouſand Pieces, every Fragment will have its determinate Poles, and will preſerve its attractive and repellent Qualities in Proportion to its Bulk; from whence it appears, that the conſtituent Particles of a Magnet are all of them placed Rank and File, in a very regular Manner, and that they are all endued with their proper Poles; becauſe, break the Stone where you will, the Conſequence is the ſame: And from hence, likewiſe, 'tis evident, that the Strength of the Attraction and Repulſion, whilſt the Magnet was whole, proceeded from the Share which every individual Corpuſcle contributed towards it.

THE whole Earth is allow'd to be a Magnet; and there is no doubt but its Poles have the ſame Influence on all the heavenly Bodies, which are within the Sphere of its Attraction and Repulſion, as we obſerve between thoſe of two Loadſtones; and it muſt be confeſs'd, that the Sum of the attractive

attractive and repulsive Force of the whole Earth, or of any Part of it, arises from the Share which every constituent Particle contributes towards it: For tho' some Parts of Matter are endued with a stronger and more visible attractive Force than others are; yet it cannot be denied but every the minutest Particle has this Property, and consequently it must have its Influence in a *Ratio* to its attractive Force, and to the Proportion it bears to the Whole.

THIS is exactly agreeable to what the inimitable Sir ISAAC NEWTON has shewn us in his *Principia*, viz. "That the Quantity of the Force "of Attraction in all similar Bodies, at equal "Distances, is exactly proportionable to the "Quantity of Matter in the attracting Body, as "being in Reality nothing but the Result or "Sum of the united Forces of all those single "Particles of which it is composed."

HENCE it appears, that if the Attraction and Repulsion, or the different Poles of our Earth, or any Part of it, arise only from the Union

Union or Conjunction of the attractive and repellent Force of all its component Particles, that then each ſingle Corpuſcle in every Parcel of Matter, muſt have its determinate Poles, (it being impoſſible for it to communicate what it has not) and does attract or repel every other ſimilar Corpuſcle, which comes within the Sphere of its Activity, according as their Poles happen to be offered to each other; and though theſe Properties are not active enough in many Things to produce viſible Effects, yet we have all the Reaſon in the World to believe that every Parcel of Matter is endued with the ſame Principles, though they may be in ſeveral Degrees, or they may be intended or remitted according to the different Shapes, Textures, and Modifications of the component Particles.

'Tis to theſe Properties of Attraction and Repulſion that we attribute the inteſtine or fermentative Motion which ariſes in the Diſſolution of ſome Bodies; for though it may be eaſily conceived that Salt or Sugar may be diſſolved by the Strength of Attraction only, yet I can't

appre-

apprehend how an Ebullition can proceed from the Mixture of different Bodies, without a repellent Force between ſome of their Particles. As, for Inſtance, I preſume, from what has been ſaid, that all the conſtituent Particles in Salt of Wormwood have their determinate Poles, and are all placed, by the common Laws of Attraction, in a regular Manner, according to their Poles; and conſequently, as long as they remain in ſuch Poſitions, all is quiet; but as ſoon as ſome Juice of Lemons, or any other Acid, is poured upon it, the acid Particles attract ſome of the ſaline Particles much more violently than they did each other before, and repel others with as great a Force, according as their Poles happen to meet: Hence ariſes a great Commotion between the acid and alcaline Particles; and from this leaping and bounding about of them, proceeds an Ebullition; and this Ebullition or Effervеſcence continues till all the Particles, both acid and alcaline, have met with each other at their proper Poles of Attraction; which is no ſooner done, but the Ebullition ceaſes, the Mixture ſubſides, and the acid and alcaline Particles

are united in a very friendly manner; that is, they attract and are attracted by each other, without any repellent Force acting among them.

I VERY well know that ſome great and learned Men have thought, where the attracting Corpuſcles of any Fluid are elaſtic, they muſt neceſſarily produce an inteſtine Motion; and this greater or leſſer, according to the Degrees of their Elaſticity and attractive Force. But, with all due Submiſſion, I am of Opinion, that Repulſion has much more to do in Ebullitions or violent Fermentations, than Attraction; for, ſuppoſing any Number of elaſtic attracting Particles to be within the Sphere of each other's Attraction, and that they fly together with any given Force, it will follow, that the Strength of their Attraction will be ſo much greater at the Point of Contact, that it was at ever-ſo ſmall a Diſtance before, that their Springineſs or Elaſticity will not be able to ſeparate them again. For ſince the attractive Power is the firſt and only *Impetus* which puts the Particles in Motion, it muſt neceſſarily follow, that the Strength of the

Attraction

Attraction does increaſe in the ſame Proportion with the Velocity of the moving Particles, and conſequently it will be ſufficient to hold them together if once they come into Contact, let them be ever-ſo elaſtic.

THAT Bodies entirely elaſtic (if any ſuch there are) may recede from one another, after they have met, with the ſame Celerity they had before they met, abating the Reſiſtance of the *Medium*, cannot be denied, when the *Impetus* is communicated to them from a third Body, and the moving Bodies have no attractive Influence on each other, even in Contact: But by all the Obſervations I have been capable of making, I never could perceive that any Bodies which flew together from the Principle of Attraction only, ever ſeparated again, unleſs they were attracted or repelled more forcibly by ſome other Body. Whereas, if we ſuppoſe the Particles of fermenting Liquors to be endued with their determinate Poles, 'tis evident that ſome of them muſt recede from, whilſt others fly towards each other; and during ſuch Commotions there muſt be violent

Colliſions: becauſe all thoſe Corpuſcles which are repelled, and in their Flight ſtrike againſt others, and their Poles, don't happen to agree, they will have ſo many freſh Impulſes communicated to them, by their repellent, as well as by their elaſtic Force; from whence their Velocities will be prodigiouſly increaſed; and thus they will keep on daſhing from one to the other, 'till they are broke into their *Minima*, or 'till all the component Particles are ſettled according to their different ſpecific Gravities and Attractions.

'Tis well known, that in an Ebullition the Maſs of Matter is rarified; that is, its Parts are ſo divided, as to occupy more Space than they did before, and to have their Interſtices larger than before; which is not ſo likely to ariſe from the Principle of Attraction, as Repulſion. Add to this, That the Attraction between the moſt minute Particles of fermenting Liquors, exerts itſelf only at the leaſt ſenſible Diſtance; whereas, by many Experiments, we have diſcovered, that a repellent Force acts at a greater

Diſtance; inſomuch that when the ſame Particles which attracted each other before, are poſited without their Sphere of Attraction, they will ſtill repell, and endeavour to fly farther from each other. Hence it evidently appears, that in all Effervescencies a vaſt many more Particles muſt be influenced by a repellent, than by an attractive Force; and as Effects are ever proportionable to their adequate Cauſes, it conſequently follows, that all violent Fermentations or Ebullitions are owing more to the Power of Repulſion than Attraction.

I AM perſuaded alſo, that Salts always preſerve their particular Shapes, Forms, and Figures, (though they are diſſolved, filtred, and cryſtallized ever-ſo often) by every Particle having its determinate Poles: For, granting that the component Particles of different Kinds of Salt are of ſo many different Shapes and Sizes; yet if they had a Power of uniting with each other indifferently at their Tops, Bottoms, and Sides, one would think they could not always coaleſce into Cryſtals of the ſame regular Figure. But if

the conſtituent Particles of any Kind of Salt are of ſuch a peculiar Shape, and at the ſame time have their determinate Poles, then they cannot poſſibly attract or unite with each other, but when their Poles ſquare with one another, and conſequently they will always fly together, and be join'd at ſuch Points only where their correſponding Poles are, which muſt of Courſe conſtantly produce the ſame regular Form and Figure in every Aggregate of ſuch particular ſaline Particles. As for Inſtance, *Sal Armoniac* very elegantly imitates the Branches of a Tree, Salt of Hartſhorn looks like a Quiver of Arrows, and Salt of Tin ſhoots into Lines like little Needles, which ſpread themſelves every way from a Point, as from a Centre, ſo as to repreſent a Star.

NOW can it be imagined, if the moſt ſimple Atoms or Parts of theſe Salts did attract each other indifferently on either Side, that they would immutably and perpetually coaleſce into Cryſtals of the ſame regular Figure and Shape?

THE learned Dr. FREIND ‖ lays it down as a *Lemma*, "That the attractive Force is greater "on one Side of the ſame Particle, than on an- "other;" but he does not ſuſpect that it atiſes from the ſame Principle that influences a Loadſtone, or that the other Side has its contrary Pole. However, Sir ISAAC NEWTON obſerves, † "when any ſaline Liquor is evapo- "rated to a Cuticle, and let cool, the Salt con- "cretes in regular Figures; which argues, that "the Particles of the Salt, before they con- "creted, floated in the Liquor, at equal Diſtances, "in Rank and File, and by Conſequence, that "they acted upon one another by ſome Power "which at equal Diſtances is equal, at unequal "Diſtances is unequal; for, by ſuch a Power, "they will range themſelves uniformly, and, "without it, they will float irregularly, and "come together as irregularly. And ſince the "Particles of Iſland Cryſtal act all the ſame way

‖ Chymical Lectures.

† Opticks, Book III. Qu. 31.

upon

" upon the Rays of Light, for cauſing the unuſual
" Refraction ; may it not be ſuppoſed, that in
" the Formation of this Cryſtal, the Particles not
" only ranged themſelves in Rank and File for
" concreting in regular Figures, but alſo by
" ſome kind of polar Virtue turn'd their homo-
" geneal Sides the ſame way ?

AND again, we are taught by the ſame *Great Man*, " That Fire is the moſt ſimple of
" all known Bodies, and conſequently the moſt
" immutable : That each Ray of Fire or Light
" has Sides differently affected, and which have
" different Properties ; and that Iſland Cryſtal
" is found to attract a Corpuſcle of Fire, if one
" of its Sides be turned toward the Cryſtal, and
" repel it, if the other be. For one and the
" ſame Ray is here refracted ſometimes after the
" uſual, and ſometimes after the unuſual manner,
" according to the Poſition which its Sides have
" to the Cryſtal ; and ſince the Cryſtal, by this
" Diſpoſition or Vertue, does not act upon the
" Rays, unleſs when one of their Sides of unuſual
" Refraction looks towards that Coaſt, this
" argues

" argues a Virtue or Diſpoſition in thoſe Sides " of the Rays, which anſwers to, and ſympathizes " with that Virtue or Diſpoſition of the Cryſtal, " as the Poles of two Magnets anſwer to one " another."

THERE are many Experiments, too tedious to mention now, which not only confirm the Truth of theſe Things, but induce one to believe that all the *Phænomena* of Nature do ariſe from the conſtituent Particles of Bodies being either impelled towards each other, and cohering in particular and regular Figures, according to their Poles, or elſe by being repelled and receding from each other; and though the real Cauſe of Attraction and Repulſion is one of the Secrets of Nature, and, I believe, likely to continue ſo, yet, by frequent Obſervations, we are arrived to a tolerable Certainty in accounting for their different Laws, and are able to deduce many uſeful Problems from thence.

AND

AND here I cannot but obſerve, That as each original primitive Particle or Atom of Matter muſt have its determinate Magnitude or Size, as alſo its peculiar Figure and Shape; ſo from a few different Sizes and Shapes, among the primitive Atoms, may ariſe all the wonderful Varieties of Matter, wherewith the World is adorn'd, according to their different Compoſitions, Aſſociations, or Modifications. For if we conſider from how few original primary Colours we are able to produce an infinite Number of others by variouſly mixing them, and that from twenty-four Letters we have formed Languages conſiſting of an infinite Number of Words; it appears to be poſſible for all the different Species in the animal, vegetable, and mineral Kingdom, to proceed from a few original Shapes and Sizes firſt impreſſed on the Atoms; eſpecially ſince 'tis well known that Nature is always frugal in Principles, though fruitful and various in Effect and Compoſitions. But to return:

WE have not yet taken ſufficient Notice of that Sort of repellent Force in Matter, which ariſes from the Particles being placed beyond the Sphere of each other's Attraction, as between Water and Oil, and generally between Water and all unctuous Bodies; between Mercury and Iron; and alſo between the Particles of any Duſt: But the moſt remarkable Repulſion of this Kind is in the Air, where the component Particles endeavour to expand and recede from one another with a mighty Force, ſo as to be the ſole Cauſe of its wonderful Elaſticity, which is ſo great, that all the Compreſſion in the World is not able to overpower it, or to condenſe its conſtituent Particles near enough together to come within the Sphere of each other's Attraction.

THE more the Air is compreſſed, and its Denſity increaſed, the more elaſtic it is; becauſe the nearer its Particles are ſqueezed together, the more they repell and endeavour to fly from each other: And let the compreſſive Power be ever-ſo great, or continue ever-ſo long, the

Moment it is taken off, the conſtituent Particles of the Air will expand and recede from one another with a Velocity proportionate to the Compreſſion; that is, the Force by which the Particles of Air fly from each other, increaſes in the ſame *Ratio* as the Diſtance in which the Centres of the Particles are diminiſh'd; or, in other Words, the repelling Force is inverſely as this Diſtance.

BUT notwithſtanding the Elaſticity of the Air proceeds intirely from a repellent Force between its component Particles, 'tis not to be inferr'd from thence, that the Elaſticity of ſolid Bodies ariſes merely from the ſame Cauſe; becauſe it is evident that their Particles are all in Contact with each other, before the elaſtic Body is bent or drawn out longer than uſual by ſome impreſſed Force. As for Inſtance: Whilſt a Spring is ſtraight, we preſume, every individual Particle of it is at Reſt; that is, they are ſituated, in regard to each other, according to their Poles, and embrace one another by their common Principle of Attraction; but no ſooner is the Spring bent, but ſome

of

of its Particles, on the convex Side, muſt of Courſe be disjoined and removed to each other, though perhaps to the moſt minute and ſmalleſt Diſtances in the World, whilſt others, on the concave Side, are crowded over one another. Hence it will follow, that if thoſe Particles which are ſeparated from each other, or touch one another in fewer Points than uſual, are yet ſo near each other as to be within their Sphere of Attraction, and not at all altered in regard to their Poles, they will conſequently attract each other very ſtrongly, and fly together again as ſoon as the impreſſed Force is removed; whereas it is no unreaſonable Conjecture to ſuppoſe thoſe Particles, on the concave Side of the Spring, which are crouded together, and, as it were, rumpled over one another, may be ſo much altered from their former Poſitions, that their Poles do not now anſwer each other; and if not, they will repell one another 'till they have attain'd their former Situations, that is, 'till the Spring has recover'd its former Shape.

THERE are thoſe indeed who have attributed the Cauſe of Elaſticity to ſome ſubtile Matter which they ſuppoſe to be conſtantly flying through all Bodies, except elaſtic ones, when they are bent: As for Inſtance; This ſubtile Matter is believed to have been a free and uninterrupted Paſſage throuh the Pores of a Spring whilſt it remains ſtraight; but as ſoon as it is bent, the component Particles on the concave Side of the Spring are forced cloſer together, whilſt thoſe on the convex Side are removed farther aſunder: So that though this ſubtile Matter enters more eaſily on the convex Side, yet it meets with much Oppoſition on the concave; from whence there ariſes a conſtant Struggle between the ſubtile Matter, and thoſe Particles of the Spring which are forced ſo near together as not to admit the ſubtile Matter to paſs between them; and as long as this *Niſus* remains, ſo long will the Spring be elaſtic.

BUT by the Aſſiſtance of the Doctrine of Attraction and Repulſion, taught us by our Great

Great Maſter, Sir ISAAC NEWTON, we are able to account for the Cauſe of Elaſticity after a more rational manner; and we are well aſſured that ſome ſoft malleable Bodies may be made elaſtic, and elaſtic Bodies may be made more ſo by ſuch Things as will increaſe their Attraction, or unite their conſtituent Particles nearer together; and *vice verſa*.

'TIS reported, * That touching a Steel Sword with a Loadſtone, makes it more elaſtic; and if ſo, 'tis probable that this Effect ariſes from the component Particles of the Steel being drawn nearer together by the magnetic *Effluvia*, or elſe by their attractive Virtue being increaſed towards each other, though their Diſtances are not at all altered.

A PLATE of Metal, by repeated Blows of a Hammer, becomes elaſtic; and being heated, does again loſe that Virtue.

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* Switzer's Preface to his Hydroſtatics.

AND

AND 'tis well known, that if a Piece of Steel be heated to a great Degree, and ſuffered to grow cold gradually, it will loſe the greateſt Share of its Elaſticity; whereas if it be ſuddenly immers'd in cold Water, whilſt it is intenſely hot, it loſes but little or none of its elaſtic Force. Now this is moſt certainly owing to the component Particles of the Steel being diſplaced and ſeparated from each other by the Force of the Fire, and ſuffered to remain ſo in the former Caſe, and to their being contracted or condenſed in the latter. Every *Blackſmith* knows that Heat will ſwell and lengthen a Bar of Steel, and make it ſoft, ſupple, and unelaſtic; and there is no doubt but cold Water does contract it in Proportion, as being diametrically oppoſite in its Nature to Heat.

THUS much being premiſed, I ſhall now return to examine into the Cauſe of Elaſticity in an animal Fibre, and am in Hopes that it will eaſily appear, from what has been ſaid.

WHEN

WHEN a muſcular Fibre is ſtretched out longer than uſual, 'tis moſt certain that ſome of its Particles ſlip by one another, and others are removed at exceeding ſmall Diſtances from each other: and if the impreſſed Force is at any time greater than the Strength of the Attraction between the conſtituent Particles of the Fibre, a Solution of Continuity happens, or the Fibre breaks. Hence 'tis evident, that when a ſtretched-out Fibre retracts itſelf into its former Shape and Dimenſion, the Particles which were diſplaced, return again to their proper Poſitions, by their attractive Power. And this Conſideration may poſſibly give us a great deal of Light, towards inveſtigating the true and real Cauſe of *Muſcular Motion*: For as all the Fibres in an animal Body are elaſtic, and as their Elaſticity is a Power of Reſtitution, by which means they recover their former Shapes, after they have been ſtretched out longer than ordinary, it may reaſonably be called a Contraction. And there is no doubt but if the ſame Cauſe which makes all the Fibres of a Muſcle elaſtic, was to be ſuddenly increaſed, it would

would contract the Muſcle ſtill ſhorter, and be the Cauſe of *Muſcular Motion* as long as ſuch additional attractive Power continued in the Fibres.

ALL the Fibres of an animal Body are elaſtic not only during Life, but after Death; as is evident from Cat-gut, Parchment, Leather, *&c.* which are all made of the Skins and membranous Parts of animal Bodies. But then this is under ſome Limitations: For if the Fibres are in the leaſt corrupted and putrified, their Elaſticity is deſtroyed; or if they are made ſo dry that their conſtituent Particles cannot ſlip by each other, or yield to one another's Motion; they will break, if you offer to ſtretch or bend them with any Force. Hence it appears, that there is a peculiar Diſpoſition or Arrangement of the component Particles required, in order to make the Fibres elaſtic; and that their Elaſticity is eaſily deſtroyed by ſome Things, and increaſed by others.

ANY mucous ſlimy Matter in the Body (and from ſuch Matter the Fibres are chiefly nouriſhed) being

being temper'd between the Fingers 'till it will draw out into Strings, has this Property of Elaſticity, or contracting itſelf, and growing thicker and ſhorter as ſoon as the Power which ſtretched it out is removed; and undoubtedly the Elaſticity of an animal Fibre ariſes from the ſame Cauſe, *viz.* from the mutual Attraction of its conſtituent Particles.

BY this elaſtic Power all the Fibres in an animal Body are kept in their proper Poſitions; ſo that whenever any of the Veſſels are dilated, expanded, or diſtracted beyond their uſual Dimenſions, 'tis owing to this Property, that they are capable of reſtoring themſelves to their natural Shapes: And how exceedingly uſeful this is towards preſerving the Body, is evident to every one who is in the leaſt acquainted with the animal Oeconomy. Without this Property in the Fibres, Life could not ſubſiſt but a few Hours, or perhaps Minutes; the Body would be like a Lump of Dough; Obſtructions, Tumours, Diſtenſions, and Swellings would ariſe every-where, and would ſoon put a Stop to the Circulation. But to proceed:

THE Fourth Thing to be taken Notice of in a Muſcle, is, That all its Fibres are, during Life, in a State of Tenſion; that is, every Fibre ſeems to be ſtretched out beyond its natural State of Reſt or Quieſcence; as is evident from an Inciſion made acroſs any Muſcle, which is no ſooner done, but thoſe Fibres which are cut aſunder fly back like ſo many ſtretched Strings, and make the Wound gape.

NOW there are Two Things which ſeem to be principally concerned in this Action; The Impulſe and Preſſure of the circulating Fluids; And a conſtant *Niſus* or Endeavour towards Contraction in the Fibres. For as the Blood is always propelled with ſome Violence through the Veſſels, it muſt neceſſarily extend and diſtract them in Proportion to its Quantity and Velocity; as is evident by cutting aſunder an Artery or a Vein: But as the *Impetus* of the Fluids does only increaſe the Breadth and Length of the Fibres, we muſt have Recourſe to ſome other Agent for their Contraction or flying back, when they happen

happen to be cut aſunder. And if we accurately examine into the Nature of it, I am perſuaded we ſhall find, that this Property in the muſcular Fibres ariſes from the ſame Cauſe with their Elaſticity, and perhaps with *Muſcular Motion*. For, 1*ſt*, It appears, that when the Fibres are relaxed, that is, when they have loſt their Elaſticity, they will not retract, if cut aſunder, though they are ever-ſo-much diſtended with Fluids; as is evident in the worſt Degree of an *Anaſarca*. 2*dly*, All the voluntary Muſcles are preſerved in *Æquilibrio* by an equal Degree of Tenſion in their Fibres: But whenever a voluntary Muſcle loſes its Uſe, its Antagoniſt immediately and involuntarily contracts itſelf, by Virtue of its Tenſion, and will remain in that State as long as the Relaxation or Weakneſs continues in the other; which argues a great Analogy between the Cauſe of the Tenſion, and that of *Muſcular Motion*. 3*dly*, I have many times obſerved ſome Muſcles and the fleſhy Pannicle of an Ox to twitch and contract a good while after he has been kill'd, and always found that as long as theſe *Muſcular Motions* continued, ſo long would the Fibres retract, if

cut aſunder, and not at all, or very little, afterwards.

HENCE it appears that the Fluids always act as an Antagoniſt againſt the retracting Power of the Fibres, by extending and dilating them; and as Action and Re-action are always equal, it may eaſily be conceived of what vaſt Uſe this is in the Animal Oeconomy. Beſides, as the Tenſion of each voluntary Muſcle is an exact Ballance to its oppoſite, it not only prevents any irregular Motions or Diſtortions in them, but it alſo prepares and makes them ready for voluntary Motion, upon the leaſt Alteration of the Ballance: And let us add to this, If the Fibres were not tenſe, they could not be elaſtic; as it appears in Strings that have their Ends fixed, without being ſtretched or contracted; for if you remove them a little from their Poſition, they do not return to it: But what the Degree of Tenſion is, which gives Beginning to Elaſticity, is not yet, that I know of, determined by Experiments.

FROM

FROM the different Degrees of Tenſion in the Fibres ariſe ſo many Conſtitutions; ſome being hard and brawny, and their Motions vigorous and ſtrong, whilſt others are flaggy, relaxed, and weakly. Now as theſe Conſtitutions are moſt times eaſily altered from one Side of the Ballance, or common Standard of Nature, to the other, and as it appears, at leaſt to me, that the Cauſe of the Elaſticity and Tenſion of the Fibres has a very near Affinity to that of *Muſcular Motion*; I beg Leave to enquire a little after ſuch Things as are commonly known to contract the Fibres, when applied to them; and from thence, perhaps, we may more eaſily inveſtigate the true Cauſe of *Muſcular Motion.*

I. IT is moſt certain, that all volatile ſpirituous Things increaſe the Tenſion of the Veſſels, and invigorate their Motions; and this Effect is generally attributed to the Subtilty of their Particles, whereby they are capable of inſinuating themſelves into the Fibres, and exciting them more frequently into a contractile Motion.

II. ALL

II. ALL Aſtringents are well known to purſe up, ſhorten, and contract the Fibres; and this they do, by ſticking their acute Angles into the Vacuities or Interſtices of the Fibres; by which Means they ſtimulate them into Motion, and increaſe the attractive Force of their component Particles towards each other.

III. A SUDDEN Application of any Thing extremely cold, will contract the Fibres, by condenſing their component Particles nearer together, as well as the Fluids within them.

FROM hence it appears, without mentioning any more, That whatever is capable of drawing the conſtituent Particles of the Fibres nearer together, either by exciting them into Motion, or by increaſing their attractive Virtue towards each other, will make them more elaſtic and tenſe: And if we ſhould inferr from what has been ſaid, that *Muſcular Motion* is moſt likely to be produced by ſome ſubtile volatile Matter flying from the Nerves into the muſcular Fibres, and increaſe-

ing

ing the attractive Quality of their component Particles towards each other, ſo as to make them run nearer together, which will conſequently occaſion the Coats of the Fibres to be both thicker and ſhorter; I ſay, If we ſhould endeavour to maintain ſuch a Thing as this, I hope it will not appear very irrational, ſince it is only comparing it to the well known and conſtant Effects of all volatile, ſubtile, and pungent Particles on the Fibres of an animal Body.

THE immediate and wonderful Efficacy that Spirits of Salt Armoniac, Hartſhorn, or human Skulls have on the Body, makes it probable that all animal Motion ariſes from the Influence of ſome refined Matter near akin or analogous to theſe Spirits: And that the Nerves are always replete with ſome ſuch volatile ſpirituous Matter, or animal Spirits, I ſhall now, in the Vth Place, prove to be more than probable.

I AM very ſenſible that many learned Men have denied the Exiſtence of animal Spirits, becauſe they are not within the Reach of our Senſes;

Senſes; that is, when a Nerve is tied up, no Swelling appears either above or below the Ligature; or if a Nerve be cut aſunder, only a little viſcid mucilaginous Juice flows from it, which by no means can be thought ſufficient to perform the chief Office in *Muſcular Motion*: But if we diligently examine into the moſt wonderful Mechaniſm and Structure of the Brain and Nerves, (thoſe Maſter-pieces of the Creation) I am perſuaded there will be a vaſt deal more to be ſaid in Favour of the Exiſtence of animal Spirits, than againſt it, though at the ſame time we are not capable of diſcovering ſuch ſubtile Matter by our Sight, Smell, *&c.* however aſſiſted.

ALL *Anatomiſts* agree, that the Brain is an Heap of exceeding minute Glands, wrapt up in two nervous Membranes, the *Dura* and *Pia Mater*; and the Nerves, which ariſe from it, are alſo allowed to be its excretory Ducts. Now ſince all the known Glands have ſo much Reſemblance, Similitude, and Analogy to one another; is it reaſonable to ſuppoſe that ſuch an infinite Number of Glands, as the Brain is compoſed

poſed of, do act contrary to the Nature of all the reſt in the Body, and not ſecrete any Thing from the Blood? If they do ſeparate or filtre any Thing from the Blood; pray, what becomes of it? That poor Pittance of viſcous Juice, which is to be ſqueezed out of a Nerve, upon Exciſion, does not ſeem at all agreeable to the Office of ſo many and ſuch exquiſitely fine Glands, from whence the nervous Cord ariſes. But becauſe all our Inventions are ſhort of diſcovering the ſubtile Matter which continually flies through the Nerves; it muſt therefore follow, according to theſe *Gentlemen*, that no ſuch Matter does fly through them. By the ſame way of Arguing, we may deny that any ſubtile Matter flies from the Loadſtone, or from many volatile Bodies, becauſe we can't ſee or diſcover what it is, or its manner of acting. Let us but think on ſome of the Experiments which are commonly made to diſcover the wonderful and amazing Diviſibility of Matter; and it will evidently appear from thence, that the Nerves may always be replete with animal Spirits, which are too ſubtile ever

to be diſcovered by our ſhallow Capacities, but by their Effects on the Muſcles, *&c.*

AGAIN: What has been ſaid, may be illuſtrated by obſerving, that the Brain receives a much greater Proportion of Blood, than moſt other Parts of the Body of like Dimenſion, ſo that a Quantity equal to the whole Maſs of Blood circulates through it in a very little Time; and the Aliment, from whence the Blood is ſupplied, is generally ſuch as will afford a good deal of the moſt volatile, ſubtile, and ſpirituous Matter; as is evident from many chymical Proceſſes on animal and vegetable Subſtances, and alſo on fermented Liquors: And it muſt be allowed, that the Brain is the moſt likely Part of the Body to ſecrete ſuch volatile ſpirituous Matter; becauſe its conſtituent Veſſels are by far the fineſt of any, and are infinitely ramified beyond any Idea we can poſſibly form of them.

THE Structure of the Nerves, alſo confirms me in my Opinion, that they were deſigned, by the

the Divine *Architect*, to convey ſome very ſubtile and ſpirituous Matter through them; their Coats being made ſo firm and ſolid, in order to prevent its Eſcape, before it arrives at their Extremities.

OUR beſt *Anatomiſts* are alſo of this Opinion. "The Nerves (ſays Mr. CHESELDEN, in his "excellent Book of *Anatomy*) ſeem, when "examin'd with a Microſcope, to be Bundles of "ſtrait Fibres not communicating with one "another: And I am inclined to think, that "every the minuteſt Nerve, terminating in any "Part, is a diſtinct Cord from its Origin in the "Brain, or Spinal Marrow; or elſe I don't ſee "how they could produce diſtinct Senſations in "every Part: And the diſtinct Points of Sen-"ſation throughout the Body are ſo very nu-"merous, that the whole Body of Nerves (which, "taken together, would not make a Cord of an "Inch Diameter) muſt be divided into ſuch a "Number, to afford one for every Part that has "a diſtinct Senſation, that ſurely ſuch a Nerve

" would be too ſmall to be ſeen by the beſt " Microſcope."

AND again, (the ſame ingenious *Author* tells us) " Diligent Enquiry has been made, " to diſcover the Cavities of the Nerves, but " hitherto in vain: And if each Nerve is diſtinct " from its Origin, and too ſmall to be the Object " of the beſt Microſcope, I don't ſee how ſuch " Cavities are like to be diſcovered. However, " I think the Nerves may be Tubes; and that a " Fluid, whoſe Coheſion is very little, and whoſe " Parts are perhaps no finer than Light, may " move very freely in them."

THE learned *Author* of the *Introduction* to *Cowper* on the *Muſcles*, obſerves, " That the " Nerve is one chief Inſtrument which puts the " Muſcle into Action; as is evident from hence, " that whenever the Nerve belonging to a Muſcle " is ſeparated from it, it is no longer in the " Power of the Animal to put the Muſcle into " Action. This Office of the Nerve is generally

" allowed

" allowed to be performed by means of ſome " very fine and ſubtile Fluid, which is called by " Authors the Animal Spirits; and that the " Contraction of the Muſcles concerned in volun- " tary Motion, ariſes from this Spirit being ſome " way operated upon at the Original of the " Nerves. All which ſeems evident from this " Obſervation, that a Ligature upon the Nerve, " deprives the Muſcle of its Motion, as effec- " tually, as if the Nerve were divided.

IF we go back as far as GALEN †, he tells us, *Nervorum Utilitas eſt Facultatem Senſûs & Motûs à Principio in Partes diducere.* And Dr. CHARLETON, in his *Enquiries into Human Nature*, takes Notice of another Obſervation of GALEN's: " GALEN (ſays he) reflecting upon " this, that if a Nerve be cut aſunder, the Muſcle " into which it was inſerted, becomes ever after " incapable of being uſed to voluntary Motion; " from thence, with great Aſſurance, concludes; " *Nervi igitur, Rivorum in Morem, à Cerebro*

† De Uſu Partium.

" *cere-*

" *ceu ex quodam Fonte, deducunt Muſculis Vires.*
" Where 'tis remarkable, that he compares the
" Nerves, not to Strings or Cords, but to
" Rivulets or Conduit Pipes; framed for the
" Conveyance of the invigorating Influence, or
" πρώτη Ὁρμὴ (as he calls it) *firſt Impetus*, from
" the Brain, as from a Fountain. And what
" could he have ſaid, either more intelligible in
" itſelf, or more favourable to the Doctrine of
" Animal Spirits? "

In ſhort; If we deny the Exiſtence of animal Spirits, I can't conceive it poſſible to give a rational Account of *Muſcular Motion*: For though the Nerves are very elaſtic Cords, when they are ſtretched out longer than uſual, and by this means, ſome have thought they may be capable of vibrating in ſuch a manner, that both *Senſation* and *Muſcular Motion* may be perform'd by them, without the Aſſiſtance of animal Spirits; yet if we conſider, that they are by no means extended or contracted in their natural State, but lie very looſe and ſlack, it ſeems impoſſible for them to communicate Motion, from the common

Senſo-

Senſorium in the Brain, to the moſt diſtant Muſcles, in an Inſtant. But ſuppoſing the Nerves, in their natural State, were tenſe enough to vibrate with the moſt inconceivable Swiftneſs, from one End to the other, I defy any one to ſhew, that a vibrating Motion in the Nerves, is the only and true Cauſe of Contraction in the muſcular Fibres; it being evident, from the ſecond Law of Nature, that the Motion of any Body is always proportional to the impreſſed moving Force, and is produced in the ſame Direction with that of the moving Force. From whence it appears, that a vibratory Motion in one String, can only impart the ſame ſort of Motion to another; but *Muſcular Motion* ariſes from ſomething which thickens the Fibres, purſes them up, and ſhortens their Length.

WE have been lately told indeed, by a very learned *Author*, † That *Muſcular Motion* is perform'd by the Vibrations of a very elaſtic Æther, lodged in the Nerves and Membranes inveſting the minute Fibres of the Muſcles; and that this Æther is capable of the moſt ſudden Expanſion from the leaſt Impulſe communicated to it; by which means it inſtantaneouſly diſtends and ſwells the Membranes, and contracts the Fibres. But, in my humble Opinion, this Hypotheſis is far from being ſatisfactory; it being abſolutely im-

† Dr. *Bryan Robinſon*'s Treatiſe of the Animal Œconomy.

poſſible

poſſible for the Membranes to be blown up by any Agent whatever, ſo as to contract the Fibres which they inveſt: For, ſuppoſing them to be inflated by the expanſive Force of an included Æther, yet no ſuch Effect could follow as ſhortning the Fibres; becauſe as the Membranes are ſoft, and equally yielding every way, and the expanding Æther preſſing *undiquaque*, it is evident that the Membranes muſt be proportionally enlarged in all their Dimenſions *, and conſequently *Muſcular Motion* cannot be performed after this manner.

As to thoſe who imagin *Muſcular Motion* may be performed by Vibrations in the Nerves themſelves, the following Difficulties will always attend their Suppoſition.

1*ſt*, SINCE every viſible nervous Cord is allowed to be a *Faſciculus* of exceeding minute Nerves tied up cloſe together by a Coat or Membrane derived from the *Dura* and *Pia Mater*, and as theſe *Capillamenta* are afterwards infinitely diſperſed to various and different Muſcles; it follows from hence, that *Muſcular Motion* could not be diſtinct, if it aroſe from a Vibration begun at the Origin of the nervous Cord: For, in ſuch a

* Dr. *Morgan*'s Phil. Princ. of Medicine.

Caſe,

Caſe, the vibrating Motion muſt be communicated to all the *Capillamenta* contained in that Cord; unleſs it can be proved, that one Thread in a Cord may vibrate with the greateſt Swiftneſs, from one End to the other, without imparting any of its Motion to the others which are cloſely connected to it: And this, I believe, is a Task that not many will undertake.

2*dly*, IT does not ſeem agreeable to thoſe ſublime Speculations which Mr. LOCKE and Others have made, concerning the Soul, to think that it is capable of giving ſo great an Impulſe to the Origin of a nervous Cord, as to vibrate ſo ſolid a Subſtance with ſuch prodigious Velocity as *Muſcular Motion* is well known to be performed, after it is once determined by the Will. Indeed, how the Soul or Thought influences Matter, is paſt our Comprehenſion: but it is moſt natural to believe, that it acts only on the moſt ſubtile, rare, and elaſtic *Aura* in the Body, or, as we may call it, the very Ending of Matter.

BUT to avoid Prolixity: Theſe, and many more, are the Difficulties which attend an Hypotheſis founded on the Vibration of the Nerves; whereas if it be granted, that the Nerves are always replete with animal Spirits, it will follow, that the leaſt imaginable *Impetus* will be ſufficient to communicate an undulating Motion to them; and an Undulation in ſuch refined Matter as the animal Spirits are ſuppoſed to conſiſt of, may fly through a nervous Fibril, without impreſſing ſo much Motion to its Coats, as to diſturb its neighbouring *Capillamenta*. For though it is moſt certain, that there muſt be ſome Friction in the nervous Tubes, from the Motion of the animal Spirits through them, let them be ever-ſo rare and ſubtile; yet if we conſider that the Middle of every Nerve ſeems to be a ſort of *Medulla*, derived from the Brain, and that this is ſoft, ſpongy, ſupple, and unelaſtic, it will appear, that the Spirits may undulate through this medullary Subſtance, without imparting ſuch Motion to the Membranes of the Fibril, as will vibrate its adjacent *Capillamenta*, though

though they are ever-ſo cloſely connected together.

'TIS true, there are ſome Inſtances which, upon a ſuperficial View, look as if the Nerves were deſign'd by Nature to have a free Communication or Conſent with each other, in order for their mutual Security. As for Inſtance: When any acrid irritating Subſtance ſtimulates the Expanſion of the olfactory Nerves, the phrenic and intercoſtal Nerves are ſoon affected, ſo as to produce that violent convulſive Motion *Sneezing*; by which means the offending Matter is often caſt out of the Noſe, and all is eaſy. The ſame Sympathy is obſerved between the Nerves of the Kidneys and Stomach, and between many others, when their Expanſions are violently contracted or diſtracted; at which time the Pain is always very great, and the Mind grievouſly afflicted with it: So that even theſe Effects cannot be properly attributed to a vibratory Motion communicated from one Nerve to another; becauſe 'tis evident, that the Idea's of Tickling or Pain are always impreſſed on the *Senſorium* in the

Brain, before their Effects, *viz.* Sneezing, Vomiting, or any other convulsive Motions arise: And if the *Sensorium* is always first affected, it is most natural to believe that the Soul or Mind influences such and such particular Parts to expell the Enemy, rather than a vibratory Motion being communicated from one Nerve to another.

If I had Time to examine into the Nature of Sensation, it might, perhaps, illustrate what has been said; but that would be going beyond the Bounds I have set myself; and therefore I'll content myself with making bur one Observation; *viz.* If the Sole of the Foot be touched only with the Down of a Feather, and in the most easy and gentle manner imaginable, the Idea of Tickling is instantly communicated from thence to the *Sensorium* in the Brain. Now 'tis beyond the Bounds of my Philosophy to comprehend how so small an *Impetus* on the Nerves, can possibly raise a Vibration in such slack Cords, quick enough to impress the Idea of Tickling on the *Sensorium* in an Instant. 'Tis true, the first Impression must be made on the *Papilla Piramidales*,

midales, or on the Extremities of the Nerves, by the Feather, and from thence it is imparted to the animal Spirits within the Nerves, ſo that the undulating Motion of the animal Spirits is in ſome meaſure the Effect of the Motion of the Nerves; but then, I preſume, the leaſt Motion impreſſed on the moſt ſubtile, elaſtic, animal Spirits will not ceaſe 'till it arrives at the *Senſorium* of the Brain; whereas ſo ſlight a Motion communicated to a ſlack ſolid Subſtance muſt be immediately loſt, and, as it were, abſorb'd in the Fleſh, which almoſt every-where ſurrounds the Nerves. Beſides, if we conſider that the Nerves which are tickled at the Bottom of the Foot, ariſe either from the three laſt Pair of the lumbal Nerves, or from the three or four firſt Pair of the *Os Sacrum*, it will appear that the ſtrongeſt vibratory Motion in theſe Nerves cannot be communicated beyond that Part of the *Medulla Spinalis* from whence they have their Origin: For the medullary Part of the ſpinal Marrow being very ſoft, yielding, and unelaſtic, and its Coats, which are elaſtic, being very firmly tied to the *Vertebræ*, by means of the inward vertebral Membrane, and thirty

Pair

Pair of Nerves which proceed from it, makes it impoſſible for a vibrating Motion in the crural Nerves to impreſs any Idea on the *Senſorium*, if it was not for ſome other Aſſiſtant.

WHERE the nervous Fibrils conjoin into one *Faſciculus*, there are formed ſome knotty oval Bodies, called by FALLOPPIUS, *Corpora Olivaria*, and generally now named *Ganglions*, whoſe Uſe or Deſign has not yet been hit on, at leaſt not ſatisfactorily: But if I may be allowed a Conjecture upon ſo intricate a Subject, I think it probable that they are deſigned to prevent any Communication of Motion from one Nerve to another, whereby Senſation is always, in a State of Health, perform'd diſtinctly. As for Inſtance: When a more violent Shock than ordinary is given to the Extremity of a Nerve, it can't be denied but the Nerve itſelf, as well as the animal Spirits within it, may be put into a *Tremor*, more or leſs, according to the Tenſion of the nervous Fibril; and though the greateſt *Tremor* may not be capable of reaching the *Senſorium* itſelf, yet if it was to continue nearly with the ſame Force after

after the Nerve is conjoined with others, it muſt follow of Courſe, that the vibratory Motion would be imparted to the adjacent *Capillamenta*, from whence the animal Spirits within them would receive the ſame ſort of Motion as was impreſſed on the firſt Nerve; and if ſo, there muſt neceſſarily ariſe ſuch a Confuſion of Idea's as the *Tremor* of all the *Fibrillæ* in that nervous Cord, would repreſent on the *Senſorium* in the Brain.

SINCE therefore the *Ganglions* are generally formed, more or leſs, where-ever the nervous *Capillamenta* meet together, and ſince theſe Knots are frequently repeated; it appears, at leaſt to me, that they may entirely intercept any vibrating Motion which may happen in the Nerves: For as theſe Knots are ſtrong and thick, or, as WILLIS obſerves, they grow out into a certain Tumour like to a callous or ſinewy-ſwelled Body, and as they are only faſten'd to the Coats of the Nerves, whilſt the middle or medullary Part of the Nerves paſſes through without any Alteration or Change; it follows, that ſuch a Check may be given to any *Tremor* in the nervous Coats, as to prevent

its

its being communicated any farther; whereas the undulating Motion of the moſt ſubtile Matter in the Nerves is not interrupted in the leaſt by theſe *Ganglions*, but flies through them to the *Senſorium*, and there impreſſes its proper Idea.

WHEN I contemplate on this moſt wonderful Mechaniſm of the Nerves; that every Part of the Body has a particular Senſation; that each ſenſitive Part has its correſponding Point of Perception in the Brain; that ſuch an infinite Number of nervous Filaments, as are diſperſed to every individual Part of the Body, are collected into forty Pair of Cords; that every Fibril in theſe nervous Cords is endued with a Power of impreſſing the Ideas of Pleaſure or Pain on the *Senſorium* in the Brain, as well as tranſmitting the ſubtile Influence from the Brain to the Muſcles, and that both *Senſation* and *Muſcular Motion* are always, in a State of Health, performed diſtinctly; I ſay, when I meditate on theſe Things, I am loſt, as it were, in a Labyrinth of Thought, and can only admire the infinite

Wiſdom

Wiſdom of the *Great Creator*, who hath thus fearfully and wonderfully made us.

BY this time I hope I have made it appear to be more than probable, that there is ſome moſt ſubtile, volatile, ſpirituous Matter ſecreted from the Blood, by the Glands of the Brain, and continually flying into the Nerves; and upon this *Data*, I proceed,

VI*thly*, TO make ſome few Obſervations on the Muſcles, during their State of Contraction, in order to illuſtrate more clearly the genuine Cauſe of it.

1*ſt*. IT is evidently demonſtrated by the following Experiment of Dr. GLISSON, † that the Muſcles are not inflated, expanded, or enlarged when they are contracted; that is, though the Belly of a Muſcle may ſwell a little during its State of Contraction, yet the Bulk of the Muſcle in general, is rather leſs than it was before:

† De Ventric. & Inteſtin. Cap. 8. Numer. 9.

" LET there be provided a Glaſs Tube, in
" Length and Bore capacious enough to hold
" a Man's Arm, and to the upper Orifice of it
" on the Outſide affix another Tube of Glaſs
" about an Inch Diameter in Bore, ſhaped like
" a common Weather-glaſs, only with a wide
" Mouth like a Funnel; ſo as the Lower-end
" may open into the greater Tube whoſe Bottom
" is firmly ſtopt: Then having erected both
" Tubes, let a Man of ſtrong and brawny
" Muſcles thruſt his whole naked Arm into the
" greater Tube up to the very Shoulder, about
" which the Orifice of the Glaſs muſt be cloſely
" luted, that no Water may flow out that way.
" This done, let as much Water be poured in
" by the Tunnel as both Glaſſes will receive,
" leaving only a little Space at the Top of the
" leſſer, empty. In fine, let the Man ſtrongly
" contract all the Muſcles of his Arm by
" clinching his Fiſt, and relax them again by
" Turns; and you ſhall obſerve, that when he
" contracts his Muſcles, the Water in the leſs
" Tube will ſink ſomewhat lower, but riſe

" again

" again when he relaxes them: Whence it is " evident, that the Muſcles do not ſwell up, nor " are inflated at the time of their Contraction, " but rather are leſſened and contracted in all " their three Dimenſions; otherwiſe the Water " would at that time, not deſcend, but aſcend " in the Neck of the Funnel."

2*dly*, NOTWITHSTANDING it is demonſtrated, by the foregoing Experiment, that the Bulk of a Muſcle is rather leſſened than enlarged, during its Contraction; it is as evident, that every ſingle Fibre muſt neceſſarily increaſe in its Thickneſs proportionally as it abates in its Length.

3*dly*, HENCE appears the Reaſon why the Belly of a Muſcle ſwells during its Contraction: For as the component Particles of each Fibre are more looſely joined together about the Middle, than towards its Extremities, which are generally tendinous, it is natural to ſuppoſe that the chief Action is between them; that is, when a Fibre grows ſhorter, its Particles which are moſt at liberty muſt run nearer together, or ſlip by one

another ; and as the Motion of all Bodies is ever in Proportion to the Impulſe and Reſiſtance they meet with ; ſo when the conſtituent Particles of the muſcular Fibres are drawn into a ſhorter Compaſs, by any impreſſed Power, the Fibres muſt ſwell either inwardly or outwardly, or both, according to the Reſiſtances they meet with.

4*thly*, SINCE the Coats of the muſcular Fibres do moſt certainly grow thicker as they contract in their Length, and the external Surface of the Muſcle in general is diminiſhed thereby ; it follows from hence, that their Cavities muſt grow leſs, and their contained Fluids muſt be preſſed out in Proportion to the Contraction of the Muſcle.

NOW from theſe Obſervations, I think, there is great Reaſon to conclude that *Muſcular Motion* ariſes from the Influence of the animal Spirits, which inſtantly increaſe the Strength of the corpuſcular Attraction in the Fibres themſelves, ſo as to make their conſtituent Particles run cloſer together, or, as it were, up into Heaps, as long as

ſuch

ſuch an additional attractive Power remains in the Fibres. And if we look back and conſider that the Elaſticity of a muſcular Fibre is owing to the mutual Attraction of its component Particles; that its Tenſion proceeds from a conſtant *Niſus* towards Contraction; and that not only theſe, but the Contraction of all the Muſcles, are well known to be made more vigorous and ſtrong, by the Uſe of ſuch Things which conſiſt of the moſt volatile and ſubtile Particles, the Thing itſelf will appear more plainly.

THAT the animal Spirits are capable of anſwering all the Requiſites towards *Muſcular Motion*, will appear from the following Conſiderations. 1*ſt*, They are generally allowed to conſiſt of Matter the moſt refined and moſt agile of any in the Body; as ſubtile, perhaps, as the Particles of Light, or *Des* CARTES's *Subtilis Materia*; and if ſo, their Velocity may be equal to that of Lightning, and conſequently voluntary Motion may be inſtantaneous. 2*dly*, The animal Spirits, being extreamly ſubtile, are capable of inſinuating themſelves into the leaſt Interſtices between

between the conſtituent Particles of the muſcular Fibres. 3*dly*, As they conſiſt of the ſmalleſt Particles of any in the Body, their attractive Power is the greateſt, as is evident from what Sir ISAAC NEWTON has calculated concerning the Rays of Light. And, *laſtly*, The animal Spirits being ſo exceeding ſubtile, they cannot be fixed, and conſequently they will immediately make their Eſcape through the muſcular Fibres, and leave them in the ſame State they found them in, as ſoon as the Supply from the Nerves is by any means diſcontinued.

THESE Things being granted us, our next Task will be, To ſhew upon what Mechaniſm it depends, that ſome of the Nerves and Muſcles are diſpoſed to produce voluntary, and others involuntary Motion; and this we will endeavour to do in as eaſy and perſpicuous a manner as the Nature of the Subject will admit of.

THE voluntary Muſcles are ſuch as are never contracted, in a State of Health, but by the Direction of the Will or Mind: From whence it evidently

evidently appears, that the Nerves which ſupply the voluntary Muſcles with animal Spirits, have ſome little Conſtrictions at their Extremities, or elſewhere, which the ordinary Impulſe of the animal Spirits is not capable of removing, but when they are under the Direction of the Will; that is, whenever it is our Pleaſure to contract ſuch and ſuch Muſcles, the Will directs or propells a greater Quantity of Spirits, or the ſame Quantity with a greater Force, into the Nerves which go to thoſe Muſcles; and by this Means the Conſtrictions are overpowered, and the animal Spirits flow freely into every Fibre of the Muſcle or Muſcles to be contracted.

By the Influence of the animal Spirits on the component Particles of the Fibres, they will be more ſtrongly attracted towards each other, and from thence the Fibres will neceſſarily ſhrink up, contract, and run cloſer together; and thus it continues as long as we pleaſe, or as long as we are able to direct ſuch a Quantity of animal Spirits to the ſame Muſcles; for 'tis evident, we are not capable of keeping any of the

voluntary

voluntary Muſcles in a conſtant State of Contraction.

THAT the Nerves, which ſupply the voluntary Muſcles, have a Power of denying a Paſſage to the animal Spirits into the muſcular Fibres at all other times but when they receive an additional Impulſe from the Will, is plain; becauſe whenever theſe very Nerves happen to loſe their reſiſting Force, the voluntary Muſcles immediately become involuntary ones, and they are alternately contracted and relaxed without the Conſent or Direction of the Mind; and from hence ariſes a Diſtemper commonly call'd a *Shaking Palſy*.

THE Muſcles being contracted meerly by the Influence of the animal Spirits, and the Influx of the Spirits being ſtop'd, by withdrawing the *Impetus* given to them from the Will, the Reaſon and Manner of their Relaxation will eaſily appear: For as the animal Spirits are moſt extreamly ſubtile, that Portion of them which is thrown into the muſcular Fibres acts but for a Moment, or the leaſt Space of Time; and no ſooner is the

Vigour

Vigour of the Attraction over, but the Tenſion of their Antagoniſts, and the Impulſe of the circulating Blood, will extend them again.

NOW let no One be ſurprized at our attributing ſo much Subtilty and Activity to the animal Spirits, that *Muſcular Motion* may be produced by them in an Inſtant, and made to ceaſe again in another Inſtant: For if we conſider how inſtantaneouſly the *Effluvia* of a Loadſtone affect the Fileings of Iron laid on a Table; that it will make them all ſtand upright in a Moment, and if you withdraw the Stone, or intercept the *Effluvia* with an Iron Plate, that theſe Effects ceaſe as ſoon; or if we conſider that even the *Effluvia* of Glaſs are ſo ſubtile, that when a Glaſs Tube is well rubbed, it will communicate an attractive Virtue to an Ivory Ball at eight hundred eighty-ſix Feet Diſtance, by the means of a Packthread only, ſo that the Ivory Ball, at the End of the Packthread, will ſtrongly attract Leaf Braſs at ſome Inches Diſtance, and make it ſuddenly leap up to it, and fall from it again, (as the ingenious Mr. STEPHEN GRAY has inform'd us,

in ſeveral of the *Philoſophical Tranſactions*); I ſay, If we conſider that theſe Things are demonſtratively true, it may eaſily be conceived that the animal Spirits are capable of performing *Muſcular Motion* after the manner we have here deſcribed.

THUS much for Voluntary Motion: And as to the Involuntary Muſcles, I don't know of any which may be truly and properly ſo called, unleſs it be thoſe of the Heart. For though we are always under a Neceſſity of alternately contracting and dilating the intercoſtal Muſcles and Diaphragm; yet theſe are evidently ſubject, in ſome meaſure, to the Will; becauſe we can contract them faſter or ſlower juſt as we pleaſe, and keep them in a State of Contraction, or Relaxation, as long as the want of Inſpiration or Expiration will admit of.

THE Sphincter Muſcles, which are thought by ſome People to be always in a State of Contraction, ſeem to me to be no otherwiſe ſo, than what one may properly call a State of Tenſion,

by

by which means thoſe of the *Anus* and *Veſica Urinaria* prevent the involuntary Effuſion of their Contents. Nothing is more evident than that it is always in our Power to contract theſe Muſcles more than ordinary : For let a Man compreſs his Bowels or Bladder ever-ſo much, by contracting the Diaphragm, abdominal Muſcles, *&c.* yet if he has a mind to contract the Sphincters of the *Anus* and *Veſica Urinaria* at the ſame time, the other Powers will not be able to overcome their Reſiſtances, notwithſtanding, perhaps, twice the Force is applied to them as is uſual in going to Stool, or in making Water.

THE Sphincter *Vaginæ* is alſo under the Command of the Will ; and the Sphincter *Oris* is ſo much a voluntary Muſcle, that it need only be mention'd. But not to diſpute any longer about which are involuntary Muſcles, and which are not, let us proceed to account for the involuntary Motion of the Heart, which we are very ſure is ſo.

THE Heart is a *Viſcus* which has already given the Learned a deal of Trouble to find out its real Mechaniſm, and the immediate Cauſe of its regular Alternations of Contraction and Dilatation. The incomparable Dr. LOWER † was the firſt that gave us a true mechanical Deſcription of the Structure of the Heart, and the Manner of its Action; and though his Hypotheſis of the Cauſe of Contraction in the muſcular Fibres is wrong, yet he has ſhewn us that the *Syſtole* depends upon the ſame Agent that influences all the other Muſcles, *viz.* the animal Spirits; and if he had given as rational an Account of the *Diaſtole*, he had left us but little Room for farther Enquiries: but to ſay that the *Diaſtole* ariſes from a Motion of Reſtitution, and the Influx of the Blood, without producing any Proofs of it, or even ſhewing the Poſſibility of it, is ſaying Nothing, at leaſt, not to the Purpoſe.

† De Corde.

Mr. COWPER

Mr. COWPER, ‖ obſerving how tranſiently Dr. LOWER paſſed over this moſt important Affair, expatiates more largely upon it, and endeavours to prove, that the Motion of the refluent Blood is a ſufficient *Momentum* to dilate the Heart, and to overpower its contractile State or *Syſtole*, which, he imagines at the ſame time, to be its natural State of Reſt or Quieſcence, and to which it always tends. But notwithſtanding this ingenious *Gentleman* has taken more Pains to prove the Thing, yet if we accurately and attentively examine into the Nature of it, it will evidently appear that neither the *Pondus* nor Impulſe which the Blood receives from the Conſtriction of the Heart, can ever be able of itſelf to overpower the contractile Force of the Heart: For (as Dr. DRAKE † obſerves) could the Blood be ſuppos'd to re-act upon the Heart, with all the Force firſt impreſſed upon it by the Heart, it would be inſufficient; unleſs we will ſuppoſe the

‖ Anatomy of the Human Body.
† Phil. Tranſact. N° 280.

Force

Force communicated to be ſuperior to the Power communicant; which is abſurd, and repugnant to the known Laws of Nature.

Now though Dr. DRAKE has ſufficiently refuted theſe Sentiments of Dr. LOWER, and Mr. COWPER, and has demonſtrated that there muſt be ſome other Agent, yet undiſcovered, in order to dilate the Heart; I am humbly of Opinion that the Hypotheſis which he has advanced concerning it, is as liable to Objections as any Thing I have met with.

" WHATEVER the Force is (ſays He) that " dilates the Heart, and is the Cauſe of the " *Diaſtole*, it muſt be equal to that of the " Heart, the intercoſtal Muſcles, and Diaphragm; " to all which it acts as an Antagoniſt. Now " ſuch a Power is not to be found within the " Body, and therefore ſome external Cauſe muſt " be found to produce this great Phænomenon; " which Cauſe muſt be either in the Air or Atmoſ- " phere, becauſe we have no conſtant and imme- " diate Commerce with any other *Media*. By the

Preſſure

" Preſſure of the Air in the Lungs the Blood is
" forcibly driven, as it were with an *Embolus*,
" through the Pulmonary Vein into the left Ven-
" tricle of the Heart; and this, together with
" the general Compreſſion of the Body by the
" Weight of the Atmoſphere, which ſurrounds
" and preſſes upon the whole Surface of it, is
" that Power which cauſes the Blood to mount
" in the Veins, after the Force impreſſed upon it
" by the Heart is broken and ſpent, and which
" is ſufficient to force the Heart from its natural
" State (of Contraction) to Dilatation."

THAT the Preſſure of the ſuper-incumbent Air on the Surface of the Body is very great, is manifeſt from many Experiments publiſh'd by Mr. BOYLE, and Others; and that Reſpiration contributes very largely towards the Circulation of the Blood, cannot be denied: but that ſuch Force is communicated to the refluent Blood by either of theſe, as to exceed the contractile Strength of the Heart, is only aſſerted by the *Doctor*, without producing one Experiment to confirm the Truth of it. Before ſuch a ſtrange Concluſion as this

this had been made, I think, it ſhould have been proved that the Blood returns to the Heart with a greater Velocity than it left it; otherwiſe it is abſolutely impoſſible for it to overpower the Conſtriction of the Heart, if that be, as the *Doctor* ſays, its natural State of Quieſcence to which it always tends.

IF the Preſſure of the Air gave ſuch Aſſiſtance to the Motion of the refluent Blood, it might eaſily be diſcovered by opening the Veins near the Heart; for in ſuch a Caſe the Blood would ſtream out of them with a greater Arch than it would out of the Arteries: But as Autopſy entirely contradicts this, 'tis unreaſonable to ſuppoſe that the refluent Blood is capable of dilating the Heart, if its Contraction after the Blood is forced out of it, was to continue with the ſame Strength as before.

'TIS almoſt needleſs to take notice that the Preſſure of the Air on the external Surface of the Body, is an Antagoniſt to the Elaſticity of the internal Air, or the Air which is contained with the

the Fluids, and in all the Cavities of the Body; and that by the Action and Re-action of these Powers an Equilibrium is preserved, and the Circulation is carried on regularly: whereas if either of these Powers was to be taken off, the other would immediately put a Stop to all Motion; the former would condense the Fluids, and press the Vessels as it were flat, and the latter would rarify the Fluids so as to distend and tear the most tender Canals to Pieces.

THE Air, being a Fluid, presses *undiquaque*; and there being always an exact Equilibrium between the external and internal Air, the Pressure of the Air on the Surface of Body must retard the Motion of the Blood in some of the Vessels, as well as promote it in others. Indeed, in the Lungs, where their superficial Dimensions are variable, by their reciprocal Dilatation and Contraction, the Pressure of the Air has a vast Influence: but even there I defy any one to prove that the Blood returns to the Heart thro' the Pulmonary Vein, with as great Velocity as it was

thrown out of it into the Pulmonary Artery; and if it does not, I can't conceive how ſuch an Effect, as above mentioned, could be attributed to it.

BUT granting the Action of the Lungs to be the ſole Cauſe of the Diaſtole of the left Ventricle of the Heart, how ſhall we inferr from thence the Cauſe of the Dilatation of the right Ventricle? For if the Preſſure of the Air on the Surface of the Body was able to increaſe the Momentum of the Blood in both the Cava's, ſo as to overpower the Reſiſtance of the right Ventricle of the Heart, it would neceſſarily follow that the right Ventricle would ever afterwards remain in a State of Dilatation; becauſe the Preſſure of the Air being conſtant and equal on the Surface of the Body, (allowing for the different Heights of the Mercury in the Barometer, its Effects muſt be ſo too; and this, of itſelf, is ſufficient to detect the Falſity of ſuch an Hypotheſis.

SINCE

SINCE therefore ſo many fruitleſs Attempts have been made to account for the Diaſtole of the Heart, by ſuppoſing the Syſtole to be its natural State of Reſt or Quieſcence, to which it always tends with its utmoſt Force; 'tis more than probable that the *Literati* have been deceived in this Aſſertion, and that there is ſome peculiar Mechaniſm or Structure in the Heart itſelf which is the Occaſion of all this, without ſeeking ſo far for Aſſiſtants, or lugging in ſuch as are quite inconſiſtent with the animal Oeconomy. I ſhall therefore, inſtead of amuſing myſelf any longer with what has been ſaid by others, conſider attentively the *Phænomena* which have fallen under my Obſervation, concerning the Action of the Heart, and then deliver, in as plain a manner as poſſible, what my own Thoughts have ſuggeſted to me on this moſt intricate Affair.

THE firſt Thing to be taken notice of, is, that the Syſtole and Diaſtole of the Heart and its Auricles regularly and alternately follow each other; that is, the Auricles are contracted when

the Ventricles are dilated, and the Ventricles contracted when the Auricles are dilated. I have oftentimes laid open the Breaſt of a Dog, and kept his Lungs playing with a Pair of Bellows, in order to obſerve this compound Motion of the Heart, and always found that the Moment the Ventricles were contracted, the Auricles were dilated by the refluent Blood, and then, they, in their Turn, contracted, and propelled the Blood into the Ventricles; ſo that the Auricles evidently act as Antagoniſts to the Ventricles, and the refluent Blood is of the ſame Service to the Auricles: But as there is ſo much Diſparity between the contractile Strength of the Ventricles and that of the Auricles, there muſt neceſſarily be ſome particular Contrivance in this Machine, which, as ſoon as it is fully contracted, makes itſelf unbend again, or ceaſe to contract; by which means the Auricles, though weak in Compariſon to the Ventricles, have Power enough to dilate the Ventricles to ſuch a Pitch before they are capable of acting again. The ſame Thing may be ſaid of the Auricles; for as the Reflux of the Blood is ſteady and equal, the Preſſure on the Auricles

muſt

muſt be ſo too; and as the Auricles are ſtrong enough to contract themſelves, notwithſtanding the conſtant Impulſe of the Blood, it naturally follows, that if they did not relax of their own accord, the Preſſure of the refluent Blood would not be able to overcome them.

WITHOUT ſome ſuch Mechaniſm as this, it plainly appears from what has been ſaid, that no Power yet known, either within or without the Body, would be able to dilate the Heart; and therefore I beg Leave to proſecute this Thought, and try if I can't make it agreeable to ſome other *Phænomena* which frequently happen in the animal Oeconomy.

IN all hydraulic Engines there is an abſolute Neceſſity for a perpetual Supply of the moving Force, though it may not always act on the ſame Part of the Machine, eſpecially if it be a compound one, but ſometimes on one Wheel, and ſometimes on another, according as the Springs and Movements are diſpoſed to receive the ſame.

THUS

THUS I believe it to be with the Heart, and its Auricles, whoſe alternate Motions, being mechanically performed, doubtleſs ariſe from an alternate Influence of the animal Spirits on their muſcular Fibres; but to illuſtrate this moſt excellent Piece of Machinery, and to ſhew the Manner of its Action, from ſuch Principles, is the Difficulty: However, I'll not deſpair, but venture to ſuppoſe (it being beyond the Reach of ocular Demonſtration) that the Nerves which ſupply the Heart and its Auricles are always open; that is, they have no Conſtrictions at their Extremities or elſewhere, as thoſe of the voluntary Muſcles have, but admit the animal Spirits to fly from the Brain into the muſcular Fibres of the Heart and its Auricles without any Lett or Impediment, or without any Impulſe or Aſſiſtance from the Will.

THIS being the Caſe, the Ventricles of the Heart will be firſt of all contracted, by reaſon of their ſuperior Power; and during their Contraction, it appears, from what has been ſaid above,

above, that every individual Fibre in them will be corrugated, thicken'd, and ſwelled by the Influence of the animal Spirits: And now if we conſider how ſtrong and uniform the Preſſure of theſe Fibres muſt be upon the Blood in the Ventricles, before it can propell it with ſo much Velocity, and in how many different Directions the Fibres run in, it will not be at all unreaſonable to think that the Extremities of the Nerves, which are inſerted into every Fibre, and are extreamly ſmall and tender, may be preſſed upon and ſqueezed during the violent Action of the Heart, and the Re-action of the Blood, ſo as to prevent the Influx of any more animal Spirits 'till the Preſſure is abated, or 'till the muſcular Fibres are relaxed and dilated again.

THE Influx of the animal Spirits being obſtructed when the muſcular Fibres of the Heart are in their State of Contraction, and the animal Spirits being extreamly volatile, the Vigour of the Attraction between the conſtituent Particles of the Fibres will inſtantly ceaſe, and the Ventricles will ſtand in need of ſome proper Aſſiſtant

to

to dilate them again to their uſual Size, and to take off all the Preſſure and Obſtructions from the Extremities of the Nerves; that is, before the animal Spirits can have a free and uninterrupted Paſſage into the muſcular Fibres again, the Fibres muſt be extended to their uſual Lengths.

NOW this friendly Office is no ſooner wanted but performed by the ſucceſſive Contraction of the Auricles, which are now ſtrong enough to propell the Blood into the Ventricles, to dilate their relaxed Fibres, to take off all Obſtructions, and to make Way for the animal Spirits to fly into every minute Fibre again; which no ſooner happens, but there ſucceeds another Contraction and Dilatation of the Ventricles, as deſcribed above.

HENCE it appears, that when the Heart is contracted, the Manner of its own Motion prevents a Continuance of it; and without ſome ſuch Mechaniſm, 'tis evident that neither the Strength of the Auricles, nor the Pondus of the refluent Blood, nor the Preſſure of the Air, nor

any

any Thing elſe which we are able to diſcover, would be ſufficient to dilate the Ventricles of the Heart, if the ſame attractive invigorating Influence was always to act with a conſtant, equal, and regular Force on their muſcular Fibres; ſo that, in all Probability, this is a true and real Deſcription of the Action of the Heart, both as to its Syſtole and Diaſtole.

THE ſame Contrivance will account for the alternate Contraction and Dilatation of the Auricles; becauſe the conſtant Preſſure of the refluent Blood is of the ſame Uſe towards extending their muſcular Fibres, after their Contraction, as the Impulſe of the Blood in the Ventricles is from the Contraction of the Auricles.

IF Time would permit it, we might here expatiate very largely on the Beauties and Excellencies of the whole Piece of Machinery; which is ſo admirably contrived, that the Impulſe given from one Part, always begets Motion in another, That on the next, and ſo on throughout the whole Body. From the Circulation of

the Blood, the Being and Motion of the animal Spirits are derived; from the Influence of the animal Spirits over the muſcular Fibres, ariſes all manner of *Muſcular Motion*; from *Muſcular Motion*, the Circulation of the Fluids is maintained; and from the Circulation of the Fluids, all the Veſſels are kept warm, ſupple, diſtended, and every way ready for Motion: but how the *Primum Mobile* or *Firſt Impetus* is given, is beyond the Reach of our frail Capacities to conceive.

THIS is my Theory of *Muſcular Motion*, which I have deduced from a very uniform, ſimple, and beautiful Structure of the Nerves and muſcular Fibres, and from the commonly-known Laws of Matter and Motion; and ſince it appears, from all the Diſcoveries which have hitherto been made, that Nature takes the moſt eaſy Courſe in all its Productions; it follows, that whenever we would inveſtigate or trace out any of the ſecret Footſteps of Nature, it muſt always be done by the moſt ſimple and uncompounded Means, by deriving two or three general Principles

Principles from *Phænomena*, and afterwards by ſhewing how the Properties and Actions of other Bodies follow from thoſe manifeſt Principles, though, at the ſame time, the Cauſes of thoſe Principles are not yet diſcovered.

THIS is the Caſe in Hand: Attraction and Repulſion are Principles manifeſtly belonging to Matter; but the Cauſes of theſe Principles are kept as Secrets in the Boſom of Nature. The Brain is a Heap of exquiſitely fine Glands, and the Nerves are their excretory Ducts; from whence we are perſuaded that they contain the moſt ſubtile Matter in the Body, though it is beyond our Power to demonſtrate its Exiſtence to any of the Senſes: So that the two main Principles upon which I have founded my Theory of *Muſcular Motion*, are ſo intricate and obſcure, that we are not able to diſcover the Cauſe of the former, nor abſolutely to prove the Exiſtence of the latter: But notwithſtanding this, what I have advanced, ſeems, at leaſt to me, ſo very like the frugal Simplicity of Nature, that the more I think of it, the more I am convinced of its Truth.

THE whole Foundation of natural Philoſophy, (as Dr. CHEYNE † obſerves) is Simplicity and Analogy; or a ſimple, yet beautiful Harmony, running through all the Works of Nature in an uninterrupted Chain of Cauſes and Effects, with proper Limitations and Circumſtances: And if theſe Principles be ſuperſeded, or this Chain broken, we can expect nothing but Abſurdities and Inconſiſtencies in Philoſophy. For Simplicity and Harmony are the ſureſt Marks that the Diſcoveries made are of the true Kind, and Analogy, the beſt Rule to make them by.

BUT before I conclude this *ESSAY*, it may be proper to obviate an Objection which might otherwiſe be raiſed againſt it; *viz.* It may ſeem reaſonable to think that the Contraction of the Fibres of the voluntary Muſcles will preſs upon and hinder the Influx of the animal Spirits after the ſame manner that I ſuppoſe it does in the Fibres of the involuntary Muſcles; ſince there

† Philoſophical Principles of Medicine.

is

is no Difference, that we know of, in their Conformation, and conſequently it would then be out of our Power to keep any of the voluntary Muſcles in a State of Contraction ſo long as we are well known to do.

TO which I anſwer; There is no doubt but the voluntary Muſcles would be alternately contracted and relaxed as the involuntary ones are; and it would be entirely out of our Power to contract any of the voluntary Muſcles a good while together, was it not for the freſh *Impetus* which the Will is capable of giving to the Spirits in thoſe Nerves which go to the voluntary Muſcles. Now 'tis from this additional Force or Impulſe which is conſtantly applied to the animal Spirits, when we contract any of the voluntary Muſcles, that I ſuppoſe they become able to remove the little Reſiſtances they meet with at the Extremities of the Nerves, from the Contraction of the muſcular Fibres; and by this Power the animal Spirits do continue to fly into the voluntary Muſcles, and there may be a conſtant Contraction of them as long as the

Will

Will is able to direct the Spirits with a ſufficient *Impetus*: Whereas this additional Power, which the Will impreſſes on the Spirits, cannot be ſuppoſed to be communicated to the Nerves of the involuntary Muſcles; and conſequently, for want of this Aſſiſtance, their Extremities, may be ſlightly block'd up, and the Influx of the Spirits interrupted, 'till the Fibres are dilated again.

BUT this may be more clearly explain'd, by an Obſervation which I have many times made on thoſe People who are afflicted with a Shaking Palſy: *viz.* That tho' the Muſcles of the *Carpus* are alternately contracted and relaxed, and the Hand is thrown about from Place to Place, when the Perſon does not at all think of it; yet if he has a mind to graſp any Thing in his Hand, 'tis always in his Power (except in the laſt Degree of this Illneſs) to keep the very ſame Muſcles in a ſteady State of Contraction for ſome little Time.

HENCE it appears, that when the Nerves are ſo far weaken'd and relaxed that the Spirits fly through them involuntarily, the voluntary Muſcles become

become involuntary ones, and they are alternately contracted and relaxed, for the ſame Reaſon that the Heart itſelf is: But when the Mind, like a skilful Muſician, ſtrikes upon thoſe Nerves which go to theſe Muſcles, it impreſſes a greater Force than uſual to the animal Spirits; by which means they remove ſuch little Compreſſions or Conſtrictions as we ſuppoſe to be at the Extremities of the Nerves, and open a Paſſage into the muſcular Fibres as long as the Will is capable of directing the animal Spirits to theſe Muſcles with a ſufficient *Impetus.*

F I N I S.

BOOKS Printed for A. BETTESWORTH *and* C. HITCH *at the* Red Lion *in* Pater-Noſter-Row.

Juſt Publiſh'd,

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