
Natura caute paulatim detegitur.
Vis centripeta
Principium
Æquilibratio
Finis.
I. Fayram Inven. deli et Sculp.

THREE

LECTURES

ON

MUSCULAR MOTION,

Read before the

ROYAL SOCIETY

In the Year MDCCXXXVIII:

As appointed by the WILL of Lady *SADLEIR*, pursuant to the Design of her first Husband *WILLIAM CROONE*, M.D. Fellow of the COLLEGE of PHYSICIANS, and of the ROYAL SOCIETY:

BEING A

SUPPLEMENT

TO THE

PHILOSOPHICAL TRANSACTIONS for that Year.

WHEREIN

The Elasticity of FLUIDS, and the immediate Cause of the Cohesion and Elasticity of SOLIDS, are proved by EXPERIMENTS, *&c.* and shewn to arise from the same Principle as Gravity: With a General Scheme of MUSCULAR MOTION, founded on ANATOMY, EXPERIMENTS, *&c.*

By ALEXANDER STUART, *M.D. Physician in Ordinary to her late Majesty Queen* CAROLINE, *Fellow of the* College *of* PHYSICIANS, *and of the* ROYAL SOCIETY.

Non tam auctoritatis in disputando, quam rationis momenta quærenda.
Cic. de Nat. Deor. Lib. I. cap. 5.

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At a Meeting of the Council of the ROYAL SOCIETY, Nov. 12. 1739.

THESE Lectures *on* MUSCULAR MOTION, *by* Alexander Stuart, *M. D. &c. having been, according to the Will of the Lady* Sadleir, *communicated before-hand to me, and approved, and afterwards read at ſeveral Meetings of this* SOCIETY, *for which he received their Thanks: I do direct the ſame to be printed.*

Hans Sloane, *P.* R. S.

To the HONOURABLE

Sir *HANS SLOANE*, Bar^{t}.

PRESIDENT,

AND TO THE

COUNCIL and FELLOWS

OF THE

ROYAL SOCIETY

Of LONDON, for

Promotimg Natural Knowledge,

Theſe three firſt LECTURES on

MUSCULAR MOTION

Are humbly Dedicated

BY

Their moſt obedient

humble Servant,

ALEXANDER STUART.

THE

PREFACE.

THE late learned and famous Dr. Croune *having observed how much the knowledge of the animal oeconomy depends upon the doctrine of the nerves and muscles, and how far the rational practice of physic might be improved by a more perfect acquaintance with the animal oeconomy, did, for the encouragement of these studies, form a plan for instituting certain* Lectures *to be read on such subjects, in the* Royal College of Physicians *on the nerves and muscles, and in the* Royal Society *on muscular motion; which was left with his Widow, afterwards Lady* Sadleir. *In pursuance of which design she by her last will bequeathed a yearly revenue of about fifty pounds, out of her estate, to the said* Royal College, *in trust for the purposes abovementioned.*

But an History of the lives of the several professors of Gresham College, *where Dr.* Croune *was many years rhetoric professor, written by the learned and accurate Mr.* Ward, *his present successor in that province, being now in the press, we may expect farther particulars relating to this donation in that treatise, to which I must refer.*

In the mean time, the Royal Society *having a fifth part of the said revenue alloted to them by the will for that end, free from all charges and incumbrances,*

brances, excepting that of procuring a body for the uſe of theſe Lectures (*which they are enabled to do by their charter*) *have undertaken, and intend to go on with a courſe of ſuch* Lectures *on this foundation annually.*

In this view the learned Sir Hans Sloane, *preſident of that illuſtrious* Society, *a great encourager and promoter of natural knowledge, having done me the honour to nominate me to open theſe* Lectures, *I have endeavoured to the beſt of my power to anſwer the intention, as far as the limits of the three following diſcourſes would permit; hoping the deſign may be better anſwered hereafter, when undertaken by ſome others of that learned body, of which there are many perfectly well qualified to make further diſcoveries and improvements in this abſtruſe and very uſeful part of natural philoſophy.*

It may be proper here to take notice, that by the conſtitution and cuſtom of that excellent Society, *every diſquiſition muſt either terminate in a mathematical demonſtration, or be founded upon ſome one or more experiments, obſervations, or hiſtories of facts, for a foundation of reaſoning; and the concluſions drawn muſt appear to flow neceſſarily from ſuch premiſſes, elſe they are accounted of ſmall value. This method therefore ſets all concluſions thus drawn at a great diſtance from gueſs, conjecture, mere ſpeculation, or hypotheſis; ſo that if no error be made in the application of them, they cannot fail to be uſeful in the ſeveral arts and ſciences, to which they belong.*

And this gives me a ſufficient handle for wiping off an unjuſt aſperſion thrown upon the labours of that

that celebrated body, as if they were imployed about uſeleſs ſpeculations, or trifling amuſements. But experience has ſhewn, how many uſeful arts and ſciences have received conſiderable improvements by the diſcoveries of this, and other ſocieties of the like kind, now eſtabliſhed in ſeveral countries abroad, by their example; though many of the practiſers perhaps may not know from whence thoſe improvements had their firſt riſe. An enumeration of particulars in proof of this would be too prolix, and improper for this place; eſpecially as the moſt learned in all arts and ſciences are not ignorant of this truth.

This method of diſquiſition therefore I have endeavoured to obſerve in the following Lectures, *which contain ſeveral experiments, not made by any one before, that I know of. But how far the explanations of them are clear, the obſervations juſt, and the concluſions neceſſary and new, muſt be left to the judicious and candid reader.*

Whatever is here advanced contrary to received opinions, or the poſitions of ſome great and learned men, being founded upon experiments, I hope may be held to conſiſt with the great and juſt regard due to the memory of thoſe, who by their incomparable works have ſo well deſerved of the learned world, and of mankind in general; and who, I am perſuaded, were ſuch lovers of truth themſelves, that they would have been pleaſed with its appearance, whenceſoever it had ariſen.

In theſe Lectures *the following propoſitions are offered to be proved by experiments, and confirmed by obſervations of facts.*

1. *That fluids are elastic; which has hitherto been universally denied of all of them, excepting the air.*

2. *That the immediate cause of the various degrees of cohesion and elasticity of solids, which has lain in obscurity, is in the fluids they contain.*

3. *That the principle of gravity, cohesion, elasticity, and hydrostatics, is one and the same.*

4. *That next to primary immaterial impulse, centripetal power, or central attraction, appears to be the natural principle not only of muscular motion, that is of all the motions in the animal oeconomy, but also of all other motions in the universe.*

5. *That there is no natural centrifugal power in matter, or any such principle of repulse, as has been generally supposed.*

6. *That repulse, in all the* phænomena *here related, appears to be solely an effect of central attraction, and by analogy is probably the same throughout all nature.*

7. *That the arteries are elastic; which has been but imperfectly known, and very little regarded in the* phænomena *of the animal œconomy, in which their elasticity bears a very considerable share.*

8. *That the veins are also elastic, which has been intirely overlooked.*

9. *That the blood is an elastic fluid, which has not been imagined.*

10. *That the nerves are not elastic, as has been generally advanced and believed.*

If these propositions be sufficiently proved here, they are to make the chief hinges of the preliminary arguments, leading to the various conclusions contained

tained in an abſtract of a general ſcheme of muſcular motion; which I ſubmit to the teſt of an application to all parts of the animal oeconomy, by which, I hope, it may appear to have a real foundation in nature, which no mere hypotheſis can have.

As I find no author to produce in confirmation of ſeveral things here advanced; I have no inclination to quote or refute ſuch, as have thought differently on theſe ſubjects: for every attempt towards the diſcovery of truth, including a good will towards mankind, has its merit, and deſerves praiſe, though it ſhould not prove ſucceſsful; but contention about it often leads inſenſibly to ſome breach of humanity, which the love of truth itſelf can never juſtify. And therefore I chooſe rather to depend upon the force of this maxim; that a diſcovery or demonſtration of truth, if it can be attained to, is the beſt refutation of error.

I am aware of the danger of drawing general concluſions from too ſcanty premiſes, or too few experiments; which I have endeavoured to avoid as far as poſſible, and, I hope, as far as is neceſſary, in an argument of this kind. For we are to conſider, that though the method by induction be the moſt demonſtrative, and therefore the moſt eligible; yet no number of experiments or effects, though ever ſo great, would be ſufficient for eſtabliſhing a general concluſion concerning the cauſe, ſuch as might be ſaid to be drawn from a complete induction of particular effects; which in nature are ſo exceeding numerous, that an indefinite number of them muſt be always out of our reach. And therefore a few experiments or effects clearly

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explained, and ſupported by the analogy of nature (which in all its operations is conſtantly ſimilar to itſelf) are ſufficient for the purpoſe of a demonſtration a poſteriori, *or from the effects to the cauſe; until ſome plain experiment, and well underſtood, contrary to the former, can be produced, and ſhewn to ariſe from a different or contrary cauſe. But this I take to be impoſſible in the caſe before us; ſince nature can admit of no direct contrariety or inconſiſtency, with regard to its principles, which are few and conſtant, and their laws of action always the ſame.*

There is indeed ſuch a ſurpriſing variety of ſeemingly contrary appearances or phænomena *of nature, as would deter one from drawing a general concluſion, with regard to the principles from whence they proceed; was it not obſervable, that this variety of* phænomena *does not ariſe from a variety of principles, or different laws of action, theſe being (as I ſaid before) very few and always the ſame; but evidently from a numberleſs variety of circumſtances, and degrees of force, not rightly conſidered, or not well underſtood, by the ſpectators. This will appear by the reconciliation of ſeveral ſuch contrary* phænomena *cited in the following* Lectures, *ariſing from the very ſame principles and laws of motion.*

And as this may not be ſo obvious to the generality, as it is to the learned reader, it will be of uſe to add, that the danger of drawing general concluſions in natural philoſophy, and phyſical diſquiſitions, lies not in arguments a poſteriori, *or in the analytic way, as here, from the effect to the cauſe: but*

but in ſuch as are carried on from the cauſe to the effect in the ſynthetic and hypothetic way; that is, when from an identity, parity, or ſimilitude of the cauſe, we would infer univerſally an identity, parity, or ſimilitude of the effects, which muſt be often, if not always, a fallacious method, and has been the ſource of manifold errors. For the ſame cauſe acting by one and the ſame power, in the ſame degree, and according to the ſame laws, is often found to produce not only different, but even contrary effects, according to the ſpecific differences of the ſubjects acted upon. I chooſe a very familiar inſtance for the explanation of this. The ſun acting by its rays, or the fire by heat, melts wax; yet by the ſame power, acting in the ſame degree and manner, they do the very reverſe in hardening clay.

Thus the moſt perfect knowledge of the power of the ſun, or of heat, as a cauſe, could not lead us with certainty, a priori, *to any one effect; much leſs to the variety of its effects, which may be innumerable, vaſtly different, and even contrary. There is therefore an irremediable inſufficiency in this method of argument* a priori, *or in the ſynthetic way, even when the cauſe is real and known. But if to this defect we add an hypotheſis or ſuppoſition of a cauſe or principle, which is not in nature, but only in the imagination, then no real effect can poſſibly proceed from it; and every particular, as well as every general concluſion, in the whole ſcheme may be falſe.*

And it is this method of diſquiſition a priori, *and by hypotheſes of imaginary principles and cauſes,*

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indulged with ſo much liberty in former ages, that has laid phyſic, with other parts of natural philoſophy, under the diſreputation of conjectural ſciences; though when purſued upon facts and experiments, that is a poſteriori, *the concluſions properly drawn appear to be as demonſtrative, as thoſe of any other ſcience whatever. The progreſs in this method indeed is ſlow, but the footing is ſure; whereas in the other way the advances are quick and extenſive, but upon infirm ground.*

Thus in the inſtances above aſſigned, if we ſuppoſe or aſſume nothing, but take the facts, effects, or phænomena, *as we find them, and conſider the apparent ſenſible qualities of the ſubjects acted upon, and compare them; we have yet made no miſtake. Then aſcending to the cauſe, we find it to be one and the ſame, acting by the ſame ſenſible power; in which alſo we cannot be deceived. Therefore the concluſion is plain and neceſſary, that whatever diverſity or contrariety appears in theſe effects, does not ariſe from a diverſity in the cauſe, but poſſibly from the different natures and circumſtances of the ſubjects acted upon. And theſe being duly conſidered, one appears to be a mixture of water and earth, the other of oily and reſinous ſubſtances. And experience, which has ſhewn us, that the heat of the ſun or of fire can make water to evaporate, warrants the concluſion; that it can in the ſame manner agitate the watery fluids in the clay, and make them to evaporate, and leave the earthy maſs more ſolid than before. But experience alſo ſhews, that the ſame degree of heat cannot evaporate oil or reſinous ſubſtances, and therefore cannot evaporate*

porate the oily or resinous particles of the wax; though it may easily separate and agitate them to a fluidity, as a greater degree of it does the most solid metalline substances.

Thus by begining at the effects, and considering the nature or qualities of the subjects, and their differences, and ascending at last to the cause or causes, these and such like different or contrary phænomena *may be solved without error or hypothesis. And if we go no farther, than an exact analogy of the subjects and circumstances will carry us, the conclusion will be universally true, with respect to the identity of the cause producing these effects; let the effects themselves be ever so different or contrary.*

Therefore though no general conclusion can be drawn with certainty a priori, *or from the cause to the effect, in the synthetic way, whether with or without an hypothesis; yet general conclusions may be drawn by analysis, or* a posteriori, *upon facts and experiments, without the necessity of any hypothesis; and such conclusions, if they have been carefully managed, will appear to be certain and demonstrative.*

Thus much I think necessary to be said for recommending the analytic method of disquisition in all physical essays or inquiries, and in vindication of physic and natural philosophy, as now generally cultivated; and also to set these two different methods of investigation in a true light, in order to take off the prejudices, which may lie against general conclusions, when they can be attained to in the analytic form of argument. Which is what I have endeavoured to observe in all parts of these

Lectures, *by laying the foundation in experiments and observations of facts considered and compared, and solving the plain* phænomena *at last without an hypothesis by a real and known principle in nature, as their universal cause acting by the known laws of mechanics and hydrostatics; the principle itself and these laws being as real, constant, and unchangeable in the present constitution of nature, as the principles of pure mathematics themselves.*

This method was first strongly recommended and illustrated by that incomparable genius the Lord Verulam, *who calls it his* Novum Organum, *his* New Method by Induction, The Art of investigating Forms or Principles, Philosophical Algebra, *&c. And it has since been successfully imployed for unfolding several of the most mysterious* phænomena *of nature by the great Sir* Isaac Newton, *Mr.* Boyle, *Dr.* Boerhaave, *and other learned men and societies, the famous reformers of natural philosophy and physic in this and the last century.*

N. B. The Doctor's Name is found written by himself sometimes *Croone*, and at other times *Croune*. See his *Life*, in Mr. *Ward's* *Lives of the Professors of* Gresham-College.

LECTURE

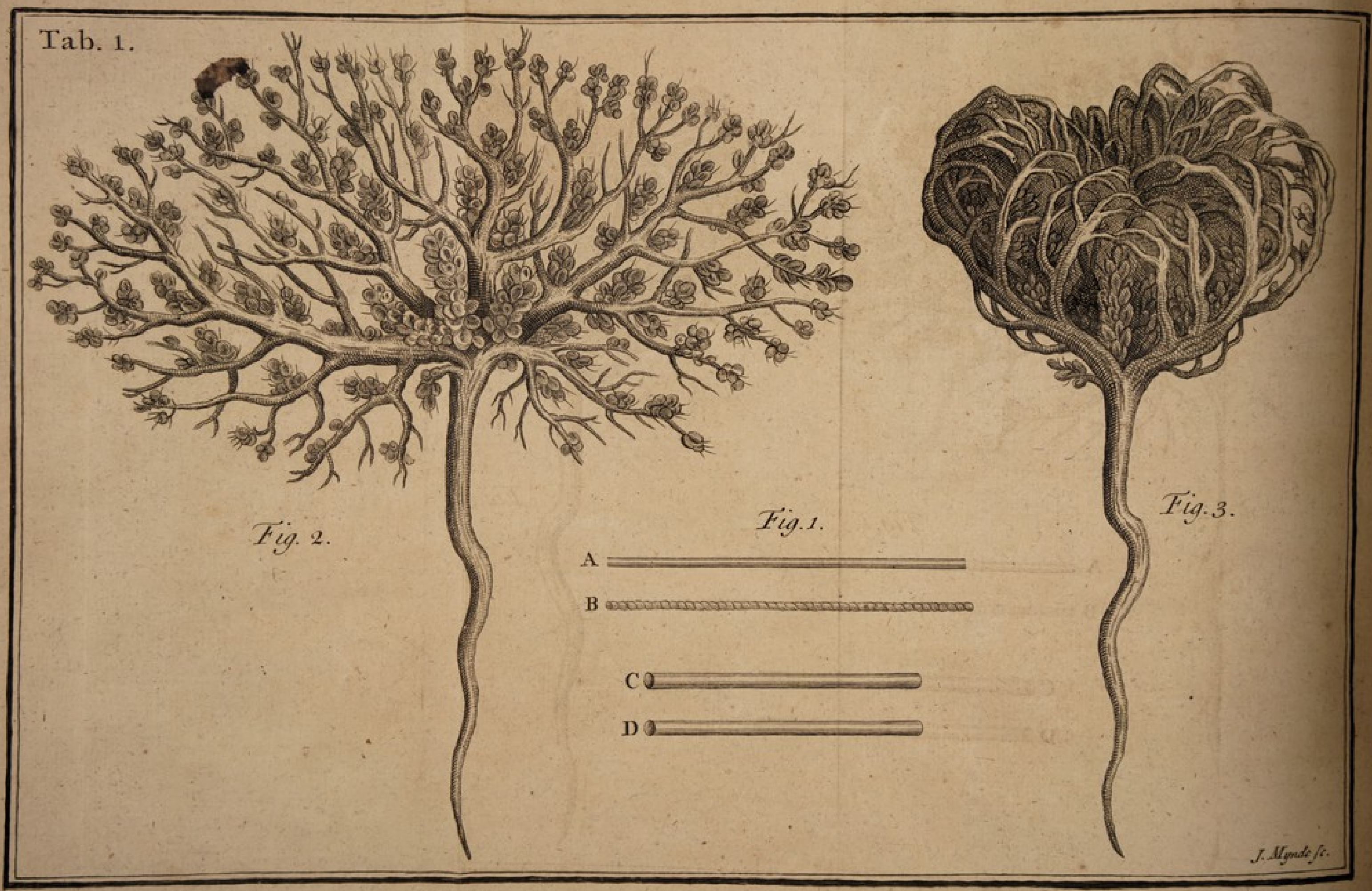
Tab. 1.
Fig. 2.
Fig. 1.
A
B
C
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Fig. 3.
J. Mynde sc.

LECTURE I.

THE design of the learned Dr. *Croone* in forming the plan of these *Lectures on Muscular Motion* seems to have been, not only for the encouraging and promoting the investigation of the muscular structure, with the cause and manner of muscular motion in general; but also for carrying on a more accurate anatomical discovery of the peculiar structure, with the manner of motion, and use of each particular muscle of the animal œconomy, in the several classes of the natural, vital, and animal functions: for in all these this learned and ingenious person well saw, that there was a large field open for improvement.

In this view the subject appears to be so copious, that three or four Lectures annually will not be sufficient to exhaust it in many years.

When the Society shall think fit to make use of the Privilege granted them by their Charter, for obtaining a body, the purpose of these Lectures may be much better answered, than it can be at present without one.

In the mean time, this laudable design may, I conceive, be best answered, and most to the satisfaction of the curious, by laying a foundation for the future Lectures, in the few Experiments and Observations following, which I shall take leave to offer in these first discourses.

EXPERIMENTS.

I. *The elasticity of the blood-vessels, and non-elasticity of the nerves, demonstrated on a nerve, artery, and vein of an human body cut out, and the degree of the elasticity measured.*

II. *The distribution of the nerves, arteries, and veins, to the antagonist muscles of the arm of an human body, shewn in an anatomical Preparation; for demonstrating the necessity of such a distribution towards the performance of muscular motion.*

III. *In the Air-pump, on the jugular vein of a Calf; to shew that there is air in the blood.*

This Experiment stands in the Minutes of the *Royal Society*, as first performed by me, about 17 or 18 years ago; and is now only repeated on occasion of these Lectures.

IV. *Upon an human Artery, and the* Rose of Jericho; *to shew that the elasticity of solids arises from the fluids they imbibe or contain.*

V. *On a Frog; to shew the existence of a fluid in the nerves, and that Muscular Motion is begun by an impulse on it through the nerves into the muscles.*

Upon these Experiments, anatomical Preparations, and Observations made upon them, the doctrine of Elasticity, and of Muscular Motion, chiefly depends; and none of them have been made by any one before, nor are they extant in any author, that I know of.

VI. *On Water, Oil, and Mercury in the Air-pump; to prove the elasticity of fluids.*

This Experiment, if it ever was made before, was at least never yet applied to prove the elasticity of fluids,

fluids, and ſhew the immediate cauſe of elaſticity, and coheſion in ſolids.

The Manner, Explanation, and Uſe of the firſt Experiment.

1. The elaſticity of the blood-veſſels, and non-elaſticity of the nerves, will appear to any, who are diſpoſed to make this Experiment, as I have done, by laying a piece of twine, about four inches in length, parallel to the nerve, artery, and vein of the inſide of the thigh, in an human ſubject; which being tied together above and below, ſo ſoon as they are cut out of the body, and laid on a board, the artery and vein will be ſeen to contract equally, to the loſs of $\frac{2}{8}$ parts of the length, which they had in the body before exciſion; as appears in thoſe in fig. 1. tab. 1. the nerve continuing of the ſame length with the twine, as in the body.

2. In Dogs the elaſticity is greater, to the loſs of $\frac{3}{8}$ parts of the length they had before exciſion; and as this elaſticity ſeems to differ in different ſpecies of animals, ſo it may vary in the individuals of the ſame ſpecies, and in the ſame individual in different ſtages of life, or degrees of health.

3. The uſe of this Experiment is not barely to ſhew, that the blood-veſſels are elaſtic; for every one who knows, that the artery is dilated in its diaſtole, and contracted in its ſyſtole, knows it therefore to be elaſtic in that ſenſe; and every one, who has performed the ligature on the artery after amputation, knows that it ſhrinks or ſhortens its axis, and therefore is alſo elaſtic in that ſenſe. But though this be known, yet the meaſure or degree of the elaſticity of

an artery has not, that I know of, been taken notice of by any body. And, *secondly*, as the vein has no pulſation, and is never deſignedly tied in an amputation, its elaſticity has been overlooked; though it be equal to that of an artery in degree, but not in *momentum*, its coats being thinner than thoſe of the artery. *Thirdly*, The non-elaſticity of the nerves has not been ſo much as once named by any Author, as I remember, before the publication of my inaugural *Theſes* at *Leyden*, *Ann.* 1711. where it is remarked, and ſince that time by Dr. *Boerhaave* only, in the ſubſequent Edition of his *Inſtitutions*, *Ann.* 1713, and the two following Editions. But on the contrary, all the Authors on Muſcular Motion, that have come to my hands, as well as thoſe who have written of the Theory and Practice of Phyſic, have ſuppoſed and aſcribed elaſticity to the nerves.

4. The Experiment therefore is ſo far uſeful, as it diſcovers ſome eſſential properties of theſe eſſential parts, which were not known before; and clears up ſome miſtakes, that paſſed for fundamental truths, relating to the nerves and veins, in explaining moſt parts of the animal œconomy, as well as muſcular motion in general.

5. And it is further very remarkable, that though the elaſticity of the artery has always been known, and indeed obvious in the pulſation: yet Authors have been conſtantly ſo full of the elaſticity of the nerves, in explaining not only muſcular motion, but alſo ſeveral other parts of the animal œconomy, and even in accounting for the ſymptoms of various diſeaſes; that they have taken no other notice of the elaſticity of the arteries, than ſolely as it propels the blood in the

the circulation through them: and even in that, by their doctrine it has been allowed but a very ſmall ſhare; and by moſt of them no ſhare at all.

6. And it may not be amiſs to obſerve, that this Experiment was never made by any, that I know of, till the ſaid year 1711; and afterwards, in the year 1735, when I firſt ſhewed it to this Society. And further, tho' it appears ſimple and eaſy to be made, yet it is of the utmoſt conſequence in all parts of the animal œconomy: for as all parts of the animal body are entirely compoſed of nerves, arteries and veins, (excepting the hardeſt fibres of the bones, which alſo are nouriſhed by them) it is certain, that all the animal functions depend upon the qualities and contents of theſe three parts. Therefore this Experiment, as it demonſtrates the qualities, and degrees of the qualities, of each of theſe, gives us the qualities of the ſolids in all parts of the body; and therefore opens at leaſt one door towards the explanation of all the animal functions, as far as they depend upon the ſolids.

Explanation and Uſes of Experiment II.

1. The next thing which we are to take notice of, is the form or manner of the diſtribution of theſe three eſſential parts to the various organs at their extremities; for upon this diſtribution, and the ſtructure of the organs, which they lead to, depends the whole variety of the functions, whether natural, vital or animal.

2. The cauſe, manner, and effect of voluntary muſcular motion, being a point that the Founder of theſe Lectures had chiefly in view, it was neceſſary

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to obſerve the manner, or order of diſtribution of theſe eſſential parts to the organs of voluntary motion, the muſcles.

3. For this purpoſe therefore I exhibited this anatomical preparation, not extant before in any Author, and, ſo far as I know, not hitherto attempted by any one; namely, the antagoniſt muſcles of an human arm, with all the nerves, arteries, and veins leading to them, intire, as they appear in the ſubject itſelf; and likewiſe laid before you a very accurate draught of them, wherein the arteries are marked red, the veins blue, and the nerves white, as in fig. 1. tab. 2.

4. The uſes of this preparation are various. *1ſt.* As it ſhews that there is no communication between the antagoniſt muſcles by their nerves, each having a peculiar trunk or trunks and branches of nerves diſtributed to it, diſtinct from thoſe of its antagoniſt; by which the mind has a diſtinct power over each, and may at pleaſure act upon either, without acting upon the other: for if both were equally acted upon at the ſame time, no motion, but a rigidity and immobility, would enſue. *2dly.* This preparation ſhews that the antagoniſt muſcles have a communication with one another, by the intervention of their blood-veſſels, as there appears to be one trunk of an artery, and one trunk of a vein, common to both.

5. This ſeems alſo to be abſolutely neceſſary towards voluntary motion, and the power and energy of it; to wit, that the acting muſcle may have a greater derivation of blood into it from the common trunk of

of the artery, than its antagonist, which is at that time to remain passive.

6. Both these very essential parts of voluntary muscular motion must have remained in the dark, without such an anatomical preparation. The mechanical cause and manner of this derivation of an accessory quantity of blood to the acting muscles, depends upon this distribution of the vessels, and the mechanism of the muscular structure, which shall be shewn in the course of the following Lectures; wherein it will appear, that the antagonist muscles of voluntary motion are like two antagonist scales of a balance; and that it is in the power of the mind, by means of this, and other parts of the muscular mechanism, not only to throw in a greater weight at pleasure into either scale, but further to throw the weight taken from the one into the opposite scale, by which the *momentum* is doubled on the side, on which the mind determines to act.

The Manner, Explanation and Use of Experiment III.

1. This Experiment is performed by laying bare the jugular vein of a Calf, before it be killed, and separating it carefully from adhesions; which is then to be tied with a close ligature, first below near the *thorax*, and then in the same manner near the head, at the distance of three or four inches from the former ligature, so as that the intermediate segment of the vein full of blood between the ligatures may be cut off beyond the ligatures.

2. This

2. This segment of the vein, turgid with blood, should be immediately put into a vessel full of luke-warm or blood-warm water, to keep the blood from coagulating within it, which would happen in a few minutes, if it was exposed to the cold air.

3. The vein being taken out of the warm water, is to be tied to a small square paste-board frame, and made fast over the mouth of a wine or jelly glass, or any such vessel tapering towards the bottom, and put into the recipient of an air-pump, which being exhausted, the vein is to be opened with a lancet, fixed at the end of a wire, passing through a collar of leathers.

4. The consequence of this is, that the blood, which runs out of the vein into the vessel set underneath, will be immediately and totally raised up in air-bubbles, and thrown out of the vessel upon the plate of the pump, by the force of the air which it contained, equally distributed through the whole mass.

5. By which it appears, that the blood is greatly stored with air, as was to be shewn.

Remarks on this Experiment.

Obs. I. § 1. It is remarkable in the *apparatus* to this Experiment, that the heat of luke-warm water, which is nearly the same with the heat of incubation, keeps the blood in the vein in a state of fluidity for some hours; and I believe it might be kept in that state much longer, which deserves a trial; this being, as I imagine, the standard degree of heat in all such outward applications, as are intended to dissolve, attenuate, and discuss stagnating animal fluids, or disobstruct the vessels: intentions which are rather hindered

hindered than promoted by too hot baths or fomentations, in which the miſtaken ſtandard degree is as hot as the patient can bear it, inſtead of what he could call a comfortable warmth, and would be the uſeful meaſure for him. This degree of heat would indeed be different to different perſons; but every one would have the due degree ſuited to his temperament, conſtitution, and feeling, in which he could not be deceived, being himſelf the beſt judge. Nay even in mortifications or ſphacelations, though neither this nor any other degree of heat can reſtore motion in the ſphacelated part, yet this degree is moſt likely to promote the circulation remaining in the confines of the mortified part; which is the only intention of fomentations and poultiſes in ſuch caſes, in order to a ſeparation of the ſphacelated ſtuff.

§ 2. This doctrine is confirmed by obſervations, that all animal fluids are thickened by any great degree of heat, or cold. Thus,

§ 3. The white of an egg becomes as hard in a night's time under the ſnow in froſty weather, as if it had been roaſted by the fire, or boiled in water; though the yolk, being more oily, is not ſo much hardened in the ſame time; whereas it is known, that all parts within the ſhell are made more fluid by the heat of incubation.

§ 4. And hence it is, that the ſame kinds of inflammatory diſtempers appear in the ſummer heats, as in the greateſt colds of winter: Whereas the temperate warmth of the ſpring and autumn is generally healthier, or at leaſt freer from theſe kinds of inflammatory diſtempers.

Obs. II. § 1. Though the vein contains such a quantity of air, yet it is no way tumified or expanded by exhausting the receiver; which shews, that the real elasticity of the muscular fibres of the vein is superior to the expansive force of the inclosed air, in which its elasticity is imagined to consist.

§ 2. This elastic power of the vessels therefore would make a rupture of them impossible in an exhausted receiver of an Air-pump, or at the top of a very high mountain, such as *Teneriff*; did not the force of the circulation, at least in this last case, contribute to that rupture of the capillary vessels; which appears by spitting of blood in such eminences.

Obs. III. The manner of this experiment upon blood, which has never had any communication with the external air, obviates an objection against an Experiment of this kind, upon blood received into a porringer, or other vessel, from the arm by venæsection, which might be supposed to have imbibed or received air in its passage, and exposition to the external air, before the experiment.

Obs. IV. § 1. As the blood circulating in the vessels appears to have such a quantity of air intimately mixed with every molecule, globule, or particle of it, the whole compound according to the common doctrine of elasticity, ought to be looked upon as an elastic fluid: even if these globules themselves were not elastic, as I formerly endeavoured to prove them to be, in an essay on the structure and motion of the heart, read some years ago in this illustrious Society, and in a dissertation *de Struct. & Mot. Musc.* lately published.

§ 2. In

§. 2. In the mean time it may be neceſſary here to obviate an objection againſt the elaſticity of all fluids, which ariſes from the incompreſſibility, and therefore, as is alleged, the non-elaſticity of water, the baſis of all the reſt; even though it be known to contain a great quantity of air. For this purpoſe the *Florentine* Experiment of filling a ſpherical veſſel of gold full of water, cloſely ſhut up in it, and expoſed to the ſtrokes of an hammer on an anvil, or to any other ſtrong compreſſion, is offered in proof. Becauſe in that Experiment it appears, that ſome part of the water will make its way through the pores of the gold; which plainly ſhews, that it cannot be compreſſed into leſs room than it had in the ſpherical veſſel, which is more capacious than the cavity of an oblate ſpheroid, to which the ſtrokes of the hammer, or other compreſſion, may have reduced it.

§. 3. The ſolving of this difficulty will give an handle for clearing up ſome miſtakes, relating to the imagined non-elaſticity of fluids, for which reaſon it may not be improper in this place to give ſome account of the nature of elaſticity.

Of Elasticity.

Elaſticity being one of the principles of muſcular motion, it is neceſſary to ſhew where it reſides, and how it acts. In order to this, I ſhall offer the following propoſitions, ſome of which are ſo evident as to want no proof, and to the reſt the proper proofs ſhall be ſubjoined.

Prop. I. The *minima* of all bodies are perfectly hard; that is, their parts are neither ſeparable, nor

capable of changing their relative ſituation, by any power in nature. This is ſupported by the incomparable Sir *Iſaac Newton*, in his treatiſe of optics, by irrefutable arguments, which I need not here repeat.

Prop II. Therefore, as the *minima* of bodies cannot be ſingly elaſtic, elaſticity muſt be a property of compound bodies only, whoſe component parts are capable of changing their relative ſituations, and can be drawn to various relative diſtances with regard to one another.

Prop. III. §. 1. This property appears to be greater or leſs in all compound bodies, whether ſolid or fluid; but the queſtion is chiefly about the elaſticity of fluids, which has been poſitively denied in water (the baſis of all the animal and vegetable fluids) upon the ſcore of its incompreſſibility, obſerved in the *Florentine* Experiment mentioned above. But notwithſtanding that Experiment, I believe it may be made to appear, that water, oil, and mercury, are not only elaſtic themſelves, but alſo the cauſes of elaſticity in all compound ſolid bodies.

§. 2. In order to this, we are to conſider: That the natural ſtate of all elaſtic bodies, whether ſolid or fluid, is contraction of all the parts of the compound towards one another, and to the common centre of the maſs. This appears in a bow, and after the ſame manner in a drop of water, dew, or mercury, whoſe particles are all equally attracted towards the common centre of the maſs, even in *vacuo*, according to the VIth Experiment, and therefore towards one another, ſo as to form the exacteſt ſphere about that centre, where they remain in *æquilibrio*, and im-

moveable

moveable by any power or force of their own; and if disturbed by any external force (short of what will dissipate them into lesser spheres) so as to be reduced to oblate or oblong spheroids, or to any other figure different from that of a sphere, they will immediately upon removal of that force resume their former spherical figure, situation of parts, and *æquilibrium*, about their common centre, as before: and in their progress towards restitution, they will either repel, or constantly endeavour to repel, the incumbent or impelling force.

Corollary. Thus fluids appear to be elastic, as they are capable of extension or expansion by any external force applied; and of restitution to their pristine figure by their own natural force, by which they repel, or endeavour to repel, every thing that stands in the way of their restitution. Which is the whole characteristic of elastic bodies.

Scholium. Repulse therefore (in this case at least) appears to be no principle of action, but the effect of that principle, which is rightly called contraction or centripetal force; which I have endeavoured to shew elsewhere. [See *Diss. de Str. & Motu Musc. Introd.*]

§. 3. As to the *Florentine* Experiment, which is offered in contradiction to this quality in water, we are to consider, that cold water is before the Experiment, in the state of its ultimate condensation or contraction which it can have at that time or season in which the Experiment is made, with an immediate contact, or the nearest possible vicinity of all parts of the compound, whose *minima* are perfectly hard, as has been already proved; and also perfectly round,

which

which its fluidity ſhews to be very probable. Such a body, I ſay, in its natural ſtate of contraction cannot be brought into a nearer contact of parts, nor into a leſſer compaſs than that of a ſphere, which is the moſt capacious of all figures, under the ſame ſurface; and therefore cold water, or any other fluid, ſhut up in a veſſel of that figure, would either conſtantly reſiſt the compreſſion, or eſcape it even through the pores of gold: which no way invalidates the arguments offered above in proof of its elaſticity. For though an elaſtic body extended, diſtended, expanded, or rarified, may be contracted or condenſed, either by its own natural power, or by an external force ſuperior to that by which it was extended or rarified; yet it does not from thence follow, that after its full natural condenſation or contraction, it can be ſtill further condenſed or contracted, by any force whatſoever: which does not at all imply a want of elaſticity, ſuch as has been above deſcribed.

§. 4. It may be further added, that if it was poſſible to condenſe any pure elaſtic ſolid body, beyond the ultimate degree of its natural contraction and condenſation, when all extraneous or heterogeneous bodies are removed; then we ſhould be able to alter the ſpecific gravity of bodies, and ſo far the tranſmutation of metals would be no longer a myſtery. But there is no known power in art or nature, by which pure gold, ſilver, mercury, or any other pure homogeneous metal, can be made denſer, or its ſpecific gravity increaſed. It is true, that in impure metals, by removing the impure or leſs weighty particles out of the way of the mutual contact of their

purer

purer parts, the remaining pure parts become heavier and denſer, than an equal bulk of the original maſs: but this is only a purification, not a condenſation of the primary eſſential component particles; which, was it poſſible, would alter the ſpecific gravity, and therefore the ſpecies of the metal, and ſo introduce a new ſpecies of pure metal. Which, I believe, is beyond the power of art, or any known power of nature.

§. 5. The ſecond thing to be conſidered in elaſtic bodies, whether ſolid or fluid, is a capacity of being extended, diſtended, expanded, or rarified; the effect of which is alſo to repel any incumbent or impinging force; which is ſometimes done with very great violence and impetuoſity in a direction exactly contrary to the centripetal force above deſcribed, and therefore has been called, though, I think, erroneouſly, the centrifugal power of elaſtic bodies, obſerved in various experiments on the air, whence it is denominated the moſt elaſtic of all bodies. Of which more hereafter.

§. 6. But I muſt obſerve, that the ſame expanſive power, and even a greater force of repulſion, appears in water, rarified in the Æölipile and Fire-Engine; though it be not allowed to be elaſtic.

§. 7. But the truth is, that this expanſion, and repulſe which attends it, do not ſeem to be natural powers either of air or water; but effects produced in them by the force of fire, the rays of the ſun, or heat, in a direction contrary to the elaſtic centripetal natural powers of theſe two fluids: ſo that rarifaction or expanſion in them is not a natural action of

their

their own, but a forced effect; and therefore the repulse arising from it must also be the same.

§. 8. And this is equally observable in all elastic solid bodies. For example, a bow that lies unbent, cannot be bent by any force of its own elasticity, but by the impulse of some adventitious external power, which really extends it, or draws it to a greater length in the bending: therefore the bow is not then said to act, but to be acted upon, in order to its subsequent action of restitution; and the man's hands and arms in acting upon it repel whatever stands in the way of their action. But this action and repulse is never ascribed to the bow, whose action is restitution, or a centripetal motion only, by which the arrow is projected by repulse, or reaction of the bow upon it in its restitution or contraction.

§. 9. It is in the same manner, that the rays of the sun, fire, or heat, expand and rarify condensed air, or water, and repel whatever stands in the way of their action, and that *undequaque* in the manner of all other fluids; in which action the velocity of the particles of fire, communicated to the particles of a weightier fluid than itself, increases the *momentum* of the expansion and repulse, in proportion to the different weights of the fluid acted upon: therefore the force of this expansion and repulse is found to be far greater in rarified water or steam, than in rarified air; as is evident in the Æölipile and Fire-Engine.

§. 10. Thus it appears, that this expansion and repulse is not owing to the natural elasticity of the air, but to a foreign power, to wit, that of fire or heat, acting upon it.

§. 11. And


Fig. 3.
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Fig. 1.
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Fig. 2.
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§. 11. And this is confirmed by obſerving, that air long ſhut up from the rays of the ſun, and from all communication with the external air, which conveys them: I ſay ſuch impriſon'd air at laſt totally loſes this expanſive power, ſo as to become unfit for reſpiration, and will extinguiſh a flame, or kill an animal, as quickly as if they were ſtifled in *vacuo*. Which indeed is the caſe. Whence it is commonly, but I think, wrongly ſaid, that ſuch air has loſt its elaſticity. As if we ſhould ſay, that a bow has loſt its elaſticity, becauſe we ſee it lie ſtill, contracted, or unbent, and no hand imployed to extend, that is, to bend it; without conſidering, that no elaſtic body can act until it be firſt acted upon.

What may be further ſaid on the head of elaſticity, ſhall be the ſubject of the next Lecture.

LECTURE II.

IN the laſt Lecture I endeavoured to ſhew, 1*ſt*, That the *minima* of all bodies are perfectly hard.

2*dly*, That elaſticity therefore is a property of compound bodies only.

3*dly*, That this elaſticity conſiſts in a capacity of a change of figure, or change of the relative diſtances and diſpoſition of the parts in the compound, without a ſolution of contiguity or continuity of its parts; and a centripetal power of reſtitution to the ſame figure again.

4*thly*, That the natural ſtate of all elaſtic bodies, whether ſolid or fluid, is contraction only.

5thly, That their forced or preternatural ſtate is extenſion, expanſion, dilatation, or rarifaction by ſome foreign adventitious force.

6thly, That this natural ſtate of contraction in homogeneous fluids ariſes from a centripetal force, by which all parts of the maſs tend to one common centre; and therefore to one another in *æquilibrio* about that centre, ſo as to form the exacteſt ſphere, as a figure capable of a greater quantity of matter, than any other figure of the ſame ſurface.

7thly, That therefore in ſuch a ſtate of ultimate contraction, they are not capable of any further contraction, condenſation, or compreſſion, ſo long as they continue in a ſtate of fluidity; which does not at all impugn their elaſticity, or invalidate the arguments produced in proof of it.

8thly, That repulſe is not a principle of action in elaſtic bodies, but the effect of that natural principle which is juſtly called centripetal power, or a *niſus* towards æquilibration about ſome common centre; by which they repel, or endeavour to repel, whatever ſtands in the way of their reſtitution to that *æquilibrium*.

9thly, That as expanſion, diſtention, and rarifaction are not the natural actions of elaſtic bodies, but the forced effects of ſome adventitious external or foreign cauſe; or of an addition of more matter of the ſame, or ſome other kind, acting upon them; therefore the ſubſequent repulſe produced is alſo the effect of that ſame external cauſe, or of ſuch addition, and not of the elaſtic body itſelf, whoſe ſole action is reſtitution towards its own centre, in a direction contrary to the power of that external agent.

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These conclusions I endeavoured to illustrate by instances from a drop of water, dew, mercury, stagnating and imprisoned air, a bow, *&c.* I shall now proceed to consider these a little further, together with some other sensible properties of fluids; that by comparing them we may be able to draw such general conclusions for our purpose, as shall appear to flow necessarily from them, in confirmation of what has been already said, and for a further illustration of this subject.

Section 1. There appears to be only four kinds of fluids, visible and obvious to the touch, namely water or watery fluids, oil, mercury, and fire; the last of which, though the most universal and most powerful of all, we are certainly the least acquainted with.

§. 2. The air as it is not a visible fluid, and is known to be an heterogeneous mixture of almost all sorts of fluids; until we are at some certainty about the properties of the other more simple and more sensible fluids, of which it is composed, it is not likely that we can come to any solid conclusions concerning it: therefore this may more usefully be the subject of some following Lectures.

§. 3. The first property that I have already touched upon in water, is, that the minutest, visible, distinct drops of it, and even pretty large ones, as well *in vacuo* as in the open air, (according to the VIth Experiment made) form themselves into exact spheres; in each of which the centre of magnitude appears to be the centre of gravity, attraction, and æquilibration, as also of vibration or elasticity. And in such small drops it continues to be so, as long as the attraction of each particle of the fluid within that sphere is greater to-

wards its own centre, than towards the centre of the Earth: that is, until the drop be fo increafed, that the gravity of the extreme particles of its furface exceeds their attraction towards the centre of the drop, as placed at too great a diftance from it, to be fenfibly or fufficiently affected by it. In which cafe, though they do not lofe their mutual attraction towards each other, and therefore retain a proportional attraction towards their common centre; yet they are forced to yeild to the fuperior power of gravity, by which they form themfelves into a fmall part or fection of a larger fphere, about that more powerful centre of the earth. This is moft remarkable in the ocean, where the water affects and obtains the fame fpherical figure about the centre of the earth, as the leaft drops do about their own peculiar centres.

§. 4. And this attraction of its particles in *æquilibrio* towards the common centre of each fmall drop, is diftinct from, and independent of, the action of the fpecific gravity of the whole drop towards the centre of the earth, the one being no ways hindred or promoted by the action of the other; which appears by the conftant fphericity of their figure, whether they afcend in fteam or vapour, defcend in rain or dew, are fufpended in a fog, or lie or hang on the leaves of grafs; either in the open air, or *in vacuo*.

Corollary. Therefore the fame hydroftatical laws, which take place in the ocean, or any other confiderable collection of water, whofe furface forms itfelf to a convexity about the centre of the earth, muft equally take place in every diftinct drop of water, whofe furface forms itfelf to a convexity about its own pecu-

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liar centre. And ſuch of theſe laws, as may ſerve for our preſent purpoſe, ſhall be taken notice of in the ſequel.

§. 5. The ſecond property that I would take notice of in water, is, that it is very plentifully attracted into the pores, veſſels, interſtices, and innermoſt receſſes of all ſolid animal, vegetable, and terreſtreous ſubſtances, where it diffuſes itſelf equally, and uniformly, *quaquaverſum*; and conſtitutes in ſome one half, but in the greateſt number more than half of their bulk or weight: to ſay nothing of tin, antimony, ſulphur, and ſome other mineral ſubſtances, where it is alſo found; for which the chymiſts may be conſulted, and particularly the moſt accurate and learned Dr. *Boerhaave*, in his incomparable Treatiſe of the Elements of Chymiſtry.

§. 6. I ſhall only offer one remarkable inſtance of this in the IVth Experiment made on a ſpecies of *Thlaſpi*, commonly called the *Roſe of Jericho*, *Roſa Hierichontea*, which in its vegetating ſtate ſpreads its branches all round, almoſt horizontally, from the top of the root, near the ground, as from a centre: ſee tab. 1. fig. 2. When it has perfected its ſeeds, it appears of a hard, woody contexture; and as it grows dry, the branches contract and curl themſelves up towards their centre, ſo as to form a ſpherical figure: ſee tab. 1. fig. 3. in which ſtate this plant weighed ſeven drachms and a few grains; but after having been ſteeped two hours in luke-warm water, it expanded its branches as you ſee; and it weighs now 13 drachms, which is but one drachm leſs than the double of its former weight in its dry ſtate: ſee tab. 1. fig. 2. How much more

water then, or watry juice, muſt it have contained in its green and growing ſtate?

§ 7. Some green plants indeed contain more juice than others, but almoſt in all of them, when pounded and ſqueezed, the juice is found greatly to exceed the husky or dry part. This exceſs of the fluids in vegetables is exceedingly remarkable in all the ſucculent kinds, and is little or nothing leſs in living animals, and recent animal ſubſtances; Experiments having ſhewn, that after waſte or expulſion of all the fluids by deſiccation or diſtillation, the remaining ſolid parts appear to bear a very ſmall proportion to the fluids.

Corollary. Therefore the few rigid and leſs moveable ſolids in all animal and vegetable ſubſtances muſt in action yield to, and be governed by, the hydroſtatical and hydraulic laws of the fluids, ſo plentifully contained in them; as that which has the greateſt *momentum*, ariſing from its weight and celerity, will in all motions overpower what has leſs.

§ 8. This is in a good meaſure remarkable in the *Heath Roſe* juſt now ſhewn, where the force of the fluids, tho' urged on by no other power than the attraction of its ſmall pores and capillary tubes, was ſufficient to expand and extend the branches, and veſſels of which they are compoſed, from being ſegments of leſſer to form ſegments of much larger circumferences of circles, or other curves; which no external force can do, without breaking them to pieces.

§ 9. This Experiment ſerves alſo to prove and illuſtrate, what I have advanced elſewhere, concerning the power

power of the blood propelled alternately by the force of the heart and arteries into the branches of the blood-veſſels, inveſting the cavities of the inteſtines and veſicles of the lungs, for forwarding the diaſtole or expanſion of theſe cavities in the periſtaltic motion and inſpiration; to wit, by a force in the direction of the tangents of the arches of theſe veſſels and cavities, which is a direction perpendicular to their centripetal elaſtic contractions; as they appear in theſe draughts of the inteſtines and veſicles of the lungs before you. See *Diſſ. de Struct. & Motu Muſc.* tab. II. fig. 1, 2, 3. and tab. V. fig. 5.

§ 10. The third property obſervable in water is, that it is the cement of union of the ſolid parts in all animal, vegetable, and terreſtreous ſubſtances. A paradox, which nothing but experience could render probable; to wit, that a fluctuating body, whoſe parts may be ſo eaſily diſturbed, diſplaced, or ſeparated, ſhould give firmneſs, hardneſs, rigidity, and ſtability, and prove a *copula* of union to other particles of a maſs, which could never unite among themſelves without it. Yet this is obvious in making of bricks, mortar, and figures in plaiſter of *Paris*, and alſo in the diſtillation and calcination of all vegetable and animal ſubſtances; where, after the total expulſion of all the fluids, nothing remains but incoherent looſe duſt or aſhes, incapable of uniting again without a new recruit of moiſture.

§ 11. The fourth property of water is, its being the univerſal diſſolvent of all theſe very ſubſtances, of which in the preceding ſection it is obſerved to be the cement. Which alſo at firſt ſight ſeems another paradox; becauſe to unite, and divide, are evidently two contrary

contrary actions. I shall therefore in the sequel endeavour to shew, how consistently they flow from one and the same principle, acting by the same instrument.

§ 12. The fifth very remarkable property of water and other fluids is, that they are capable not only of an alteration of figure, or different position of parts, without the loss of contiguity, as has been said already; but are also liable to have their parts separated to small distances by expansion or rarifaction, or to greater distances by evaporation or dissipation; which is evident in water, spirit of wine, oil, mercury, and all other kinds of fluids exposed to the fire, or heat, of any sort. In which circumstances they very forcibly, and in some cases almost irresistibly, repel every moveable thing, that stands in the way of their expansion or evaporation, even to the pitch of explosion at the places of least resistance: as appears in the Æölipile and Fire-engine.

§ 13. The principles from whence this expansive power and repulse arise have been mentioned already. I shall now apply what has been said in this, and the former lecture, towards a further explanation of the universal elasticity both of fluids and solids.

§ 14. 1*st*. It has been generally supposed, that when the solid particles of an elastic body are drawn out of contact to some very small distance by extension, they have a power of restoring themselves to their former contacts again by their mutual attraction; in which the elasticity of compound solid bodies has been said to consist. But if we may depend upon what is visible, we shall never see the dry solid fibres or particles of any solid body, once divided or drawn out of contact, coalesce or unite again, or recover the close

contacts

contacts they had before; without ſome fluid medium ſuperadded. And therefore if the leaſt fibre of a bow, or other elaſtic ſolid dead body, be once crack'd or broken, the rupture will always continue the ſame; and notwithſtanding the elaſticity remaining in the other parts of the bow, by which the broken or divided parts are brought again within the ſame bounds of vicinity, through which this attractive power is ſaid to extend, nevertheleſs they do not again coaleſce or cohere.

§ 15. It is further obſervable, that if a drop of water, oil, or mercury be divided into many leſſer drops, and placed at the leaſt imaginable diſtance from mutual contact, they always remain diſtinct and diſunited; but upon contact they are abſorbed into each other with a viſible rapidity, and become one as before.

Corollary. Therefore there is ſome reaſon to conclude, That the power of attraction does not reach much, if at all, beyond contact, either mediate or intermediate; and that it takes effect in ſolids only by the mediation of fluids. Again, it is apparent, that within the limits of contact it is very ſenſibly ſtrong in fluids.

§ 16. This quality in fluids with their capacity of change of figure, or diſpoſition of parts in the maſs, to every imaginable ſhape, without a ſolution of continuity or contiguity; and with a power of returning to their priſtine figure, or diſpoſition of parts, within their former ſurface again, when left to themſelves; theſe qualities, I ſay, are ſufficient to eſtabliſh elaſticity as a natural and eſſential property of fluids, not diſcoverable in pure or ſimple ſolids, without their mediation or aſſiſtance.

§. 17. For by what has been ſaid of ſolid bodies, when deſtitute of all humidity, or deprived of all their fluids, it appears evidently, that none of the aforeſaid qualities can belong to them; and therefore as ſolids they can have no elaſticity of their own, nor any degree of it, but what is borrowed from the fluids they contain. An inſtance of this is in the artery before you, whoſe elaſticity while recent and moiſt was ſhewn before in the firſt Experiment; but being now dried is neither capable of extenſion or diſtenſion, but remains rigid and contracted, until it be ſteeped again ſome hours in water, by which it will recover its former elaſticity. In which ſtate it ſhall be ſhewn again at the next meeting.

§. 18. If elaſticity therefore reſides ſolely in fluids, and only by their intervention in ſolids, we are now to conſider how, and with what force or *momentum*, it acts there.

§. 19. Elaſticity then, at leaſt in animal and vegetable ſubſtances, being an eſſential property of their fluids, and of them only, the laws of elaſticity and hydroſtatics muſt be the ſame, theſe laſt ariſing from the nature of fluids, as well as the firſt; and there can be no incongruity, contradiction, or inconſiſtency in the ſame nature or eſſence: therefore the known hydroſtatical laws will give us the laws of elaſticity, which muſt take place equally *in minimis ut in maximis*, in a drop of water as in the ocean.

§. 20. It is a general law in hydroſtatics, that the preſſure of fluids is in proportion to their altitude or height, and the ſurface againſt which they preſs; and not in proportion to their breadth.

§. 21. Another

§. 21. Another general law is, that in the ſame altitude they preſs equally in all directions, or *quaquaverſum*.

§. 22. From theſe two general laws ariſes another ſpecial one, which is commonly called an hydroſtatical paradox: to wit, that a cylinder of water of any given height, communicating with a veſſel ſet under it of any given diameter larger than its own, and full of the ſame fluid, preſſes upon the bottom, ſides, and cover of that veſſel, with a force equal to the weight of a cylinder of water of the height of that cylinder, and of the diameter of the underſet veſſel; and, if the veſſel be diſtenſile, it will diſtend it, or inlarge its cavity by all that force; which may be indefinitely greater than the weight of the whole water, contained both in the veſſel and in the cylinder: which mechanical diſpoſition of the fluid produces a great multiplication of power, in proportion to the height of the cylinder, and breadth or diameter of the communicating underſet veſſel.

§. 23. Let us then only for the preſent ſuppoſe, what ſeems highly probable, that the pores and interſtices, at leaſt, of ſolid animal and vegetable bodies are round, as their veſſels are known to be cylindrical; and that the water, every drop of which tends naturally to ſphericity, being attracted into them, is lodged there in ſmall *ſpherules* or *cylinders*; this being the contracted ſhape, which they naturally take, as comprehending moſt matter within the leaſt ſurface. Now if the ſolid body containing them in its pores or veſſels be drawn, bent, or extended to a larger ſurface, containing the ſame quantity of matter, the fluids in it muſt yield to that force; and therefore each drop muſt take ſome figure different from that of a ſphere, or become a

 cylinder

cylinder of a leſſer diameter; that is, its ſurface muſt be extended or expanded, ſo as to become an oblate or oblong ſpheroid; or it muſt take ſome other figure different from that of a ſphere, and adapted to the figure, which the pores and interſtices of the ſolids or the veſſels themſelves are reduced to by the extenſion. But ſo ſoon as the bending or extending force ceaſes, and the whole ſolid body is left to itſelf, the particles of each drop will endeavour to recover their *æquilibrium* about their peculiar centres, whereby they recover their ſphericity, or contraction again into the leaſt poſſible ſpherical or cylindrical ſpace; by which the reſtitution in every part, and therefore of the whole, is performed, the contiguous ſolids yielding to, and conſpiring with, the *momentum* of the fluids in this action.

§. 24. But for the ſake of illuſtration only, let us again ſuppoſe a thing leſs probable: to wit, that by the extenſion of the containing ſolid a part of each diſtinct drop ſhould be raiſed beyond the ſurface, in the ſhape of a ſmall cylinder, by which the diameter of the drop would be leſſened; this ſmall cylinder then would preſs towards the centre, and all ſides of the drop, with the ſame force mentioned in *Section* 22; and in the reſtitution the diameter of the drop would increaſe proportionally, as the length of the cylinder in its deſcent or acceſſion towards the centre of the drop decreaſed: therefore it would deſcend or accede to that centre by a motion uniformly accelerated; as in gravity. And in this view we have gravity and elaſticity ariſing from one and the ſame principle.

§. 25. But the ſame argument will hold, and the ſame concluſion will follow, upon the other more probable ſup-

ſuppoſition: to wit, if by the extenſion of the ſolid containing body, mentioned before, each diſtinct drop be ſuppoſed to be drawn from its ſphericity into an oblong ſpheroid, or preſſed to the form of an oblate one; for the reſtitution in both caſes will produce the ſame effect from the ſame hydroſtatical principles, ſince what-ever part of the fluid is extended beyond the bounds of its former ſpherical ſurface, will thereby have an increaſed preſſure towards the centre, ſuch as the cylinder has been ſaid to have, or in ſuch a *ratio*: becauſe the rays terminating in the uncompreſſed parts of the ſurface of the oblong or oblate ſpheroids of fluids, are lengthened by the new acceſſion of particles from the compreſſed ſides, by which the preſſure towards the centre in ſuch lengthened lines will be increaſed, in proportion to their lengths; and the ſhorter diameters of each *ſpheroid* will be proportionally lengthened, as theſe lines in acceding to the centre are ſhortened: that is, the particles, which lie in the direction of the longer diameters of the *ſpheroid*, in the reſtitution will accede towards the centre, with a motion uniformly accelerated, as in gravity. The ſame will be true of a cylinder, whoſe diameter is ſhortened, and its axis lengthened, by the compreſſion or extenſion.

Corollary. Therefore the laws of gravity, hydroſtatics, and elaſticity, are probably the ſame, and ariſe from the ſame principle of central attraction, only diverſified in almoſt an infinity of *phænomena* both natural and artificial, by the diverſity of centres, circumſtances, and different qualities of the bodies acted upon.

§. 26. And

§. 26. And this conclusion seems to be corroborated by the VIth Experiment made at last meeting on water, oil, and mercury, in which it was apparent, that the centripetal force of these distinct fluids differed one from another in the proportion of their specific gravities. The drop of mercury, as the heaviest, formed the most perfect sphere about its own centre, and the least; the drop of water, though spherical, touched the plain in more points; and the oil, though its upper surface was spherical, lay much flatter on the plain, forming as it were a section of a small sphere. Therefore the centripetal force in each was proportional to its specific gravity; which seems to shew, that it flows from the same principle, acting on the same subject always with the same degree of force, only on each species to a different centre with a different degree of force or *momentum*; whereas, if the centripetal force in each of these drops did arise from some other principle than that of gravity, it might be stronger in the lightest than in the heavier fluids. For as gravity is a power, which acts equally on all bodies in the *ratio* of their contents, if this centripetal power, being equal in all bodies, was in some other *ratio* or proportion, than that of their contents; then it would act most strongly and sensibly on the lightest fluid, whose gravity and contents could least resist its force: and therefore the drop of oil would form a perfecter sphere, than the mercury; the reverse of which appeared in the Experiment.

§. 27. Another thing that I would suggest from the Experiment is, that if a drop of each of these three fluids could be taken equal one to another in weight, the cubes of the diameters of the spheres formed by them

would

would be one to another reciprocally as their ſpecific gravities; in the ſame manner as the ſpaces they take up in the ſame cylindrical veſſel are reciprocally as their ſpecific gravities. Which confirms the former concluſion, that this centripetal power in fluids, and therefore their elaſticity ariſing from it, does not differ from gravity, and is governed by the ſame laws; producing a motion uniformly accelerated, as in the deſcent of heavy bodies.

Corollary. Therefore the laws of gravity, elaſticity, and hydroſtatics, are the ſame; and ariſe from the ſame principle.

Having thus endeavoured to prove, that water and watery fluids are not only elaſtic themſelves, but alſo the immediate cauſe of the elaſticity of all animal, vegetable and terreſtrial ſolid ſubſtances, of whoſe compoſition they make a very conſiderable part; it is now incumbent to ſhew, how its other ſeemingly contrary properties formerly mentioned, are reconcileable one with another, and alſo with this eſſential property of elaſticity: particularly how water and watery fluids can prove the cement, and likewiſe the diſſolvents of animal and vegetable, and alſo of many terrene bodies: or can become the cauſes of ſo very different and even contrary effects, as to unite and divide the parts of the ſame ſubject; and this by that ſingle property of central attraction.

In order to the eaſier illuſtration of this, I would offer the following propoſitions, which are either evident of themſelves, and univerſally acknowledged, or founded upon Experiments, or proved in this and the preceding Lecture.

Prop.

Prop. I. There is a natural centripetal power in water, and indeed in all other fluids, by which every distinct drop, or certain small quantity, left to itself, gains and retains an exact sphericity. This I hope has sufficiently appeared by the observations and experiments already made.

Prop. II. The degrees of the intensity of powers propagated in rays from a centre, or impelled in a contrary direction towards the centre, are found to be reciprocally, as the squares of the distances from the centres of the respective spheres of their activity.

Cor. Therefore as water appears to have such a centripetal power, it follows, that the extreme or superficial particles of the smallest drop of water press towards one another, and towards their common centre, more strongly, than the superficial particles of a larger drop, or of the same drop, augmented to a larger size by the accession of more water.

Prop. III. There is an universal impenetrability in matter, so that one quantity cannot take place, without dislodging another of equal bulk or surface.

Prop. IV. And in this action, that which has the greater *momentum* will overcome or displace that which has less.

Prop. V. The quantity and celerity or *momentum* of a fluid in motion may be such, as to overcome the resistance of solids at rest.

Prop. VI. Water and other fluids in contact with solids, acquire a degree of motion by attraction into their pores, capillary tubes, and interstices, even to their innermost recesses, so as to swell, extend, or expand them. Instances of this were shewn in the *Rose of Jericho*, and in an human artery.

Prop.

Prop. VII. And the degree of attraction of the same species of fluids into the same kind of solid being always equally the same, the celerity of the motion arising from it will also be always the same. Therefore the increase of the *momentum* of the fluid in this action must arise from the increase of the quantity of the fluid so absorbed; which may therefore be accumulated not only to the pitch of extension, expansion, and softness, but even to a perfect solution. Which all observations confirm.

§. 28. These propositions being admitted, it will appear, that the cohesion of solids in their various degrees of hardness, solidity, rigidity, or less sensible elasticity, manifest elasticity, and softness; and also their perfect solution, even to the state of fluidity, do all arise purely from the different quantity of water, or other fluids, lodged in their pores, or between their solid particles.

§. 29. Thus the incoherent dust of dry clay, and fine gravel, by a considerable quantity of water added in making of bricks, become a soft ductile kind of paste, *Prop.* VII. but by losing a great deal of this moisture in drying, or baking, becomes a hard solid mass. In which nevertheless a considerable quantity of water still remains in distinct drops, lessened in their size by the evaporation, and therefore having their remaining particles more strongly attracted to their respective centres, and one to another; and consequently producing a stronger adhesion of the contiguous solid particles to the pitch of hardness, rigidity, and a less sensible degree of elasticity. As in *Cor. Prop.* II.

§. 30. This alſo appears for the ſame reaſon in dried lime-mortar, and plaiſter of *Paris*; and muſt be the ſame in the natural concretions of common ſtones, marble, *&c.* in all which the moiſture has been by degrees evaporated to their ſpecific pitch of hardneſs. And hence it is that all quarry ſtones, by being expoſed to the open air for ſome time, become gradually harder, than when they were cut out of the quarry.

§. 31. But when the remaining moiſture is farther or totally expelled by the force of fire, they return to their original incoherent duſt, dry powder, or lime.

§. 32. So that the coheſion of parts in ſolids of this kind to the pitch of hardneſs, rigidity, or leſs ſenſible elaſticity, ariſes from the ſmallneſs of the ſpherules or drops of water interſperſed in their pores; which makes them leſs capable of extenſion, dilatation, or ſenſible elaſticity. See *Cor. Prop.* II.

§. 33. The ſame appears in dry wood, and other vegetable ſolid ſubſtances; and in the dry bones, horns, and nails of animals; whoſe hardneſs or rigidity is owing to their deſiccation, or to the evaporation of a certain proportion of their moiſture; the remaining ſmall portion making the ſolids in them cohere more ſtrongly, for the reaſons mentioned in the ſame *Prop.* II.

§. 34. And when this remainder is alſo expelled by the force of fire, having loſt the *copula* of union, they fall to duſt and aſhes.

§. 35. Or if the proportion of water be greatly increaſed by infuſion, maceration, or decoction, they

are

are brought to a softness or solution by the *momentum* of the increased fluid. As in *Prop*. VII.

§. 36. This is farther evident in the making glue of the dry skins of beasts, and of fishes; and paste of starch; whose agglutinating quality is owing solely to the proportions of water absorbed, or intermixed by infusion, maceration, or decoction.

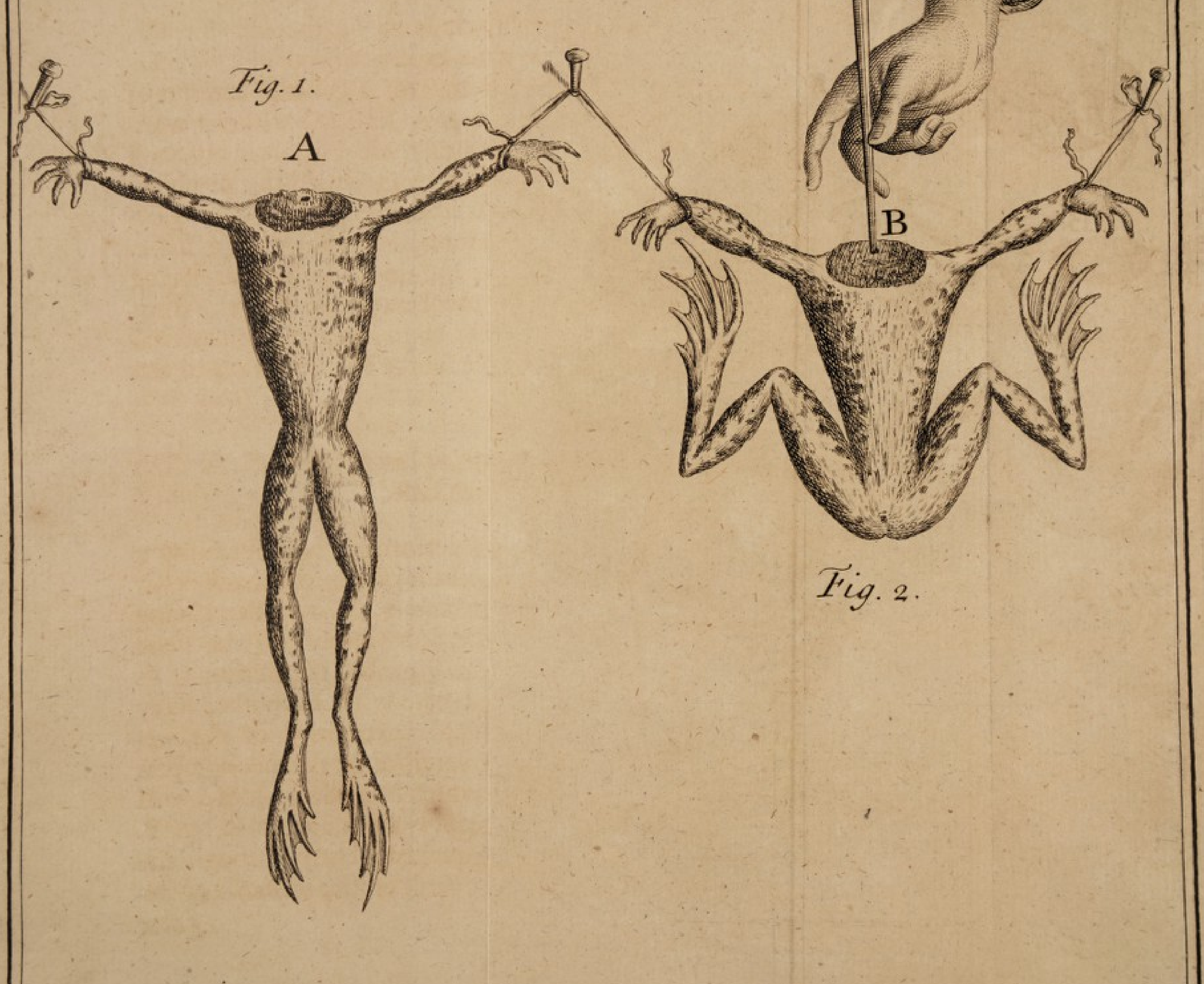
§. 37. Again, a certain greater proportion of water or watery fluids, than is found in these dry substances mentioned above (observeable in the green twigs and branches of trees, and other vegetables; and in the fresh arteries, veins, and other recent parts of animals) produces a sensible elasticity, easily to be brought into action; because the larger molecules or drops of the interspersed fluids by a lesser or weaker *nisus* of their extreme-particles one to another, and to their respective centres, admit an easier change of figure in the bending or extension, and thereby gain a more sensible motion in their restitution. That is, by this greater proportion of fluids in their pores and vessels, they become more sensibly elastic. As in *Cor. Prop*. II.

§. 38. But if this proportion of fluids be farther increased, all these substances become soft and pulpy, and thereby lose their elasticity; because the interspersed molecules of the fluids are now so large, that the particles of their extreme surfaces, contiguous to the solid parts of the compound, are less attracted towards their centres, and therefore upon change of figure are incapable of restoring themselves. That is, by a redundant moisture their elasticity is lost, and they become soft; they fall into a degree of solution, or the lowest degree of fluidity. See *Prop*. VI. and VII.

§. 39. And if this proportion of fluids be yet more or greatly increaſed, the ſolid is completely diſſolved, (ſee *Prop.* III. V. and VII.) its ſolid particles being repelled, or driven aſunder by the interpoſition of a copious fluid, as by ſo many wedges ſucceeding one another, increaſing in bulk, and impelled by attraction, the prime ſpring of motion in all ſolutions, fermentations and putrefactions; but as this opens a very large field of diſquiſition, which would lead us too far from the purpoſe of theſe Lectures, it muſt therefore be left to ſome other opportunity.

§. 40. Thus the ſeemingly contrary or repugnant properties of water and other fluids in cementing and diſſolving, hardening and ſoftening, as well as communicating elaſticity to ſolids, are reconciled; as ariſing from the ſame principle of central attraction, producing different and even contrary effects, by its different degrees of force, in different proportions of the fluid.

§. 41. By which it alſo appears, that there is no ſuch principle in nature, as a centrifugal power: but that repulſe (at leaſt in all theſe *phænomena*) ariſeth from the principle of central attraction in the reſtitution to equilibration; and from the impenetrability of matter; and the ſuperior *momentum* of an increaſed fluid, forced into action by the ſame attraction: and therefore that it is no natural principle, but a forced effect, which was to be proved. See *Prop.* III. IV. V. VI. VII.


Tab. 3.
Fig. 1.
A
B
Fig. 2.
J. Mynde sc.

LECTURE III.

THIS Lecture, which is to be the laſt for this ſeaſon, contains an explanation of the Vth Experiment, and a ſhort abſtract of a general ſcheme of muſcular motion, which may lead us, without wandering from the purpoſe of theſe Lectures, through the whole animal œconomy: in which the principle of elaſticity, which I have been endeavouring to explain in the former Lectures, bears ſo great a ſhare, as it does indeed in other innumerable and ſurprizing *phænomena* of nature; the centripetal power, from whence it ariſeth, ſeeming to be, next to immaterial impulſe, the inexhauſtible ſource of all motion in the univerſe.

The Manner, Explanation and Uſe of the Vth Experiment.

1*ſt*, This Experiment is performed by ſuſpending a live Frog by the fore legs in a frame, or in any other commodious manner, as in Tab. 3. fig. 1. when having cut off the head from the firſt vertebre of the neck with a pair of ſciſſars, a ſmall probe, the button at its extremity being firſt filed flat, is to be puſhed very gently down upon the upper extremity of the *medulla ſpinalis*, in the firſt vertebre of the neck; upon which the inferior limbs, which hung down looſe, will be immediately contracted, as they appear in fig. 2. tab. 3. The ſame probe puſhed gently through the hole of the occiput of the ſcull on the *medulla oblongata*,

gata, will make the eyes move, and ſometimes the mouth to open.

2*dly*, The ſame being repeated at ſome ſmall interval of a few ſeconds, ſucceeds for ſeveral times in the ſame manner; until the extremity of the ſpinal marrow be either puſhed down too far out of the reach of the probe, or contuſed by it, which laſt effect appears ſooneſt on the *medulla oblongata*: but after this the Experiment will not farther ſucceed, the compreſſion then ceaſing to be equal or uniform.

Obſervations on this Experiment.

Obſ. 1. It muſt be obſerved, that this Experiment ſucceeds better in the ſummer months ſome time after the Frogs have ſpawned, than it does early in the ſpring, or in winter when thoſe creatures are almoſt dead by cold, and want of food.

Obſ. 2. The interval of a few ſeconds in repeating this Experiment on the ſame Frog, ſeems to be neceſſary for recovering the equality of the circulation, which was diſturbed by the immediate preceding convulſion, as it throws the blood violently out of the muſcles in the time of their contraction or ſyſtole, which cannot be reſtored immediately in ſuch a languid ſtate of circulation, as this Experiment muſt bring on; and as the aſſiſtance of the blood will appear by the following ſcheme to be neceſſary to muſcular motion, where it is deficient, the motion muſt alſo be defective or imperfect, as it appears in repeating the puſhes too quick.

Obſ. 3. As the inferior proceſs of the brain called the *medulla oblongata*, and its continuation called the ſpinal

ſpinal marrow, are only a continued or prolonged collection of the nerves ariſing from the brain and *cerebellum*; by this Experiment it appears, that the nerves contribute remarkably to muſcular motion; and that their aſſiſtance in it is owing to the fluid they contain, I have endeavoured to prove, by ſhewing the non-elaſticity of the nerves in the firſt Experiment.

Obſ. 4. The motion here excited is in the muſcles of voluntary or ſpontaneous motion, which are under the command of the will.

Obſ. 5. The effect of the impulſe by the probe is the ſame, which is or may be produced in theſe muſcles by the mind or will; or is the very ſame in its manner as voluntary or ſpontaneous motion, and performed by mediation of the ſame inſtruments, to wit, the animal ſpirits, or fluid of the nerves, and the muſcles of voluntary motion.

Obſ. 6. The extremity of the probe applied in this Experiment being flat, cannot produce this effect by irritation, but by compreſſion; and the compreſſion of the pliable extremities of tubes full of any fluid, muſt depreſs or propel the contained fluid towards the lower or oppoſite extremities, with an increaſed degree of velocity. Therefore at leaſt the beginning of this motion may be juſtly aſcribed to a propulſion of a ſmall quantity of the contained fluid, through theſe ſlender canals into the muſcles, in which they terminate, with ſome greater degree of velocity, and in ſome greater quantity than uſual. Whence we may conclude, that voluntary muſcular motion in a living animal is begun in the ſame manner, by an impulſe of the mind or will on the animal ſpirits through the nerves, into the muſcles.

Cor. And as the quantity of animal ſpirits propelled into the muſcles in this Experiment muſt be ſuppoſed very ſmall; it follows, that the waſte of this fluid by moderate voluntary motion in life is very inconſiderable, or little more than what ariſes from the common courſe of the circulation, moderately promoted by eaſy exerciſe, and uſeful for health.

Obſ. 7. In the following ſhort abſtract of a general ſcheme of muſcular motion, the ſtructure of a muſcular fibre is ſuppoſed veſicular, with a reticular *plexus* of blood-veſſels inveſting each veſicle; which is confirmed by an univerſal analogy in the ſtructure of all the moving parts in the animal œconomy, viſible in the heart, lungs, ſtomach, inteſtines, urinary bladder, *&c.* whoſe motions conſiſt in an alternate ſyſtole and diaſtole. Therefore the nature and manner of the muſcular motion produced in this Experiment muſt be the ſame, while the heart continues to beat, and the blood to circulate in the limbs, in the ſame manner, though not with the ſame force, as before the Experiment. Which will be farther explained in the following ſcheme.

An Abſtract of a general Scheme of muſcular Motion. *See* Diſſ. de Struct. & Mot. Muſc.

THE order of accounting for muſcular motion conſiſts in aſſigning, 1. The principles. 2. The immediate cauſe or cauſes. 3. The inſtruments. 4. The manner of action, or *modus*. 5. The effects of it.

1. The

1. The principles or sources of all motion whether natural or artificial, are only two; impulse, and centripetal power.

2. Original impulse, and therefore every new motion, must arise from some immaterial being, as its immediate cause. *Diss. de Struct. & Motu Musc. Cap.* 1.

3. Impulse, as the beginning of every new muscular motion, is in the power of the mind or will, which must therefore be an immaterial being. *Diss. de Struct. & Motu Musc. Cap.* 2. 5.

4. Centripetal power, or the power of contraction, is the most universal principle in nature, producing repulse; and is properly the elasticity of the instruments of muscular motion.

Schol. 1. Inquiries into the intermediate cause or causes of this universal centripetal power, of which elasticity is only one branch, are not to be dropt, or neglected; but after all our researches and discoveries we shall be forced at last to acknowledge, that at the origin of the chain of natural causes, in all its real or imaginary length, there must be an omnipresent and immaterial agent as the prime cause.

Schol. 2. In the mean time, in many *phænomena* of nature it is much to be doubted, whether that chain be so long as is generally imagined; and whether God himself be not the immediate, acting, ubiquitary cause of centripetal power; which seems to be the immediate cause of all the *phænomena* of nature; the indefinite variety of them appearing to arise only from the different structure of the machines or instruments, and other circumstances of action. And it is evident, that all those *phænomena*, which by some of the antient philosophers have been attributed to a *fuga*

 vacui,

vacui, arise from a perpetual *nisus* to equilibration, the ultimate aim of nature, and the immediate effect of this centripetal power.

And though this universal centripetal power was to be admitted as the *ne plus ultra* in the line of causes or principles, (which I do no ways pretend to determine) and was to be resolved into the immediate and ubiquitary agency of GOD as the prime mover; this would nevertheless be far from putting an end to all further disquisitions, or inquiries in natural philosphy; as some may have inadvertently apprehended: for there would be still an almost infinite work behind, for exercising all the faculties of the mind, in explaining the innumerable varieties of the *phænomena* or effects arising from this principle. We should still be far from knowing all its laws of motion, all the degrees of its force, and the indefinite variety of its directions in the innumerable productions of nature, with all their various structures; which would still remain the inexhaustible subjects of inquiry in natural philosophy; by unfolding of which, she would not only nominally, but really, become the mistress of all arts and sciences; the former being only imitations of the works and designs of nature, and the latter the doctrine or explanations of the same works, whether physical or moral. But to return from this digression.

5. The universal instrument of all animal motion is a MUSCLE. *Diss. Cap.* 3.

6. No other vessels are observed to enter into, or to make a part of the composition of a muscle, but nerves and blood-vessels; therefore a Muscle, or the compound instrument of all animal motion, must be made up of these only. *Diss. Cap.* 4. *& Conclus.*

7. The

7. The nerves are not elaſtic, but ſerve to convey an aqueous fluid, called the animal ſpirits, from the brain, *cerebellum*, or ſpinal marrow, to the muſcles. *Diſſ. Cap.* 5, 6. Which fluid is the immediate ſubject of impulſe, or the immediate inſtrument of the mind for beginning muſcular motion. As appeared by Experiment V. made on a Frog.

8. The blood-veſſels and blood are elaſtic; whence the centripetal power, or contraction and repulſe in muſcular motion. *Diſſ. Cap.* 6.

9. The external diſtribution of the nerves and blood-veſſels to the antagoniſt muſcles formerly exhibited in Tab. 2. fig. 1. ſhews, that each antagoniſt has its diſtinct nerve or nerves without communication; but the antagoniſt muſcles communicate one with another by one common trunk of an artery, and one common trunk of a vein: ſo that they are like two antagoniſt ſcales *in æquilibrio*, over which the mind has a diſtinct power by diſtinct nerves for determining the animal ſpirits, and thereby the blood, to either ſide at pleaſure, without affecting the other.

10. The internal diſpoſition of theſe veſſels in the compoſition of this inſtrument is taken from the univerſal analogy, viſible in all the moving parts of the animal machine: to wit, the heart, lungs, inteſtines, urinary bladder, *&c.* wherein ſuch a ſtructure appears to the naked eye, as gives us the following Idea of the ſmalleſt muſcular fibre, deſcribed in *Diſſ. Cap.* 8. that is, *a nervous fibre produced from its entrance into the muſcle along or in the axis of each carnous fibre, in the form of a chain of diſtenſile veſicles, whoſe ſides are covered with a net-work of elaſtic longitudinal and tranſverſe blood-veſſels; the extremities of all theſe nerves compacted forming the ten-*

don, which being ſpread out or expanded again, forms the perioſteum. See fig. 2. and 3. Tab. 2.

11. By the naked eye, or with the help of a microſcope, this ſmalleſt muſcular fibre appears of the ſame blood-red colour, and of the ſame ſhape or figure with the whole muſcle, whence it is taken; and the whole muſcle of voluntary motion is no more than a faſcicle or bundle of ſuch ſmall muſcular fibres: therefore its action can be nothing elſe, than the joint action of all theſe. *Introd. to Diſſ. page* 1, 2.

12. But the action of the whole muſcle by Dr. *Gliſſon's* Experiment, appears to be only an alternate diaſtole and ſyſtole: and therefore, by what has been ſaid in the laſt paragraph, there muſt be ſuch a diaſtole and ſyſtole alternately in each of the ſmall carnous fibres of which it is compoſed. *Diſſ. Exp.* 1. *Cap.* XI.

13. And by the Vth Experiment already mentioned on a Frog, it appears, that a very ſtrong muſcular motion may be eaſily excited by a very ſlight impulſe through the nerves. As in Experiment V.

14. But ſuch an eaſy production of motion is not conceiveable, without the niceſt equilibration of all parts of the machine moved.

15. Therefore a ſtatical equilibration of the antagoniſt muſcles of each limb is deſcribed, and delineated in *Diſſ. Tab.* 4. ſhewing the equilibration of their elaſticity.

16. And an hydroſtatical equilibration of the fluid of the nerves is deſcribed and figured in *Diſſ. Tab.* 5.

17. Now equilibrated bodies may be eaſily moved, by adding or diminiſhing the leaſt imaginable force of either ſide; but if what is taken from one be added to the other, the *momentum* of the motion will be doubled, without the loſs or expence of what is

taken

taken away, *Diff. Theor.* 19, 20. which is the case in muscular motion, in its progress from utmost extension to final contraction; as will appear in the sequel.

18. We are now to shew how easily a very strong motion may be excited, and carried on in a machine of this fabric, whose parts are in so just and accurate an equilibration.

19. Previous to which it may be necessary to remove the following objection or difficulty, which occurs in *Diff. Cap.* 10. where it appears, that the power of absolute elasticity in the muscles greatly exceeds the utmost force of impulse in the power of the mind. But the statical equilibration of that elasticity, and the hydrostatical equilibration of the nervous fluid mentioned before, take off all resistances, that would else be in the way of that impulse, by which it becomes sufficient for the purpose, so as to be able to begin muscular motion; which is carried on in the following manner.

20. The whole progress of muscular motion is from the state of utmost extension, through the states of relaxation, equilibrium, complete inflation or diastole, to the state of ultimate contraction or systole. In all which courses from the first term to the last each vesicular fibre shortens its axis; and therefore draws the limb affixed into flexion, or extension, at the pleasure of the mind. *Diff. Tab.* 4.

21. The mind can act upon the muscular fibres in any state, but that of ultimate contraction, which is the termination of the progress of muscular motion; as the beginning of it is from the state of utmost extension. *Diff. Cap.* 10.

22. In the state of utmost extension then, the longitudinal capillary blood-vessels on the surface of

each vesicle in the fibres must be extended, and therefore their transverse diameters must be lessened: that is, these vessels thereby become straiter, and the circulation in them therefore more difficult; and in this state also the transverse blood-vessels of each vesicle will be forced into serpentine flexures, which must render the passage of the blood through them still more difficult. *Diss. Cap.* 9.

23. In this, and all other states of the antagonist muscles, both the statical and hydrostatical equilibration, mentioned above, take place to such a degree, as to remove all resistances, that would else be in the way of any supervening impulse. *Diss. Cap.* 10.

24. Therefore if the mind impels but a very little more of the nervous fluid than usual, through the slender tubes of the nerves, into these extended vesicles, they will be uniformly dilated as in the known Experiment of the Water-bellows. *Diss. Cap.* 9. and *Th.* 22.

25. By this distension of the vesicles their axes being shortened, and their diameters lengthened, the longitudinal capillary vessels on their surface must be shortened, and thereby their diameters inlarged; and the serpentine flexures of the transverse vessels will be extended; which in both kinds will lessen the resistance they gave to the transit of the blood, which both by the diastole and systole of the arteries is continually urged on to its passage through them; and being thus facilitated, every globule of blood in its progress, by endeavouring to fly off by the tangents of these vessels and vesicles, tends to expand them more, and thereby opens the way for the further and easier influx of the nervous fluid; to which the blood-vessels contribute as so many elastic levers acted upon by the

blood

blood in its progress. Thus by the assistance of these three powers, of the nervous fluid, the blood, and blood-vessels, the progress from extension to inflation or diastole of the vesicles is made, with such a degree of celerity as the will commands. *Diss. Cap.* 9.

26. The muscle is at that time tumid and inlarged by the afflux of the nervous fluid and blood, which increases its bulk.

27. The mind may keep up this inflation, as long as it pleases, only by impelling constantly such a small quantity of the nervous fluid into the distended vesicles, as is sufficient to supply the usual expence of them in their common course.

28. But if the mind desists to send in this recruit, or suspends it, then these circular or arched elastic vessels now turgid with elastic blood, whose areas have been thus forcibly inlarged, endeavour to contract themselves every way towards the centres of their areas, which are the centres of the vesicles; and, the mind giving no resistance, this *nisus* takes place to the complete contraction of each fibre; by which the limb affixed is brought into complete flexion or extension, according as this or the other antagonist has been acted upon. *Diss. Cap.* 9.

29. In this state the whole muscle becomes shorter, and less in all its dimensions; harder and paler by expulsion of a great part of its fluids through the veins towards the heart, and through the extremities of the nerves into the tendon and *periosteum*. And such are the visible *phænomena* of this and all other moving parts of the animal machine.

30. It may be imagined, that such interruptions of the course of the blood in the capillaries of the arteries and veins, and such uncertain subsultory changes in the

figure

figure of the parts as have been deſcribed, might interrupt the regular circulation of the blood, and thereby diſturb the motion of the heart; which is not obſerved to happen by moderate exerciſe. But this difficulty is removed by conſidering, that the whole is carried on in extenſile and diſtenſile blood-veſſels, communicating one with another, as in Tab. 2. fig. 1. and therefore what cannot be received into one is immediately communicated to, and eaſily received by the other, and by it forwarded in its return to the heart, in the ſame time and quantity, as if the paſſages through all the veſſels were equally open, and paſſable. Therefore though an acceleration does ariſe in all exerciſes, yet an irregularity of the circulation in a healthy perſon is not obſerved to happen by any degree of exerciſe.

What I have here briefly recited, I have at large endeavoured to explain in a *Diſſertation* on this ſubject lately publiſhed, with ſeveral figures annexed for illuſtration of the whole; by which, I hope, the principles, cauſes, inſtruments, manner of action, and effects, in which the *ratio* of muſcular motion conſiſts, have been pointed out from anatomy, mechanics, hydroſtatics, obſervations and experiments. To which, for the ſake of brevity, I have every-where referred.

The proof and illuſtration of this general ſcheme will appear in the application of it, for explaining the various functions of the animal œconomy; which may naturally become the ſubjects of ſome future inquiries towards anſwering the intention of the worthy Founder of theſe Lectures.

FINIS.

EXPLANATIONS OF THE TABLES.

TABLE I.

FIGURE I.

CONTAINS a nerve, artery and vein of an human ſubject, which before exciſion were all of equal length with a piece of twine applied to meaſure them.

A. The nerve after exciſion, continuing of the ſame length as it was in the body; to wit, equal to the twine *B*.

B. The twine or common meaſure of all the veſſels before exciſion.

C. The artery, which in the body was of the ſame length with the nerve and twine; but being cut out and left to itſelf ſhrinks, or contracts, to the loſs

loſs of $\frac{3}{8}$ of its length; as thoſe of Dogs loſe about $\frac{3}{8}$.

D. The vein, which was equal to the nerve and twine in the body; but being cut out and left to itſelf ſhrinks, or contracts as much as the artery, though not with the ſame degree of force.

Hence it appears that the arteries and veins are evidently elaſtic, and that the nerves have not the leaſt apparent elaſticity. See *Exp.* I. Lect. I.

FIGURE 2.

A. The *Roſe of Jericho*, expanded by being ſteeped two hours in water, weighing 13 drachms, and reſembling its ſtate of growth in the ground.

FIGURE 3.

The ſame dry and contracted, weighing 7 drachms and a few grains.

TABLE II.

FIGURE 1.

Contains the antagoniſt muſcles of an human arm, placed at a little more than their natural diſtance, with the nerves, arteries, and veins diſtributed to them in their natural ſituation and order.

A.A.A. The muſcle *biceps*, one of the flexors or benders of the cubit or fore-arm.

B,B,B.

B.B.B. The internal brachial muſcle, another flexor or bender of the fore-arm.

C.C.C.C. The external brachial muſcle called *triceps*, an extenſor of the fore-arm.

The muſcle called *anconaeus*, another extenſor of the fore-arm, is hid here.

D. The common trunk of the branchial artery, diſtributing the blood by its branches to all theſe antagoniſt muſcles on each ſide of the arm; red, expreſſed by the lines thus |||| as in Heraldy.

E. The common trunk of the vein, through which the blood brought back from the muſcles on each ſide returns towards the heart; blue, expreſſed as in Heraldy thus ≡.

F. The trunk of the nerve peculiar to the flexors of the fore-arm, whoſe branches are peculiarly diſtributed to theſe flexors only, but not to the extenſors; white.

G.G. Two trunks of nerves peculiar to the extenſor muſcles of the fore-arm, whoſe branches are peculiarly diſtributed to theſe muſcles only, but not to their antagoniſts the flexors; white.

The number of the branches of theſe ſeveral veſſels, and the manner of their diſtribution and inſertion into theſe muſcles, appear in the figure. I need only to obſerve, that the antagoniſt muſcles, that is, the muſcles of each ſide communicate one with another by their blood-veſſels, but not by their nerves.

 By

By the help of this figure the mechanical manner of mufcular motion delivered in Lecture III, will be eafily underftood.

FIGURE 2.

A. Reprefents a mufcular fafcicle, or fmall part of a mufcle, macerated in water, and carefully feparated longitudinally from the reft of the mufcle, with its tendinous extremities; expreffing together the figure of the intire mufcle, as mentioned §. 11. Lect. III. and at greater length in *Cap*. VII. §. 5. *Diff. de Struct. & Mot. Mufc.* and *Introd.* §. 2. and 18.

B, B, B, &c. The carnous red fibres drawn afunder, that the nervous white *fibrillæ* or fillaments diftributed to them may better appear.

C, C, C. The nervous white fillaments, entering the carnous fibres at angles more or lefs acute.

D, D. The tendinous extremities of the mufcular fafcicle; being the nerves and nervous membranes of each mufcle or part of a mufcle collected, and compacted to the firmnefs of a tendon; whence being again expanded, it is juftly called the *aponeurofis*; and being farther continued over and into bones, is called their *periofteum*.

F, H, G. Shew the directions and diftributions of thefe proceffes of the nerve, artery, and vein to the mufcular fafcicle, fimilar to their directions and diftributions to the whole mufcle.

This

This figure is the ſame with the next following; excepting that in this the ſmall nervous veſicles in each carnous fibre are ſuppoſed to be covered by the blood-veſſels.

FIGURE 3.

A. Shews the angle of inſertion of the nerve into this faſcicle, as into the whole muſcle, with the direction and diſtribution of its branches into the muſcular veſicles.

B, B, B. The chains of the muſcular veſicles, ſuppoſed to lie in the direction of the axis of each carnous fibre, and to be inflated or diſtended by the influx of the nervous fluid, at the command of the will in the diaſtole of the muſcle. See *Diſſ. de Struct. & Motu. Muſc. Cap.* VIII. §. 2, 4, 5, 7, 8. and *Abſtr.* in Lect. III.

This verſicular ſtructure of the ſmalleſt muſcular fibre, pointed out and confirmed by a ſimilar ſtructure in all the viſible moving parts of the animal œconomy, may be juſtly inferred from the plain analogy of nature, which is always ſimilar to itſelf; by which it will be eaſy to underſtand what is ſaid of the general muſcular ſtructure in *Diſſ. Cap.* VIII. and of the manner of muſcular motion *Cap.* IX. and more compendiouſly in the *Abſtract* of that general ſcheme in Lect. III.

TABLE III.

FIGURE 1.

A. A live Frog, the head being cut off, hanging by the fore-legs without motion.

FIGURE 2.

B. The ſame Frog, whoſe inferior limbs, which hung looſe and free, are brought into a ſtrong and complete contraction by a very ſlight impulſe with the button end of a probe, on the upper extremity of of the ſpinal marrow; the end of the probe being filed flat and ſmooth for that purpoſe. See *Experiment* V.

ERRATA.

Lect. II. *Page* 25. *l.* 19. *for* intermediate, *read* immediate.

Lect. III. *Page* 41. *l.* 15. *for* of muſcular motion, *read* in muſcular motion.

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Tabula XIII.

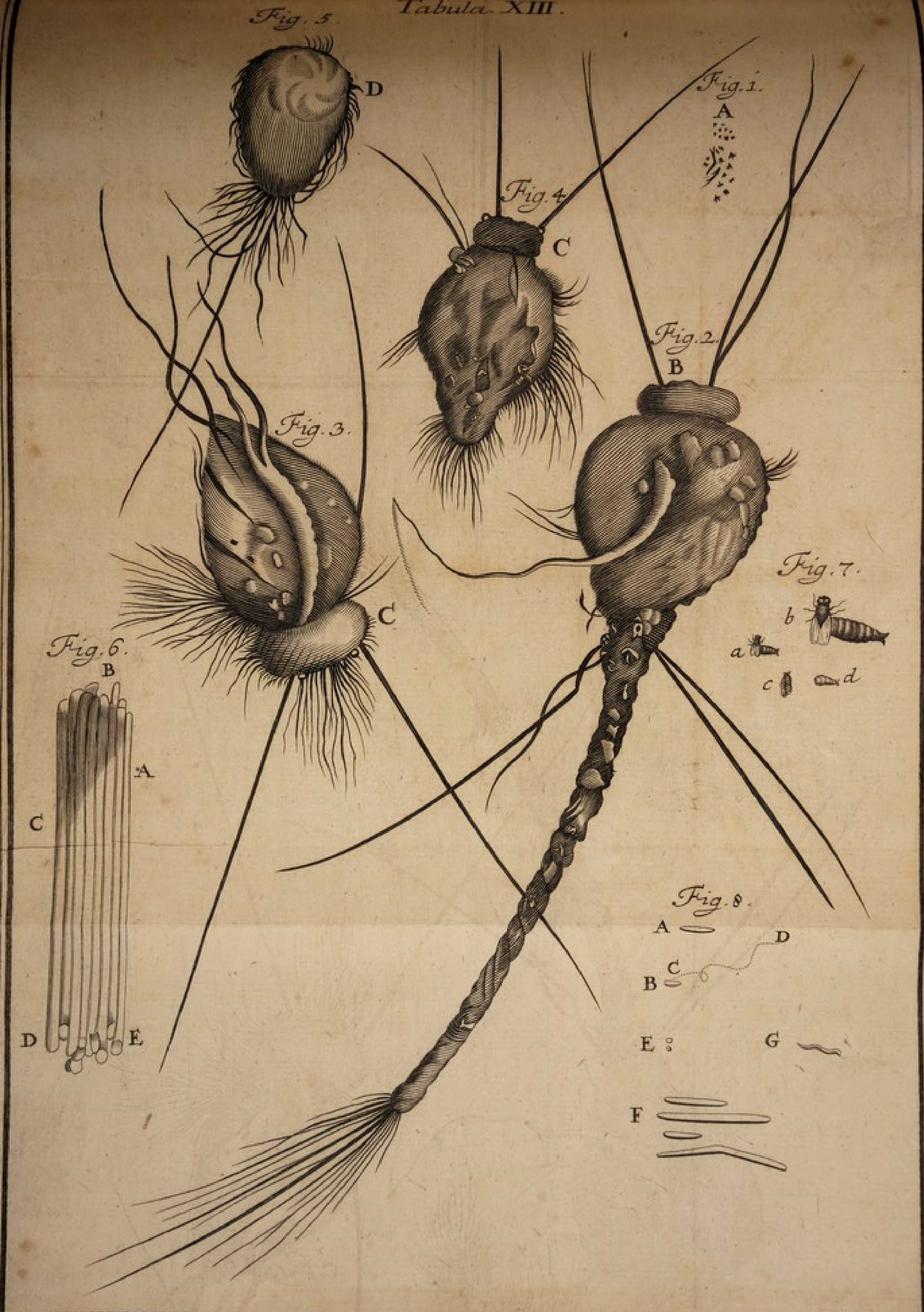

Fig. 5.
D
Fig. 4
C
Fig. 1.
A
Fig. 2.
B
Fig. 3.
C
Fig. 7.
a
b
c
d
Fig. 6.
A
B
C
D
E
Fig. 8.
A
B
C
D
E
F
G