Whytt, Robert. **An essay on the vital and other involuntary motions of animals**

Edinburgh : Hamilton, 1751.

AN

ESSAY

ON THE

VITAL and other INVOLUNTARY MOTIONS of ANIMALS.

By ROBERT WHYTT, M.D.
Fellow of the Royal College of Physicians, and
Professor of Medicine in the University of *Edinburgh*.

Inanimum est omne quod pulsu agitatur externo; quod autem est animal, id motu cietur interiore & suo. Nam hæc est propria natura animi atque vis.——Quæ sit illa vis, & unde sit intellegendum puto. Non est certè nec cordis, nec sanguinis, nec cerebri, nec atomorum.

CICERO. Disput. Tuscul. lib. I.

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M,DCC,LI.

To the RIGHT HONOURABLE

JAMES Earl of MORTON,

Lord ABERDOUR, *&c. &c. &c.*

IT is not your Lordſhip's high ſtation in the world, but your extenſive knowledge of the works of nature, and taſte for Philoſophical inquiries, which has determined me to inſcribe the following Eſſay to your Lordſhip, and makes me, with pleaſure, embrace this opportunity of publickly declaring the great reſpect with which I am,

My LORD,

Your LORDSHIP'*s*

moſt obedient, and

moſt humble Servant,

ROBERT WHYTT.

ADVERTISEMENT.

ABOUT twelve years ſince, not long after the Author of this Eſſay had left the ſchools of Medicine, he began to be diſſatisfied with the common theories of reſpiration and the heart's motion; and as he had not met with any writer, who had given, as he thought, a juſt account of the vital and other involuntary motions of animals, or derived them rightly from their true SOURCE, *he purpoſed ſometime or other to write on this ſubject, if not for the publick, at leaſt for his own ſatisfaction. In purſuance of this reſolution, the following Eſſay was begun in the year* 1744; *and might have been finiſhed long ago, had not the Author's time been greatly taken up with more neceſſary buſineſs.—In compiling it, he has been careful not to indulge his fancy, in wantonly framing* hypotheſes, *but has rather endeavoured to proceed upon the ſurer foundations of experiment and obſervation.*

obſervation. No doctrine in Philoſophy, which was not built on theſe, has ever been able to ſtand its ground for half a century; and the theories of NEWTON, *and ſome few others of the more happy Philoſophers, have therefore triumphed over all objections, becauſe they were founded on nothing elſe but plain facts; facts indeed, whoſe exiſtence was perhaps unknown before, and whoſe influence is ſo extenſive, that while they are ſimple and uniform in themſelves, they ſerve as* cauſes *for explaining innumerable effects. On the other hand, in the hypothetical method of philoſophiſing, cauſes are uſually aſſigned, which not only cannot be proved to exiſt, but which are frequently more intricate and complex than even the effects to be explained from them. And indeed, it cannot be expected that unguided imagination ſhould hit upon the truth, ſince nature has ſo cloſely concealed many of her operations, that they often elude the united efforts of genius, induſtry and experiment.*

There

There is one favour which the Author would ask, of thoſe *who may take the trouble to peruſe this performance,* viz. *that they would delay paſſing judgment upon any* PART *of it, till they have attentively and fairly conſidered the* WHOLE ; *becauſe it is apprehended, that the theory of every one of the motions here explained, ſupports and ſtrengthens what is ſaid of the reſt, and that when all are taken together, each receives an additional weight of argument, and appears in a ſtronger light.*

OCTOBER I. 1751.

ERRATA.

Pag. 52. *lin.* 6. *for* heated *read* treated.
P. 63. *l.* 21. *after* duct, *add* in a cat.
P. 155. *l.* 3. *f.* following *r.* flowing.
P. 184. *l.* 2. *f.* the *r.* theſe.
P. 206. *l.* 6. *f.* actions *r.* action.
P. 227. *l. ult. after* abridged, *add* vol. iii.
P. 317. *l.* 1. *f.* theſe organs *r.* this organ.
Ibid. l. 3. *f.* them *r.* it.
P. 318. *l. ult. after* med. *add* vol. iv.

Of the VITAL and other INVOLUNTARY MOTIONS of ANIMALS.

INTRODUCTION.

PHYSIOLOGICAL writers have divided the motions of animals into voluntary, involuntary, and mix'd.

THE voluntary motions are ſuch as proceed from an immediate exertion of the active power of the will. The involuntary and mix'd motions, which laſt, though ſubject to the power of the will, yet are not ordinarily directed by it, may be aptly enough comprehended under the general denomination of SPONTANEOUS; ſince they are performed by the ſeveral organs as it were of their own accord, without any attention of the mind, or conſciouſneſs of an exertion of its active power: ſuch are the motions of the heart, organs of refpiration, ftomach, guts, *&c.*; which have been alfo diftinguifhed by the name AUTOMATIC; though perhaps there is an impropriety in this term, as it may feem to convey the *idea* of a mere inanimate machine, producing fuch motions purely by virtue of its mechanical conftruction: a notion of the animal frame too low and abfurd to be embraced by any but the moft MINUTE philofophers!

THOUGH we may be at a lofs to explain the nature of that fubftance in the nerves, by whofe intervention the mind feems enabled to act upon the mufcles; and though we may be unacquainted with the intimate ftructure of the fibres upon which this fubftance operates, yet we have no room to doubt that voluntary motion is produced by the immediate energy of the mind; manifold experience convincing us, that though there be required certain conditions in the body in order to its performance, it is neverthelefs owing to the will. Nor ought we to be furprifed when we meet with thefe kind of difficulties; for they attend moft of our inquiries and refearches:—Thus, though the laws of mo-

tion

tion and gravitation be fully underſtood and demonſtrated by philoſophers, yet the firſt cauſe of motion, the manner in which it is communicated to bodies, and the nature of gravity itſelf, have never been explained.

BUT how it comes to paſs that many of our muſcles are brought into contraction, not only without the concurrence of the will, but in oppoſition to its ſtrongeſt efforts, and why moſt of the organs of ſpontaneous motion are continually agitated with alternate contractions and relaxations, of which we are no way conſcious, while the muſcles of voluntary motion remain at reſt, and are not contracted but in conſequence of a determination of the will to that end; are queſtions which have occaſioned no ſmall debate among medical writers, and which as yet they are far from being agreed about.——To clear up theſe points, is the principal deſign of this *Eſſay*; and I flatter myſelf that the following account of the vital and other involuntary motions of animals, will not leſs recommend itſelf to equal judges by its ſimplicity, than by its agreeableneſs to the known laws of the animal œconomy, and the eaſy ſolution it affords of all

all the *phænomena* of the human frame reſpecting its involuntary motions.

NATURE, as far as we can judge from the plan and ſcheme of things ſurrounding us, delights in ſimplicity and uniformity, and, by general laws applied to particular bodies, produces a vaſt variety of operations; nor is it at all improbable that an animal body is a ſyſtem regulated much after the ſame manner. Following the path, therefore, which Nature has pointed out in her other and more grand operations, I have in this Eſſay endeavoured to ſhew, that all the ſpontaneous motions of animals are explicable upon the ſame principle, and owing to one general cauſe. How far ſome authors of great note have been unſucceſsful in their inquiries into this matter, from their neglecting ſo obvious an analogy, and endeavouring to explain the vital motions of almoſt every different organ, by a different theory, is left to the Reader to judge.

As the heart is one of the principal organs of the body, and its action immediately neceſſary to life, we ſhall begin with inquiring into the cauſe of its alternate contraction and relaxation, and whence it comes about that

theſe

these motions are performed without the mind's seeming to have any concern in them, nay in opposition to the strongest efforts of the will. But it will be necessary previously to lay down a few *postulata*, as a ground-work upon which is to be built our theory of the involuntary motions of animals in general, and of that of the heart in particular.

SECT. I.

Principles and facts necessary to be premised.

1. A CERTAIN power or influence proceeding originally from the brain and spinal marrow, lodged afterwards in the nerves, and by their means conveyed into the muscles, is either the immediate cause of their contraction, or at least necessary to it.

THE truth of this is put beyond all reasonable doubt, by the convulsive motions and palsies affecting the muscles, when the *medulla cerebri*, *medulla oblongata* and *spinalis*, are pricked, or any other way irritated or compressed; as well as from the observation, that animals lose the power of moving their muscles mufcles, as foon as the nerve or nerves belonging to them are ftrongly compreffed, cut through, or otherwife deftroyed. Of this many inftances might be given: But we fhall content ourfelves with mentioning one, which is too ftrong and unexceptionable to admit of any evafion. When the *recurrent* nerve on one fide of the *larynx* is cut, the voice becomes remarkably weaker; when both are cut, it is entirely and irrecoverably loft *, *i. e.* the animal lofes all power of moving the mufcles which ferve to increafe or diminifh the aperture of the *glottis*; for I prefume it will be needlefs now-a-days to go about to fhew, that the tying of thofe nerves can only affect the voice, by rendering thefe mufcles paralytic.

IF the brain, or fome part of it, were not in a manner the fountain of fenfation and motion, and more peculiarly the feat of the mind than the other bowels or members of the body; why fhould a flight inflammation of its membranes caufe madnefs, or a fmall compreffion of it produce a palfy or apoplexy, while a like inflammation of the ftomach or liver,

* Edinburgh Medical Effays, vol. 2. art. 8.

liver, or a compreſſion or obſtruction of theſe bowels, have no ſuch effects? If the nerves were not immediately concerned in muſcular motion, why, upon tying or deſtroying them, does the member to which they are diſtributed, inſtantly loſe all power of motion and ſenſation? —— Becauſe animals have lived with a brain ſo diſeaſed, that it is difficult to conceive how it could perform its functions, or becauſe monſters have been born without a head, which lived ſome ſhort time, and had the power of motion; to conclude, I ſay, from hence, that the brain and nerves in perfect animals are not immediately neceſſary to motion and ſenſation, is altogether as abſurd, as it would be to aſſert, that the heart was not deſigned to propel the blood through the body, becauſe muſſels, oyſters, and other animals of the loweſt claſs, have no ſuch organ *, and monſtrous fœtuſes have ſometimes wanted it †, or becauſe we are told of a rat every way healthful, which being diſſected was found to have no heart ‡.

——No

* *Harvey* de motu ſang. cap. 17.

† Memoires acad. ſciences 1720, edit. 8vo, p. 16.

‡ *Van Swieten* comment. in Boerhaav. aphoriſm. vol. 1. p. 256.

——No reafoning drawn from a few monftrous cafes, can be fufficient to overthrow a doctrine founded upon the plaineft *phænomena* obferved in perfect animals, and confirmed by almoft numberlefs experiments made upon them. The neceffity therefore of the influence of the brain and nerves towards producing mufcular motion, is not to be difproved by a few rare inftances of offified, petrified, or otherwife morbid brains found in animals, which feemed tolerably healthy, and had the motion of all their mufcles; fince it is not more unreafonable to fuppofe, that the nerves may derive a fluid from a porous fpungy offified brain, than that a tree fhould fpring out of a ftone-wall; dry ftone and lime being not lefs different from moift earth, than fuch an offified brain from one in its natural ftate; nay the latter feems more capable of affording moifture to the nerves, than the former to roots of the tree *.——When the brain is wanting,

* The brain mentioned by *Duverney*, in Memoires acad. des fciences 1703, edit. 8vo, p. 318. &c. was not wholly petrified; its inferior part from which the nerves take their rife, ftill retained its medullary form. And the fame has probably been the cafe of other petrified or offified brains, tho' perhaps not fo accurately obferved.

wanting, Nature may have other ways than we can eaſily imagine, of ſupplying the nerves, and of keeping them in ſuch order, as that they may be able in ſome ſort to perform their functions.

THE immediate cauſe of muſcular contraction, which, from what has been ſaid, appears evidently to be lodged in the brain and nerves, I chuſe to diſtinguiſh by the terms of the *power* or *influence of the nerves*; and if, in compliance with cuſtom, I ſhall at any time give it the name of *animal* or *vital ſpirits*, I deſire it may be underſtood to be without any view of aſcertaining its particular nature or manner of acting; it being ſufficient for my purpoſe, that the exiſtence of ſuch a power is granted in general, though its peculiar nature and properties be unknown.

2. WHILE the nervous power is immediately neceſſary to muſcular motion, the arterial blood ſeems to act only in a ſecondary or more remote manner.

MUSCLES are immediately rendered paralytic upon tying or deſtroying the nerves diſtri-

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buted to them *. But when the arteries beſtowed upon any muſcles are tied, the action of theſe muſcles is only gradually weakened, and not totally aboliſhed till after a conſiderable time. The ingenious Dr. *Langriſh* tied up and cut aſunder both the carotid and both the crural arteries of the ſame dog, without deſtroying the motion of one muſcle †; and *Swencke* aſſures us, that, after having tied the crural artery of a dog cloſe by the groin, the animal continued to move his leg and foot for a whole day; the ſame experiment he repeated in another animal, and did not find that the muſcles of the leg became paralytic till this member was almoſt quite dead ‡. 'Tis true indeed, that, by a ligature made on the *aorta* immediately above its diviſion into the iliacs, the hinder limbs of a dog gradually loſt their motion, and became quite paralytic after two minutes ||: from which it ſeems probable, that, in the experiments of *Langriſh* and *Swencke*, the motion of the muſcles continued longer, becauſe they had ſtill ſome blood

* *Kaau* impet. faciens, N°. 288.

† Cronean lectures on muſcular motion, § 93.

‡ Hematalog. p. 8. See alſo Brunner. de pancreat. p. 188.

|| *Kaau* impet. faciens, N°. 291.

blood tranſmitted to them by lateral communicating branches, from arteries which were not tied. But, on the other hand, it is alledged, that the tying the *aorta* renders the muſcles of the legs paralytic, not ſo much by intercepting the blood, as by affecting the ſpinal marrow *.

HOWEVER, from theſe experiments, it ſeems pretty clearly to follow, that the arterial blood no otherwiſe conduces to muſcular motion, than as it ſupplies the veſſels and fibres of muſcles with fluids proper for their nouriſhment, gives them a ſuitable degree of warmth, and thus preſerves them in ſuch a ſtate, as may render them moſt fit to be acted upon by the nervous power. While therefore the life and nouriſhment of the muſcles are owing to the motion of the arterial blood through their veſſels, their power of motion and ſenſation proceeds from the nerves alone.

3. THE muſcles of live animals are conſtantly endeavouring to ſhorten or contract themſelves. Hence ſuch as have antagoniſts are always

* *Haller* prim. lin. phyſiolog. N°. 410.

always in a ſtate of tenſion; and the ſolitary muſcles, as the ſphincters, and theſe whoſe antagoniſts are weakened or deſtroyed, are always contracted, except when this natural contraction is overcome by ſome ſuperior power.

4. THE natural contraction of the muſcles [3.] is owing partly to all their veſſels being diſtended with fluids, which ſeparate and ſtretch their ſmalleſt fibres.

As a proof of this; the muſcles of animals that are in full health, and abound with proper fluids, retract themſelves much more remarkably towards each extremity when cut acroſs, than the muſcles of ſuch animals as are in a languiſhing ſtate, and exhauſted of their fluids; beſides that, ſoon after death, muſcles become flaccid, and, when cut tranſverſely, retract themſelves but little.

BUT, 2. the natural contraction of the muſcles is in a great meaſure to be aſcribed to the influence of the nerves, which is perpetually operating upon them, though in a very gentle manner: and that to this is chiefly owing the conſtant contraction of the ſphincters, and the tenſion of ſuch muſcles as are balanced by by antagonifts, the palfy affecting the fphincters as foon as their nerves are compreffed or deftroyed, and the conftant contraction of fuch mufcles whofe antagonifts are deprived of the nervous power, evidently demonftrate.

BECAUSE the heart, and other mufcles of animals, often continue to move for fome time after they are feparated from their bodies, and confequently, after all communication between them and the brain is cut off, fome have thought the contraction of the mufcles not owing fo much to the nervous influence, as to fome latent property in their fibres; with what juftice will afterwards appear *. But we may obferve in this place, that, unlefs the brain and nerves were in an efpecial manner concerned in the motion of the mufcles, it would be difficult to conceive why in animals newly killed, an irritation of the *medulla oblongata* fhould caufe more violent convulfions of the mufcles, than an irritation of the mufcles themfelves †.

5. THE natural contraction of the mufcles

[3. and 4.]

* Vid. below, Sect. x. and xii.

† *Kaau* impet. faciens, N° 530. & 333. and Sect. xiii. N° 26. of this Effay.

[3. and 4.] arifing from the conftant and equable action of the nervous power on their fibres, and of the diftending fluids on their veffels, is very gentle, and without any fuch remarkable hardnefs or fwelling of their bellies as happens in mufcles which are contracted by an effort of the will. And although the fphincters and thofe mufcles whofe antagonifts are paralytic or hindered from acting, do always remain in a ftate of contraction; yet at any time, by an effort of the will, they can be much more ftrongly contracted. 'Tis fomewhat ftrange that Dr. *Stuart* fhould have been fo far miftaken, as to affert, that the mind has no manner of power over fuch mufcles as are deftitute of antagonifts; not only that it cannot unbend them, which is allowed by all, but alfo that it cannot make them contract more ftrongly *; for every one muft be fatisfied, that though the *fphincter ani* is naturally in a conftant ftate of contraction, yet he can at pleafure make it contract more ftrongly; and though the *biceps flexor cubiti* contracts and fwells upon the arm's being bent by an external force, even in fpite

* Differtatio de motu mufculari, p. 22. 23. and 77.

ſpite of any effort of the will to the contrary, yet any one, if he pleaſes, can make it ſwell more, grow much harder, and contract itſelf with vaſtly greater force. But into what miſtakes may not a preconceived favourite theory betray the beſt of men!

FROM what has been juſt now advanced, it follows, that it is not neceſſary, in order to the mind's acting upon the muſcles, that they ſhould be ſtretched or extended beyond that length to which they would naturally reduce themſelves, if not prevented by the action of their antagoniſts.

6. As often as the influence of the nerves is determined into the muſcles ſo as to operate more powerfully on them, they are excited into ſtronger contractions which are not natural, and therefore may be called violent. This extraordinary determination of the nervous influence, may be owing either to the power of the will, or to a *ſtimulus*.

7. VOLUNTARY contraction is owing to the ſtronger action of the nervous influence upon any muſcle, excited by the power of the will.

8. A

8. A *ſtimulus*, or any thing irritating, applied to the bare muſcles of live animals, immediately excites them to contract themſelves.

THIS appears from numberleſs experiments and obſervations; and is equally true with reſpect to the muſcles of voluntary and involuntary motion.—The muſcles of a live frog, when laid bare and pricked with a needle, are ſtrongly convulſed.—A ſolution of white vitriol no ſooner touches the internal ſurface of the ſtomach, than this bowel is brought into convulſive contractions.—Smoke of tobacco or acrid clyſters injected by the *anus*, bring convulſive motions on the great guts.—Pricking the inteſtines or heart of a living animal, or applying any acrid fluid to them, remarkably increaſes their contraction *.—Many other inſtances might here be given of the effects of *ſtimuli* on the muſcles of animals; but theſe may ſuffice, as we ſhall have

* *Harvey*, ſpeaking of the *punctum ſaliens*, or heart of the chick in the ſhell, ſays, "Vidi ſæpiſſime ab acus, ſtyli, "aut digiti contactu, imo vero a calore aut frigore vehe-"mentiore admoto, aut cujuſlibet rei moleſtantis occurſu "punctum hoc, pulſuum varias permutationes, ictuſque "validiores ac frequentiores edidiſſe." De generatione animal. exercitat. 17.

have occaſion to treat of this matter more fully afterwards.

WHATEVER diſtracts the fibres of any muſcle, or ſtretches them beyond their uſual length, excites them into contraction almoſt in the ſame manner as if they had been irritated by a ſharp inſtrument, or acrid liquor. Thus the motion of the heart in pigeons newly dead, is as remarkably renewed or increaſed by drawing the ſides of the divided *thorax* aſunder, and conſequently ſtretching the great veſſels to which the heart is attached, as by pricking its fibres with a pin *. In luxations, muſcles, by being over ſtretched, are often convulſed; and the *veſica urinaria* and *inteſtinum rectum*, are not only excited into convulſive contractions by the acrimony of the urine and *fæces*, but alſo by their bulk and weight ſtretching the fibres of theſe hollow muſcles †.

9. IN proportion as the *ſtimulus* is more or leſs gentle, ſo (*cæteris paribus*) is the contraction of the muſcle to which it is applied.

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* Vid. *infra*, Sect. xii. N° 16. and 17.

† Vid. *infra*, Sect. v.

THE truth of this propoſition, like the former, is not only proved by experience, but may be deduced from reaſon alone; for if the irritation is to be conſidered as the cauſe, and the ſubſequent contraction of the muſcle as the effect; then, in proportion as the cauſe is increaſed or diminiſhed, ſo muſt be its effect.—— The motions occaſioned by ſtretching the fibres of any muſcle will be greater or leſs, as the muſcle is more or leſs ſtretched; unleſs it be ſo far extended, as quite to loſe its tone, and become paralytic. —It deſerves however to be obſerved, that the effects of different *ſtimuli* depend very much upon the peculiar conſtitution of the nerves and fibres of the muſcles to which they are applied: Thus what will prove a ſtronger *ſtimulus* to the nerves of one part, will more weakly affect thoſe of another, and *vice verſa*.

10. AN irritated muſcle does not remain in a contracted ſtate, although the ſtimulating cauſe continues to act upon it; but is alternately contracted and relaxed.

THUS the *ſtimulus* of an emetic received into the ſtomach, does not cauſe a continued

nued contraction of its mufcular coat; and an irritation of the lower extremity of the gullet, is followed by alternate convulfions of the diaphragm. The heart of a frog or eel taken out of the body, continues its alternate motions while a needle is fixed in it. When the heart or other mufcular parts of dying animals ceafe to move, heat will renew their contraction, which is regularly alternate, although the *ftimulus* be unvaried: After the auricle of a pigeon's heart had ceafed to move, I made it renew its alternate contractions, by filling the *thorax* with warm water *; and after the vibrations of a frog's heart had begun to languifh, they recovered their former vigour and quicknefs, by expofing it to the heat of a fire.

WHEN mufcles have been long in action, or too highly ftrained, the member to which they belong is obferved to be affected with a *tremor*, which often lafts for a confiderable time; *i. e.* thefe mufcles are agitated with fmall alternate contractions and relaxations, notwithftanding the ftimulating caufe continues prefent with them.

IT

* Sect. xiii. N° 15. of this Effay.

IT might perhaps be imagined *a priori*, that a muſcle ought to remain contracted as long as the *ſtimulus* or cauſe of its contraction continues to act upon it: but the fact we ſee is otherwiſe; and the reaſon of it ſhall be explained afterwards *. There are indeed a few inſtances of muſcles which are not alternately relaxed, but remain uniformly contracted as long as the ſtimulating cauſe continues to act with the ſame degree of force, ſuch as the orbicular muſcle of the *uvea*, and ſome others; the reaſon of which ſhall alſo be aſſigned below †.

II. IRRITATED muſcles are not only agitated with alternate motions while the ſtimulating cauſe continues to act upon them, but alſo for ſome time after it is removed; though they become gradually weaker, and are repeated more ſlowly. If the irritation be great, theſe alternate motions laſt longer, and follow one another more quickly; if weaker, they are repeated after longer intervals, and ſooner ceaſe; if extremely gentle, and the muſcle not

* Sect. x. near the end.

† Ibid.

not very ſenſible, perhaps only a ſingle contraction or two will enſue [9.].

SOME of the fibres of the *platyſma myoides* which were diſſected off with a tumor, have been obſerved to palpitate like the heart of a dying animal for a conſiderable time; and the ſame motions have been often obſerved in the muſcles of brute animals, when their fibres were irritated after their ſeparation from the body *.

THE heart of an animal newly killed, is excited into motion by blowing upon it, or touching it with the point of a pin; and this motion often laſts a great while, although the *ſtimulus* is not renewed. After a pigeon's heart had ceaſed to move, its vibrations were not only renewed by drawing aſunder the ſides of the divided *thorax*, but continued for a conſiderable time †.

12. THE motions of muſcles from a *ſtimulus* are quite involuntary.

EVERY one muſt be ſenſible of the truth of this aſſertion, who has ever felt any of thoſe

* Vid. Sect. xiii. N° 3.

† Sect. xiii. N° 16. & 17.

thofe fmall convulfions or pulfatory contractions, which frequently happen in different parts of the body, and which feem to be owing to fome irritation of the fibres or membranes of the mufcle contracted, either from acrid particles in the fluids irritating their fenfible nerves, or from too great a diftenfion of their tender veffels by the ftagnation of the circulating fluids. The mufcles called *acceleratores urinæ*, though at other times entirely under the power of the will, yet while the *femen* continues to be poured into the beginning of the *urethra*, are agitated with ftrong convulfive contractions, which we can neither increafe nor prevent.—When the tendinous fibres of the *obliquus inferior* of the eye, or of any other of its mufcles, are gently ftimulated with the point of a file, the alternate contractions which enfue, are altogether involuntary, and can neither be accelerated, retarded, augmented, nor diminifhed by the power of the will. The fame thing is true of the motions of the ftomach and diaphragm, excited by emetics. From which it follows that,

13. THE power of *ftimuli* in exciting the mu-

fcles

fcles of living animals into contraction, is greater than any effort of the will.

THE truth of this is ftill further confirmed, by the following obfervation. A man aged 25, who, from a palfy of twelve years continuance, had loft all power of motion in his left arm, after trying other remedies in vain, at laft had recourfe to electricity; by every fhock of which the mufcles of this arm were made to contract; and the member itfelf, which was very much withered, after having been electrified for fome weeks, became fenfibly plumper.— If then the voluntary mufcles can, even in a palfied ftate, be excited into contraction by the action of a *ftimulus* on their fibres, it follows, that when this is applied to them in a found and more fenfible ftate, any effort of the will to prevent their contraction, muft be vain and impotent.— Hence the mufcles of voluntary as well as of involuntary motion ceafe to be under the power of the will, while their fenfible fibres or membranes are irritated by a *ftimulus*.

14. THERE are therefore three kinds of contraction obfervable in the mufcles, all of them

them different from each other, *viz.* natural [4. and 5.], voluntary [7.], and involuntary, from a *ſtimulus* [8. 9. 10. 11. 12. 13.]. The firſt is very gentle, equable and continued, and is owing to the cauſes mentioned N° 4. The ſecond proceeds from the immediate power of the will, is always ſtronger, and may be continued for a longer or ſhorter time, or performed with more or leſs force, as one pleaſes. The third is ſtrong, but ſuddenly followed by a relaxation, ſeems to be a neceſſary conſequence of the action of the *ſtimulus*, upon the muſcle, and cannot be affected, either as to its force or continuance, by the power of the will.

15. THE natural contraction above explained, is what we obſerve in the ſphincters and muſcles deſtitute of antagoniſts.

16. WHILE the ſphincters of the *anus* and bladder, and thoſe muſcles whoſe antagoniſts are deſtroyed, remain always in a ſtate of contraction, and while ſuch muſcles as have antagoniſts, are kept in *equilibrio*, or without any motion, except when the will interpoſes; the

the heart, which has no proper antagoniſt, is alternately contracted and dilated, without our being able, by any effort of the will, directly to hinder or promote its motions.

17. THE contraction of the heart is therefore not only involuntary, but of a different kind from that of the ſphincters and muſcles deprived of antagoniſts; and ſeems, as to its *phænomena*, to agree with the contraction of muſcles from a *ſtimulus*. [14.]

18. THE mind may, by diſuſe, not only loſe its power of moving even the voluntary muſcles, except in a particular way, but alſo of exciting them into contraction at all. Of the former we have an example in the uniform motions of the eyes; and of the latter in the muſcles of the external ear, and of ſuch members as have remained long without motion.

SECT. II.

An examination of the opinions of ſome of the moſt conſiderable authors concerning the motion of the heart.

IT ſeems to have been the prevailing opinion among many of the antient Phyſicians, that the motion of the heart was owing to a vital principle particularly reſiding in it. *Galen* thought motion as natural to the heart, as reſt to the other muſcles.—*Des Cartes*, much leſs verſed in Phyſiology than in Mathematics, attributed the motions of this organ wholly to the ebullition of the blood dropping into its ventricles; and contended, that this fluid was not puſhed into the arteries by the muſcular contraction of the heart, but that it forced its way into them by its own exploſive power.——After *Harvey*'s doctrine of the circulation was fully eſtabliſhed, the heart was allowed to be a muſcle, and its *ſyſtole* to be analogous to the contraction of other muſcles; the vital ſpirits of the nerves were ſup-poſed

poſed to flow alternately into its fibres, either on account of valves, which by turns admitted and denied them a paſſage; or becauſe it was thought that the ſpirits could only be diſcharged by drops, and not in an equable ſtream, from the extremities of ſuch ſubtile tubes as the nerves *.

VARIOUS other *hypotheſes* were framed to explain the alternate motion of the heart; a problem not leſs difficult than curious! Theſe I ſhall paſs over in ſilence, leaving them to fall by their own abſurdity, or the arguments of others; and content myſelf with mentioning the defects of ſome of the latter ſyſtems, which, from their plauſibility, or the high character of their authors, are intitled to the greateſt regard.

THE theory of the heart's motion, which has of late years met with the moſt favourable reception, is that of the celebrated *Boerhaave*, who deduces the alternate *ſyſtole* and *diaſtole* of this muſcle, chiefly from the peculiar circumſtances of the cardiac nerves; for as much the greateſt part of theſe nerves paſſes between the auricles and large arteries of

* *Borell.* de mot. animal. lib. II. cap. 6. prop. 79.

of the heart, he concluded that they muſt be compreſſed at the end of every *ſyſtole*, when theſe cavities and veſſels are greatly diſtended with blood; whence the motion of the ſpirits being intercepted, the heart muſt be rendered paralytic; but that whenever, upon the ſubſequent contraction of the auricles and arteries, this compreſſion ceaſes, and the nerves tranſmit their fluid as formerly, the heart muſt contract anew *.

THIS *hypotheſis*, however ingenious, will appear altogether inſufficient, if we impartially attend to the following conſiderations.

1. ALL the cardiac nerves don't paſs between the auricles and arteries. Not to mention many ſmaller ones, there are two very conſiderable branches from the *par vagum* diſtributed to the muſcular ſubſtance of the heart, which neither paſs between the two auricles, nor the two arteries, nor between the auricles and arteries, and therefore cannot be liable to any alternate compreſſion from them †.

2. I

* Inſtitut. med. ſect. 409

† Vid. *Lower*. de corde, edit. Lugdun. Batav. p. 18. tab. A. lit. ll.

2. I believe it will be difficult to perſuade unbiaſſed inquirers, that the nerves (ſuppoſing they all had their courſe between the auricles and arteries) can ſuffer any ſuch compreſſion as is here required; conſidering the ſoftneſs of the parts, and the fat upon the external coat of the arteries and auricles which may well be imagined to defend them in a great meaſure from it: beſides it is ſtrange that we don't obſerve other muſcles of the body become alternately or conſtantly paralytic, whoſe nerves run contiguous to any conſiderable artery, or are compreſſed by any preternatural tumor. *Qui fit, obſecro,* ſays the accurate *Morgagni, ut nervi intercoſtalis munera ab aſſidua arteriæ carotidis pulſatione non turbentur, præſertim cum is nervus non poſſit cedere, ſed communis ipſi, & arteriæ oſſei foraminis parietibus allidatur? Qui fieri poſſet, ut in Veneta muliere, quam cum amicis diſſecuimus, cum arteriæ ſubclaviæ ſiniſtræ ſuperiores poſticique parietes in aneuriſma expanſi, duos treſve nervos ex iis qui ab inferioribus cervicis vertebris ad brachium deſcendunt, nulla prorſus interpoſita re contingerent; qui fieri, inquam, poſſet,*

poſſet, ut nulla tamen debilitas, nullus torpor in eo brachio fuerit animadverſus * ?

WHY are not all the *viſcera* in the abdomen, to which the intercoſtal nerves are diſtributed, agitated with alternate contractions anſwering to thoſe of the diaphragm, ſince theſe nerves, by paſſing through the fleſhy part of this muſcle, muſt be liable to compreſſion every time inſpiration is performed? And why do not many of the voluntary muſcles, when ſtrongly contracted, cauſe palſies or ſtupors of the parts below them, by preſſing upon the nerves to which they are contiguous?

3. It is to be remarked, that a ſlight compreſſion of a nerve is not ſufficient to render the muſcle it ſerves paralytic: thus the ulnar nerve muſt be pretty ſtrongly compreſſed againſt a hard bone, before the ring and little fingers are deprived of their power of motion; nor does this happen without being attended with a diſagreeable ſenſation in theſe parts.

4. As

* *Morgagni* adverſar. anat. vi. animad. 24.

4. As the compreffion of the ulnar nerve does not immediately bring a palfy on the mufcles of the fingers now mentioned, but after it has been continued for fome confiderable time; fo when this preffure is removed, the motion of thefe mufcles does not return immediately and all at once, but by degrees, and not till after fome time: wherefore, allowing the cardiac nerves were alternately compreffed by the auricles and arteries, yet the heart ought not to be rendered inftantly paralytic by fuch compreffion, nor fhould immediately, upon its ceafing, recover its motion. But further,

5. GRANTING the cardiac nerves fuffered as great compreffion in their paffage between the auricles and arteries to the heart, as the advocates for this opinion could defire; what will follow? an effect furely altogether different from that which is here contended for; fince the immediate confequence of fuch compreffion muft be the fqueezing forward towards the heart, the fpirits fuppofed to be contained in that portion of the nerves which is below where the compreffion is made. If then

then the nerves are hollow tubes which convey a fluid to the heart in order to its contraction, the firft and moft immediate effect of their being compreffed by the dilatation of the auricles and arteries, muft be a quicker propulfion and more copious derivation of the fpirits into its fibres; *i. e.* the heart ought to be moft ftrongly contracted, at the time its *diaftole* is obferved to begin. And in fact we find, that a ligature made on the *par vagum* is fo far from rendering the heart immediately paralytic, and preventing its contraction, that it caufes ftrong convulfive motions or palpitations of this mufcle.

6. THIS fuppofed alternate compreffion of the cardiac nerves by no means accounts for the motion of the auricles, whofe *fyftole* happens when their nerves ought to be compreffed, and confequently when the derivation of the fpirits into them fhould be intercepted. If it be faid, that the auricles are ready to contract when the *fyftole* of the ventricles begins, but that, being weaker mufcles, they muft wait till this is over *? I anfwer, that then, during

* *Bellin.* de motu cord. prop. 2. *Keil*'s anatomy cap. 3. fect. iv.

during the contraction of the ventricles, the auricles ſhould become pale and tenſe; ſince, when the influence of the nerves is copiouſly determined into any muſcle, it becomes equally hard, whether it be allowed to contract, and its extremities to approach each other, or not. But further, as an influx of ſpirits into the fibres of any muſcle, muſt be immediately followed by an endeavour in them to contract, ſo if this be prevented, as ſoon as the ſpirits are again intercepted, their influence to produce any contraction will ceaſe. This is evidently the caſe with ſuch muſcles as are under the power of the will, where any ſudden but not continued effort, if it is not allowed that inſtant to take effect, immediately vaniſhes; nor is it to be doubted, that the ſame thing muſt happen to the auricles of the heart. But, be this as it will, it is evident, that the alternate motions of the auricles cannot be owing to any compreſſion of their nerves; ſince it is acknowledged, by the beſt Anatomiſts, that the courſe of theſe nerves is ſuch, as cannot ſubject them to any alternate preſſure *; which

E is

* *Lower* de corde, p. 18. tab. A. lit.II.

is alſo true of all the cardiac nerves in thoſe a-nimals whoſe hearts have only one ventricle.

7. IN dying animals, the right ventricle continues to contract after the left one has ceaſed, and the right auricle performs its motions for ſome time after its ventricle *. Theſe alternate motions of the right ventricle and auricle cannot, however, poſſibly ariſe from any compreſſion of their nerves; ſince, in the firſt caſe, neither the *aorta* nor left auricle are dilated with blood at the end of the *ſyſtole* of the right ventricle; and in the latter, the pulmonary artery alſo remains empty. Further, the hearts of many animals, after being ſeparated from their bodies, continue for ſome time to be alternately contracted and relaxed with great regularity, when there can be no alternate compreſſion to intercept the nervous influence at the end of every *ſyſtole*.

8. LASTLY, It may well be looked upon as a defect of this theory of the heart's motion, that it does not any way aſſiſt us in explaining the ſpontaneous action of other organs in the body,

* *Harvey* de mot. cord. et ſang. cap. 4.

body, whofe nerves cannot with any colour of reafon be fuppofed liable to an alternate compreffion.

SOME have imagined, that, as the intercoftal nerves pafs through the fame holes of the *cranium* with the carotid arteries, they muft therefore fuffer fuch compreffion from the *diaftole* of thefe arteries, as fhall render the heart paralytic at the end of every *fyftole*. In anfwer to which, it may be fufficient to afk, why the other mufcles and *vifcera* which receive nerves from the intercoftals, do not exactly correfpond with the heart in their motions; or why the auricles and ventricles of the heart are not contracted and relaxed at the fame time?

THE learned *De Gorter*, fully aware that the fuppofed alternate compreffion of the cardiac nerves afforded no fatisfactory account of the motions of the heart, fuppofes that vital or involuntary motion is owing to one and the fame caufe, both in the heart and other organs of the body: this caufe he imagines to be fuch a ftructure of the involuntary mufcles, that, when their fibres are dilated by the fpirits, the fmall nerves which pafs between them are compreffed;

compreſſed; ſo that no ſooner are the fibres inflated, than the ſpirits are intercepted, and conſequently the muſcle begins to be relaxed; but this relaxation of the muſcular fibres, freeing the nerves from compreſſion, the ſpirits are tranſmitted as formerly, and the muſcle is contracted anew. And in this manner he fancies that, as long as life remains, the muſcles of involuntary motion muſt be alternately contracted and relaxed *. But,

1. Not to inſiſt, that this ſtructure of the vital organs is entirely hypothetical, and unſupported by any experiment, or microſcopical obſervation; it may be aſked, why all the vital organs are not contracted, and relaxed at the ſame inſtant; or at leaſt why the motions of ſome are renewed after ſhorter, of others after longer intervals?

2. If ſuch were the ſtructure of the muſcles of ſpontaneous motion, that their contraction muſt be immediately followed by their relaxation, how comes it, that, by an effort of the will, we can keep the diaphragm in its

* *Gorter* de motu vitali, ſect. 39.

its ſtrongeſt ſtate of contraction, as long as we pleaſe? and why does not the relaxation of this muſcle neceſſarily follow its contraction, if its alternate motions depend on a general ſtructure, common to it with the heart and inteſtines?

3. IN caſes where the lungs are obſtructed and reſpiration is rendered difficult, we find, that, even in time of ſleep, other muſcles beſides the common inſpiratory ones are brought into alternate contractions, in order to raiſe the ribs, and enlarge the cavity of the *thorax*; whence it appears, that muſcles of the voluntary kind may, on certain occaſions, be employed in the performance of the vital motions; and that there is nothing therefore in the ſtructure of theſe muſcles peculiarly fitting them for ſuch alternate motions.

4. FURTHER, the pupil (whoſe motions are as involuntary, and as little perceived by us as thoſe of the heart) is not immediately relaxed, after having been contracted by the admiſſion of light into the eye, but it remains

remains in the ſame degree of contraction, as long as the ſame quantity of light is tranſmitted to the *retina*; which could not happen, if any ſuch ſtructure really obtained in the muſcles of the *uvea*, as *De Gorter* ſuppoſes in the muſcles of involuntary motion. We reject therefore his theory, not only as a mere *hypotheſis* without any foundation, but as wholly inſufficient to explain the various *phænomena* of ſpontaneous motion.

SOME ingenious Phyſiologiſts have imagined the contraction of the heart to be owing to the elaſtic power of its fibres, which, after they have been ſtretched by the returning venous blood dilating the auricles and ventricles, reſile, like a bent bow, with a conſiderable force. But the force with which a ſpring recoils, is ever proportional to the power which bent it; wherefore, ſince the ſides of the heart contract with a much greater power than that with which they were forced aſunder, the *ſyſtole* of this muſcle cannot ariſe merely from the elaſticity of its fibres, but muſt be owing to ſome additional *impetus* at that time communicated to them.

THUS

THUS much being premifed, in order to fhew the weaknefs and infufficiency of fome of the moft plaufible theories, that have hitherto appeared concerning the heart's motion; we fhall endeavour, in the following Section, to give fuch an account of its *fyftole*, as it is hoped will appear no lefs fupported by reafon and analogy, than founded in experiment and obfervation, as well as ftrongly confirmed from its fully anfwering all the *phænomena*.

SECT. III.

Of the fyftole of the heart.

BEFORE we inquire into the caufes of the alternate motions of the heart, it will be proper briefly to mention and defcribe the three different ftates of that mufcle, *viz.* its contraction, relaxation, and dilatation; of which the firft and laft may be faid to be violent, and the fecond only natural to the heart. During its *fyftole*, the heart is is contracted in all its dimenſions *, and its ſubſtance becomes remarkably hard: This ſtate, which ſcarcely laſts one third of the time interveening between each contraction, is followed by a general relaxation of the heart, by which this muſcle becomes ſoft and flabby, and is rendered ſomewhat longer. *Bartholine* calls this the *periſyſtole* of the heart †. It continues a much ſhorter time than the *ſyſtole*, the ventricles being inſtantly, after their relaxation, filled with the returning venous blood, and diſtended much beyond their natural capacity, or that which they are obſerved to have in animals newly dead; when the fibres of the heart are neither contracted nor dilated by any adventitious force, but left entirely to themſelves. The *diaſtole* of

* It has been warmly diſputed, whether the heart is ſhortened or elongated in the time of its *ſyſtole*. But, after carefully inſpecting the hearts of frogs and eels, both in the body and when ſeparated from it, I can't help (notwithſtanding the authority of *Winſlow* on the other ſide) agreeing with Dr. *Hunauld* and others, who affirm, that the heart is diminiſhed in length, as well as in breadth, when it begins to contract. Vid. hiſtoire acad. des ſciences 1731, edit. 8vo. p. 33. &c.

† Anatom. p. 37. 377. 378.

of the heart being thus fully completed, its *ſyſtole* immediately enſues.

SUPPOSING the heart now in its full *diaſtole*; let us inquire what change has happened to it ſince the end of the preceeding *ſyſtole*, which may be ſuppoſed capable of bringing it into a new contraction.—We have already ſhewn, that the nerves of the heart are not, at this time, freed from any compreſſion which a little before could have rendered it paralytic. And if one ſhould ſuppoſe ſome general ſtructure in the *cerebellum*, which determines the vital ſpirits through its nerves alternately, and as it were in ſucceeding waves, yet this would not account for the motions of the heart; ſince the alternate contractions of this muſcle continue for ſome time after all communication between it and the *cerebellum* has been cut off. Further, as the contractions of ſome of the organs of vital motion are performed after ſhorter, of others after longer intervals, we muſt neceſſarily ſuppoſe, at the origin of the nerves belonging to each organ, a different cauſe alternately determining the ſpirits into it. But of ſuch *hypotheſes*, without either proof or probability, there can be no end.

F DURING

DURING the *diaſtole* of the heart, all its coronary veſſels, which were in a great meaſure emptied by the preceeding *ſyſtole*, are filled with blood violently puſhed into them by the contraction of the *aorta*: but as the arterial blood is not immediately neceſſary to the contraction of a muſcle *, and ſeems only to contribute to it in a ſecondary way, this alone will be thought far from being ſufficient to account for the ſucceeding *ſyſtole* of the heart. 'Tis true indeed that warm water, injected into the arteries of an animal newly dead, excites the muſcles, to which theſe arteries are diſtributed, into contraction. But this contraction is ſo weak and ſo unlike that of the heart, that I perſuade myſelf, hardly any one, will, from this experiment alone, imagine the *ſyſtole* of the heart, to be owing to the arterial blood puſhed forcibly through all its veſſels, in the time of its *diaſtole*; eſpecially ſince we don't obſerve the leaſt degree of an alternate motion in the ſphincters of the *anus* and bladder, from the blood being more ſtrongly impelled through their veſſels, upon every contraction of the heart, than during its *diaſtole*. This matter however is put entirely beyond diſpute, by

* Sect. I. N° 3. of this Eſſay.

by the heart's continuing to repeat its contractions, not only after the coronary arteries, and pulmonary veins are tied, but after it is ſeparated from the body.——The blood then with which the coronary veſſels of the heart are filled during its *diaſtole*, being as inſufficient as is the ſuppoſed compreſſion of the cardiac nerves, to account for its ſucceeding *ſyſtole*; it remains, that we next inquire, what influence the returning venous blood, with which the ventricles of the heart are diſtended during its *diaſtole*, may have in producing its ſubſequent *ſyſtole*. And is it not reaſonable to ſuppoſe, that this fluid returning by the *cavæ* and pulmonary veins, and ruſhing into the cavities of the heart, with a conſiderable force, muſt by diſtracting its fibres, as well as by its motion and attrition upon the ſcabrous ſurface and fleſhy pillars of the ventricles, ſo ſtimulate and affect the ſenſible nerves and fibres of the heart, as to bring it immediately into contraction *.

THOUGH ſome authors have long ſince aſcribed the alternate motion of the heart, to the irritation of the blood received by turns into

* Sect. I. N° 8. 9. &c.

into its cavities *; yet as this caufe has been much overlooked by many later writers, and not rightly underftood by fome others, we fhall endeavour to confirm, and illuftrate the manner of its influence, by a variety of arguments.

WHILE fome authors have afcribed the contraction of the heart folely to the blood, confidered as a ftimulating fluid, which irritates the internal furface of its ventricles; others have been unwilling to allow, that the blood acts in any other fenfe as a *ftimulus*, upon the heart, than as by its weight and impulfive force it ftretches and diftracts the fibres compofing its ventricles †. But the increafed motion of the blood, from the contagion of the fmall pox, meafles, *&c.* and after eating or drinking any thing acrid, as well as the power which acrid or ftimulating things have in renewing

* Certumque eft, veficulam dictam, ut et cordis auriculam poftea, (unde pulfatio primum incipit) a diftendente fanguine, ad conftrictionis motum irritari. *Harvey* de general. animal. exercit. 51.

Fibræ cordis virtute micationis vitalis fanguinis in ejus ventriculis contenti, per vices irritatae, excitantur ad fe contrahendas et pulfationem faciunt, mox irritatione remiffà relaxantur. *Gliffon* de ventricul. et inteftin. cap. 7. p. 170.

† *Senac.* traite du COEUR lib. 2. cap. 4. fect. 4.

newing the heart's motion after it is ſeparated from the body, are circumſtances which ſhew, that the contraction of the heart is not ſolely owing to its fibres being diſtracted by the moment of the blood, but partly to the irritation communicated to its internal ſurface by the particles of this fluid. And the remarkable diminution of the periſtaltic motion of the guts, when the cyſtic byle is hindered from flowing into them, makes it evident that the ſtretching of the fibres of the inteſtines, by the contained air and aliment, is not the ſole cauſe of their ſucceeding contraction. On the other hand, the increaſe of the heart's motion from exerciſe, or from any other cauſe, whence the blood is returned in greater quantity, and with more force, its diminution by blood-letting, the *phænomena* of the motion of the ſtomach, and of the expulſion of the urine and *fæces* *; all theſe particulars, I ſay, prove, that even the diſtenſion of hollow muſcles has, a remarkable influence towards exciting them into action †.—And that the blood is extremely well fitted, to act upon the heart as a *ſtimulus*, in both theſe ways, will appear, if

* See ſect. 5. below.

† See ſect. 1. N° 8. above.

if we confider its compofition, heat, inteftine motion, what qualities it may probably receive from the air, and the force with which it rufhes into the cavities of the heart.

1. As to its compofition. The blood confifts of the fame principles with our aliments, and confequently abounds with falts and oils. The falts of the blood are partly of the fixed neutral kind, and partly rendered as it were femivolatile by the heat and motion to which they are fubjected; both are extremely apt to irritate very fenfible nervous parts; for we know that any kind of falt applied to the eye gives remarkable uneafinefs.—The oils in the blood are either thofe of animal fubftances, the expreffed oil of vegetables, their attenuated oil by fermentation, commonly called *alchol*, or laftly the acrid oil of aromaticks. The two firft are no way acrid or fit to act as a *ftimulus*, unlefs they have been highly attenuated by long expofure to heat, or by attrition; the two latter, *viz.* ardent fpirits and the oil of aromatics are very apt to irritate the tender fibres

fibres of live animals. Hence it is that ſpirituous liquors largely drunk and hot ſpices too freely uſed, quickly raiſe the pulſe, and make the heart as it were redouble its contractions. Hence eating animal food or drinking ſtrong liquors, which abound with ſaline and acrid particles, remarkably quickens the circulation, and increaſes the heat of the body, while a dinner of milk, mild herbs, or cooling fruits, makes little alteration in the pulſe. The blood therefore as it is impregnated with ſalts and attenuated acrid oils, muſt be very well fitted to give a gentle *ſtimulus* to thoſe ſenſible nerves and membranes which line the auricles and ventricles of the heart.

IF it be objected, that the blood diſcovers no acrimony to the tongue, nor ſenſibly irritates the eye; it may be ſufficient to anſwer, that, though this fluid be remarkably ſalt to the taſte, yet I don't aſcribe the whole ſtimulating power of the blood to its acrid particles alone, but to theſe in conjunction with ſeveral other qualities and circumſtances juſt now to be conſidered. But further, although the blood did not diſcover the leaſt

degree

degree of acrimony when applied to the nerves of the tongue (which however is not the cafe), yet it might be fitted to act as a very powerful *ftimulus* upon other nerves of the body, differing from thefe in their conftitution and greater fenfibility.—Many poifons, efpecially of the antimonial kind, are void of almoft any degree of acrimony, as far as we can judge by the tafte; yet they fo ftrongly and difagreeably affect the nerves of the ftomach, as to bring this bowel, together with the neighbouring parts, into violent convulfions, and produce a train of the moft direful fymptoms; by which all the functions of the animal frame are greatly difordered, interrupted or finally ftopt. The roots of the *cicuta aquatica* are fweetifh, but neither acrid nor difagreeable; and cataplafms of them applied to inflammed or ulcerated parts, occafion no bad fymptoms *; yet, when taken into the ftomach, they foon throw the whole body into the moft terrible convulfions, which generally end in death.——The berries of the *rhus myrtifolia monfpeliaca*, though there be nothing in their tafte or fmell to render them fu-

fpected,

* *Wepferi* hiftoria cicut. aquat. p. 84.

ſpected, yet act ſo powerfully upon the nerves of the ſtomach, when ſwallowed, that, in half an hour after, they bring on an epilepſy, whoſe repeated attacks kill the patient in leſs than 24 hours *.—Viper's poiſon affects neither the nerves of the tongue nor ſtomach with any diſagreeable ſenſation; yet the ſmalleſt drop of it received by a wound into the blood, ſeems not only to act as a ferment upon this fluid, but, by its ſtimulating quality, to affect moſt violently the whole nervous and vaſcular ſyſtem.——The putrid excrement which gives no diſturbance to the *colon* or *rectum*, till by its quantity it overſtretches their fibres, would create ſickneſs and vomiting in the ſtomach.—Urine which ſcarce ſtimulates the bladder till it begins to diſtend it too much, when injected into the great guts, proves a good purgative clyſter.—Warm blood received into the ſtomach by a rupture of any of its veſſels, proves very ungrateful to its nerves, but no way offends the nerves of the heart or arterial ſyſtem.—Every one knows what remarkable changes happen in the body about the time of puberty: theſe changes are generally

* Memoires acad. ſciences 1739. edit. 8vo, p. 627.

nerally and not without reafon afcribed to the *femen*, which now begins to be duly prepared: they do not however feem to be owing fo much to the reception of the finer parts of this fluid into the blood, as to its peculiar action upon the nerves of the *teftes* and *veficulæ feminales*; yet the *femen*, when applied to the nerves of other parts of the body, neither fenfibly titillates them, nor produces any remarkable effects.

THUS it appears from a variety of examples, that the nerves of different organs in the fame animals are fo conftituted, as to be very differently affected even by the fame things: So that we cannot abfolutely take upon ourfelves to judge, by our tafte or fmell, how far any liquor may or may not be adapted to act as a *ftimulus* upon the nerves of a particular organ; and, confequently, that although the blood fcarce acts as a *ftimulus* upon the eyes and tongue, it may neverthelefs give fuch a gentle irritation to the nervous *papillæ* of the heart, as may be fufficient to excite this mufcle into contraction: which will further appear, if we confider the heat of this fluid.

2. HEAT

2. HEAT ſeems to be no more than a violent vibration or motion in the ſmaller parts of bodies; therefore the blood, as it is a warm fluid, muſt have its particles agitated by perpetual vibrations, which muſt be communicated to the nervous *papillæ* on the ſides of the heart, and excite in them correſponding oſcillations: beſides, as the blood abounds with oily and ſulphureous particles, it muſt, by its motion and attrition againſt the veſſels, acquire vibrations ſtill more remarkable.

THE effect which heat has in exciting the muſcular fibres of animals into contractions, and thus promoting the circulation of the fluids, is too well known, to admit of any doubt. By different degrees, of warmth or cold, inſects and the chick in the ſhell, may at pleaſure be made more or leſs lively, conſigned to death or reſtored to life *.

3. THE particles of the blood, beſides the oſcillations they are put into by heat, are agitated by a motion of another kind.
As

* Vid. *Harvey* de motu cordis, cap. 17. de generatione animal. exercitat. 17. & *Reaumur*. hiſtoire des inſectes. tom. 2. memoire 1.

As vegetables make up the chief part of our aliment, the chyle is generally acefcent; yet the blood and other perfectly elaborated animal juices are of a contrary nature, ever tending to putrefaction, and when heated by the fire, afford a volatile inftead of a fixed alcaline falt: fuch a change in the nature of the chyle, could not be produced without an inteftine motion of its particles; which we find to be the grand inftrument of nature in changing the texture and difpofitions of all vegetable and animal bodies *. This inteftine motion added to the vibrations of the particles of the blood from heat, will ftill better qualify it for acting as a *ftimulus* upon the extremely fenfible and tender nerves of the heart.

4. SIR

* It is as unreafonable to deny any degree of inteftine motion in the fluids of animals, becaufe this is not perceived by our fenfes, as it would be to argue againft their being poffeffed of any degree of heat, becaufe we are not fenfible of their warmth when moving through our veffels. A fluid, fuch as the blood, compofed of various and difagreeing particles, whofe attractive and repulfive powers are very different, and upon which the fame degrees of heat and friction muft have different effects, cannot fail, by its rapid motion, to have its globules and their conftituent parts agitated with brifk vibrations.

4. SIR *Iſaac Newton* imagined, that the beating of the heart was continued by an acid vapour in the air, received into the blood by means of reſpiration *. Even the hints and conjectures of ſo great a man deſerve uncommon regard; and, as he was no leſs remarkable for his caution in advancing *hypotheſes*, than for his deep knowledge of nature, we may readily believe he did not propoſe this opinion to the world without ſome good reaſons, although, as they were not quite ſatisfying to himſelf, he has ſuppreſſed them, and left the further clearing of this matter to poſterity.

WHAT it is in the air which is ſo neceſſary to the continuance of animal life, I ſhall not pretend to ſay; but it ſeems highly probable, that the death of animals in a confined ſtagnant air, is neither wholly owing to its want of elaſticity, its too great heat, or moiſture: and if this be ſo, reſpiration does not ceaſe in ſuch air, on account of its abſolute unfitneſs to dilate the veſicles of the lungs, but becauſe the animal ſoon becomes unable to

* Optics, edit. 8vo, p. 355.

to move duly the mufcles, whofe action is required for enlarging the *thorax:* This feems to happen only from a failure or want of the influence of the brain and nerves, and this laft from a more languid propulfion of the fluids by the heart. If then we allow the air to be impregnated with an extremely active vivifying fpirit, which being mixed with the blood in the lungs, befides its other effects, acts powerfully as a *ftimulus* upon the auricles and ventricles of the heart; 'tis eafy to fee, that, as foon as this fpirit is confumed in a confined air, the heart's motion muft flag, and confequently all the vital and animal functions become more and more languid, till death at laft enfues. But this only by way of conjecture.

5. A body, whether fluid or folid, of a nature which qualifies it to act as a *ftimulus*, will excite fo much the ftronger irritations, by how much the greater force it is applied with, to the fenfible part; fince its acute, acrid, or otherwife active particles, muft by this means ftrike more ftrongly againft the extremities of the tender nerves. Hence the blood,

blood, which we have ſhewn to be well fitted for gently irritating the ſenſible membranes of the cavities of the heart, muſt, by its being puſhed into them with a conſiderable force, act with ſo much the greater energy. But further, as by the blood ruſhing impetuouſly into the auricles and ventricles of the heart, theſe cavities are dilated beyond their natural capacity, ſo the diſtraction which their fibres muſt ſuffer on this occaſion, cannot fail to produce ſome ſort of irritation, and thus prove a *ſtimulus* to their ſubſequent contraction *. Agreeable to this, *Wepfer* has obſerved, that after one vermicular contraction of the ſtomach is performed, another does not ſucceed, till this bowel begins to be remarkably ſwelled in its middle part by the rarified air contained in it, or generated by the diſſolving aliments: But this diſtenſion of the ſtomach no ſooner

* It here deſerves particular notice, that while the ventricles of the heart are extended much beyond their natural ſize, by the force of the refluent venous blood, the tendineo-carnous chords which often run from one ſide of the ventricles to the other †, muſt be conſiderably ſtretched and elongated; which cannot fail to produce an irritation in theſe parts, and conſequently to contribute towards exciting the ſucceeding *ſyſtole* of the heart.

† Vid. *Cowper*'s myotom. reformat. tab. 39. let. *h*. & tab. 40. let. *f*.

fooner happens, than a new contraction of it begins, which proceeding on towards the *pylorus*, expels part of this air, and of the digefted aliment, into the *duodenum*; after which this orifice collapfes, and a new intumefcence of the ftomach quickly enfues *. Hence it appears how great an analogy there is, between the caufes of the alternate contraction of the heart and ftomach; both being excited, partly by the diftraction of their fibres by a diftending caufe, and partly by the irritation of their fenfible nerves by a ftimulating one. In like manner the contraction of the bladder of urine, and the defire of evacuating this fluid, is not only owing to its acrimony ftimulating the nerves of the bladder, but alfo to its quantity overftretching the coats, and diftracting the fibres of this organ.

UPON the whole, from what has been faid, it may appear, that as the violent motion of the fluids, and uncommon contractions of the heart and arteries in the fmall pox, meafles and other feverifh difeafes, is in a great meafure owing to fome foreign particles mixed with the blood, whence it ftimulates the folids more

* *Wepfer* de cicut. aquat. p. 177.

more ſtrongly; ſo the ordinary and leſs violent motion of the heart, is owing to the gentler *ſtimulus* of the fluids in a ſound ſtate.

FURTHER, that the alternate contractions of the heart are excited in the manner above explained, a variety of other arguments concur to ſhew.

1. THE quickneſs and ſtrength of the heart's motion are, *cæteris paribus*, always proportional to the force with which the venous blood returns to its ventricles by the *venæ cavæ* and pulmonary veins: hence exerciſe of any kind accelerates the motion of the heart, and increaſes the force with which it contracts: a fit of laughter will quicken the pulſe above twenty beats in a minute *: upon an intermiſſion of reſpiration, the pulſe becomes ſmaller, but recovers its former ſtrength immediately after repeating it again †.

2. IT appears from Dr. *Hales*'s experiments, that the blood returns to the heart by the two *venæ cavæ* with nearly $\frac{1}{10}$ of the force with

H which

* *Robinſon* on the animal œconomy, prop. 21.

† Ibid. prop. 24.

which it was puſhed into the *aorta*; and as the left ventricle of the heart is at leaſt three times ſtronger than the right, the returning venous blood will endeavour to dilate the right ventricle with a force nearly equal to $\frac{1}{3}$ of the power with which it uſually contracts in the time of its *ſyſtole*; and this even without taking into the computation the additional *impetus* communicated to the blood by the contraction of the right auricle: but, by violent ſtraining, the force of the blood in the veins is often rendered above four times greater than ordinary *, and conſequently ſuperior to that with which the right ventricle contracts when the body is at reſt: wherefore, if we do not allow the ſtrength with which the ventricles of the heart contract, to depend in a great meaſure upon the action of the venous blood upon them, it will be difficult to conceive how the right ventricle ſhould be able to overcome the force with which the blood ruſhes into it, upon any ſtraining or violent exerciſe, and in horſes running at full ſpeed. Moreover, it is evident, from the ſtate of the pulſe in peripneumonies, both before and after blooding, as

* *Hales*'s ſtatical eſſays, vol. 2. p. 14. & 161.

as alſo from the remarkable increaſe of the force of the blood in the *aorta* and its branches after deep ſighing *, that the ſtrength with which the left ventricle of the heart contracts, is immediately increaſed or diminiſhed, according as the blood is ſqueezed with more or leſs force through the pulmonary veins into its cavity.

3. IT is very obſervable, that the auricles and ventricles of the heart are no ſooner filled with the refluent blood, than they immediately begin to contract; which ſtrongly indicates the influx of this fluid to be the cauſe exciting their ſubſequent contraction. In dying animals, thoſe cavities of the heart ceaſe from motion firſt, which are firſt deprived of the returning venous blood: hence in live diſſections, a little before death, when the blood is not puſhed by the force of the right ventricle beyond the capillary arteries of the lungs, the left ventricle being deprived of its *ſtimulus*, is obſerved firſt of all to give over motion, and ſoon after it the left auricle: but the right ventricle, being ſtill ſupplied with blood

* *Hales's* ſtatical Eſſays, vol. 2. p. 6. & 16.

blood from the two *cavæ*, continues its motions for ſome conſiderable time; and, even after it ſeems to die, the alternate motions of the right auricle are kept up by the ſmall ſtream of blood which flows into it from the *cava*. This however is not ſufficient to actuate the right ventricle, till after ſeveral contractions of the auricle, more blood being collected in it, it begins anew to tremble, and, as it were with ſome ſtruggle and difficulty, ſlowly performs another contraction. Laſtly, after both the right ventricle and auricle have wholly loſt their motion, the right *ſinus venoſus* continues for ſome little time gently to palpitate, and its tremulous motion, when about to ceaſe, may, like that of the heart, be renewed by heat, or any thing elſe that is capable to irritate its fibres *. Dr. *Langriſh* tells us, that in a dog whoſe *thorax* he opened, and whoſe lungs he kept playing with a pair of bellows, the auricles begun the motion, and the *ſyſtole* of the ventricles always inſtantly followed that of the auricles. When he deſiſted from blowing freſh air into the

* *Harvey* de motu cord. cap. 4. & *Walæus* de motu chyli & ſang. epiſt. 1. ad fin. *Bartholin.* anat. p. 783. & 784.

the lungs, the heart lay ftill, but recovered its motion when the lungs were ftrongly diftended anew. In this action he never could difcern that the ventricles began the motion, but the auricles always contracted firft, and immediately after them the ventricles; tho' at laft he obferved feveral contractions of the auricles which were not fucceeded by any motion in the ventricles *. From what has been faid it plainly appears, why the motions of the auricles and ventricles are not fynchronous, *viz.* becaufe they receive into their cavities at different times the returning blood, which, as a *ftimulus*, excites them into contraction.

4. PEOPLE frequently recover from a *leipothymia* and *fyncope* as it were fpontaneoufly, and without any external affiftance, becaufe the chyle and lymph continue, by means of the periftaltic motion of the guts, to be forwarded to the fubclavian vein and *cava*; at the fame time that the venous blood, partly by the contractile power of the greater arteries, and the ofcillatory motions of the *vafa* *minima*

* Cronean lectures, p. 61. 62.

minima, and partly by the conſtriction of the cutaneous veſſels from cold, is tranſmitted into the branches of the two *venæ cavæ*, and forwarded to the right auricle of the heart, which it firſt ſtimulates into contraction; and immediately afterwards ſets the right ventricle alſo a going. Nay many people who have been dead in appearance, have been reſtored to life by blowing air into their lungs, and thus communicating a new motion to the ſtagnating blood in the *cava inferior* and pulmonary veins. Of this we have a remarkable inſtance recorded in the *Edinburgh Medical Eſſays*, *vol.* 5. *art.* 55.; where we are told, that a man was brought to life, by diſtending his lungs with air, and putting the blood in the pulmonary veins and left *ſinus venoſus* into motion, after his heart had remained at reſt for at leaſt half an hour *: and that it was in this way that the blowing into his lungs recovered him, is evident; ſince no ſooner were the lungs thus dilated, than immediately the heart begun to move, and ſix or ſeven very quick

* The inflation of the lungs, by preſſing the *vena cava inferior*, muſt alſo have communicated a motion to the blood in the right *ſinus venoſus*.

quick beats were felt below his left breaſt; after this, the lungs continuing of themſelves to play, a pulſe was ſoon perceived in the arteries. Hence it appears, that, in order to ſet the heart a going, and reſtore life in animals which are not irrecoverably dead, it is only neceſſary to communicate ſuch a motion to the blood in the *cava* or pulmonary veins, as may enable it a little to dilate the auricles and ventricles of this muſcle.

5. THE heart after it has ceaſed to move, is not only ſet a going again by determining the venous blood into its cavities, but, in animals which have been for ſome time dead, its motion may be renewed by blowing air through the thoracic duct or *vena cava* into its right auricle and ventricle, or through the *aorta* into its left ventricle. Thus, while *Peyerus* was endeavouring to diſtend the *receptaculum chyli* and thoracic duct with air, the heart was not only rendered turgid by this fluid which had made its way into it, but immediately began to vibrate, and continued its motions for ſeveral hours *. The ſame

* *Peyeri* parerg 7. p. 199. and *Wepfer* de cicut. aquat. p. 89.

ſame experiment was afterwards repeated by *Brunnerus* on a dog with equal ſucceſs *. And *Harderus* relates that in a ſtork, which had beeen killed by poiſon, he made the heart renew its motion, by blowing air into the *aorta* †. Since, in theſe experiments, and in others which might be recited from other authors, the heart, which had lain quiet, and without any motion for a conſiderable time after death, was readily excited into contraction by the air ſtretching its fibres, and probably ſtimulating its nervous *papillæ*; and ſince the heart, as we are told by Dr. *Harvey*, may, after it has ceaſed to move in an animal newly killed, be again put in motion, by applying to it a little warm *ſaliva* ‡; we need not be at a loſs to account for the alternate motions of this muſcle in live animals,

* Experiment circa pancreas p. 21.

† Additamen ad *Peyeri* parerg. 7. p. 201

‡ In columba certe experimento facto, poſtquam cor deſierat omnino moveri, et nunc etiam auriclæ motum reliquerant per aliquid ſpatium, digitum ſaliva madefactum, et calidum cordi ſuperimpoſitum detinui: hoc fomento quaſi vires et vitam poſtliminio recuperaſſet, cor, et ejus auriculae, moveri et ſeſe contrahere atque laxare, et quaſi ab orco revocari videbantur. *Harv.* de motu. cord. cap. 4.

mals, where a warm active fluid is alternately puſhed into its cavities.

THERE is only one objection, which at preſent occurs, to the above account of the heart's contraction, *viz.* that its alternate motions may be owing to ſome peculiar power reſulting from the ſtructure and conſtitution of its fibres, and that by virtue of this, it is enabled to continue theſe motions long after the blood has ceaſed to act upon it. In anſwer to which, it is ſufficient to obſerve, that in dead animals in whom the motion of the blood is ſtopt, the heart remains at reſt till its vibrations are renewed by expoſing it to the open air, or by otherwiſe ſtimulating it *: whatever power therefore may be ſuppoſed to reſide in the fibres of the heart, a *ſtimulus* of one kind or other is always neceſſary to excite it into action. In living animals this *ſtimulus* is, as we have ſhewn, no other than the returning venous blood: in animals newly dead, warm water, air, and a variety of other *ſtimuli* excite into action this power which ſeems to reſide in the fibres of the heart; which, whether it is

I owing

* Sect. xiii. below.

owing merely to their mechanical ſtructure, to the animal ſpirits lodged in them, or to ſome other cauſe, will more fully appear in the ſequel of this Eſſay.

SECT. IV.

Of the relaxation and diaſtole *of the heart.*

HAVING ſhewn that the *ſyſtole* of the heart is owing to the returning venous blood acting upon its auricles and ventricles as a *ſtimulus*, it remains that we next inquire in what manner its relaxation and *diaſtole* are brought about.

THE ventricles of the heart having, by their contraction, expelled their contained blood into the *aorta* and pulmonary arteries, are immediately after relaxed; their fibres loſing that tenſion and firmneſs which they had the moment before. This relaxation of the heart muſt neceſſarily follow its *ſyſtole*, ſince the muſcles of living animals, after being excited into contraction by any *ſtimulus* applied to them, are quickly relaxed again *.

What

* Sect. i. N° 10. & 11. above.

What may be the reaſon of this *phænomenon* we ſhall not now inquire, but refer it to be afterwards diſcuſſed in a more proper place *; it being ſufficient for our preſent purpoſe that the thing is allowed to be true. Only we may obſerve with reſpect to the heart, that as the ſtimulating cauſe (*viz.* the blood) is, during the *ſyſtole*, expelled out of its cavities, it is reaſonable to think that the fibres of this muſcle which were in a violent ſtate, will of themſelves endeavour to return to their moſt natural condition †.

THE ventricles of the heart, in conſequence of the relaxation which happens to their fibres after their *ſyſtole* is finiſhed, give no reſiſtance to any cauſe that begins to dilate them,

* Sect. x. below.

† Dr. *Langriſh* is of opinion, that when the heart is in *ſyſtole*, ſome of its fibres are always ſtretched out beyond their natural tone; ſo that by their elaſtic reſtitutive property, they act in a certain degree as antagoniſts to the contracted fibres, and ſo contribute to unbend them at the end of every *ſyſtole*. *Cronean lectures*, p. 55. But whatever may be in this, it does not appear that the heart is, by any thing in its make, better fitted to relax itſelf, than the other muſcles; ſince theſe, or even a few of their fibres, when ſeparated from the body, and ſo deprived of their antagoniſts, are obſerved to be alternately contracted and relaxed like the heart. Vid. Sect. xiii. below.

them, but will not without violence allow their ſides to be removed from each other, ſo much as happens during their *diaſtole*. From Drs. *Hales* and *Langriſh*'s experiments compared, it appears that the capacity of the left ventricle of an ox's heart, in conſequence of the natural relaxation of its fibres, is to its capacity, when fully dilated by the refluent blood, nearly as 1 to $2\frac{1}{2}$ *. As therefore the relaxation of the heart at the end of every *ſyſtole*, is owing to the contraction of its fibres ceaſing at that time; ſo its full *diaſtole* is produced by the returning venous blood, which enters its cavities with a very conſiderable force. Without this, it is impoſſible that any relaxation of the heart could produce its *diaſtole*; ſince a hollow muſcle, ſuch as the heart or bladder of urine, can never be fully dilated by means of its own internal mechaniſm, or without the aſſiſtance of a diſtending cauſe introduced into its cavities. But although the *diaſtole*, or full dilatation of the ventricles of the heart, muſt neceſſarily be aſcribed to the force of the refluent blood; yet this alone, without

* Vid. *Hales*'s ſtatical eſſays, vol. 2. p. 25. & *Langriſh*'s Cronean lectures, N° 147.

without a preceding relaxation of their fibres, would be inſufficient to produce this effect. 'Tis true indeed, that the contraction of the auricles, and *momentum* of the refluent blood, are in ſome ſenſe antagoniſts to the ventricles*; but both theſe taken together, falling much ſhort of the force with which the ventricles contract, there muſt neceſſarily be ſome other cauſe, which relaxes the fibres of the heart, and renders them as it were paralytic at the end of every *ſyſtole*. Beſides this, the flaccid appearance of this muſcle, immediately after its contraction is finiſhed, and before its ventricles are filled with blood, demonſtrates beyond all doubt, that its fibres are then in a ſtate of relaxation.

WHAT has been juſt now ſaid of the relaxation and *diaſtole* of the ventricles of the heart, is

* It is a miſtake to think, that no blood is puſhed into the ventricles of the heart during their *diaſtole*, except what was contained in the auricles properly ſo called. A certain quantity of blood from the *ſinus venoſi* alſo enters them, without being previouſly received into the auricles: of this the ſmallneſs of the left auricle alone, is a demonſtration. We are therefore to conceive of the blood during the *diaſtole* of the heart, as ruſhing into its ventricles, both from the auricles and *ſinus venoſi*, and with the united force ariſing from its *momentum* in the veins and the contractile power of theſe hollow muſcles.

is ſo applicable to its auricles, that it would be quite ſuperfluous to ſay any thing of their dilatation.

WE have already obſerved *, that the force with which the ventricles of the heart contract, is, *cæteris paribus*, always proportional to the *momentum* with which the blood flows into them, or, in other words, to the cauſe dilating them: the *ſyſtole* of the ventricles will therefore be, *cæteris paribus*, always proportional to their preceding *diaſtole*; and hence it is that a full pulſe ſtrikes the finger with ſo much greater force than a ſmall one.

As the left ventricle of the heart muſt, on account of its ſuperior ſtrength, require a greater force to complete its *diaſtole* than the right ventricle, the blood ought to return to it with a greater *momentum*; and that it really does ſo, will, I preſume, evidently appear from what follows.—The force with which the blood returns to the right ventricle of the heart by the two *venæ cavæ*, is in animals at reſt and not agitated with convulſions, according to Dr. *Hales*'s experiments, nearly equal

* Sect. iii.

qual to $\frac{1}{10}$ of the force with which it was puſhed by the left ventricle into the *aorta*; *i. e.* in a man of an ordinary ſize, it acts in dilating the right ventricle with a force equal to the preſſure of a column of blood whoſe height is between 8 and 9 inches, and whoſe baſe is equal to the internal ſurface of this ventricle, *i. e.* with a force equal to the preſſure of about five pounds *.—The force with which the blood returns by the pulmonary veins to the left ventricle of the heart, is not ſo eaſily determined; but that it muſt be very conſiderable, is evident, from the preſſure of the air upon the veſſels of the lungs in reſpiration; the preciſe force of which as it is difficult to inveſtigate, ſo it is not to be wondered, that ſeveral learned men who have attempted it, have fallen into miſtakes. It ſeems, however, demonſtrable, from an experiment of *John Bernouilli*, that when one endeavours to expire with all his might, the whole ſurface of all the veſicles of the lungs may ſuſtain a preſſure equal to 420 lib. weight †. But as this can only happen upon the moſt violent

* *Hales's* ſtatical eſſays, vol. 2. p. 40.

† *Michellot*. de ſeparatione fluidor. p. 181.

violent ſtraining, it is of little uſe to determine the preſſure of the air upon the lungs in ordinary reſpiration; which muſt bear a very ſmall proportion to this, and is not only different in different perſons, according to the eaſe with which they breathe, but vaſtly different in the ſame perſons at different times: and although the preſſure of the air upon any particular portion of the lungs muſt appear to be ſmall in ordinary reſpiration, if we conſider how ſoftly, and with what eaſe this is carried on, yet the preſſure upon the whole internal ſurface of all their veſicles may be very conſiderable. Thus, if the force of the air ruſhing out at the aperture of the *glottis* in ordinary expiration, be ſuppoſed equal to the preſſure of 2 grains, (which is far from being an extravagant demand), then, ſince fluids preſs equally on all ſides, every portion of the internal ſurface of the lungs of the ſame dimenſion with the aperture of the *glottis*, *i. e.* every $\frac{1}{8}$ of a ſquare inch of their ſurface (for the aperture of the *glottis* does not exceed this) muſt ſuſtain at that time a preſſure from the air equal to 2 grains; wherefore, ſuppoſing the ſum of the ſurface of all the veſicles

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of the lungs in a man to be 20,000 ſquare inches, it muſt, in ordinary exſpiration, ſuſtain a preſſure equal to 320,000 grains, or 666 ounces *. If to this force alternately preſſing on the lungs, we add the *momentum* which the blood in the pulmonary veſſels has from the contraction of the right ventricle of the heart, it will appear highly probable, that this fluid returns by the pulmonary veins to the left ventricle with a much greater force, than it did to the right one by the two *venæ cavæ*.

BUT, to put this matter beyond all doubt, we need only compare the capacities of the two *cavæ* and pulmonary veins. According to the meaſures of the accurate *Santorini*, the *area* of the tranſverſe ſections of the two *venæ cavæ*, is to that of the pulmonary veins, nearly as 3 to 2 †. Now the *momentum* of the blood in theſe different veſſels, muſt be as the tranſverſe ſection of the veſſels multiplied into the ſquares of

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* Dr. *Keil* has eſtimated the ſum of the ſurface of all the veſicles in the human lungs to be 21906 ſquare inches; which computation is in Dr. *Hales*'s opinion too low, who has determined this ſurface in a calf to be 40,000 ſquare inches. *Hales*'s ſtatical eſſays, vol. I. p. 242.

† Obſervat. anatom. p. 145.

the velocities: but ſince equal quantities of blood paſs through them in equal times, the velocities muſt be inverſely as the ſum of the tranſverſe ſections; therefore (by compounding *ratio's*) the *momenta* will be inverſely as the ſum of the ſame tranſverſe ſections, *i. e.* the *momentum* of the blood in the *cavæ*, taking *Santorini*'s meaſures for a ſtandard, is to its *momentum*, in the large trunks of the pulmonary veins, as 2 to 3: and this upon the ſuppoſition that the reſiſtance to the blood's motion in the *cavæ* and pulmonary veins were equal; which however is not the caſe, ſince the left ventricle of the heart muſt require a greater force to complete its *diaſtole* than the right one, and conſequently give a greater reſiſtance to the blood flowing into it from the pulmonary veins, than this laſt does to the blood in the *cavæ*. Suppoſing therefore, with *Santorini*, that the capacities of the *cavæ* and pulmonary veins are generally as 3 to 2, the *momentum* of the blood in the latter, will exceed its *momentum* in the former, in a proportion ſomewhat greater than that of 3 to 2.

Mr. *Helvetius*, 'tis true, has drawn a different concluſion from the ſmall capacity of the

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pulmonary veins, when compared with that of the *venæ cavæ*, or pulmonary artery *, *viz*. that the blood is denſer in the former than in the latter, but not that its velocity is greater †; and this denſity, he imagines, it chiefly acquires by being expoſed to the cool air, in its paſſage through the ſmall veſſels of the lungs. In anſwer to which, it is ſufficient for

* The ſum of the tranſverſe areas of the pulmonary veins, is not only leſs than that of the two *cavæ*, but alſo leſs than the ſum of the tranſverſe areas of the branches of the pulmonary artery, contrary to what is obſerved every where elſe in the body. It has been warmly diſputed, whether this diſcovery was firſt made by *Helvetius* or *Winſlow*, or if it does not rather belong to Dr. *Drake*, who has painted the branches of the pulmonary artery larger and more numerous than thoſe of the veins, (anat. tab. 12. & 13.); although he ſays nothing of this inequality either in his deſcription of the lungs, or in his explication of theſe figures. This debate, of no great importance indeed, might have been eaſily decided, if the perſons concerned in it, had looked into the proem of Dr. *Harvey*'s book *de motu cordis*, &c.; where we find the following paſſage; from which it appears, that this ſpeciality in the pulmonary veins was not unknown to that illuſtrious author. "Quum venam arterioſam, vas amplum magnum cum tunica arteriæ factum, non niſi privato & uni uſui, (viz. alendis pulmonibus) deſtinarint: cur arteriam venalem *vix pari magnitudine* cum tunica venæ molli, laxa, pluribus uſibus, tribus vel quatuor videlicet, fabrefactam eſſe aſſeverant?"

† Memoires acad. des ſciences 1718. edit. 8vo, p. 281. &c.

for our purpoſe to obſerve, that unleſs the blood is condenſed in the lungs into $\frac{2}{3}$ of its former bulk, (a ſuppoſition evidently ridiculous), it muſt needs flow through the pulmonary veins, with a greater velocity, and conſequently with a greater *momentum*, than through the two *cavæ*. The ſmall expanſion and condenſation of water, oil, ſpirit of wine, and other liquors, in thermometers, ariſing from conſiderable degrees of heat and cold, ſhew, that the cool air applied to the ſurface of the lungs, can have but little influence in condenſing the blood; beſides that it ſeems not at all improbable, that the blood may acquire a heat in the lungs, ſufficient to compenſate the refrigeration it is here expoſed to. It is generally thought, and indeed not without good reaſon, that the blood in the pulmonary veins is ſomewhat denſer than in the artery of that name: but this perhaps is not ſo much to be aſcribed to the coldneſs of the inſpired air, as to its preſſure, and to the action of the elaſtic veſſels of the lungs.

If it be objected to what we have offered in proof of the blood's returning with greater force to the left, than to the right ventricle of of the heart, That in a *fœtus in utero* this ſeems not to be the caſe; it may be anſwered, that the ſtrength of the left ventricle in a *fœtus*, exceeds that of the right but little; or however, not near ſo much as in adult animals: — that the right ventricle not only puſhes part of the blood through the veſſels of the lungs, but alſo diſtributes a good deal more than $\frac{1}{3}$ of the whole maſs to the *aorta* and its branches: —that the force of the blood returning by the two *cavæ* to the right ventricle is greatly leſſened, by its having a free paſſage through the *foramen ovale* into the left *ſinus venoſus*; while the blood by this means enters the left ventricle, not only with the force with which it returns from the lungs, but alſo with a great part of that with which it flows in the *cavæ*.

IN ſpeaking of the force with which the blood returns to the two ventricles of the heart, we have taken no notice of the additional *impetus* communicated to it, by the contraction of the auricles and *ſinus venoſi*, becauſe this is common to both ventricles; although it muſt be confeſſed, that the right auricle ſeems to be ſtronger, as well as more capacious

pacious than the left; and perhaps it was ſo formed, as the blood returning with great impetuoſity from the lungs, after having been intimately mixed and elaborated there, may not require ſo large an auricle, as the venous blood of the *cavæ*, which moves with leſs force, and is compoſed of parts leſs perfectly united.

UPON the whole, if it ſhall be aſked, why the heart being a ſolitary muſcle, and deſtitute of any antagoniſt, does not, like the ſphincters, always remain equally contracted; the anſwer is obvious, *viz.* that muſcles brought into action by a *ſtimulus*, are immediately relaxed again *; which relaxation therefore happening to the heart, the blood, in its return, enters the ventricles with conſiderable force, and, by dilating them, acts in ſome reſpect as antagoniſt muſcles do in other parts of the body; at the ſame time that, by its gentle irritation, it is the cauſe of their ſubſequent contraction. The heart muſt of neceſſity, therefore, be alternately dilated and contracted ſo long as the returning blood continues to be poured

* Sect. 1. N° 10.

poured into its cavities *: nay, ſince the contractions of muſcles from a *ſtimulus* are alternately repeated both in living and newly dead animals, although the *ſtimulus* is not renewed after every contraction †, and ſince the heart continues to vibrate for ſome time after injecting warm water or air into its cavities, it is highly probable, that the irritation of the returning blood in a ſound ſtate, is capable of making it perform not only one, but ſeveral contractions; which ſeems to be confirmed by the heart's ſtill palpitating after the *vena cava* and pulmonary veins have been tied, and conſequently after the blood is intercepted; though indeed it may be alledged, that, in this laſt inſtance, the pulſations are partly owing to the irritation communicated to the heart by the ligature made on theſe veſſels. Perhaps, when a *ſtimulus* is very ſlight, it may cauſe only one ſingle contraction of a muſcle; but when it is greater, it will produce repeated convulſions, and always the more, the ſtronger it is. The action therefore of the returning blood upon the auricles and ventricles of the heart

* Sect. I. N° 12. 13. & 14.

† Sect. I. N° 11.

heart in living animals, may be ſuppoſed not only to excite them once into contraction, but likewiſe, without the acceſſion of new blood, or any other *ſtimulus*, to cauſe ſome ſubſequent vibrations, always indeed decreaſing in force and frequency; but as in the intervals of theſe vibrations, the heart is again filled with blood, its alternate contractions being always ſolicited by a new cauſe, do not become weaker or ſlower, but continue the ſame, while the quantity and quality of the blood are unvaried.

It can be no juſt objection, therefore, to our account of the heart's motion, that in many animals newly killed, this muſcle, by ſeparating it from the body, or otherwiſe ſtimulating it, is excited into alternate contractions, which continue to be repeated for a conſiderable time, though the *ſtimulus* be not renewed; ſince the motions of muſcles ariſing from this cauſe, do not ceaſe immediately upon its removal, but decreaſe in ſtrength and quickneſs by ſlow degrees, before they quite diſappear *: nor ought we to be ſurpriſed that the violent

* Vid. Sect. i. N° 11. & Sect. xiii. where the motion of the heart after death, or its ſeparation from the body, is particularly inquired into.

violent irritation from pricking and tearing the fibres of the heart, or cutting its large veſſels, makes it repeat its vibrations more frequently, and continue them for a much longer time, than the gentle *ſtimulus* of the returning blood.

AT what time the motion of the heart begins in naſcent animals, and what is the cauſe which firſt ſets it a-going, are queſtions not uſually inquired into, nor indeed eaſily anſwered; although the ſecond ſeems to admit of a much eaſier ſolution than the firſt.

IF all the parts and organs pre-exiſt in miniature in the animalcle *in ſemine*, it will ſcarce be diſputed, that while it ſwims in this liquor, the fluids are propelled through its veſſels by the action of its heart, and circulate in the ſame manner as in the *fœtus in utero*. If the heart does not pre-exiſt in the animalcle, but is formed after conception, then the beginning of its motion muſt be later. But, be this as it will, we know that in impregnated eggs, the animalcle lies in a death-like ſtate, reſembling that of many inſects and ſome larger animals in winter; and that its heart remains at reſt, till by the heat of incubation it

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is roufed into action: after the motions of the chick's heart become vifible, they may be rendered more lively or languid by a greater or lefs degree of warmth; nay may be made entirely to ceafe by cold, and be as quickly renewed again by heat *. Hence it follows, that though it be not certain when the heart begins firft to move in nafcent animals, yet the caufe which fets it firft a-going, and recommences its motions after being ftopt, is heat, which, by rarifying and agitating with an inteftine motion the particles of the fluids, enables them to ftimulate its fibres into contraction.

SECT. V.

Of the motions of the alimentary canal, and bladder of urine.

HAVING thus accounted for the alternate contraction and relaxation of the heart; we come next to inquire into the caufe of the other

* *Harvey* de generation. animal. exercitat. 17.

other in voluntary motions; and ſhall begin with thoſe of the alimentary tube.

IN deglutition the contraction of the muſcles which pull up the *larynx* and *os hyoides*, and ſo puſh the *bolus* into the dilated *pharynx*, is generally ſpontaneous, and owing to the irritation of the ſenſible membrane of the *fauces*, by the food paſſing this way. In like manner no ſooner is the aliment received into the *pharynx*, than this muſcular tube contracts, and, embracing it cloſely, puſhes it on to the *œſophagus*, which having its nerves irritated, and its fibres ſtretched by the food in its deſcent, makes each ringlet of this tube contract itſelf, and ſo tranſmit the *bolus* to the next, till at laſt it is puſhed into the ſtomach.

THE aliments which are generally compoſed of parts fit to act as a gentle *ſtimulus* on the ſenſible membranes of animals, are no ſooner received into the ſtomach, than, by its heat and motion, as well as the action of the humours flowing into it, they begin to ſwell, and continue, during the whole time of their diſſolution, to emit bubbles of elaſtic air: at the ſame time, the cool air ſwallowed every now and then with the *ſaliva*, is quickly rarified

rified by the heat of the ſtomach. Here then we ſee in the aliments, air and humours, cauſes which may gently ſtimulate the nervous *papillæ* of the ſtomach, and ſtretch its fibres ſo as to excite them into contraction: and this exactly agrees with *Wepfer*'s obſervations, which ſhew, that the contraction of the ſtomach never happens but in conſequence of a preceding intumeſcence. *Motum ventriculi*, ſays this author, *oculis obſervare licet in vivarum beſtiarum anatome, & non ſemel vidi illum conſtringi lentè verſus ſtomachum ſubſequente vomitu, aut verſus pylorum contentis in duodenum exploſis; nonnunquam gracilior & brevior reddebatur; mox iterum intumuit, ſubſequente rurſus nova coarctatione, quæ vel verſus pylorum vel ſtomachum progrediebatur* *. And, in another place, *Quando vero circa medium ſe contraxerat (ſcil. ventriculus) motus lentè verſus pylorum procedebat, illeque erigebatur liquorque ſubpallidus, nunc ſpumeus nunc viſcidus, quandoque ſenſim aliquando cum impetu protrudebatur: conſtricto pyloro rurſus intumuit totus ventriculus, moxque rurſus circa medium ſe conſtrinxerat, novuſque liquor*

* Hiſtor. cicut. aquat. p. 87.

quor per pylorum ejiciebatur *. Thus we find the *diaftole* of the ftomach always fucceeded by its contraction, which expelling by the *pylorus*, the diftending caufe, *i. e.* part of the air and aliments, the fibres of this bowel are immediately relaxed, fo as eafily to give way to the diftending force of the rarified air arifing from the aliments, and thus to fuffer a new *diaftole*; which, as before, is foon followed by a new contraction. Hence there appears a remarkable analogy between the caufes of the alternate motions of the ftomach and heart, even in thofe animals whofe make as to thefe parts agrees with that of the human kind; but which is ftill ftronger in granivorous birds, whofe ftomach more nearly refembles the heart in its ftructure, and in the force of its motions†.

IF it be afked, why the ftomach is not brought into a new contraction by the ftimulating quality of its contents, before a new intumefcence

* Hiftor. cicut aquat. p. 177

† The fmall rough ftones which granivorous birds fwallow, are not only ufeful to break and grind their food, but alfo to excite their lefs fenfible ftomachs into proper contractions; for thefe, on account of the hard fkin which lines them, would be little affected by the diffolving aliments and rarified air, without the attrition of thofe ftones.

intumeſcence of it has happened; it is ſufficient to anſwer, that, in order to excite a new contraction of the ſtomach, or hinder its yielding to the dilating force of the rarified air, the gentle *ſtimulus* of the aliment may require the additional irritation which the diſtraction of its fibres produce. Beſides, as the convulſive contractions of the diaphragm which happen in conſequence of an irritation of the left orifice of the ſtomach, do not follow one another very quickly, although the ſtimulating cauſe continues to operate, but after longer or ſhorter intervals, according as the irritation is weaker or ſtronger; ſo in the ſame manner, after one contraction of the ſtomach is over, ſome time may be required for the ſtimulating cauſe to act, before a new contraction is produced.

THAT the ordinary vermicular motion of the ſtomach is chiefly owing to the ſtimulating quality of its contents, is confirmed by a variety of facts: thus when any thing is received into the ſtomach, which ſtrongly irritates or diſagreeably affects its nerves, it is thrown into convulſive contractions, which are renewed, after ſhort intervals, till the

the offending cauſe is either quite expelled, or greatly weakened. On the other hand, *opium*, which renders ourfibres and nerves inſenſible of an irritation, has of all things the greateſt power to quiet convulſive and irregular motions of the ſtomach. At the ſame time the *nauſea* and vomiting, which are brought on by ſuddenly drinking too great a quantity of the mildeſt liquids, ſhew that the ſimple intumeſcence or diſtenſion of the ſtomach, conduces to its contraction independent of any *ſtimulus* affecting its nervous *papillæ*.

THE vermicular motion of the guts, is quite a-kin to that of the ſtomach, and produced by the ſame cauſes. Small quantities of rarified air and digeſted aliment are puſhed from one portion of the inteſtinal tube into the next, and from this again into the ſucceeding one, and ſo on; *i. e.* the part dilated by the air and aliments acquires ſuch a power of contraction, as to overcome the elaſticity or contractile power of the contracted part next it. Whence ſhould this happen? It cannot be owing to the more copious influx of arterial blood into the veſſels of the diſtended ſegment,

ment, as Dr. *Stuart* would perſuade us *; ſince it appears that this fluid does not immediately conduce to the contraction of a muſcle †.—There is no reaſon to imagine, that, on account of any alternate compreſſion of their nerves, the animal ſpirits flow into the guts in ſucceſſive ſtreams: nor would this, if ſuppoſed, anſwer the *phænomena*; ſince the whole inteſtinal tube is not, like the heart, alternately contracted and relaxed, but, as to time, is altogether irregular in the motions of its ſeveral parts. It remains therefore that the diſtraction of the fibres of the inflated part of the gut, together with the *ſtimulus* of the bile, air, and digeſted aliments which it contains, is the cauſe of its ſubſequent contraction. And ſurely, if warm air impelled through the *vena cava*, or thoracic duct, into the heart of an animal newly killed, excites it into contraction, it may reaſonably be ſuppoſed to have an equal effect on the ſtomach and inteſtines, between whoſe motions and thoſe of the heart there is a ſtrong analogy.

WE have already ſeen from *Wepfer*, that, by every

* Differt. de motu muſcul. cap. 12.

† Sect. i. N° 2. above.

every contraction of the ſtomach, ſome part of the more liquid aliment and rarified air is puſhed through the *pylorus* into the *duodenum*; which, not finding a free paſſage through this gut, on account of its valves and the natural contractility of its coats, will dilate that part of it next the ſtomach, and conſequently excite it into contraction, by which its contents will be tranſmitted to the next portion of this gut, and ſo on through the whole tract of the *jejunum* and *ileum*, where the valves being larger, will, by ſtopping the progreſs of the chyle and rarified air, occaſion more remarkable intumeſcences, and conſequently ſtronger ſucceeding contractions.

IT will further appear, that the periſtaltic motion of the guts, is owing to digeſted aliment, bile and rarified air, acting upon them as a *ſtimulus*, if we conſider that purgatives, which act chiefly by vellicating the inſide of the guts, greatly increaſe this motion: —— that in animals opened alive, the inteſtines are excited into ſtronger contractions, by pricking them with a ſharp inſtrument, or applying any acrid liquor to them: —— that ſuch things as render our nerves and fibres lefs fenfible of any irritation, leffen or deftroy the periftaltic motion of the guts; thus Dr. *Kaau* not only found the vermicular motion of the inteftines extremely weakened and flow, in a dog to whom he had given fix grains of *opium*, but that pricking their external furface with the point of a needle, did not fenfibly increafe it *: —— and, laftly, that when the bile from any caufe becomes inert, or is hindered from flowing into the guts, coftivenefs generally follows. Nay, that the *ftimulus* of the bile is in a particular manner neceffary to the right performance of the periftaltic motion, and that without it the guts would not be able fufficiently to refift the diftending power of the rarified air, feems highly probable from the remarkable inflation of the inteftines in fuch as die of an inveterate jaundice; and from the hiftory given by Dr. *Stuart*, of one who died of a wound of the gall-bladder, who was not only incurably coftive, but whofe guts were fo diftended with air, that before opening him a tympany was fufpected †.

WHILE

* Impet. faciens, dictum *Hippocrat*. N°. 435.

† Philofoph. Tr anf. N° 414.

WHILE the chyle is taken up, as it paſſes along, by the lacteal and abſorbent veins of the ſmall guts, the groſſer and leſs nutrititious parts of our humours and aliments are tranſmitted from the *ileum* by the valve of the *colon* into the great guts, where they remain for ſome time without giving any diſturbance; till, by the preſſure of the diaphragm and abdominal muſcles in reſpiration, together with the gentle contractions of the guts themſelves, they are puſhed into the *rectum*, where, partly by their acrimony, but chiefly by their weight and bulk overſtretching its fibres, they excite this gut into ſtrong contractions, and bring on an inſuperable deſire of emptying it. When any acrid matter lodged in the *plicæ* of the *rectum*, irritates its nervous *papillæ*, as in a *teneſmus*, its muſcular coat is excited into frequent and ſtrong contractions, and there is almoſt a perpetual deſire of going to ſtool. This is beſt cured by oily and mucilaginous clyſters, with *opium*; which at the ſame time that they ſheathe the acrimony, blunt alſo the ſenſe of pain.

THE bladder of urine is a hollow muſcle, which being deſtitute of any proper antago-

niſt,

nift, would always, if not hindered by fome foreign caufe, reduce itfelf to its fmalleft capacity, by means of that natural contraction which is owing to the force of the circulating fluids, the elafticity of its fibres, and the conftant but gentle operation of the nervous influence upon them *. This contractile power of the bladder, whereby it reduces itfelf to its fmalleft fize, is overcome by the urine gradually dropping into its cavity from the ureters; which at length, by overftretching its coats, excites them into ftrong contractions; but thefe being of themfelves unable to overcome the *fphincter*, the diaphragm, abdominal mufcles, and *levatores ani*, are called in to their aid: however, after the *fphincter* is opened, the contractile power of the bladder alone is fufficient to expel the whole urine.

THIS fluid, though fenfibly acrid, does not, when accumulated in the bladder of a healthy perfon, give uneafinefs fo much by the irritation of its nervous *papillæ*, as by overftretching its fibres: but when the *mucus*, deftined to defend thefe nerves from the acrimony of the urine, is abraded, or when the inner coat of the bladder is inflamed or excoriated,

* Sect. i. N° 4.

excoriated, no ſooner does the urine begin to be collected, than, by fretting this tender and extremely ſenſible part, it brings the muſcular coat of the bladder into ſtrong convulſive contractions, and along with it the diaphragm and abdominal muſcles; hence in ſuch caſes the patient is afflicted with a violent and almoſt conſtant deſire of paſſing his urine, while in the mean time there are only a few drops to be expelled. Mares and cows, after evacuating their urine are obſerved for ſome time alternately to contract and relax their *urethra* and *ſphincter veſicæ*; at firſt very briſkly, afterwards more weakly and with longer intervals between each contraction. Theſe motions, which ſeem to be of the ſpontaneous kind, are ſolely owing to the irritation of the parts by the urine; and it is a proof of this, that as the uneaſy ſenſation begins to abate, ſo does the force and quickneſs of theſe motions.

SECT.

SECT. VI.

Of the motions of the blood-veſſels, and ſeveral others of the ſpontaneous kind.

THE moſt remarkable of the ſpontaneous motions which remain to be accounted for, are the alternate *ſyſtole* and *diaſtole* of the arteries; the leſs perceptible motion of the veins; the oſcillatory contractions of the ſmaller veſſels; the erection of the *penis*; the convulſive motions of the *muſculi acceleratores urinæ* in coition; the motions of the fallopian tubes, whereby they embrace the *ovaria*, and convey the *ovum* to the womb; the alternate action of the muſcles of reſpiration; their convulſive motions in coughing and ſneezing; and the contraction of the pupil and muſcles of the internal ear, in order to adapt theſe organs exactly to the degree of light and ſound applied to them.

1. THE *diaſtole* of the arteries is, like the dilatation of the heart, owing to the blood puſhed into their cavity, with a conſiderable force, and their *ſyſtole* or ſucceeding contraction

ction is effected chiefly by their elaſticity, and partly by the proper contraction of their muſcular coat, excited by the blood gently ſtimulating their internal ſurface, at the ſame time that it diſtracts their fibres. That the *ſyſtole* of the arteries is not wholly owing to the elaſticity, but alſo to the muſcular contraction of their fibres, is generally acknowledged by Phyſiologiſts; and that the blood alternately puſhed into them and acting as a *ſtimulus*, excites this muſcular contraction, the analogy of the heart, and other ſpontaneous motions, already explained ſeems fully to evince.

2. BESIDE the alternate *diaſtole* and *ſyſtole* of the larger arteries, which, in a great meaſure, depend upon the projectile force of the heart, and the elaſticity of their coats, there is a vibrating or oſcillatory motion in the inferior orders of veſſels, to which the direct force of the heart does not reach, and where elaſticity is no way concerned. And as the food is conducted from the mouth through the whole courſe of the alimentary canal, by its exciting the muſcular coat of this tube into contractions, as it paſſes along; ſo the motion of the

the fluids through the inferior orders of veſſels and ſecretory tubes of the glands, to many of which the impulſive force of the heart, ſeems not to extend, is chiefly carried on by the vibrating contractions of theſe veſſels, excited by the gentle *ſtimulus* of the circulating fluids *.

3. As the ſmaller veſſels, though deſtitute of any alternate pulſation depending upon the contraction of the heart, are nevertheleſs agitated with a kind of oſcillatory motion; ſo it is highly reaſonable to think, that the veins are not inactive canals, but ſo affected by the *ſtimulus*

* In an eſſay on the motion of the fluids through the ſmaller veſſels of animals, read at ſeveral meetings of the Philoſophical Society in this place, in the years 1745 and 1746, I have ſhewn at great length, that the circulation of the juices in the inferior orders of veſſels, and particularly in the ſecretory tubes of the brain, cannot be accounted for, merely from the projectile force of the heart and alternate *ſyſtole* of the larger arteries; but muſt in a great meaſure depend upon the oſcillatory motions or ſmall alternate contractions of theſe veſſels, which in ſome animals may be diſcerned by the microſcope; and which have neither been rightly derived from the oſcillations of the *dura mater*, nor from the alternate motions of the heart and larger arteries; being ſolely owing to the gentle titillation of the fluids, as they glide along the ſides of the veſſels, whoſe fibres are ſo conſtituted, as to be excited into contraction by the ſmalleſt irritation.

ſtimulus of the circulating blood, as to have their muſcular coat excited into alternate, but weak contractions, by means of which the return of this fluid to the heart is conſiderably promoted. As a proof of this, the *vena cava* may be plainly ſeen to contract alternately in dying animals whoſe *thorax* is laid open*; tho' it is probable that the motions of this vein near the heart, are more remarkable than elſewhere, on account of ſome kind of alternate depletion which it ſuffers. And may not the *vena cava* continue to palpitate longer than the heart in dying animals, becauſe, after the circulation of the blood through this organ has ceaſed, it is ſtill tranſmitted in ſmall quantity from the arteries into the naſcent veins, and conſequently into the *cava*; which being therefore longer ſupplied with the cauſe exciting its motions, muſt continue them longer?

HENCE we ſee that the fluids are in ſome ſenſe the cauſe of their own motion; ſince, without their ſtretching power and ſtimulating quality, the heart and arteries, however well fitted for muſcular contraction, would remain altogether unactive and at reſt: and that

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* Sect. xiii. N° 16. below.

as the contractile power of the folids is altogether neceffary to carry on the vital functions, fo likewife is the action of the fluids upon the folids, in order to excite their mufcular power into action. Hence alfo we may eafily underftand how it is that heat has fo great an influence in promoting the circulation of the fluids, that infects and many other animals, after they are to all appearance dead, may be quickly brought to life by it. Heat, by raifing an inteftine motion and brifk vibrations in the particles of the fluids, muft neceffarily communicate fome degree of irritation to the fenfible veffels; and thus bring them into alternate contractions.

4. THE erection of the *penis* has been generally afcribed to the contraction of the mufcles called *erectores*; yet as their fituation is fuch, that the veins of the *penis* can fcarcely be affected by their action, and as an erection of this member cannot be procured at pleafure, by ftrongly preffing it againft the *os pubis*, feveral later authors feem juftly to have rejected this opinion, but, as far as I know, without fubftituting any thing fatisfactory in its place.

BUT

BUT as the taſte, nay even the ſight or remembrance of grateful food, cauſes to a hungry perſon an uncommon flow of *ſaliva* into the mouth, by increaſing the oſcillatory motions of the ſalivary veſſels [N° 2.]; ſo, why may not the *ſtimulus* of the ſeed in the *veſiculæ ſeminales*, or the ſight, nay even the recalled idea of laſcivious objects, cauſe a more than ordinary flow of blood through the ſmall arteries of the *penis*, by greatly increaſing their vibrating contractions? If this happens, the ſmall capillary red arteries will, by the increaſed *momentum* of the fluids, be all enlarged, and the ſerous ones, at leaſt many of them, will be rendered capable to admit red blood: thoſe arteries which end in veins, will tranſmit their fluids to them as uſual, only with greater impetuoſity, while ſuch as terminate with open orifices in the cells, will, through their dilated mouths, pour forth not only a ſerous or lymphatic fluid, as uſual, but alſo red blood itſelf; which not being faſt enough carried off by the abſorbent veins, whoſe orifices are not enlarged proportionally with thoſe of the arteries, muſt fill and diſtend theſe cavities, and conſequently produce an erection of the *penis*.

As

As ſoon as the cauſes exciting an uncommon oſcillatory motion in the ſmall veſſels of the yard ceaſes, it begins to ſubſide, becauſe the fluids are now poured in much leſs quantity into its cells.

THIS account of the erection of the *penis* ſeems to be much more agreeable to the laws of the animal œconomy, than that propoſed by *Duvernoi**, and embraced by Dr. *Haller*†, who ſuppoſes that the ſmall veins of the *penis* may be ſo ſtraitened, by I do not know what conſtriction of the nervous filaments ſurrounding them, as in a great meaſure to prevent the return of their blood. *Vieuſſens* is the firſt who conſidered the nerves which in ſome places appear to ſurround the blood-veſſels as ſo many ſmall cords, capable of conſtricting them more at one time than another, and conſequently of producing remarkable changes in the circulation. Thus he deduces the paleneſs of the face in ſome paſſions, and its redneſs in others, from the nerves ſtraitening the carotid arteries in the former, and the

* Act. Petropolitan. tom. 2. p. 379. 383. 384.
† Prim. lin. phyſiolog. N° 800.

the jugular veins in the latter caſe*. However, none of the authors now mentioned, have condeſcended to ſhew us how the nerves can be ſo drawn as, like a ligature, to ſtraiten the veſſels which they encompaſs. Nor indeed can this be eaſily conceived. There is no example to be found of any motion or action in the animal body being performed by the traction or conſtriction of nerves, whoſe office is not to be drawn or rendered more tenſe at one time than another, but to ſupply the muſcular fibres every where through the body, with that influence or power which ſeems to be immediately neceſſary to their contraction: but, by the increaſed oſcillatory motion of the ſmall veſſels, which we have aſſigned as the cauſe of the erection of the *penis*, we daily obſerve a variety of ſudden and ſurpriſing changes produced in the circulation. To this is to be aſcribed the profuſe ſecretion of pale limpid urine, to which hyſterical people are ſo liable; as alſo the great diſcharge of tears from the lachrymal veſſels, in people affected with great joy or grief. And the bluſhing, or redneſs and glowing warmth of the face, which attends

* Neurograph. lib. iii. cap. iv. p. 182.

tends a fenfe of fhame, is not owing to the conftriction of the temporal veins by means of the nervous filaments from the *portio dura*, which furround them *, but to an increafed ofcillatory motion of the fmall veffels of the face, which in moft people, more or lefs, accompanies a confcioufnefs of fhame: for as the rofy colour, and fudden warmth, which are the neceffary confequences of the increafed motion of the blood in the fmaller veffels, ill agree with the ftagnation of this fluid, as arifing from any compreffion of the temporal veins; fo their being often diffufed over the neck and breaft, clearly fhews that they can't proceed from this caufe. Why this affection of the mind fhould produce fuch a change in the circulation of the blood in thofe parts rather than any other, we don't pretend to fay. Sufficient it is, that from experience we know that the body and its feveral parts are varioufly affected by the different paffions of the mind.

AFTER what has been faid, it will be eafy to account for the erection of the nipple of a woman's breaft, and the fwelling of a turkey-cock's

* *Haller* not. in *Boerhaav.* inftitut. med. parag. 573. & prim. lin. phyfiolog. N° 552.

cock's comb and rattles, which are much akin to the erection of the *penis*, and which, as Dr. *Haller* has juftly obferved, are certainly not owing to the contraction of any mufcle, hindering the return of the blood by their veins *. For why may not the paffion of anger or pride caufe an inflation of the above mentioned animal's comb and rattles, as well as the fenfe of fhame does a flufhing of the face? and may not titillation increafe the motion of the fluids in the fmall veffels of the nipple, in the fame manner as in the *penis*?

THE unufual fenfation of heat in the face, which attends blufhing, and is fo quickly raifed, may enable us to account for the many fudden complaints of heat and cold, and other fymptoms of a like nature common to hyfterical people; for if an affection of the mind, can raife an uncommon heat in the face, by determining the influence of the nerves more copioufly into its veffels, and thus increafing their ofcillations, why may not the fame thing happen in other parts of the body, from an irregular diftribution of the nervous power? and is it not probable, that the

* Prim. lin. phyfiolog. N° 800.

the ſudden ſenſations of cold, which people ſubject to nervous complaints often feel in various parts of their bodies, are owing to the ſtagnation or ſlower motion of the fluids in the ſmaller veſſels of theſe parts, occaſioned by the diminution or ſuſpenſion of their oſcillatory motion?

BUT to return from this digreſſion; whether the erection of the *penis* is effected in the manner above explained, or by the contraction of certain muſcles compreſſing its veins; it is nevertheleſs, like the other ſpontaneous actions, owing to an irritation, *viz.* the *ſtimulus* communicated to the nervous *papillæ* of the *veſiculæ ſeminales* and teſticles by the ſeed; ſince, in proportion to the abundance or defect of this, erections are *cæteris paribus* more or leſs frequent, ſtronger or weaker. 'Tis true, that laſcivious thoughts, titillation, and other cauſes, often produce erections of the *penis*; but even their power of doing this, is in a great meaſure owing to the preſence of the ſeed. An erection of the *penis* frequently happens from the bladder being full of urine, at leaſt is increaſed by this; which is no way ſtrange, ſince the urine, by ſtretching and ſtimulating the coats of the

the bladder, may be eafily fuppofed to affect the nerves and veffels of the *penis*, with which they are fo nearly connected.

5. IN time of coition, as foon as the feed is fqueezed into the beginning or bulbous part of the *urethra*, the *mufculi acceleratores urinæ* which furround this part, are brought into convulfive contractions, which continue to be repeated till the feed is entirely expelled; and that thefe convulfive contractions are owing to the *femen* acting as a *ftimulus* upon this part of the *urethra*, cannot with any colour of reafon be denied; fince their number and force are always greater or lefs, as this liquor is more or lefs in quantity, or more or lefs concocted.

6. BY the titillation of the *rugæ* of the *vagina* in time of coition, not only is the *uterus* affected, but the *tubæ fallopianæ* becoming rigid, fuffer a kind of erection; at which time their fimbriated extremities are turned to the *ovaria*: nor do they change this fituation till the *ovum* has made its paffage through the coats of the *ovarium* into their cavity,

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through which it is preffed forward to the *uterus*, by the contraction of the mufcular coat of the tube, which, from the analogy of the other fpontaneous motions already explained, we may eafily imagine, is excited by the *ovum* as it paffes along the internal furface of this hollow mufcle; fo that every fmall ringlet of it, will, by its contraction, tranfmit the *ovum* to the fucceeding one, till at laft it drops into the womb; in the fame manner as the food in a horizontal pofture is conveyed through the *œfophagus* into the ftomach.

THAT the convulfive motions of the mufcles of refpiration in coughing and fneezing, and of the diaphragm in the hiccup, are owing to an irritation of the fenfible membrane of the nofe, windpipe, and inferior part of the gullet, is too evident to need any particular proof; and this the rather, as thefe motions will be occafionally illuftrated in the fequel of this Effay. Nor is it lefs true, that the motions of the pupil and mufcles of the internal ear, are owing to light and found acting as *ftimuli* on thefe organs: but as thefe motions, whereby the eye and ear are accommodated to different degrees of light and

found,

found, are more intricate and lefs generally underftood, I fhall treat of them particularly in the following Section. And as the alternate motion of the organs of refpiration differs from the other fpontaneous motions already explained, in being fo far under the power of the will, that we can accelerate, retard, or entirely (at leaft for a confiderable time) put a ftop to it; and is a fubject upon which a great deal may be faid, I fhall alfo treat of it afterwards in a particular Section by itfelf; where its caufe will be fhewn to be entirely analogous to that of the other fpontaneous motions.

SECT. VII.

Of the motions of the pupil and mufcles of the internal ear.

AS the degrees of light to which the eye is expofed, and the fplendor of objects prefented to it, are various, had the pupil been of a determinate fize, incapable of enlargement or diminution, this organ would have been adapted only to contemplate objects in in one particular degree of light; every thing remarkably brighter than this, would have dazzled it, while a fainter light would not have affected it fufficiently. Further, as the rays of light coming from very near objects, are much more divergent than thofe from remote ones, had the pupil been incapable of variation as to its extent, the eye would have been ill fitted for feeing diftinctly at different diftances; fince fuch objects alone are feen diftinctly, whofe images are accurately painted upon the middle and moft fenfible parts of the *retina*.

To prevent thefe inconveniencies, and that the eye might be capable of properly receiving the impreffions of objects in a great variety of lights and diftances, that membrane called by Anatomifts the *uvea* or *iris*, which encompaffes the pupil, is furnifhed with a double fet of mufcular fibres, by whofe contraction or relaxation, the diameter of this paffage can be greatly augmented or diminifhed. One plane of thefe fibres is circular, and immediately furrounds the circumference of the pupil: it may very properly be called the *fphincter pupillæ*, fince, by its

its contraction, the pupil is leſſened. The other is compoſed of a number of radiated fibres, which take their riſe from the great circumference of the *uvea*, where it is attached to the *circulus albus*, or union of the *cornea* and *ſclerotica*, and are inſerted into the orbicular muſcle above mentioned, all round the circle of the pupil, as the ſpokes of a wheel are into its nave. This plane of muſcular fibres acts as antagoniſt to the orbicular one, and may be called the *laxator* or *dilatator papillæ*.

THE circular plane of fibres is ſo thin and delicate, that ſome authors ſeem ſtill to doubt of its exiſtence; but in admitting it, we are not only juſtified by the authority of the beſt Anatomiſts *, but by reaſon and analogy; ſince the equable and regular contraction of the pupil cannot well be conceived, without ſuppoſing ſome ſuch mechaniſm; and ſince we find the other paſſages in the body which are endued with a power of conſtricting themſelves, furniſhed with *ſphincter* muſcles.

THE figure of the pupil, as well as its degrees

* *Winſlow* anatom. ſect. 10. N° 220. *Ruyſch.* theſaur. anatom. 2. tab. 1. fig. 5. lit. *c.*

grees of contraction and dilatation, are different in different animals. In man the pupil is at all times perfectly round; in horſes, cows, *&c.* it is oblong and tranſverſe; and in cats in the day-time, it forms a narrow chink perpendicular to the horizon, but in the dark acquires nearly a circular figure, and becomes almoſt as large as the *cornea*. If in cats the pupil had been perfectly circular as in man, it could not well have admitted of ſo great degrees of dilatation and conſtriction, which yet are neceſſary to an animal which muſt ſeek its prey in the night-ſeaſon; at leaſt when moſt contracted, its edges muſt have been remarkably furled, and their thickneſs greatly increaſed, by being folded together in ſo ſmall a ſpace. Moreover, 'tis obſervable, that all thoſe animals which have the pupil of an oblong or oval ſhape, are capable of ſeeing in a much fainter light than man.

Galen, who did not allow any motion to the pupil, except when one of the eyes is ſhut, aſcribed the dilatation of the pupil of the open eye, to its having the ſpirits which uſed to be beſtowed on both eyes, now determined into it alone. *Achillinus*, who flouriſhed in the be-

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ginning of the ſixteenth century, is the firſt who mentions the motions of the pupil from different degrees of light *; which however was ſo little attended to, that its firſt diſcovery is generally aſcribed to Father *Paul* of *Venice*, who lived about a hundred years after him †. However, neither Father *Paul*, nor *Aquapendente*, who followed him, ſeem to have known any thing of the manner in which theſe motions are performed. Nor ought it to appear ſtrange, if, before the muſcular ſtructure of the *uvea* was known, Phyſiologiſts were quite in the dark with regard to the pupil's motions, or if their accounts of this matter be altogether as wide of the truth, as different from each other.

THE natural ſtate of the pupil is that of dilatation; for ſince the longitudinal fibres of the *iris* are much more conſpicuous and ſtronger than the circular plane, they muſt, by their natural contraction ‡, keep the pupil always dilated, unleſs the latter are excited into action by ſome particular cauſe.

WHAT

* *Morgagni*. adverſar. anatom. 1. p. 34.

† *Fabricius* ab *Aquapendente* de oculo, part. 3. cap. 6. & *Douglas* bibliograph. anatom. p. 228.

‡ Sect. i. N° 3. and 4. above.

WHAT this cauſe is, could be no difficult matter to diſcover: for, as in a *ſyncope*, apoplexy, or at the moment of death, when the eye is quite inſenſible to external objects, the pupil is always greatly dilated; as in the ſhade it is remarkably large, and always the more ſo, the greater the darkneſs; while in a bright light it is contracted almoſt to a point; it clearly follows, that the coarctation of this paſſage is owing to the action of light on the eye as a ſenſible organ, and its dilatation to the ſuperior contractile power of the longitudinal fibres of the *uvea*, when the eye is left to itſelf, and not affected by any external cauſe.

THE pupil is contracted more or leſs in proportion to the quantity of light admitted into the eye, not on account of any immediate action of this ſubtile fluid on the fibres of the *iris*, as ſome have imagined *, but in conſequence of its affecting the tender *retina* with an uneaſy ſenſation. Hence whatever intercepts the rays of light ſo as to prevent their affecting the *retina*, or renders this membrane

* Hiſtoire acad. des ſciences 1704, edit. 8vo, p. 18. & Memoires, p. 360.

brane inſenſible to their action, cauſes a preternatural dilatation of the pupil. Thus in a cataract, where the cryſtalline humour being conſiderably opaque, intercepts a great part of the luminous rays in their way to the bottom of the eye, the pupil loſes a good deal of its contractility. In a confirmed *gutta ſerena*, or perfect inſenſibility of the *retina*, the orbicular muſcle of the pupil loſes its power of contraction altogether, inſomuch that this paſſage remains equally wide in the brighteſt ſunſhine, as in the obſcureſt ſhade. If the action of light on the circular fibres of the *iris* were the cauſe of their contraction, this ought not to happen; ſince the nerves of this membrane, as they have no connexion with the optic nerve, ought to remain equally fit for actuating its orbicular muſcle, and equally ſenſible of the *ſtimulus* of light, when the *retina* is thus diſeaſed, as in a ſound eye. But if it ſhall be alledged, that in a *gutta ſerena*, the nerves of the *uvea* become ſome how paralytic, and that the immobility of the pupil is owing to this, and not to the inſenſibility of the diſeaſed *retina*; I anſwer, that a plain experiment ſhews the contrary: thus when one eye is quite loſt by a confirmed *amauroſis*; if the ſound one is covered or kept ſhut, the pupil of the diſeaſed eye remains in every degree of light immoveable, and of the ſame ſize; but if the ſound eye is expoſed to the ſun-beams, the pupil of the other, which ſhewed no motion before, will be evidently obſerved to contract. This contraction can only ariſe from the ſympathy between the two pupils; and ſhews, that when the ſound eye is covered, the defect of motion in the morbid one is not owing to the nerves of the *uvea* being any way paralytic, but merely to the want of a cauſe determining their influence into the orbicular muſcle of the pupil.

FURTHER, if the contraction of the pupil proceeds from light acting as a *ſtimulus* on the fibres of the *iris*, why does it not excite its longitudinal fibres equally into action as its circular ones?

WHEN the head of a living cat is put under water, its pupil, which was much contracted before, is immediately greatly dilated, though expoſed to the ſun-beams. If the contraction of the *ſphincter pupillæ* aroſe from the action of light on its fibres, this *phænomenon* would hardly admit of a ſolution; ſince

ſince it does not appear that the rays of light ſhould act with much leſs force upon the *iris* of an animal under water, than in the open air: but, on ſuppoſition that the contraction of the pupil is owing to the *ſtimulus* of light affecting the *retina*, it is eaſily accounted for. The rays of light paſſing from air into the eye through the *cornea*, ſuffer a conſiderable refraction on account of its greater denſity; by which means they are made to approach one another, ſo as, by the refractions of the cryſtalline and vitreous humours, they may be collected in a point on the *retina*. But when the head of an animal is under water, the rays of light ſuffer little or no refraction in paſſing through the *cornea* and aqueous humour, becauſe their denſity ſcarce differs from that of water: hence they will not, as in the former caſe, be made to approach one another, nor will they have their *focus* in the *retina*, but a great way behind it; this membrane, therefore will be very weakly affected by them, and conſequently the pupil muſt be dilated. In water there is a general and faint light diffuſed over a great part of the *retina*; in air all this light is collected, and acting

acting on a much ſmaller ſpace, is greatly more vivid and ſtriking.

MR. *Mery* indeed has given a different ſolution of this *phænomenon*; but ſuch a one as will not give a philoſophical reader any very exalted *idea* of his knowledge either in phyſiology or in optics. His account of the matter is this. Under water, the animal is hindered from breathing, but the motion of the ſpirits, to which he aſcribes the conſtriction of the pupil, depends on the circulation of the blood, and this again on reſpiration; therefore, notwithſtanding the uſual action of light on the *iris*, the pupil in an animal under water, muſt be relaxed merely on account of the interruption of reſpiration *.— It is moſt certain, that in a *ſyncope*, when the vital motions ceaſe, the pupil is dilated in air, as well as in water, becauſe the *retina* loſes its ſenſibility; but a cat plunged into water, does not become immediately inſenſible, nor does the motion of its heart ceaſe with that of reſpiration; and if a man can reſtrain breathing near a minute, without loſing any of his ſenſes, this animal, which bears the air-pump

* Memoires acad. des ſciences 1704. edit. 8vo. p. 353.

pump ſo long, muſt continue ſenſible and lively under water for a much longer time: add to this, that the cat's pupil is obſerved to be greatly dilated immediately after immerſion; whereas, according to Mr. *Mery*'s principles, it ſhould become gradually wider, as the animal languiſhes more and more.

SINCE the optic nerve and thoſe of the *uvea* ariſe from different parts of the brain, and have no communication with each other in their courſe to the eye, it ſeems evident, that light affecting the *retina*, cannot excite the *ſphincter* of the pupil into contraction, by any immediate mechanical change which it produces, either in the muſcle itſelf, or in the nerves which actuate it; but the uneaſy ſenſation occaſioned in the *retina* by the admiſſion of too much light into the eye, may ſo affect the ſentient principle, which is preſent and ready to act, where-ever the nerves have their origin, as to excite it to determine the ſpirits more copiouſly into the orbicular muſcle of the *uvea*, in order to leſſen the pupil, and exclude the offending cauſe. While the eye remains in the ſame degree of light, and directed towards the ſame object, the pupil

remains

remains invariably of an equal ſize, as the ſame cauſe continues uniformly to excite the mind to determine the nervous influence in the ſame degree into its *ſphincter* muſcle: but no ſooner does the light become fainter, than the ſentient principle, being leſs affected, ceaſes to contract this muſcle, and allows the curtain of the pupil to be opened by the natural action of its longitudinal fibres, by which means more light is admitted into the eye.

When the eye is ſuddenly removed from a very faint into a bright light, a conſiderable dazzling, with an uneaſy ſenſation, is plainly perceived; and though in ſmaller changes this is much leſs perceptible, yet it may be ſufficient to excite the mind to contract the pupil ſo far as may be neceſſary in ſuch caſes to defend the tender *retina*.

If it be aſked, why the orbicular muſcle of the *uvea* is rather contracted than its longitudinal fibres, upon the admiſſion of light into the eye; the anſwer is, that the contraction of the latter, would not tend to remove the uneaſy ſenſation, but to increaſe it: and ſuch is the original conſtitution of our frame, that the mind or ſentient principle is, in con-

ſequence

fequence of uneafy fenfations, inftantly determined to produce fuch motions or changes in the body, as naturally tend to remove or leffen them.

When a candle is placed before the eyes, if one of thefe organs is covered with one's hand, or any opaque body, the pupil of the other will be obferved immediately to become wider. Now, as the mufcles of the *uvea* of the one eye have no manner of connexion with thofe of the other, either by means of nerves or blood-veffels, unlefs it be that the former are derived from different parts of the fame brain, and the latter from the *aorta*, this confent in their motions muft be altogether inexplicable upon mechanical principles alone: for if the action of light on the eye is the caufe of the contraction of the pupil, why fhould not the pupil of the open eye remain equally contracted when the fame degree of light continues to act upon it; or why fhould it be affected by the relaxation of the other pupil, with which it has no immediate connexion, while the mechanical caufe of its own contraction continues to act with undiminifhed force?

But

BUT if we allow the contraction of the pupil to be owing to a ſentient active principle, which, in proportion as it is more or leſs affected, by the uneaſy ſenſation ariſing from the action of light on the *retina*, conſtricts the pupil in a greater or leſs degree; then, when one eye is ſhut, its *retina* being no more expoſed to the light, and conſequently the ſentient principle being no longer excited to contract the orbicular muſcle of the *uvea*, its pupil muſt be widened by the natural contraction of the ſtronger longitudinal fibres of this membrane: but as the mind has, from the time of birth, been always accuſtomed to contract the pupils of both eyes at the ſame time, the one pupil can no more be relaxed without the other being partly ſo, than one eye can be directed to the noſe, while the other is turned from it: for how much ſoever the motions of certain muſcles are owing to the immediate energy of the mind, yet it is undeniable, that, by conſtant habit, we ſoon loſe the power of moving them, except in a particular way; and as this is true of the eyes, whoſe motions are quite of the voluntary kind, and may be performed

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or reſtrained at pleaſure, it cannot with any ſhew of reaſon be denied to take place in ſuch muſcles, whoſe action is from the beginning neceſſary and independent on the will.

As in the above mentioned experiment the pupil of the open eye is conſiderably relaxed, on account of the conſent of its motions with the pupil of the other, ſo it is not to be doubted, but that the pupil of the covered eye is leſs enlarged than it would be, if no light was admitted into the open one: thus in a *gutta ſerena*, the blind eye has its pupil ſenſibly contracted, when the ſound one is expoſed to a bright light, *i. e.* the diſeaſed pupil follows in ſome degree the motions of the ſound one, and, by the action of light upon it, is hindered from being ſo much relaxed as it would be otherwiſe. It is however probable, if a perfect *amauroſis* was to continue long in one eye without affecting the other, that this conſent between the pupils, as to their motions, would gradually become leſs remarkable, till at laſt the pupil of the diſeaſed eye would ceaſe to be leſſened almoſt in any degree by the action of light on the ſound one.

Q WHEN

WHEN a candle is ſo placed as to ſhine full upon one eye, without any of its rays having acceſs to the other, the pupil expoſed to the light is obſerved to be ſomewhat leſs than the other; though neither of them is ſo much contracted, as if both eyes were equally affected by the light. Hence it follows, that notwithſtanding there is a remarkable uniformity between the pupils of both eyes as to their motions, yet they don't exactly keep pace, but the pupil immediately expoſed to the greateſt light is moſt contracted. And this ſerves further to ſhew, that when one eye is covered, the pupil of the open one becomes wider, from the conſent between its motions and thoſe of the darkened one; and not, as ſome may perhaps imagine, becauſe the mind receiving only the impreſſion of light acting upon one eye, and therefore being leſs affected than when both eyes are open, makes a leſs effort to exclude the light, by contracting the pupil. The reader will, however, eaſily perceive, that in both ways of explaining the above *phænomenon*, the neceſſity of deducing theſe involuntary motions from the ſentient principle, is equally acknowledged.

IF

IF it ſhall be alledged, that the contraction of the pupil is not owing to the action of light on the *retina*, but on the choroid coat, and that the *uvea* being a continuation of this membrane, and having its nerves from the ſame ſource, may eaſily be ſuppoſed to have a remarkable ſympathy with it. Without entering into the diſpute, whether it is the *retina* or choroid that receives the impreſſion of objects, and feels the *ſtimulus* of light; I anſwer, that as the agreement juſt now obſerved between the two pupils as to their motions, cannot poſſibly ariſe from any mechanical conſent between them, but muſt be owing to ſome common PRINCIPLE in the brain; ſo it is highly reaſonable to imagine, that the contraction of the orbicular muſcle of the *uvea*, in conſequence of light being admitted into the eye, proceeds from the ſame cauſe, and not from any connexion between the choroid and *uvea*: for ſuppoſing it did, why ſhould its circular fibres rather than its longitudinal ones be contracted; ſince, as the latter are nearer to, and more immediately derived from the choroid than the former, one would

would be apt to think their ſympathy with it ſhould be the more remarkable.

HAVING, as we hope, given a clear and conſiſtent account of the pupil's motions, ſo far as they are owing to different degrees of light applied to the eye; it may not perhaps be improper, briefly to point out a few miſtakes of ſome authors of conſiderable character, with reſpect to this matter.

MR. *Mery*, not being able to obſerve any circular fibres in the *iris*, whoſe contraction might account for the conſtriction of the pupil, endeavours to prove that this is owing to the inflation and elongation of its longitudinal fibres by the animal ſpirits being more copiouſly derived into them; and that the dilatation of the pupil is owing ſolely to the ſpring or elaſticity of theſe fibres, whereby they become ſhorter when left to themſelves*. But there is no inſtance in the human body, of any muſcle being elongated by a more copious derivation of the nervous influence into it; the conſtant effect of this is, to ſwell, harden, and ſhorten the muſcle at the ſame time. Nor indeed would it be eaſy to conceive (al-

lowing

* Memoires acad. des ſciences 1704, edit. 8vo. p. 352.

lowing a fingular ftructure in the longitudinal fibres of the *iris*) how they could be fo lengthened by the influx of animal fpirits, as to reduce the pupil almoft to a point, without, at the fame time, being fo inflated as to make a very remarkable difference in the thicknefs of this membrane.

THE ingenious Mr. *de la Hire* imagines, that as a bright light, by difagreeably affecting the bottom of the eye, excites us to contract the pupil; fo, in the dark, we do our utmoft to dilate it, that we may fee more diftinctly *; that is, its dilatation is owing to an effort of the will, determining the nervous influence more copioufly than ufual into the longitudinal fibres of the *iris*. To prove this, he fays, that cats in a luminous place, when they don't feem to be taking notice of any thing around them, have their pupils almoft quite fhut, but that, as foon as any extraordinary object prefents itfelf, fo as to draw their attention, they immediately, and at once, open their pupil confiderably †. If this be true, as I dare fay it is, then cats muft be allowed to have a power of dilating, and probably

* Memoires acad. des fciences 1709. edit. 8vo. p. 121.

† Ibid. p. 121. 122.

probably alſo of contracting their pupil at pleaſure, when the quantity of light applied to their eyes remains the ſame; which however is not the caſe with men, in whom the wideneſs of the pupil in a *ſyncope*, apoplexy and confirmed *gutta ſerena*, ſhews, that, in order to dilate the pupil to its largeſt ſize, no effort of the mind is neceſſary, but only the ſuperior contractile power of the longitudinal fibres of the *uvea*, when its circular muſcle is not excited into action by the *ſtimulus* of light on the *retina*. Nor have I ever been able to obſerve that the pupil is narrower in a light room, when one does not attend to any thing around him, and becomes wider as ſoon as he looks ſtedfaſtly at any object, and endeavours to ſee it diſtinctly.

THE ſame author, in conſequence I ſuppoſe of his above mentioned notion of the voluntary dilatation of the pupil, alſo alledges, that, in a bright light, when we look attentively at an object in order to ſee its ſmall parts, the pupil is not ſo much contracted as it would be by the action of this degree of light alone, did we make no ſuch effort to ſee any thing diſtinctly *. This, however, is

* Memoires acad. des ſciences 1709, edit. 8vo. p. 121. 122.

is ſo far from being true, that it will appear, from experiments to be mentioned below, that in the ſtrongeſt light the pupil is leſs contracted when we make no effort to ſee any thing diſtinctly, than when we look with great attention to a near object, ſo as to obſerve its minute parts.

THE learned Dr. *Haller*, equally doubtful of the exiſtence of the circular, and of the action of the longitudinal fibres of the *uvea*, deduces the contraction of the pupil from the *ſtimulus* of light affecting the *iris*, and cauſing a greater flux of humours into its fine pellucid veſſels, by which means they are extended in length, the *iris* is rendered broader, and conſequently the pupil narrower. The dilatation of the pupil, he aſcribes to the aqueous humour preſſing its edges outward, when the powers contracting it, and conſequently reſiſting the preſſure of this fluid, are weakened *. But, if the contraction of the pupil was owing to the elongation of the veſſels of the *iris*, from the humours moving with greater force through them; then, in animals newly dead, warm water injected into the carotid

* Primæ lineæ Phyſiolog. ſect. 506. & 515.

rotid artery, ſhould make the pupil contract ſenſibly. Further, the *iris* ſhould become thicker and its veſſels ſwell; ſince the greater force of the fluids moving in them muſt increaſe their tranſverſe diameter, as well as their length: thus when the *penis* is erected by the effuſion of blood into its cells, it becomes thicker, as well as longer. Laſtly, as this theory ſuppoſes the contraction of the pupil to proceed from the action of light as a *ſtimulus* upon the ſenſible veſſels of the *iris*, it may be looked upon as ſufficiently confuted, by what has been offered above, to ſhew that it is to the action of light on the *retina*, and not on the *iris*, that the contraction of the pupil is owing.

WITH reſpect to Dr. *Haller*'s account of the dilatation of the pupil; it were ſufficient to obſerve, that as the watry humour, like all other fluids, muſt neceſſarily preſs the parts of the *iris* as much inwards toward the pupil, as outwards toward the *cornea*, 'tis evident it can have no effect in widening the pupil. Unleſs therefore the *Doctor* will ſhew, contrarary to the firſt and hitherto univerſally received principles of hydroſtatics, that the parts of the aqueous humour are not in *equilibrio* among

mong themſelves, his opinion muſt neceſſarily fall to the ground. But further, if the dilatation of the pupil was not owing to the natural contractility of the longitudinal fibres of the *uvea*, but merely to the preſſure of the aqueous humour upon its edges, when the power conſtricting it ceaſes to act; the pupil ſhould, contrary to experience, continue to grow wider for ſome time after death, becauſe the veſſels and fibres of the *iris*, becoming then remarkably more flaccid, muſt be leſs able to reſiſt the ſuppoſed preſſure of the aqueous humour: but if the enlargement of the pupil, is owing to the natural contraction of the longitudinal fibres of the *iris*, as has been above explained, then it will evidently appear why the pupil does not become wider, but rather narrower after death, becauſe theſe fibres which retract its edges, gradually loſe their contractile power, and are ſomewhat elongated.

THE accurate *Winſlow* is, I believe, the firſt who obſerved that the pupil becomes leſs after death. In ſome bodies he found it of a moderate ſize, in others a good deal more contracted, but never much dilated, as we know happens in a *gutta ſerena*, *ſyncope*, apoplexy, *&c* *. The pupil, however, not only thus becomes narrower after death, but alſo ſometimes before it.

THUS in a boy of 5 years of age, who had been for ſome days comatous, the pupil firſt became remarkably wide, and was not ſenſibly affected by a lighted candle brought very near the *cornea:* about 15 hours after this, looking into his eye, I obſerved, with ſurprize, the pupil not larger than in a ſound eye in a moderate light. At this time having endeavoured to rouſe him, by holding ſpirit of *ſal ammoniac.* to his noſtrils, and making him ſwallow ſome cinnamon water with *ſp. ſalin. aromat.* the pupil was thereby ſuddenly dilated, and became as wide as it had been the evening before. After half an hour, he fell into a greater degree of *ſtupor*, and his pupil became remarkably leſs as above, and remained equally ſo in all degrees of light; but upon applying ſpirit of *ſal ammon.* to his noſe, was quickly enlarged, ſo as to occupy two thirds of the *cornea*, This experiment I repeated four times in the ſpace of two days, and

* Memoires acad. des ſciences 1721. edit. 8vo, p. 416.

and always with the ſame ſucceſs. During moſt of this time, his pulſe was ſtrong and full. When this child's head was opened after death, there were found immediately below the *corpus calloſum*, about two ounces of water.

FROM this remarkable hiſtory, it ſeems manifeſt, that the dilatation of the pupil ſoon after the coming on of the *coma*, was owing to the compreſſion of the *thalami nervorum opticorum*, by the water collected in the brain, which rendered the *retina* inſenſible to the *ſtimulus* of light. Soon after, the origin of the nerves of the *uvea* beginning to be compreſſed by the growing collection of lymph, the longitudinal fibres of this membrane loſt their power of contraction, and became flaccid, almoſt as in dead bodies; whence the edges of the pupil were leſs retracted. The volatile ſpirits applied to the olfactory nerves, by giving a ſhock to the whole brain and nervous ſyſtem, in ſome degree opened the obſtructed nerves of the *uvea*, ſo as to allow their influence to be derived into its fibres, the neceſſary conſequence of which was the dilatation of the pupil. But as ſoon as the effect of this

ſtimulus

ſtimulus was over, the influence of their nerves being again intercepted, the longitudinal fibres of the *uvea* were relaxed, and therefore the pupil was leſs dilated. As theſe different ſtates of the pupil were more remarkable in the left than in the right eye, it is probable, that one ſide of the medullary ſubſtance of the brain was ſomewhat more compreſſed than the other. Laſtly, ſince, after the pupil was enlarged by the *ſtimulus* of the volatile ſpirits, the eye ſtill remained wholly inſenſible to the action of light, it is reaſonable to think, that the preſſure upon the origin of the optic nerves was greater, than upon that of the nerves of the *uvea*: but although the origin of both theſe nerves had been equally affected by the diſeaſe, yet the volatile ſpirits applied to the membrane of the noſe, ought to have produced a more remarkable effect upon the latter, becauſe the opthalmic branch of the fifth pair of nerves which ſerves the *uvea*, ſends off a branch, which, along with the olfactory nerve, is diſtributed to this membrane.

2. THE

2. The motions of the pupil are not only neceſſary to adapt the eye to different degrees of light, but alſo to the diſtinct viſion of objects at different diſtances. Thus if a book which one can eaſily read at the diſtance of two feet, is gradually brought nearer the eye, till the letters can be no longer diſtinguiſhed, the pupil will be obſerved to become narrower in proportion as the book approaches the eye. Again, if one looks firſt to a candle two or three feet diſtant, and immediately after to the point of a quill, or any ſuch object, within five or ſix inches of the eye, and nearly in the ſame direction with the candle, the pupil will be ſenſibly contracted: now, as the ſame quantity of light from the candle, ſhines upon the eye in theſe two caſes, the greater contraction of the pupil in the latter caſe, cannot be owing to the light more ſtrongly affecting the *retina*, but to an effort of the mind to ſee the object more diſtinctly. This is ſtill further confirmed by the following experiment; let one with his back to the light, firſt look to an object of a lively colour at the diſtance of three or four feet from his eyes, and afterwards to a dark one at

at the diſtance of one foot, and the pupil will be obſerved to become ſenſibly narrower when he looks at the near object, although the quantity of light reflected from it is leſs. Hence the learned Dr. *Jurin* is miſtaken when he ſays, that in a faint light the pupil is ſo far from contracting in order to diſtinct viſion, that there is rather a neceſſity of dilating it in order to take in more light *.

THE neceſſity of this contraction of the pupil when we look at near objects in order to render viſion more diſtinct, is eaſily underſtood; for as in near objects the divergency of the rays is much greater than in diſtant ones, and as thoſe rays only ſerve for diſtinct viſion, which do not diverge much from the *axis* of each pencil, the pupil muſt be contracted, in order that the uſeleſs or diſturbing ones may be excluded. The contraction therefore of the pupil in viewing near objects, is not ſolely owing to the ſpiſſitude of the rays reflected from them, as *Plempius*, who firſt obſerved this motion, and others after

* Eſſay on diſtinct and indiſtinct viſion at the end of *Smith's* Optics, p. 145.

ter him, have thought *, but chiefly to an effort of the will in order to diſtinct viſion: in like manner, when we look at remote objects, the pupil not only becomes wider, becauſe the rays are thinner, and conſequently their light fainter, but chiefly becauſe the contraction of its *ſphincter* muſcle is no longer neceſſary to leſſen the diſſipation of the rays. In viewing diſtant objects, the pupil is not widened by any effort of the mind, but its ſize is entirely determined by the quantity of light applied to the eye, which, as it is, *cæteris paribus*, fainter in diſtant than in near objects, muſt occaſion a ſmall degree of dilatation in the pupil, when we contemplate the former: but in looking at any thing nearer the eye, than that diſtance at which we ſee diſtinctly, and with the greateſt eaſe, the contraction of the pupil is principally owing to a voluntary exertion of the mind's power in order to render viſion more diſtinct; and but in a very ſmall degree, to the ſtronger and more vivid light, which the object, on account of its vicinity, reflects upon the eye.
Hence

* *Plemp*. opthamogr. lib. 3. cap. 8. and *Haller*. comment. in inſtitut. Boerhaav. ſect. 536.

Hence its dilatation in the former caſe, is much leſs remarkable than its contraction in the latter.

Maitre-Jan has, by a wonderful miſtake, aſſerted, that the pupil is leſſened when we look at diſtant objects, and enlarged when we behold near ones; and is at great pains to ſhew the uſefulneſs of theſe motions to diſtinct viſion. But his reaſoning on this head is extremely weak, and ſcarce conſiſtent with any tolerable knowledge of optics *.

THE author of the *Eſſais de phyſique*, ſuppoſed to be Dr. *Senac*, has fallen into an error not leſs inconſiſtent with the laws of viſion, when he affirms, that the images of objects in the bottom of the eye, are greater or leſs, as the pupil is more or leſs dilated; and hence accounts for the ſun's appearing much larger when he firſt gets above the horizon, than at mid-day, when his greater ſplendor makes the pupil to be more contracted †. But if this were ſo, objects ought to appear always largeſt in the fainteſt light; which we

* Maladies de l'œil. chap. viii. & xxi.

† L'Anatomie d'Heiſter, avec Eſſais de phyſique, edit. 2. p. 703.

we do not find confirmed by experience. Further, ſince the image of any object is formed by the union of the pencils of rays that flow from each point of the object in correſpondent points of the *retina*, it is evident, that its magnitude depends on no other circumſtances, but the real magnitude of the object, and its real diſtance from the eye *. The different ſize of the pupil may, agreeably to what has been obſerved above, affect the luſtre and accuracy of the ſeveral points of the image, but cannot alter their diſtance, becauſe the *axis* of the ſeveral pencils, and their angles of inclination, continue the ſame, whatever is the bulk of the pupil.——Any one may ſatisfy himſelf at once, by an eaſy experiment, that the contraction and dilatation of the pupil cannot alter the bulk of the image of any object formed on the bottom of the eye; for the picture which is made by a common *lens* on a ſheet of paper, will not be found to

S ſhrink

* It is not affirmed, that the apparent magnitude of objects depend on the circumſtances here mentioned alone; for we are well aware, that experience, the known diſtance of objects, and other things, have great influence in this matter.

ſhrink or ſwell, when greater or leſſer concentric portions of the *lens* are covered.

As we have already ſeen, that the pupil cannot be ſo much contracted by the action of light alone on the eye, as when, along with this, there is an effort of the will to ſee a near object more diſtinctly; ſo the pupil cannot, by any effort, in order to diſtinct viſion, be as much leſſened in a faint light as in a bright one. Thus, if one with his back to the windows of a room, brings a ſmall printed book ſo near his eyes, that he cannot, without ſtraining, diſtinguiſh the letters; upon turning his face quickly to the light, he will be able to read with little difficulty; becauſe, by the action of the ſtronger light on the *retina*, the pupil is immediately leſſened, and therefore its power, to prevent the diſſipation of the rays, and conſequently indiſtinct viſion, is increaſed. Hence neither the ſingle effort of the mind to avoid indiſtinct viſion, nor a vivid light alone, can contract the pupil to its leaſt ſize, that is, not ſo much as when both theſe cauſes of its contraction are united.

In infants, but more eſpecially in ſuch as are newly born, the pupil is obſerved to be conſiderably confiderably wider than in grown people, when the eyes of both are expofed to the fame degree of light; 1. becaufe in *fœtufes* and new-born children, the *cornea* being thicker, lefs tranfparent, flatter, and not fufficiently ftretched, on account of the fmall quantity of aqueous humour *, vifion is very indiftinct, and the *retina* is lefs affected by the rays of light, which are neither freely tranfmitted to, nor properly collected upon it; and, 2. becaufe they want in a great meafure the faculty of contracting the pupil, in order to the more diftinct vifion of near objects, which feems to be partly acquired by habit. The caufes, therefore, to which the contraction of the pupil are owing, being weaker in infants than in adults, 'tis no wonder that this paffage appears more dilated in the former than in the latter. Dr. *Jurin* has given a different account of this *phænomenon*; but fuch as we can by no means think fatisfactory †.

IN old people the pupil becomes lefs moveable, becaufe the *retina* grows lefs fenfible of the

* Memoires acad. des fciences 1727. edit. 8vo. p. 348. 349. & 350.

† Effay on diftinct and indiftinct vifion, p. 147.

the *ſtimulus* of light, and the muſcular fibres of the *iris* loſe in part their contractile power: further, in old age the *cornea*, on account of the decreaſe of the aqueous humour, not only loſes its brilliancy, but becomes alſo in ſome degree wrinkled; whence the *retina* will be leſs affected by light, and conſequently the pupil will be leſs contracted.

THE motions of the pupil from light, differ from thoſe which are performed in order to render viſion leſs indiſtinct; ſince the former are owing to an uneaſy ſenſation affecting the *retina*; whereas the latter ariſe from an act of volition, or effort of the will in order to the more diſtinct viſion of objects at certain diſtances. The former are of the ſame kind with the contraction of the diaphragm in the hiccup and in vomiting, of the muſcles of reſpiration in ſneezing, and of the *accelerators urinæ* in expelling the *ſemen*. The latter agree with the motions of the cryſtalline, by which the eye is adapted to ſee diſtinctly at different diſtances, and with the uniform motions of the eyes in looking at objects. The firſt are ever neceſſary and independent of the will; but the ſecond are plainly

plainly voluntary, and can be reſtrained if we pleaſe, though they are often not attended with conſciouſneſs of volition.

IN looking at near objects, the pupil is leſſened, at the ſame time that the cryſtalline humour is brought forward towards the *cornea*, by the contraction of the ciliary proceſſes; but when we contemplate diſtant ones, the contraction of the ciliary proceſſes and orbicular muſcle of the *uvea* ceaſing, the cryſtalline returns to its natural ſituation, and the pupil to that ſize to which it is fixed by the quantity of light applied to the eye. Theſe motions though both voluntary, yet come to be ſo connected by habit, that we cannot perform them ſeparately; nay, as often as we direct our eyes to any near object, the motion of the cryſtalline and contraction of the pupil naturally go along, and are performed in ſuch a degree, as is moſt proper to procure diſtinct viſion at that particular diſtance: nor can we ſeparate theſe three motions; although as they are all voluntary, they may be reſtrained or performed at pleaſure.

THE pupil differs from the *anus*, neck of the bladder, and other paſſages guarded by *ſphincters*,

sphincters, in being always dilated when nothing adventitious acts on the eye, while the latter, left to themselves, are constantly contracted; the reason of which is, that the natural and equable contraction of the longitudinal fibres of the *uvea*, which serve to dilate the pupil, is strongest, while the contrary holds true of the other passages now mentioned, whose *sphincter* muscles have either no proper antagonists, or such as are much weaker than themselves. Further, after death, when these *sphincters* are relaxed, and consequently their passages rendered more patent, the pupil becomes sensibly less, because the longitudinal fibres of the *iris*, to whose contraction its dilatation was owing, lose their contractile power, grow flabby, and are elongated. Hence we see, that at death the eye-lids remain partly open, for the same reason that the pupil is lessened after it.

If from any cause the longitudinal fibres of the *uvea* are rendered quite paralytic, while its circular muscle retains its usual power, the pupil will, by the natural contraction of the latter, be at all times very much constricted, so that in a bright light it will become little less

leſs than in the ſhade. If the circular, as well as longitudinal fibres of the *iris*, are entirely paralytic, the pupil will be altogether deſtitute of motion, and much in the ſame ſtate that it is ſome time after death, *i. e.* it will be generally as much contracted as the pupil of a ſound eye is in a moderate degree of light. If the muſcular fibres of the *iris* are not wholly deprived of their contractile power, but greatly weakened, the pupil in a dark place will have its edges a little retracted by the action of the longitudinal fibres, and in a bright light will be ſomewhat leſſened by the contraction of the circular ones; but theſe motions will be much more inconſiderable than in a ſound eye.

In all the caſes now mentioned, the diſeaſe called by *Hippocrates*, and others among the antients, ἡμεραλωπία, will happen, *i. e.* the patient will ſee in the day-time, but in the twilight and night-ſeaſon, he will not be able to diſtinguiſh objects. An inſtance of this I had lately occaſion to ſee in a young man of about 27 years of age, who had ſerved for ſome time in the navy, where he had been expoſed to much fatigue and cold: his eyes appeared

appeared ſound; nor could I obſerve that they differed from the eyes of other people, excepting that the pupil had very little motion: it remained always pretty narrow, and was neither remarkably contracted by light, nor dilated in the dark. This perſon ſaw well enough in the day-time, eſpecially if the weather was ſerene; but in the twilight, or in an obſcure place, was ſo far from diſtinguiſhing objects, that he could ſcarcely find his way: as his pupil had ſome motion, 'tis probable, that the fibres of the *iris* were not quite paralytic, though greatly debilitated: his ſeeing in the day-time ſhewed, that the *retina* was either wholly, or in a great meaſure, ſound; and that his blindneſs in a faint light, was owing to the pupil's not being dilated ſo as to admit a ſufficient quantity of rays into the eye.

IF, after an inflammation of the *iris*, a rigidity is left on its circular or longitudinal fibres, the pupil will be deprived, either wholly, or in a great meaſure, of its uſual motions; and may be either too much contracted, or greatly dilated: if the former, the patient will only ſee well by day; if the latter, the eye will not be able to bear a bright light,

light, and therefore the patient will ſee beſt in the ſhade and by candle light; *i. e.* he will labour under the diſeaſe called νυκτάλωπία.

ALTHOUGH in an *amauroſis* the pupil is generally very wide, yet this is not always the caſe, for as often as the fibres of the *uvea* are entirely deprived of their contractile powers, the pupil appears as much or rather more contracted than in a ſound eye. Of this I ſaw an inſtance, not long ago, in a woman who was almoſt totally blind of both eyes, where there was no opacity in the *cornea* or cryſtalline humour, but only a want of motion in both pupils. The pupil of the right eye was immoveable, and always as much contracted as it ſhould have been in a moderate light; the other was dilated, as is uſual in a *gutta ſerena*, but when expoſed to the light ſeemed to contract a very little. By means of this eye ſhe diſcerned light from darkneſs, but could not diſtinguiſh objects: with the other eye ſhe ſaw nothing.

IN this patient both eyes ſeem to have been affected with a *gutta ſerena*; in the right eye the *retina* was not only inſenſible, but the muſcular fibres of the *uvea* muſt have been

T quite

quite paralytic, whence the pupil remained always moderately contracted, as *Winslow* has commonly observed it sometime after death *. In the left eye the *retina*, though considerably diseased, was not wholly destitute of feeling, and the fibres of the *uvea* seem to have been found and possessed of their usual contractile power.

Of the motions of the muscles of the internal ear.

AS, without the motions of the pupil, the eye would have been ill contrived for vision in different degrees of light, and at different distances; so the ear would have been unfit for hearing distinctly a diversity of sounds, were not some of its parts capable of various degrees of tension. A musical chord, of a determinate length and tension, can only vibrate harmonically with one particular sound; if therefore there was no mechanism, by means of which the membranes of the *tympanum* and *fenestra ovalis* could be more or less

* Memoires acad. sciences 1721. edit. 8vo. p. 416.

leſs ſtretched or relaxed, they could only be harmonically affected by one ſound; which therefore alone would be heard diſtinctly, and all others more or leſs confuſedly. To prevent this inconveniency, the *malleus* is furniſhed with three muſcles, and the *ſtapes* with one; by the various contractions of the former, the membrane of the *tympanum*, and by means of the latter, the membrane of the *feneſtra ovalis*, is rendered more or leſs tenſe, and ſo accommodated to almoſt all poſſible ſounds.

IT may well appear wonderful, how the ears ſhould be ſo exactly adapted by the various contractions of theſe muſcles, to ſuch a vaſt variety of ſounds; but with what exquiſite ſkill and amazing wiſdom, is every thing in the animal frame adjuſted!——As the *ſtimulus* of light upon the *retina*, and the ſenſation of indiſtinctneſs in near objects, excite the mind to contract the pupil, ſo the leſs diſtinct *tremor* of different ſounds, affecting the auditory nerves, is the cauſe of the ſubſequent contractions of the muſcles of the internal ear; for no ſooner does the mind perceive the firſt indiſtinct noiſe of any ſound, but

but it inftantly contracts fome of the above mufcles, fo as moft nicely to adapt to it the membranes of the *tympanum* and *feneftra ovalis:* if the found be acute thefe membranes are juft as much ftretched as is neceffary for their vibrating harmonically with it; if it be flat, they are duly relaxed: and thus, by a moft fimple mechanifm, the ear is rendered fenfible of the fmalleft variations of found or difference of notes in mufick. As infants feem, by habit, to acquire a faculty, or at leaft a greater dexterity of adjufting their eyes, by the motions of the pupil and cryftalline humour, to the various diftances of objects, fo it is not altogether improbable, that they may at firft hear lefs diftinctly, till, by degrees, they come to acquire a power of readily accommodating their ears more exactly to different founds. And is not the want of an EAR (as it is ufually called) owing to a deficiency of this power*? While that exquifite difcernment of mufical founds, which many poffefs, fhews, that they can adjuft their ears to different notes with the greateft accuracy.

THAT

* This may arife either from a lefs degree of fenfibility in the auditory nerves, or of agility in the mufcles of the ear, or from both.

THAT the motions of the mufcles of the internal ear proceed from the mechanical action of found or vibrating air on their fibres, the analogy of the motions of the pupil forbids us to believe. Further, if this was the cafe, why fhould not all the mufcles of the *malleus* be equally contracted by the fame found? And why fhould thofe which ferve to ftretch the membrane of the drum, be excited into motion by acute founds, while the mufcle which relaxes it, is only brought into action by grave ones?—As brute animals upon the firft perception of any noife, turn their external ears towards the place from whence it comes, fo, at the fame time, they adapt their internal ear to it; the firft of thefe motions cannot be denied to flow from their fentient principle actuated by the found; why then fhould we doubt that the latter proceeds from the fame caufe?

THE motions of the mufcles of the internal ear in confequence of various founds, are not only unattended with confcioufnefs of volition, but altogether neceffary and involuntary, for we cannot move them except when found ftrikes the ear, nor hinder them to act when it does.

SECT.

SECT. VIII.

Of the alternate motions of respiration.

RESPIRATION is that action whereby a certain quantity of air is alternately received into the lungs and expelled out of them: it consists of inspiration and expiration. Inspiration, or the reception of air into the lungs, is owing to the contraction of the *intercostal muscles* and *diaphragm*, whereby the cavity of the *thorax* is both lengthened and widened; for as the lungs, together with the heart, &c. perfectly fill the cavity of the breast, and as their exterior surface is every where contiguous to the *pleura* and *diaphragm* *, it necessarily

* Some authors, I know, contend, that the lungs are not contiguous to the *pleura*, and that, in the space between them, there is contained, what they call internal air, the use of which in respiration, they are at great pains to shew; but the arguments, upon which this opinion is founded, are no way conclusive, and might be easily refuted, were it not foreign to our present design; nor is the authority of the accurate *Morgagni* here of any weight *, since the best Anatomist may be deceived in making a single experiment, and since we have the repeated experiments of some of the greatest Anatomists against him; nay in every dead body, where the integuments and intercostal muscles are carefully taken off, the lungs, are seen contiguous to the *pleura*.

* Adversar. anat. 5. animadver. 33. p. 46.

ceſſarily follows, that when the *diaphragm*, by its contraction deſcends, and the ribs, by the action of the intercoſtals, are raiſed, the lungs muſt follow them, and conſequently the external air ruſh in by the *glottis*, to fill the vacuity that would otherwiſe happen in the cavity of the cheſt.

INSPIRATION being thus performed, the inſpiratory muſcles are relaxed, upon which the ribs by the renitency of their elaſtic cartilages return to their former ſituation, and the diaphragm, by the reaction of the ſtretched *peritonæum*, *pericardium*, and abdominal muſcles, is puſhed up into the *thorax*; whoſe cavity being therefore diminiſhed, the air contained in it, muſt be expelled by the *glottis* *.

IN order to account then for the alternate motions of reſpiration, it is only neceſſary to ſhew, why the intercoſtal muſcles and diaphragm are alternately contracted, and relaxed, ſince their contraction produces inſpiration, and their relaxation allows the reni-

tency

* While the cavity of the *thorax* is leſſened by the cauſes here mentioned, the muſcular fibres of the *bronchia*, by their contractile power, contribute to the expulſion of the air out of the lungs.

tency of the cartilages of the ribs, &c. to cauſe expiration *. But as Mr. *Bremond* has in the *memoires* of the *acad.* of *ſciences* for 1739, favoured us with a ſet of pretty extraordinary experiments, which, he thinks, clearly prove, that the lungs are not paſſive in the affair of reſpiration, but endued with a power of dilating and contracting themſelves, independent of the motions of the *thorax*; it will be neceſſary, before we proceed any further, to ſhew, how far this ingenious Gentleman has been deceived; and that the lungs have really no proper alternate motion of their own, but follow the motions of the cheſt.

Of the experiments related by Mr. *Bremond* the following are the moſt remarkable.

1. After a wound made in the *thorax* of a dog, the lungs, inſtead of collapſing, continued to be contracted and dilated alternately, but their motions were aſynchronous to thoſe of the

* If any one doubts of both rows of intercoſtal muſcles conſpiring to pull up the ribs, he need only compare what *Winſlow* has ſaid on this head (anat. ſect. 3 N° 1057, 1058, 1059,) with the courſe and direction of theſe muſcles in a freſh ſubject, or if that can't be had, with the elegant figures of them publiſhed by Dr. *Hoadly* at the end of his lectures on reſpiration.

the *thorax*; for when the ribs were depreſſed, a ſmall portion of the lungs was thruſt out at the wound with a conſiderable force *.

2. AFTER making an opening in the breaſt, and breaking four or five of the ribs, the lungs continued for ſome time to be alternately expanded and contracted †; iſſuing out at the wound always when the *thorax* collapſed.

3. AFTER three ligatures were made upon the *trachea* of a dog, and the *thorax* was opened, the alternate motions of the lungs were obſerved to go on very briſkly; but they appeared to be dilated, and iſſued out at the wound when the cheſt was contracted, and *vice verſa* ‡.

HOWEVER difficult it may be thought, at firſt ſight, to account for the appearances in theſe experiments, yet it is eaſy to ſhew, that the lungs cannot poſſibly be endued with a power of expanding themſelves, independent of the dilatation of the *thorax*,

U as

* Memoires 1739, edit. 8vo. p. 463. and 465.

† Ibid. p. 464. and 465.

‡ Ibid. p. 468.

as Mr. *Bremond* ſeems to think, after *Platerus*, *Sennertus*, and others, who in this followed the doctrine of the *Arabian* phyſicians.

As the lungs are compoſed of an infinite number of veſicles and cellular interſtices *, which are partly made up of elaſtic contractile fibres, 'tis eaſy to perceive that when diſtended with air, they muſt endeavour to reduce themſelves to their former bulk; but, ſuppoſing the veſicles of the lungs empty and collapſed, by what mechaniſm can they expand themſelves, or where are the antagoniſt muſcles that can overcome the natural contraction of their fibres? All the hollow muſcles of animals are continually endeavouring to contract, nor can they be dilated by any mechaniſm of their own: thus the bladder of urine, which may aptly enough be compared to a ſingle veſicle of the lungs, ſpontaneouſly contracts itſelf, when the urine is evacuated, and would

* The reader may eaſily ſee, that our reaſoning here is of equal force, whether the lungs are ſuppoſed entirely cellular, with *Helvetius* *, or partly veſicular partly cellular, with *Winſlow* †.

* Memoires acad. des ſciences 1718, edit. 8vo. p. 30. 31. &c.

† Anatomie. ſect. ix. N° 105.106.107.

would for ever remain in this ſtate, were it not dilated by the urine following anew into it. In the ſame manner the ſtomach and inteſtines, which are hollow muſcles, have nothing in their ſtructure by which they can expand themſelves: they are ever endeavouring to arrive at their leaſt capacity, and are only prevented by the aliment, air, and other fluids contained in them. It follows, therefore, that the pulmonary veſicles and cells, which are compoſed of elaſtic contractile fibres, cannot poſſibly be dilated by any power or action of their own.

BUT further, if Mr. *Bremond*'s experiments prove any thing, the lungs have not only a power of inſpiring air by the *trachea*; but, although this fluid is denied its uſual acceſs by the *glottis*, can expand themſelves alternately, notwithſtanding the preſſure of the atmoſphere upon their external ſurface reſiſting ſuch expanſion; which is not leſs abſurd, than if one ſhould affirm, that a bladder perfectly empty, with a tight ligature about its neck, could, by its own proper power, ſwell and overcome the preſſure of the external air.

HAVING

HAVING ſhewn that the lungs cannot poſſibly be endued with a power of expanding themſelves, it remains, that we now inquire, to what cauſes their apparent motions, in *Bremond*'s experiments, were owing.

IN the two firſt experiments above mentioned, when the cavity of the *thorax* was enlarged by the action of the inſpiratory muſcles, a ſmall portion of air would be received by the *glottis* into the lungs of the wounded ſide: but as this could bear no greater proportion to the air entering by the wound, than the aperture of the *glottis* did to this opening, the ribs would at that time recede from the lungs, which therefore would ſeem to ſubſide.—When the *thorax* collapſed, the air contained betwixt the ribs and the ſurface of the lungs eſcaping by the wound, the lungs would ſoon become contiguous to the ribs, and even part of them would be puſhed out at the opening, not only on account of the convulſive conſtriction of the *thorax* ſqueezing the lungs much more, than in ordinary expiration, but partly from the ſmall quantity of air received by the *glottis* during the former inſpiration, and not yet wholly

wholly expelled, which being rarified by the heat of the lungs, muſt conſiderably increaſe their bulk.

The apparent conſtriction therefore of the lungs, when the dogs endeavoured to inſpire, remarked by *Bremond* in his experiments, is wholly to be aſcribed to the enlargement of the *thorax*, which at this time riſes from the anterior ſurface of the lungs; while they following the diaphragm now ſtrongly drawn down towards the *abdomen*, really recede from the *ſternum*. And if, during expiration, upon the ribs being depreſſed, and the diaphragm being forcibly thruſt up into the cavity of the breaſt, by the ſtrong convulſion of the abdominal muſcles, the lungs really appeared to ſwell, and ſome portion of them was even forced out at the aperture made in the *thorax*; yet this ought not to be attributed to an expanſion of the lungs happening at this time, but rather to the ſubſiding of the ribs and the protruſion of the diaphragm into the cheſt, whoſe cavity being therefore greatly diminiſhed, the lungs (in ſome degree inflated) not only fill it, but being preſſed on all ſides, are thruſt out at the wound,

wound, where there is leaſt reſiſtance, as ſoft clay, leaven, or ſuch like ſubſtances, when ſtrongly ſqueezed in the hand, are forced through the interſtices between the fingers.

BUT further, while the *thorax* is wounded only on one ſide, the lung of the other ſide continues to follow the motions of the cheſt as uſual, and to be alternately inflated with air ruſhing into it by the *glottis* *: when therefore, during expiration, the air is forcibly expelled out of this lung, although the greateſt ſhare of it eſcapes by the *glottis*, yet, ſince fluids preſs equally every way, ſome part muſt enter the large branches of the *trachea* which belong to the lung of the wounded ſide, and conſequently dilate it; and this the more remarkably, as the animal in howling conſtricts its *glottis* more or leſs, and ſo renders the egreſs of the air through it more difficult; hence, during expiration, this lung will appear to ſwell conſiderably, and part of it will be puſhed out at the opening in the *thorax*, not only as its cavity is at this time greatly leſſened, but as the lung itſelf is really in ſome degree inflated: 'tis plain however,

* *Highmore* diſquiſit. anatom. p. 188.

ever, that even this inflation is owing to the conſtriction of the *thorax* forcing the air out of the lung of the ſound ſide.

THIS is further confirmed by an obſervation of Dr. *Houſton*, who tells us, that when the dog howled, his lungs burſt out at the wound, but when he was ſilent, they retired within the *thorax* *; and ſeems to be put beyond doubt, even by an experiment of *Bremond*'s own making, in which although, after making an opening into one ſide of the *thorax*, and breaking three or four ribs, the lungs were puſhed out at the wound, every time the breaſt was contracted; yet, as ſoon as the anterior part of the *thorax* and *ſternum* were raiſed, and both ſides of the breaſt thus laid open, the lungs inſtantly collapſed, and remained ſo without any motion, notwithſtanding the heart, ribs and diaphragm continued their alternate motions for ſome time †.

DR. *Highmore*, who ſpeaks of the number of his experiments made upon dogs, in order to ſatisfy himſelf concerning the manner in which reſpiration is performed, as having almoſt

* Philoſophical Tranſactions abridged, vol. 9. p. 141.

† Memoires acad. des ſciences 1739, edit. 8vo. p. 464.

almoſt threatened the entire deſtruction of that ſpecies of animals, obſerves, that when both ſides of the *thorax* had large wounds made in them at once, the lungs always collapſed *: nay there is not one of the many experiments related by *Bremond* himſelf, in which the lungs were puſhed out of the *thorax*, when both ſides of it were opened.

It muſt be owned indeed, that, in two experiments of *Van Swieten*, the lungs did not collapſe, after both ſides of the *thorax* were perforated, but were protruded through the apertures, during expiration †. However, it is to be obſerved, that the wounds ſeem to have been but ſmall; ſince he afterwards adds, that when the opening in each ſide of the *thorax* parallel to the ribs, was half an inch or more in length, the animals quickly died. Further, while the animals lay quiet, the lungs kept within the cavity of the breaſt, and were only thruſt out of the wounds, when, on account of pain, they made great efforts; and ſince in ſtraining, or any violent motion of our muſcles, we always conſtrict the *glottis*, and retain the inſpired air in the *thorax*, it

* Diſquiſit. anatom. p. 188.

† Comment. in *Boerhaav.* aphor. p. 271.

it is more than probable, that the eruption of the lungs through the wounds, in expiration, was owing to the air being retained in them while the *thorax* collapſed. Laſtly, *Van Swieten* obſerved, that during inſpiration the orifices of the wounds became leſs patent, by the ribs being drawn nearer one another, ſo that a leſs quantity of air would enter by them, and a greater proportion by the *glottis*: hence the lungs did not collapſe; as always happened in *Highmore*'s experiments, when very large openings were made at the ſame time in both ſides of the *thorax*; but when a hollow tube, whoſe aperture greatly exceeded that of the *glottis*, was introduced into the wound of each ſide, the lungs inſtantly ſubſided, reſpiration ceaſed, the voice failed, and the dog ſeemed to die *.

WITH regard to the *phænomena*, in experiment 3d above mentioned, it ought to be obſerved, that the lungs in a natural ſtate, equally fill the cavity of the *thorax* in inſpiration and expiration; if therefore we ſuppoſe the lungs to have been in a middle ſtate of diſtenſion, when Mr. *Bremond* made his liga-

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* Commentar. in aphoriſm. *Boerhaav.* tom. 1. p. 271.

tures on the *trachea*, their bulk muſt have been conſiderably leſs than the cavity of the *thorax* when moſt enlarged, but at the ſame time greater than this cavity when the cheſt is violently conſtricted: ſo that we ought not to be ſurpriſed, if, upon the elevation of the ribs and depreſſion of the diaphragm in inſpiration, the lungs appeared to ſubſide, and no longer filled the *thorax*, or if, upon the conſtriction of the breaſt in expiration, they ſeemed to ſwell, and part of them was puſhed out at the wound.

BUT though we ſuppoſe the *trachea* to have been tied during inſpiration, yet ſince *Bremond* found, notwithſtanding the ligatures, that after the dog's death, a ſmall quantity of air blown forcibly through the *trachea* paſſed into the lungs, it is not improbable that the diaphragm and ribs ſtrongly ſqueezing the lungs in expiration, had forced out part of the air contained in them through the windpipe, ſo as to have reduced them to a moderate ſtate of expanſion.

LASTLY, if we ſhould ſuppoſe the ligatures to have been made even about the end of expiration, yet the air remaining in the lungs, being

being rarified by their heat, would ſoon increaſe their bulk to ſuch a degree, as that, when the *thorax* was greatly conſtricted, part of them muſt neceſſarily be puſhed out at the wound. Perhaps alſo, during the enlargement of the *thorax*, a ſmall quantity of air might, notwithſtanding the ligatures, be received by the *trachea* into the lung of the ſound ſide, which, upon expiration, would be chiefly puſhed into the lung of the wounded ſide, ſince its egreſs by the *glottis* would be very difficult, on account of the conſtriction of the *trachea*.

THAT the apparent motions of the lungs in the above experiments of *Bremond*, were in fact chiefly owing to the motions of the *thorax*, particularly to the alternate depreſſion and aſcent of the diaphragm, an experiment related by this writer himſelf muſt convince us; for we are informed by him, that the *abdomen* of a living dog being laid open, and a hole made in the fleſhy part of the diaphragm on the left ſide, the lung of this ſide inſtantly collapſed, and remained without any motion, although the *thorax* continued to be alternately dilated and contracted for a conſiderable

ſiderable time *. Now, if the lungs were endued with a power of expanding and contracting themſelves, why did the lung of that ſide, where the diaphragm was perforated, immediately collapſe and ceaſe to move? Beſides, does not this experiment ſhew, that the apparent motions of the lungs, and their egreſs by the wounds, were chiefly owing to their being alternately puſhed up into the cavity of the *thorax*, when the diaphragm was relaxed? That the aſcent of this muſcle into the cheſt, by the convulſive contraction of the abdominal muſcles, eſpecially when the dogs attempt to howl, contributes much more to the apparent ſwelling of the lungs and their iſſuing out of the *thorax* during expiration, than the falling of the ribs, is evident from another experiment of *Bremond*, who obſerved theſe motions of the lungs to continue, although, with his hands, he forcibly hindered the ribs of the wounded ſide from moving, and conſequently from preſſing the lungs alternately †.

Bremond

* Memoires acad. des ſciences 1739, edit. 8vo. p. 471.
† Ibid. p. 482.

Bremond always obſerved, that when the ribs were elevated, the lungs appeared red, but became paler when the cavity of the breaſt was diminiſhed *. The lungs being no longer preſſed while the *thorax* was enlarged, admitted the blood from the right ventricle of the heart more readily into all their veſſels; but being ſtrongly compreſſed by the aſcent of the diaphragm, and depreſſion of the ribs, this blood muſt in part be expelled; when of courſe they become paler.

WHAT has been ſaid above, may ſerve alſo to ſhew how far Mr. *Heriſſant* is miſtaken, when, from ſome experiments of a like nature with thoſe of *Bremond*, he concludes, that the apparent alternate dilatation and contraction of the lungs in animals whoſe *thorax* is laid open, is owing ſolely to the blood puſhed into the pulmonary artery by the right ventricle of the heart, which, by dilating and unfolding all its branches and ramifications, muſt make the whole ſubſtance of the lungs ſwell, and cauſe the air to ruſh into their veſicles by the *glottis* †.—

If

* Memoires acad. ſciences 1739, edit. 8vo. p. 483.
† Hiſtoire acad. des ſciences 1743, edit. 8vo. p. 103.

If this account of the matter was juſt, the alternate ſwelling and falling of the lungs would be very inconſiderable, and ought to correſpond with the contraction and dilatation of the heart; which however is not the caſe. Beſides, it ought not to be obſerved at all, when the paſſage of the air into the veſicles of the lungs is obſtructed by ligatures made on the *trachea*, contrary to what happened in *Bremond*'s experiments.

THUS much being premiſed, to ſhew that the lungs have not properly any inherent power by which they can alternately contract and dilate themſelves, but that, in ordinary and healthful reſpiration, they always follow the motions of the *thorax*, we proceed next to inquire, by what power or mechaniſm inſpiration and expiration alternately ſucceed each other, or why the intercoſtal muſcles and diaphragm are contracted and relaxed by turns, ſo long as life remains.

THE learned *Boerhaave*, in order to account for the alternate motions of the *thorax* in reſpiration, ſuppoſes, that, at the end of inſpiration, the blood is tranſmitted in ſmaller quantity to the left ventricle of the heart,

ſince

ſince the pulmonary veſſels muſt be conſiderably compreſſed by the lungs, which at that time are diſtended greatly with air: hence he conceives, that not only leſs blood will be diſtributed to the intercoſtal muſcles and diaphragm, but alſo that the influence of their nerves muſt be weakened; as the ſecretion of the ſpirits in the *cerebellum* muſt be diminiſhed, when a ſmaller quantity of blood is puſhed into its veſſels by the heart: the cauſes, therefore, which are ſuppoſed to contract the inſpiratory muſcles being weakened at the end of inſpiration, theſe muſcles will be overcome by the natural reſilition of the elaſtic cartilages of the ribs, together with the reaction of the abdominal muſcles, *&c.* *i. e.* expiration muſt neceſſarily follow; but no ſooner does the blood, by the motion of the lungs in expiration, flow in a more plentiful ſtream to the left ventricle of the heart, than the cauſes actuating the inſpiratory muſcles begin to be increaſed; whence theſe muſcles are contracted anew, *i. e.* inſpiration is produced, to which, for the reaſons above mentioned, expiration muſt neceſſarily ſucceed; and in this way the alternate motions of the

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cheſt in reſpiration are carried on through the whole of life *. This theory it muſt be owned is very ingenious, and has an air of ſimplicity which cannot fail to recommend it; but if ſtrictly inquired into, it will be found altogether inſufficient to account for the alternate motions of the *thorax*, or to anſwer the *phænomena* of reſpiration. For,

1. IF at the end of inſpiration the intercoſtal muſcles and diaphragm were relaxed, on account of the ſmaller quantity of blood and ſpirits then diſtributed to them, why ſhould not the heart, which alſo receives its nerves from the *cerebellum*, be affected in the ſame way? If the ſecretion of vital ſpirits were diminiſhed, on account of leſs blood's flowing from the lungs to the left ventricle of the heart at the end of inſpiration, how could the pulſe be then equally ſtrong as at the end of expiration? which however is the caſe, ſo far as our ſenſe of feeling can determine. But,

2. ALTHOUGH we ſhould grant, that at the end of inſpiration the blood flows in a ſmaller ſtream to the left ventricle of the heart, yet it will by no means follow, that the *cerebellum* will

* *Boerhaave* inſtitut. med. § 619. & 620.

will ceaſe to ſupply the vital organs with ſpirits ſufficient for their alternate motions; ſince we know, that after both the carotid arteries have been tied in a dog, the motions of the heart and reſpiration went on in the ordinary way, while in the mean time the *cerebrum* and *cerebellum* were deprived of more than one half of the blood uſually beſtowed upon them *.

3. AFTER the lungs have been kept for ſome conſiderable time in a collapſed ſtate by an effort of the will, the inſpiratory muſcles are no ſooner left to themſelves, than immediately they contract, and cauſe a new inſpiration; which however could not poſſibly happen if *Boerhaave*'s theory was true, ſince in this caſe the blood muſt flow with more than ordinary difficulty through their veſſels, and conſequently the cauſes actuating the inſpiratory muſcles muſt be greatly weakened †.

* *Van Swieten* comment. in Boerhaav. aphor. vol. I. p. 266.

† This argument muſt conclude with the greater force, ſince even *Boerhaave* himſelf allows, that the blood paſſes leſs freely through the lungs when they are collapſed than

BUT, 4. The inſufficiency of this account of reſpiration, is demonſtrated beyond doubt, by the experiments of *Highmore* and *Bremond*, who tell us, that, after both ſides of the *thorax* were laid open, the diaphragm and intercoſtal muſcles continued their alternate contractions for a long time, although the lungs were collapſed and without motion *. Here we find the motions of inſpiration and expiration continued in the *thorax*, while the lungs remained always in the ſame ſtate, and when there was no cauſe which could make the blood flow alternately through the pulmonary veſſels with greater or leſs eaſe, nor conſequently render the inſpiratory muſcles alternately paralytic, through a defect of blood and ſpirits.

5. LASTLY,

than when they are inflated. "Pulmone per aerem diſtento, ſanguini pulſo ex cordis dextro thalamo, latiora "vaſa arterioſa, & venoſa, minus reſiſtunt; tranſitum expediunt; faciunt ut omnis ille rapiatur eo quam celerrime ventriculum ſiniſtrum verſus: collapſus idem vix "per arteriam pulmonalem impleri poteſt liquore impulſo; inflatus per vaſa aerifera, facile ſanguiferorum impletionem patitur." *Boerh.* inſtitut. med. § 200. N° 2.

* *Highmore* diſquiſit. anat. p. 185. & Memoires acad. des ſciences 1739, edit. 8vo. p. 464. 467. 468.

5. Lastly, The different *phænomena* of reſpiration, in the air-pump, diſeaſes of the head, *aſthma*, and in melancholy people, are not to be accounted for from *Boerhaave*'s theory, and are alone ſufficient to overturn it: but of this more afterwards.

The late ingenious Dr. *Martine*, aware of the difficulties attending *Boerhaave*'s account of reſpiration, has propoſed the alternate compreſſion of the phrenic nerves at the end of inſpiration, as the cauſe which, at that time, renders the diaphragm paralytic, and conſequently produces expiration: he ſeems indeed to doubt, whether the alternate preſſure of the inflated lungs on the poſterior part of the *pleura*, can, at the end of inſpiration, intercept the influence of the nerves belonging to the intercoſtal muſcles which ly behind it: but as the phrenic nerves run between the lungs and *pericardium*, and are only covered by the thin *mediaſtinum*, he thinks, that, at the end of inſpiration, when the lungs are much diſtended with rarified air, theſe nerves muſt undoubtedly ſuffer ſuch a remarkable compreſſion, as to render the muſcle to which they are diſtributed paraly-

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tic *. But this account of the motions of refpiration, however ingenious, will be found ftill more defective and lefs fatisfactory than *Boerhaave*'s, which we have already rejected.

1. THIS account of refpiration muft at beft be allowed to be defective, as it does not inform us how the intercoftal mufcles come to be alternately contracted, as well as the diaphragm.——It is by no means probable, that the nerves of the intercoftal mufcles can fuffer any more compreffion than ufual at the end of infpiration; nor would it ferve the Doctor's purpofe to fuppofe they do, fince he feems to agree with thofe who are of opinion, that the two orders of intercoftal mufcles are antagonifts to one another, and confequently are contracted at different times.

2. SINCE the Doctor allows, that during infpiration the nerves become rather freer from compreffion, why fhould not the diaphragm remain contracted, and confequently the lungs continue in their moft expanded ftate? He fays indeed, that the infpired air, rarified by the heat of the breaft, and not finding an exit free or wide enough by the *glottis*,

* Medical Effays, vol. 1. art. 12.

glottis, will at this time preſs more upon the veſicles and membranes of the lungs; which preſſure muſt be communicated to the phrenic nerves running along the *pericardium*, and which are covered only by the *mediaſtinum*.

BUT ſurely the rarefaction of the inſpired air at the end of inſpiration, is not ſo remarkable or ſudden, but that it can iſſue faſt enough out by the aperture of the *glottis*, to preſerve it in *æquilibrio* with the external air: beſides, as inſpiration does not immediately follow expiration, but after a ſhort pauſe, ought not the air contained in the lungs at the end of expiration to be rarified, and ſo produce the ſame effect, by its preſſure upon the veſicles of the lungs and phrenic nerves, as at the end of inſpiration? The Doctor, it is true, ſeems to have been aware of this; and therefore ſuppoſes, that, at the end of expiration, the contractile fibres and membranes of the lungs, will, by their reaction, prevent in ſome meaſure the inflating air from preſſing with its whole force on the phrenic nerves. But will not this hold equally true at the end of inſpiration? and will not the elaſtic fibres and membranes of the lungs re-

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act with much greater force when they are remarkably diſtracted by inſpiration, than when they are conſiderably relaxed at the end of expiration? As the lungs, therefore, both in expiration and inſpiration, equally fill the cavity of the *thorax*, the compreſſion which the phrenic nerves ſuffer from them, will be pretty much the ſame at the end of expiration, as in a ſtate of full inſpiration; and conſequently the difference of this preſſure cannot account for the alternate motions of the muſcle to which they belong.

3. IF, at the end of inſpiration, the phrenic nerves ſuffered ſuch compreſſion from the inflated lungs, as to render the diaphragm paralytic, how comes it to paſs, that, after a full inſpiration, we can, by an effort of the will, keep this muſcle for a conſiderable time in a ſtrong ſtate of contraction, and thus hinder expiration from following inſpiration?

4. FURTHER, in one of Mr. *Bremond*'s experiments, where the lungs remained collapſed and without motion, and conſequently where the phrenic nerves muſt have been expoſed to an equable compreſſion, the intercoſtal muſcles and diaphragm continued in al-

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ternate contraction and relaxation for above a quarter of an hour *.

5. THAT the motions of refpiration vary according to the quantity or quality of the blood thrown into the pulmonary artery, to the free or difficult paffage it meets with in the veffels of the lungs, and to the heat or coldnefs, rarity or denfity of the air, are circumftances of great truth and importance, but utterly inexplicable upon this theory.

6. LASTLY, N° 2. 3. 4. and 5. of the arguments adduced in Sect. 2. to fhew that the alternate motions of the heart cannot be owing to the compreffion of the nerves, are here of equal, yea of greater force; for the foft and fpungy lungs are much lefs capable, even when inflated, of compreffing the nerves, than the firmer arteries and auricles of the heart.

THE various opinions of other writers, I fhall not ftay to enumerate, much lefs undertake to refute; but proceed to give an account of the motions of the *thorax*, which we hope will tend equally to explain the appearances obferved in refpiration, whether the lungs and

* Memoires acad. des fciences 1739, p. 468.

and other inſtruments concerned in it, be in a natural or diſeaſed ſtate.

1. DURING inſpiration and expiration, the blood finds an eaſy paſſage through the veſſels of the lungs, as by their alternate inflation and contraction, it is preſſed forward to the left ventricle of the heart. After inſpiration is completed, it begins to flow with more difficulty; and at the end of expiration (if inſpiration does not ſoon ſucceed) its motion is ſtill leſs free. After expiration, therefore, the blood, on account of its difficult paſſage through the pulmonary veſſels, is partly accumulated in them, and, by diſtracting their ſenſible fibres and membranes, acts as a *ſtimulus* upon the pulmonic nerves, occaſioning an uneaſy ſenſe of fulneſs, ſtoppage, or ſuffocation in the breaſt, which is more or leſs remarkable, according to the time during which reſpiration is ſtopt, the capacity of the pulmonary veſſels, and the quantity of blood thrown into them by the right ventricle of the heart.

THAT a *ſtimulus* affecting the heart and alimentary tube, ſhould be the cauſe of their alternate

ternate contractions, as we have ſhewn above, is no way improbable, the irritating cauſe being applied immediately to the organ to be moved; but that the diaphragm and intercoſtal muſcles ſhould be brought into contraction, by a *ſtimulus* acting upon the lungs, may at firſt appear ſomewhat extraordinary, tho', upon further conſideration, we may aſſure ourſelves of the certainty of the fact, from the ſtrongeſt and juſteſt analogy.—Thus, for example; if a few drops of water, or any other liquor, by an accident in ſwallowing, fall into the *trachea* the diaphragm and intercoſtal muſcles are inſtantly called into action, and continue to be agitated with alternate contractions and relaxations, till the ſtimulating cauſe is removed.—Again, if a thin pituit ſecerned in too great quantity, by the veſſels and glands of the *bronchia*, diſtills upon the veſicles of the lungs, alternate convulſions of the diaphragm, intercoſtal and abdominal muſcles, enſue; which are repeated over and over again, till the irritating cauſe is leſſened or expelled.—In a true peripneumony alſo, when, by reaſon of an obſtruction in the pulmonary arteries, the blood paſſes

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through the lungs with great difficulty, a ſhort cough is almoſt a conſtant ſymptom. Is it not therefore reaſonable to infer, that a leſs remarkable *ſtimulus* or uneaſy ſenſation in the veſſels of the lungs, will be followed by gentler contractions of the inſpiratory muſcles?

AFTER expiration is finiſhed, the blood beginning to be accumulated in the lungs, will, not only by its quantity diſtracting their veſſels, but alſo by its heat, occaſion an uneaſy ſenſation, that is, act upon theſe parts as a *ſtimulus* *; in conſequence of which the diaphragm and intercoſtal muſcles are contracted, and inſpiration is performed; by which the blood being not only cooled by the external air, but its paſſage alſo promoted towards the

* The uneaſy ſenſation which ariſes when breathing is interrupted, may perhaps be partly owing to the want of ſomething neceſſary to the continuance of life, which the air communicates to the blood in the lungs. When therefore in other places of this Eſſay, I ſpeak of the *ſtimulus* of the blood in the lungs as the cauſe of reſpiration, I deſire it may be underſtood, that I not only include the diſagreeable ſenſation occaſioned by the accumulation of the blood in the pulmonary veſſels, but alſo the uneaſineſs which may ariſe from its being deprived of air to refrigerate, and perhaps otherwiſe fit it for the purpoſes of life.

the left ventricle of the heart, the *ſtimulus* or uneaſy ſenſation ceaſes: hence theſe muſcles are relaxed; and conſequently, by the reaction of the cartilages of the ribs, and the ſtretched abdominal muſcles, *&c.* the cavity of the *thorax* is leſſened, *i. e.* expiration is performed; which, on account of the diſagreeable ſenſation which begins to be felt in the lungs, is ſoon ſucceeded by a new inſpiration. Although, in ordinary breathing, we are but little ſenſible of this uneaſineſs, ariſing from the difficult paſſage of the blood through the lungs after expiration is finiſhed; yet if one attends to it, and reſtrains inſpiration for ſome time, it becomes very perceptible: and as in aſthmatic patients, the laborious contractions of the inſpiratory muſcles are beyond all queſtion owing to an anxiety and ſenſe of ſuffocation in the breaſt; ſo it is highly reaſonable to think, that in healthful people, the gentler *ſtimulus* of the warm blood accumulated in the pulmonary veſſels, is the ordinary cauſe of inſpiration.

FURTHER, a variety of *phænomena* concur to perſuade us, that the blood acting as a *ſtimulus* on the veſſels of the lungs, after expiration,

ration, is the caufe of the fucceeding contraction of the infpiratory mufcles. Thus we obferve, that as the blood flows in greater or lefs quantity through the lungs, infpiration and expiration more quickly or flowly fucceed each other: hence the quick breathing obferved in a fmart fever, or upon violent exercife.—Though the quantity of blood flowing through the lungs remains the fame, yet if its heat and bulk be increafed, refpiration becomes more frequent: hence in bagnios, and in the warm fummer's air, we breathe oftener, than in our common rooms, and in more temperate feafons.—Again, when any obftruction happens in the pulmonary veffels, which renders the paffage of the blood through them more difficult than in health, refpiration is more laborious and more frequently repeated: hence the quick breathing in peripneumonies, and other diforders confequent upon the lungs being obftructed.—If a portion of the lungs be rendered ufelefs, or be wholly confumed by an ulcer, the patient is fhort-breath'd and fubject to afthmatic fits, upon the leaft fatigue, or upon any increafe of motion or rarefaction in the blood.

SINCE

SINCE therefore it appears, that the motions of refpiration are always proportional to the quantity of blood thrown into the pulmonary veffels, and its eafy tranfit through them, this fluid ought undoubtedly to be efteemed the caufe which excites, regulates and continues thefe motions; and fince refpiration is more frequent and laborious, when a lefs quantity of blood paffes with greater difficulty through the lungs, than when a larger ftream flows through their veffels with more eafe; thefe increafed motions of the *thorax* cannot be owing to the infpiratory mufcles being more plentifully fupplied with blood and fpirits, but muft proceed from the *ftimulus* or uneafy fenfation accompanying the difficult paffage of the blood through the pulmonary veffels, or its ftagnation in them. And does not this plainly fhew, why blood-letting gives more fpeedy relief in fits of difficult breathing, than any other remedy?

2. IF it be afked, how a *ftimulus* or uneafy fenfation in the lungs can affect the infpiratory mufcles, with which they feem to have no immediate connexion; I anfwer, It were eafy

eafy to afcribe this effect to the fympathy of nerves, a phrafe indeed oftener ufed than well underftood! but as the pulmonic *plexus* has no greater connexion or communication with the phrenic nerves, and thofe which fupply the intercoftal mufcles, than with the nerves of the ftomach, guts, and other abdominal *vifcera*, which are no way affected by the gentle *ftimulus* of the blood as it paffes through the pulmonary veffels; I think we cannot fairly afcribe the motions of the infpiratory mufcles to any fympathy or connexion their nerves have with thofe of the lungs. Further, as the nerves of the infpiratory mufcles and lungs, moft certainly do not terminate precifely in the fame part of the brain, but probably in places fomewhat diftant from each other, any fympathy that obtains between them, as proceeding from one common origin, muft be owing to SOMETHING equally prefent in thefe feveral places, *i. e.* to the mind or fentient principle: for without fuppofing fome percipient BEING in the brain, how can an irritation of the extremities of the nerves, taking their rife from one part of the brain, occafion a more than ordinary derivation of fpirits ſpirits into ſuch nerves as have their origin from a different part? If external objects act on the nerves only, by putting a ſtop to the equable progreſſion of their fluid, or by exciting ſome vibratory motions in them, how can any of theſe occaſion, not only a more copious derivation of ſpirits through the nerves thus affected, but alſo through a variety of other nerves with which they have no connexion, and whoſe riſe is from a different part of the brain? The ſympathy, therefore, or conſent obſerved between the nerves of various parts of the body, is not to be explained mechanically, but ought to be aſcribed to the energy of that ſentient BEING, which ſeems in a peculiar manner to reſide in the brain, and, by means of the nerves, moves, actuates, and enlivens the whole machine.

BUT further, if the ſympathy obſervable between different parts of the body, be wholly owing to the connexion or communication of their nerves, how comes the pupil to be contracted by the action of light on the *retina*, when the nerves of the *uvea* have not only no communication with the optic nerve, but ariſe from a pretty diſtant part of the brain?

or,

or, if there were ſome general ſympathy between the nerves, why ſhould not the longitudinal fibres of the *uvea* be contracted, as well as the orbicular ones, and ſo the conſtriction of the pupil be prevented? If the alternate contractions of the inſpiratory muſcles were owing merely to their receiving a few nervous twigs from the intercoſtals, which furniſh the *plexus pulmonicus*, why is not the heart and alimentary tube equally affected with them, by a *ſtimulus* or uneaſy ſenſation in the lungs? why are not the intercoſtal muſcles as much convulſed in vomiting as the diaphragm and abdominal muſcles? and why, upon an irritation of the membrane of the noſe and *trachea*, are not the abdominal muſcles contracted, till the inſpiratory muſcles begin to be relaxed? Theſe queſtions will ſcarce be anſwered ſatisfactorily, upon any ſcheme of ſympathy depending wholly on the communication or connexion of nerves; but have no difficulty in them, if the motions now mentioned be referred to the mind or ſentient principle.

WHEN, therefore, in conſequence of a diſagreeable ſenſation in the lungs, ariſing from the

the difficult paſſage of the blood through their veſſels ſoon after expiration is finiſhed, the inſpiratory muſcles are contracted; we are not to aſcribe this to any unknown ſympathy acting mechanically upon theſe muſcles or their nerves; but to the MIND or ſentient principle, which being affected by the uneaſy perception in the lungs, is thereby excited to determine the influence of the nerves more copiouſly into the intercoſtal muſcles and diaphragm; by which the cavity of the *thorax* being enlarged, and the lungs inflated with freſh air, the diſagreeable ſenſation in them is removed; and conſequently the extraordinary derivation of the nervous influence into the inſpiratory muſcles ceaſes: hence, by the renitency of the elaſtic cartilages of the ribs, abdominal muſcles, *&c.* the cavity of the *thorax* is leſſened; *i. e.* inſpiration is naturally followed by expiration; which again muſt ſoon be ſucceeded by a new inſpiration, on account of the particular ſenſation which begins to ariſe in the lungs.

3. IT does not appear, that any effort of the mind or ſentient principle is neceſſary to

expiration; for this naturally takes place as ſoon as the muſcles of inſpiration ceaſe to act. The renitency of the cartilages of the ribs and ſtretched *pericardium* and *peritonæum*, are wholly owing to the elaſticity of the parts, and not to any muſcular contraction or additional force communicated to them at this time; nay, the reaction of the abdominal muſcles in expiration, ſeems to be pretty much of the ſame kind; although it is not improbable, that the extenſion of their fibres, by the depreſſion of the diaphragm in inſpiration, may, as a very gentle *ſtimulus*, excite in them a true muſcular contraction *. However, this irritation prompting the abdominal muſcles to contract at the end of inſpiration, muſt be very inconſiderable, and in no way like the convulſive motions induced on other muſcles by a *ſtimulus*; ſince, when they are greatly ſtretched by a very full inſpiration, we don't find any difficulty in preventing their contraction, or in moderating it as we pleaſe; while,

* The ſame thing may be ſaid of the ſternocoſtal muſcles, which are generally thought to pull the *ſternum* and cartilages of the ribs downwards and backwards in expiration, but which ſeem ſcarcely, if at all, to act in ordinary and gentle expiration.

while, on the contrary, in vomiting their motions are altogether convulſive and involuntary. Further, the *thorax* of dead animals being in a full ſtate of expiration, ſhews that this is brought about, after all muſcular action ceaſes, by the mere elaſtic force of the parts. Nor is it any objection here, that when air is blown into the *thorax* of a dead body, expiration is performed more ſlowly than in a living one; becauſe, by the cold and total ſtagnation of the fluids, the parts not only become more rigid, and the articulations of the ribs leſs moveable, but the inſtruments of expiration loſe, in a good meaſure, their elaſtic power.

LASTLY, the *phænomena* obſervable in comatous patients, and which we ſhall hereafter take notice of, ſhew, that whereas inſpiration is owing to the energy of the ſentient principle, and is here, therefore, in a manner interrupted, expiration is performed as uſual; which could not happen, if, like inſpiration, it proceeded from the mind, or from any particular ſenſation directing it to put certain muſcles in action; for in that caſe there ought to be a pauſe at the end of inſpiration, as well

as

as at the end of expiration. Upon the whole then, we may conclude, that expiration naturally enſues as ſoon as ever the inſpiratory muſcles ceaſe to act, chiefly by virtue of the elaſticity of the diſtracted parts, and ſcarcely at all by the power of any muſcular contraction *.

HERE we may obſerve a remarkable analogy betwixt the motions of the pupil, and of the *thorax* in reſpiration. The coarctation of the pupil, when light is admitted into the eye, is owing to the muſcular contraction of the circular fibres of the *uvea*, in which, therefore, it ſeems to correſpond with inſpiration; but its relaxation when the *ſtimulus* of light ceaſes, is produced merely by the natural contraction of the longitudinal fibres of this membrane, and conſequently in this it reſembles expiration.

4. IF it be demanded, why, after the lungs, by an effort of the will, have been kept for ſome

* What is ſaid here, is only meant of ordinary and gentle expiration, which is performed without conſciouſneſs, or the aſſiſtance of any of thoſe muſcles which act in violent expiration.

ſome time in a ſtate of full inſpiration, the inſpiratory muſcles are immediately relaxed, when this effort ceaſes, and not rather continued in a ſtate of contraction, ſeeing there is an uneaſy ſenſation in the lungs, equal to what happens after expiration; the anſwer is, that the diſagreeable ſenſation is of a different kind, and which, the keeping the lungs in a ſtate of inſpiration, would tend rather to increaſe than remove: for ſuch is the conſtitution of our frame, and the law of that wonderful union connecting the ſoul and body, that the former, upon any uneaſy perception, produces ſuch motions and changes in the latter, as naturally and moſt effectualy tend to leſſen it, or expel the irritating cauſe.—Thus the uneaſy ſenſation ariſing from the action of light upon the tender *retina*, is not followed by a contraction of the longitudinal fibres of the *uvea*, becauſe this would not have the effect of diminiſhing, but of adding to the diſagreeable perception. For the ſame reaſon, the mind, in conſequence of a *ſtimulus* or uneaſy feeling in the lungs, determines the influence of the nerves into the intercoſtal muſcles and diaphragm, and not into the

muſcles

mufcles of the abdomen, back, or loins. But further, the continuing the infpiratory mufcles for any time in a ftate of full contraction, never fails to give fome degree of uneafinefs; fo that it is no wonder, if they be relaxed as foon as the effort of the will ceafes.

5. SUDDEN furprize, or any thing that will but for a few moments ftrongly fix the attention of the mind, prevents the hiccup, if it be from a weaker caufe.—Sneezing is ftiffled in the beginning, whenever an attempt to perform it raifes an acute pain in any part of the body; as frequently happens in rheumatifms affecting the mufcles of the back or *thorax*. In thefe cafes, the mind, being more ftrongly affected by fomething elfe, becomes in a great meafure infenfible of the irritation *; wherefore no violent or convulfive motion enfues.—In the fame manner, if there be only a gentle irritation in the *trachea*, any thing that renders the mind lefs fenfible of this, will prevent coughing. Hence in time of eating a

* How a ftronger fenfation fhould deftroy, or render the mind infenfible of a weaker one, is a queftion attended with fome difficulty; concerning which fee below Sect. xi. anfwer to objection 2.

a tickling cough generally ceafes, or is lefs frequent; for not only the chewing and fwallowing of the food engage the attention of the mind at that time, but the motions of the *larynx* in deglutition have almoft the fame effect in leffening the fenfe of irritation in the *trachea*, as friction has in diminifhing a fmall degree of pain, or itching, in any part of the body. As therefore the convulfive motions of coughing, fneezing and the hiccup, are undoubtedly owing to an uneafy fenfation affecting the mind, may we not juftly conclude, that the gentler *ftimulus* of the blood, in the veffels of the lungs, becomes, through the intervention of the mind or fentient principle, the caufe of the lefs violent motions of the infpiratory mufcles?

6. This however will ftill further appear, from confidering the *phænomena* of refpiration in fome morbid cafes, and in animals placed in a receiver partly exhaufted of air.

α In acute difeafes, where the head is much affected, a remarkable alteration often happens in the breathing: expiration indeed fucceeds infpiration in the ufual way; but fometimes,

times, after expiration is finiſhed, there is a long pauſe before a new inſpiration is begun. In a patient, whoſe brain was affected from an *iſchuria*, I obſerved this interval between the end of one expiration, and the beginning of a ſubſequent inſpiration, to be many times from ſeven to ten ſeconds: but in a young Lady, who died apoplectic, inſpiration ſometimes did not ſucceed the expiration, till after I had counted 20, 30, 40, or even more beats of my pulſe, which did not vibrate above 75 times in a minute. This *phænomenon*, which is eaſily explained, upon the principles we have laid down, is altogether inconſiſtent with every mechanical account of reſpiration that has hitherto appeared, or indeed with any, we preſume, which may poſſibly be deviſed hereafter.

In theſe caſes, the brain, and common ſenſory, being greatly affected, the mind or ſentient principle muſt have been much leſs ſenſible than it uſually is of any impreſſion, irritation or *ſtimulus* affecting the nerves. Hence after expiration which, from the reſilition of the cartilages of the ribs, *&c.* naturally, and without the intervention of the

mind

mind ſucceeds inſpiration, a long pauſe intervenes before a new inſpiration comes on; becauſe the mind is not rouſed up to exert her influence, till the uneaſineſs and ſenſe of ſuffocation in the breaſt becomes ſo conſiderable, as to awake her, as it were, out of a profound ſleep. Let any one, after expiration is finiſhed, keep his *thorax* in that ſtate for half a minute or more, and he'll feel, before that time is elapſed, ſuch an uneaſineſs in his breaſt, as will beget in him the ſtrongeſt deſire of dilating the lungs, and taking in freſh air.

IT is plain, that, after ſuch a ſtop, if *Boerhaave*'s theory were true, inſpiration never could ſucceed, becauſe it muſt neceſſarily occaſion a much greater obſtruction to the motion of the blood through the lungs, than can ever happen at the end of inſpiration, and conſequently render the inſpiratory muſcles altogether unable to overcome their antagoniſts, and dilate the *thorax*.—If reſpiration were owing to the alternate compreſſion of the phrenic nerves, would not theſe nerves, on account of the blood accumulated in the veſſels of the lungs, be more compreſſed 20 or 30 ſeconds after expiration, than juſt when it was finiſhed, and conſequently be rendered then more incapable to actuate the inſpiratory muſcles?

β BUT the truth of what we have been contending for, will ſtill further appear from the following hiſtory. A child of five years of age, having, at 7 o' clock in the evening, ſwallowed, by miſtake, about a dram and a half of liquid *laudanum*, ſoon became merry, and laughed, then delirious, and in half an hour was ſeized with a ſleepineſs and *ſtupor*; at 10 her breathing was high, with a ſnoring noiſe, her pulſe full and equal, though ſlow; ſhe could not be fully awaked, but looked up a little, and ſeemed to be ſenſible of pain, when ſeverely pinched: about 11 her face became pale, her eyes fixed and glazed, and her breathing would often gradually decreaſe, and at laſt ſtop, for near a minute; then it began again with a very deep inſpiration and ſighing. At firſt when the breathing began to be thus interrupted, the intervals were ſhorter, but became gradually longer till the patient died. While the motions of reſpiration were decreaſing, the pulſe was ſmaller; and when they were altogether ſtopt, it was very

very weak and ſlow, but equable and without intermiſſions: when reſpiration began to be renewed, the pulſe recovered its ſtrength, and became leſs ſlow.

THE interrupted breathing is eaſily accounted for, from the *ſtupor* and inſenſibility which *opium* never fails to occaſion when taken in too great quantity; and the intervals becoming gradually longer, could be only owing to the ſenſes being more and more lock'd up by the further action of the *laudanum*, till at laſt, the mind becoming altogether inſenſible of the *ſtimulus* or ſuffocation in the lungs, a final ſtop enſued.—Further, it is evident, from the remarkable weakneſs and ſlowneſs of the pulſe while reſpiration was ſuſpended, that its recommencement could not be owing to any mere mechanical cauſe; for the ſecretion of ſpirits, and every function of the body depending on the general circulation of the fluids, muſt have been more languid immediately before the renewal of reſpiration, than when it began to ceaſe. It would be vain to pretend to account for the *phænomenon* now mentioned from any compreſſion of nerves, or alternate oſcillations of

a

a highly elaftic fluid in the fibres of the infpiratory mufcles; for when the heart itfelf was finking, and all motion in the body ready to ceafe, every mechanical power that can poffibly be imagined to excite refpiration, muft have been lefs able to renew this motion, than it was a little before to have continued it.— Laftly, fince the pulfe was at all times flow, and in the intervals of refpiration, not only weaker than ufual, but alfo more remarkably flow, it appears that the heart was in fome meafure rendered lefs obedient to the *ftimulus* ufually affecting it *. Nor is this furprifing; fince, from live diffections, we know, that a large dofe of *opium* almoft entirely fufpends the periftaltic motion of the ftomach and guts †. The heart feems to be endued with a much greater degree of fenfibility than the lungs; and this perhaps may be the reafon, why its motion was lefs remarkably difturbed by the *ftupor* occafioned by the *laudanum*, than that of refpiration, which, befides, is performed by mufcles whofe fibres

* See below Sect. xiii. N° 24. & 25.

† *Kaau* impet. faciens, N° 434. & 435.

fibres or membranes have no *ſtimulus* immediately applied to them.

γ IN the *Edinburgh Medical Eſſays*, *vol.* V. *art.* 55. we are told, that, after blowing into the lungs of a man, who had been dead to all appearance for above half an hour, the *thorax*, which was by this means elevated a little, continued alternately to riſe and fall, gradually acquiring greater degrees of motion, till at laſt reſpiration came to be as fully performed as in healthful people. Could this be owing to any mere mechanical powers in the body? No, ſurely. A machine adjuſted according to the moſt exquiſite rules of art, tho' it might for ſome time have preſerved the motion communicated to it, could never of itſelf have generated a greater motion! In order therefore to account for the renewal of reſpiration in this caſe, we muſt have recourſe to the energy of the SENTIENT PRINCIPLE, exerted here in conſequence of the motion imparted to the fluids in the lungs, by their firſt inflation.

δ THOUGHTFUL melancholy people, whoſe minds are greatly taken up with, and ſtrongly attached to certain objects, being hence leſs

affected

affected by the *ſtimulus* or ſlighter uneaſineſs which begins to be felt in the lungs, after expiration is ended, uſually perform reſpiration more ſlowly, and after longer intervals, than thoſe who are in perfect health; by which means, the blood paſſing leſs freely through the pulmonary veſſels, and being partly accumulated in them, a ſenſe of weight and ſuffocation ariſes, which more powerfully affects the mind, obliging them often to draw in a more than ordinary quantity of air, and occaſioning what is uſually called a deep ſigh.

ε BY what mechaniſm can it be, that in the half-exhauſted receiver of an air-pump, animals breathe quicker and higher? Certainly, upon *Boerhaave*'s principles, the motions of reſpiration ought not to be redoubled in this caſe, ſince the blood flows with greater difficulty through the lungs. And if, according to *Swammerdam* and *Pitcairn*, the alternate motions of the *thorax* were owing to the inſpiratory muſcles having no antagoniſts, how could this be altered by the air's being rendered lighter, or in what poſſible way could this or the ſtagnation of the blood in the lungs, make theſe muſcles repeat their contractions more

more ſtrongly and frequently? But it is evident, that, upon the ſcheme we have advanced, in proportion as the air in the receiver is exhauſted, and reſpiration becomes more difficult, the mind muſt redouble its efforts, in order to dilate the lungs more fully, and to get rid, if poſſible, of that anxiety, or ſenſe of ſuffocation, which ever accompanies the ſtagnation of the blood in the pulmonary veſſels, or its difficult paſſage through them.

ʒ LASTLY, upon what *hypotheſis*, founded wholly in the received properties of bodies and the laws of motion, can it be ſhewn, that the frequency and fulneſs, ſlowneſs and ſmalneſs of reſpiration ſhould, in healthy people, conſtantly be in proportion to the heat and cold, rarity and denſity of the air?

7. RESPIRATION differs from moſt of the other ſpontaneous motions, in that the will has an abſolute power over it: thus we can at pleaſure accelerate, retard, or put an entire ſtop, for a conſiderable time, to the motions of the intercoſtal muſcles and diaphragm: nor is this power of the will over theſe muſcles owing (as *Boerhaave* thinks *) to the mind's pre-

* Inſtitut. med. N° 624.

preventing their alternate contraction, by means of the ſtronger voluntary muſcles, which are employed in laborious reſpiration; for any one, by trying the experiment, may quickly ſatisfy himſelf, that, without the aſſiſtance of any other muſcle, he can, when he pleaſes, contract the diaphragm with different degrees of force, or hinder its motion altogether.—But though reſpiration thus differs from the proper involuntary motions, yet it does not perfectly agree with the voluntary, ſince it is regularly performed in time of ſleep, and when we are not conſcious of it.

α THE motions of the intercoſtal muſcles and diaphragm are not, like thoſe of the heart and guts, independent on the will, becauſe the *ſtimulus* exciting their action is applied to a diſtant part, and not to the organs moved; and while ſuch *ſtimulus* is gentle, and the part affected by it not very ſenſible, as is plainly the caſe of the lungs, the contraction of the muſcles that is wont naturally to follow it, may be prevented by the interpoſition of the will; but if the *ſtimulus* and uneaſy ſenſation be greatly increaſed, the uſual motions enſue, in ſpite of any determination of the will to the contrary,

contrary. Thus, when the membrane of the *trachea* is only ſlightly irritated, we can reſtrain coughing; but when it is more ſtrongly affected, all endeavours to hinder it are in vain.—When an ordinary *ſtimulus* to go to ſtool or make urine urges, though the diaphragm and abdominal muſcles be, as it were, ſpontaneouſly contracted, yet we can reſtrain their motions if we pleaſe; but in a violent *teneſmus* or ſtrangury, they are convulſively contracted, notwithſtanding any effort of the will to the contrary.—In like manner, the *ſtimulus* exciting the ordinary motions of the inſpiratory muſcles is ſo gentle, that we can at pleaſure prevent their taking place; but in ſevere aſthmatic fits, where the uneaſy ſenſation is vaſtly increaſed, the will begins to loſe its power of reſtraining them; nay, even ſome of the voluntary muſcles, at this time, are forced into action for their aſſiſtance: and if, in ſuch caſes, the will can at all ſtop the motions of the inſpiratory muſcles, it is not ſo much by its immediate power over them, as by means of the ſtronger muſcles employed in voluntary reſpiration.

IT muſt indeed be acknowledged, that although the contraction of the orbicular muſcles of the *uvea* be not owing to any *ſtimulus* immediately applied to them, but to one acting upon a diſtant part, yet it is altogether independent on the will; and in this differs from reſpiration, and from the motion of the muſcles employed in coughing, and in voiding the urine and *fæces*. Perhaps the reaſon of this difference may be, that the action of light upon the very ſenſible *retina* affects the mind ſo ſtrongly, that we cannot, by any power of the will, prevent the contraction of the pupil: further, it is not impoſſible that the will, merely through diſuſe, may have loſt its power of reſtraining the motions of the muſcular fibres of the *uvea*, even when the *ſtimulus* is ever ſo gentle *.

BUT whatever may be the efficient cauſe, which thus ſubjects reſpiration to the government of the will; the final cauſe of this difference between it and the other vital motions is pretty evident: for were it not that the motions of the muſcles employed in reſpiration may be varied at pleaſure, we ſhould not only

* See above, Sect. 1. N° 18.

ly be unable to evacuate the urine and *fæces*, but muſt have been deprived of the happineſs and advantage of communicating our thoughts to one another in the way of ſpeech.

β If it ſhall be objected againſt the mind or ſentient principle's being the cauſe of reſpiration, that it obtains at all times, and is kept up when we are aſleep, and not conſcious of it; it may be a ſufficient anſwer, to obſerve, that a variety of actions are performed by the influence of the mind, without our adverting to them in the leaſt. To give but one inſtance: The eye-lids never ceaſe, after ſhort intervals, to move, whether we be ſenſible of this or not, nay frequently, as when any thing threatens the eye or touches the *cornea*, they move whether we will or no; and yet theſe their motions are undoubtedly owing to the mind. Why, therefore, may not reſpiration be carried on much in the ſame manner, without our attending to it; eſpecially ſince we have ſhewn that there is a material cauſe in the lungs, influencing the mind to continue this action?

In time of ſleep, don't we often ſwallow the ſpittle, talk, move our limbs, and entirely change the poſture of our bodies? Nay, ſome

ſome perſons get out of their beds, and traverſe about from one room to another. Here, then, are actions certainly performed in ſleep, which, nevertheleſs, muſt neceſſarily be aſcribed to the action of the mind.—Further, in caſes where breathing is difficult, when the patients are no way conſcious of it, nay even in time of ſleep, reſpiration ſeems to be performed, partly by the aſſiſtance of other muſcles beſides the proper inſpiratory ones, *i.e.* by muſcles which commonly are not employed except in voluntary motion, and whoſe action, therefore, in ſuch extraordinary caſes, muſt be attributed to the mind alone. On what pretence of reaſon then can it be urged, that the motions of the diaphragm and intercoſtal muſcles, ſince they continue to be performed while we are aſleep, are in no way owing to the mind?—Let a child, when aſleep and breathing ſoftly, have a thick cloth laid over its face; immediately it will begin to breathe deeper and quicker, and will go on to reſpire in this manner, till, the cloth being removed, the cool air is admitted into the lungs. This undoubtedly muſt ariſe from the uneaſineſs which

which the mind feels from the difficult paſſage of the blood through the lungs, and the want of proper air; in order to get rid of which inconveniencies, it moves the *thorax* with uncommon force and frequency, whence a greater quantity of air is inſpired, and the lungs are more widely dilated.—In an *aſthma*, does not the ſenſe of ſuffocation excite the mind to redouble the motions of the inſpiratory muſcles, and are we not ſenſible of this when awake? In ſleep, when we are leſs conſcious of this uneaſineſs, does not the mind perſevere in exerting its influence in the ſame manner upon theſe muſcles? A ſtrong argument this, that the mind, as a ſentient principle, is often affected by what paſſes in the body, and is, in conſequence of this, excited into action, when, in the mean time, we don't advert to any ſuch thing.

SECT.

SECT. IX.

Of the beginning of respiration in animals.

As it would be altogether unneceffary to prove, that the *fœtus* cannot poffibly perform the actions of refpiration, when it is in the womb, and inclofed in its membranes; fo I fhall take it for granted that animals don't begin to breathe, till the external air has accefs to them, at the time of birth; though I find, not indeed without furprize, fome of the moderns going into the contrary opinion *.

It may perhaps have the appearance of prefumption, if I undertake the folution of a problem, which fome of the greateft Phyfiologifts have attempted in vain: however, I can't help thinking it full as eafy to account for the firft commencement of refpiration, as for its continuance when once begun; and that both are owing to the fame caufe, namely, to an uneafy fenfation in the lungs.

OUR

* *Mazini* opera tom. 3.

OUR bodies, framed, as they are, with the moſt exquiſite ſkill, would ſoon periſh if deprived of the benefits of food and air. The former of theſe, muſt be ſupplied at ſhort intervals, but the latter can hardly be wanted for a moment. The *fœtus*, while in the womb, ſtands not in need either of the one or the other; the mother's juices, tranſmitted to it through the veſſels of the *placenta*, ſupplying the want of aliment; and the peculiar circumſtances of its heart making the alternate motion of reſpiration, which is requiſite for carrying on the circulation of the blood in animals after birth, unneceſſary here; while the mother's fluids, having ſuſtained the action of the air in her lungs, are duely fitted for all the purpoſes of the *fœtus*, without any reſpiration of its own. The neceſſity, therefore, of air and aliment commences with our birth; and as we are excited to take in meat and drink by the uneaſy ſenſations of hunger and thirſt, which, as faithful monitors, never fail to warn us when theſe are wanted, but immediately ceaſe upon the appetite's being ſatisfied; ſo, to prevent our being in danger of periſhing through the want of of fresh air, there arises, unless the action of breathing be continually repeated, and new supplies of fresh air thus brought into the lungs, an uneasy sensation, which may not improperly be termed the APPETITE of breathing.

IF then an appetite for fresh air be as natural to animals after birth, as a desire of aliment; and if no one ever yet thought of accounting either for the sensations of hunger and thirst, or for the taking of food consequent upon them, merely from the mechanical construction of the stomach, gullet and *fauces*, without having recourse to a sentient principle; is it not highly unreasonable and unphilosophical to attempt to explain the action of respiration from principles purely mechanical, and to deny the perception and operation of a sentient active principle to be the cause which at first begins, and ever after continues it? This analogy is too strong not to strike every unprejudiced mind!

BUT it may be here asked, in the way of objection, why, if the *fœtus*, during its confinement in the womb, has an inclination to breathe, is not the *liquor amnii*, like the air after birth, received into its lungs, and expelled

led alternately *: The anſwer to which is,

1. THAT had the *fœtus in utero* ever ſo ſtrong a deſire to perform the action of reſpiration, it could not admit the *liquor amnii* into its lungs; partly on account of water being a fluid altogether improper for the purpoſes of reſpiration, but more eſpecially becauſe, whenever it ſo much as touches the top of the *larynx*, the *glottis* is ſo conſtricted, by the convulſive contraction of its muſcles, that ſcarcely can even one drop paſs into the lungs. This appears evidently from the obſervation, that thoſe animals, which have been immerſed and kept under water, don't admit any of this fluid at all into their lungs, much leſs ſuch a portion of it as might properly be eſteemed the cauſe of their deaths †. If, therefore, a ſmall quantity of water has at any time been found in the lungs of drowned ani-

D d mals,

* Dr. *Martine* has propoſed it as a problem, why the *fœtus* in time of geſtation never dilates its *thorax*, nor at any time before birth performs, however ſlowly, the motions of inſpiration and expiration ſucceſſively. Medical Eſſays, vol. 1. art. xii.

† Hiſtoire academie des ſciences 1719, edit. 8vo. p. 32. & 1725, p.16.

mals, we are not to fuppofe it made its way thither while they were alive, but only after their death, when, the mufcles of the *glottis* lofing their power of contraction and becoming flaccid, its fides recede from each other.

THE different cravings or appetites have feverally their correfponding objects: frefh air, on account of its cooling quality and perhaps vital principle, and becaufe it equably and gently dilates the lungs, and thus promotes the circulation of the blood through their veffels, is as well adapted to fatisfy the appetite of breathing, as thin cooling drink to quench thirft; whereas water would be altogether as improper for the purpofes of refpiration, as dry bread for diluting our fluids, or fatisfying the cravings of a thirfty animal. Hence as food has the higheft relifh to a hungry perfon, fo, to one half fuffocated for want of air, nothing is more refrefhing or more greedily taken in than this fluid.

SINCE, therefore, it appears from what has been faid, that water is wholly unfit for anfwering the appetite of breathing, and that animals which have been long accuftomed to refpiration,

refpiration, never fo much as attempt, when under water, to draw it into their lungs; it follows, that the *fœtus in utero*, even fuppofing (what feems not however to be the cafe) it had the fame appetite of breathing with animals after birth, could not receive the liquor of the *amnios* into its lungs, and expel it thence alternately. Thus we fee how eafy a folution Dr. *Martine*'s problem admits of; and that, for this purpofe, it is quite unneceffary to have recourfe to any imaginary compreffion of the phrenic nerves. But,

2. IT feems probable that either the appetite of breathing does not take place in *fœtufes* till birth, or that then it becomes much ftronger; for,

α THE uneafy fituation of the *fœtus*, when the birth is juft at hand, and its various motions and ftruggles in confequence of this uneafinefs, muft remarkably quicken the circulation of the blood through its veffels; whence the lungs will not only receive a larger fhare of fluids in a given time than formerly, but the blood paffing in greater quantity than ufual from the left ventricle of the heart into the

the *aorta*, and making therefore a ftronger refiftance to the paffage of this fluid through the *ductus arteriofus*, it muft now be more copioufly determined into the pulmonary artery, from whofe beginning this duct arifes. But if the blood be thus pufhed in greater ftreams into the veffels of the lungs at, and even fomewhat earlier than the time of birth, muft there not hence enfue a greater degree of heat, and fulnefs, a more active *ftimulus* and uneafinefs in thefe veffels; or, in other words, muft not the appetite of breathing be hence neceffarily increafed? After birth, when the *fœtus* remains for fome time inclofed in its fecundines before it is allowed to breathe, this increafed motion of its blood may well be fuppofed to be much abated; however the cold, which it is now much more expofed to than formerly, by conftringing the placentary and cutaneous veffels, muft accelerate the return of their blood to the right ventricle of the heart, and, by this means, increafe the force of the circulation in the interior parts of the body.

β IT is not improbable, that the air, befides its acting as a cool elaftic fluid upon the blood contained

contained in the lungs, may alſo communicate to it ſomething more immediately neceſſary for preſerving the flame of life.—So long as the *fœtus* remains in the womb, its fluids are ſupplied with this vivifying quality of the air, by their having ſuſtained the action of its mother's lungs; but at the time of birth, when the communication lately kept up, by means of the umbilical veſſels, between the mother and child, is at an end, may not the defect of this *pabulum vitæ* (if I may be allowed the expreſſion) which the air is ſuppoſed to convey, and which was wont to be tranſmitted to the *fœtus* along with the mother's juices, produce ſome ſort of uneaſineſs, not hitherto perceived, which ſhall beget, or at leaſt enhance, the deſire of reſpiration? What is here offered by way of conjecture, is rendered highly probable by the following obſervation; namely, that when the *uterus* of a living bitch is laid open, the puppies incloſed in their membranes remain quiet for ſome time; but, about the time of the mother's death, begin to ſtir about and ſtruggle, as if affected by ſome very uneaſy ſenſation; and that if their membranes be laid

laid open at this time, or a little after, ſo that the air ſhall be admitted to them, they immediately begin to breathe, and ſeem to be relieved from what before oppreſſed them; but if this is not done, they quickly begin to languiſh and at laſt die *. Does not this argue that a neceſſity of reſpiration, and a deſire, ſtronger at leaſt than before, of dilating the *thorax* for the admiſſion of air, commences on the part of the *fœtus*, immediately after its intercourſe with the mother is cut off by the birth?

γ As the water ſurrounding the *fœtus* would certainly hinder its making any efforts to inſpire, though it were ſuppoſed ever ſo deſirous of doing it, ſo the air, the proper *medium* for reſpiration, being applied after birth to the face, mouth and noſtrils of the animal, may put it upon eſſaying a new function, which, by reaſon of the peculiar ſenſation in its lungs, it cannot but be extremely

* "Fœtum cum ſuis involucris eximo, & exteriori "effracto involucro per interius valde pellucidum oſtendo "quî fœtus reſpirare conetur, quamque pulchre interiori "quoque fracto aerem ducat." *Veſalii* anatom. lib. 7. c. 19.

extremely anxious to exert. We may obſerve that a new-born child rarely performs the motion of ſuction except ſomething be applied to its mouth; and, perhaps, in the ſame manner the appetite of breathing itſelf may be increaſed in a *fœtus* by the preſence of a fluid fitly anſwering its demands.—The chick, after it is become large and ſtrong, is obſerved to gape when the ſhell is opened; and does not this indicate a deſire of breathing? this opening of the mouth cannot be in order to take in the liquor of the *amnios*, ſince the chick is nouriſhed, not by the mouth, but by the umbilical veſſels alone *.

UPON the whole, although it is not improbable that the *fœtus*, during its ſtay in the womb, may, from the difficult paſſage of the blood through its compreſſed lungs, have a deſire to breathe, provided it could enjoy the benefit of air, yet it ſcarcely can be doubted that this appetite of breathing muſt be conſiderably increaſed at birth. Nor is breathing the only action of a child newly born, which before it was a ſtranger to; ſucking being equally new to it as breathing.

* Medical Eſſays, vol. 2. art. 10.

ing *. The former has been generally referred to inftinct, and fo perhaps may the latter: but as I would decline, as much as poffible, the ufe of words, whofe meaning may be obfcure or indeterminate; fo I chufe rather to fay, that fucking and breathing are owing to particular fenfations in the body, determining the mind or fentient principle to put certain mufcles or organs in motion.

HAVING thus accounted for the beginning of refpiration in animals, we fhall, in a few words, fhew the weaknefs of what has been advanced on this head by fome of the moft confiderable writers in Phyfiology.

OUR celebrated countryman Dr. *Pitcairn* derives the firft infpiration in new-born animals, from the air rufhing, by the *glottis*, into the cavity of the *thorax* at birth, as it were into a *vacuum*, and thus enabling the intercoftal mufcles to raife the ribs †. But as the

* That the *fœtus in utero* does not fwallow the *liquor amnii*, has been fo clearly demonftrated by my worthy friend and collegue Mr. *Monro*, that I think it one of the few points in Phyfiology which ought for the future to pafs undifputed. See Medical Effays, vol. 2. art. 9

† Differt. de cauf. quâ fanguis fluit per pulmon. fect. 14. p.53.

the lungs, before birth, fill the cavity of the *thorax*, there can be no *vacuum* into which the air may rufh: for, if there were, the *liquor amnii* muft have been forced into it, while the *fœtus* was in the womb; and in dead-born *fœtufes*, the air ought to rufh into the lungs and expand them; both which circumftances are contradicted by experience. The Doctor adds, *Irrumpit, inquam, aer vi elateris et gravitatis, non autem dilatati prius pectoris, compulfus* *; whence it is evident he was quite unacquainted with the true manner in which infpiration is performed: for it is owing, as has been fhewn above, to the enlargement of the cavity of the breaft, made by the contraction of the intercoftal mufcles and diaphragm. Befides, fince the *thorax* is in a ftate of full expiration in all dead animals, it evidently appears that the air cannot, by its gravity, &c. dilate the lungs; but that, in order to the firft infpiration, the diaphragm and intercoftal mufcles, by their contraction, muft enlarge the cavity of the cheft.

THE great *Boerhaave*, after *Thrufton* and

* Differt. de cauf. qua fang. fluit per pulmon. Sect. 15. p. 54.

Borelli, aſcribes the beginning of reſpiration to the *fœtus* moving all its muſcles violently in the time of birth, and, among the reſt, the intercoſtals and diaphragm *. But this account is by no means ſatisfactory; ſince *Veſalius* and Mr. *Boyle* have obſerved, that puppies cut out of their mother's womb begin to gape and breathe as ſoon as they are expoſed to the open air †. And when infants, which ſeemed to be dead-born, have begun ſoon after to breathe, we are not, with *Senac*, to aſcribe this to the action of any ſecret *reſſort*, or undiſcovered piece of mechaniſm, bringing the muſcles of inſpiration at this time into play ‡; but to the energy of the ſentient principle, which, as ſoon as its little heart begins to vibrate, is rouſed, by a diſagreeable feeling in the lungs, to dilate the *thorax* and take in air. The cauſe, therefore, of the firſt reſpiration in this caſe, is evidently the ſame as of its recommencement after a *ſyncope*, namely, the blood puſhed by the heart, upon its recovering

* Inſtitut. Med. § 691.

† *Veſal.* Anatom. lib. vii. cap. 19. & *Boyle's* exp. phyſic. mechan. p. 41.

‡ Traité du coeur, lib, 3. chap. 8. Sect. vi.

vering motion, into the pulmonary veſſels, and there acting as a *ſtimulus*.

THE induſtrious *Haller* chuſes to deduce the beginning of reſpiration, from the endeavours of the *fœtus* to cry, upon account of its uneaſy ſituation and the pain it ſuffers in the time of birth *. But, if the commencement of breathing were owing to no other cauſe than this, why ſhould not this action ceaſe ſoon after the child is delivered, when it is free from pain and gives over crying? Or why ſhould it begin in *Veſalius* and *Boyle's* experiments now mentioned, where the uſual cauſes exciting the animal to cry were wanting? And why ſhould the *fœtus* ſhew ſuch marks of anxiety when incloſed in its membranes, and be quickly at eaſe, upon its having acceſs to the air and being allowed to breathe?

BUT what is crying in infants? Why, no more than an irregular kind of breathing, which affects the expiration chiefly, and is owing to ſome painful ſenſation; for, hence, the air being forcibly expelled through the *glottis*, which is conſtricted now more than uſually, produces

* Not. *a* in Boerhaave Inſtitut. Med. § 691. & prim. lin. Phyſiolog.

produces the noiſe called CRYING. To tell us therefore, that the beginning of reſpiration in animals is owing to their attempting to cry, is, in other words, to ſay, that it depends upon a painful ſenſation, which, in animals accuſtomed to breathe, prevents the muſcles of reſpiration from being moved in a regular and natural way. But, as the action of theſe muſcles is performed in a more regular and equable manner as ſoon as the cauſe of crying ceaſes, it ſeems more reaſonable to believe that the firſt inſpiration is owing to the ſame cauſe as the ſecond, third, and every ſucceeding one, namely, to a particular ſenſation in the lungs affecting all new-born animals: while the pain, which occaſions crying, is merely accidental, and ſeems not to give riſe to reſpiration, when it does happen; though, after it is once begun, it is the cauſe of its being performed after an irregular and interrupted manner.

ANIMALS, when drowned, or ſuffocated with bad air, are many times brought to life again by friction, agitation, or by blowing air into their guts or lungs; all which expedients, as they communicate motion to the blood ſta-

gnating

gnating in the great veins adjoining to the heart, tend to renew the contractions of this organ and confequently the circulation of the blood through the veffels of the lungs, to which alone the recommencement of breathing is owing, and not to any attempt to cry or howl, which, in thefe cafes, is feldom obferved.

FURTHER, in batts, hedge-hogs and other animals which ly in a death-like ftate during the winter's cold, and without any alternate motion of their *thorax*, can the recommencement of breathing, in the fpring feafon, be afcribed to any painful fenfation exciting them to cry? No, furely. But the returning heat of the fun agitating their fluids, and communicating a new motiou to their heart, the blood is pufhed, as is ufual in living animals, into the pulmonary veffels, where, chiefly on account of its difficult paffage, it excites a peculiar fenfation, which roufes the foul or fentient principle, as it were, from its ftate of indolence and inactivity, to contract the infpiratory mufcles, and thus perform the action of refpiration.

UPON the whole, I think it evident that the beginning of refpiration in new-born animals, or the recommencement of it in thoſe in which it has been for a long time interrupted, cannot with any ſort of juſtice or propriety be deduced from an inclination to cry; but is owing to a peculiar ſenſation in the lungs, which as it at firſt gave riſe to this action, ſo it is the cauſe of its being ever after continued. And if we are ſo formed, that we feel a craving appetite, as often as our bodies require a new ſupply of food, and a different ſenſation when our fluids need to be diluted with drink, can it be thought ſtrange that an appetite ſhould be given us for air, the want of which becomes much ſooner fatal?

A Solution of HARVEY'S *Problem.*

QUi ſit, ut fœtus in lucem editus, ac membranis integris opertus, et etiamnum in aqua ſua, manens, per aliquot horas, citra ſuffocationis periculum, ſuperſtes ſit: idem tamen ſecundis *exutus, ſi ſemel aerem intra pulmones attraxerit, poſtea ne momentum quidem temporis abſque eo durare poſſit, ſed confeſtim moriatur* *?

THIS

* *Harvey* de generat. animal. cap. de partu, p.591.

THIS problem, which was firſt propoſed by the great Dr. *Harvey*, appears to be of ſo very eaſy ſolution, that it is not a little ſurpriſing, that many Phyſiological writers ſhould have attempted it in vain.

THE *fœtus* lives in the womb without reſpiration, becauſe the greateſt part of the blood, by means of the *foramen ovale* and *ductus arterioſus*, is conveyed from the right *ſinus venoſus* and ventricle of the heart, into the left ventricle and *aorta*, without paſſing through the lungs; and becauſe its fluids, being derived from the mother's blood which has ſuſtained the action of the air in her lungs, muſt be equally fit for its nouriſhment and ſupport, as for her's.——When the *fœtus*, after being ſeparated from its mother, remains involved in its ſecundines, it lives for a conſiderable time without breathing; becauſe the circulation of the blood continues to be carried on in the ſame manner as when it was in the womb, only a ſmall proportion of it paſſing though the lungs: ſo that there is nothing to hinder the animal from living, till it is extinguiſhed by cold, or perhaps

through

through the want of ſomething neceſſary to life, which the air may ſupply.

AFTER birth, when the *fœtus* has once been accuſtomed to breathe, it quickly dies, if reſpiration is diſcontinued; becauſe the blood, which formerly went by the *foramen ovale* and *ductus arterioſus*, paſſes now through the veſſels of the inflated lungs: and although we cannot ſuppoſe theſe paſſages to be inſtantly ſhut after breathing begins, yet as the veſicles of the lungs, after having been once inflated, never collapſe ſo far as to occupy as little ſpace as before, their veſſels muſt go on to receive a greater quantity of blood than before birth, and conſequently to tranſmit this fluid in greater abundance to the left *ſinus venoſus*; by which means the paſſage of the blood into this *ſinus*, by the *foramen ovale*, will, in a great meaſure, be prevented; at the ſame time, by the inflation of the lungs, the pulmonary artery will be raiſed, and perhaps the ſituation of the *ductus arterioſus* ſo changed, as to render the paſſage of the blood through it leſs favourable. Further, after birth, when the umbilical arteries are tied, the blood paſſing through the *ductus arterioſus* into the

aorta

aorta will find greater refiftance than formerly; fince the fluids pufhed into this artery by the two ventricles of the heart, will find a lefs ready paffage, as a confiderable part of the veffels through which they ufed to flow are thus obftructed.

HENCE if refpiration be once begun, though performed but for a very fhort time, the blood, notwithftanding its being afterwards reftrained, will continue to take the *route* of the lungs chiefly, through whofe veffels, however, it cannot pafs near fo faft as it is thrown into them from the right ventricle of the heart; whence it follows, that an animal, having been once accuftomed to breathe, and after this happening to be deprived of air, muft be quickly fuffocated by an accumulation of blood in the pulmonary veffels *.

* As there are fome who doubt of the alternate motion of of the lungs in refpiration, being neceffary to carry on the circulation of the blood through their veffels, I fhall here mention a few experiments, which feem to put this matter out of doubt.

1. When the lungs are collapfed, *i. e.* in a ftate of expiration, as is the cafe in all dead animals, any fluid injected

SOME may perhaps think the sudden death of animals deprived of the benefit of respiration, is owing rather to the want of something

jected into the pulmonary artery, passes with difficulty to the left ventricle of the heart.

2. When the lungs are inflated with air, an injected liquor flows through their vessels more easily and in greater quantity.

3. When the lungs are agitated with an alternate motion, something like natural respiration, water or any other thin fluid passes still more freely through them, and penetrates into their most subtile vessels *.

4. If respiration be restrained for any considerable time, one's face becomes of a purple colour, and its veins are much distended with blood; which shews that this fluid, on account of its difficult passage through the lungs, is accumulated in the trunks of the *cava* and right *sinus venosus*.

5. But the necessity of the alternate motion of respiration in order to the free transmission of the blood through the pulmonary vessels, is still more evidently demonstrated by the following experiment of Dr. *Musgrave*: A dog whose *trachea* was cut just below the *pomum adami*, and close stopt with a cork, after a few violent struggles, died in two minutes; and, upon opening the *thorax*, the pulmonary artery, right ventricle and auricle of the heart, together with the great trunks of the *cava*, were distended with blood to an excessive degree; while the pulmonary veins, left auricle and ventricle of the heart, were almost quite empty, not containing more than a spoonful of blood †.

It may be thought perhaps that the force of this experiment is weakened by one of Dr. *Hook*'s, who having cut away the ribs, diaphragm and *pericardium* of a dog, and pricked

* Vid. *Kaau* perspirat. Hippocrat. dicta, sect. 160. 161. 162. & 170.
† Philosophical Transact. abridged, vol. 3. p. 67.

thing in the air which ſupports the vital flame. But although it is not improbable that the air, beſides

pricked the outer coat of the lungs with a penknife, preſerved him alive, by keeping his lungs fully diſtended with a continued blaſt of air which he made to paſs through them by means of a pair of double bellows *. But as the blood flows much more freely through the pulmonary veſſels when the lungs are inflated, than when they are collapſed, it is by no means ſurpriſing, that in this dog, which had loſt a great deal of blood during a former experiment, the inflated lungs ſhould afford an eaſy enough paſſage to the ſmall quantity of this fluid that would be thrown into their veſſels by the contraction of the right ventricle of the heart; eſpecially if we conſider, that the conſtant ſtream of air muſt neceſſarily, while it was paſſing through the lungs, and eſcaping by the ſmall wounds made in their external ſurface, have communicated a conſiderable oſcillatory motion to all their veſicles and veſſels, whence the motion of the blood through them would be greatly promoted. And that a very ſmall agitation of the lungs may be ſufficient to keep up the circulation through their veſſels, and preſerve life, plainly appears from the faintings which hyſterical people are ſometimes ſubject to. In theſe faintings, which I have ſeen laſt from 5 to near 15 minutes, the pulſe, perhaps, beats a very little ſlower than before, but with its uſual regularity; while in the mean time there is no motion of the *thorax* obſervable to the eye, notwithſtanding that, by holding a lighted candle near the mouth, one can eaſily diſcover that they breathe, though it be very weakly and ſlowly. Further, in Dr. *Hook*'s experiment, the paſſage of the blood through the pulmonary veſſels muſt have been much freer than it is in ſound animals, whoſe lungs are kept in a ſtate of full inſpiration, becauſe they are, while in this ſtate, conſiderably preſſed upon by the rarified air endeavouring to inflate them more and more on the one hand, and the ſides of the *thorax* reſiſting this inflation on the other.

* Philoſoph. Tranſact. abridged, p. 66.

befides its action on the lungs, as a cool ela-ftick fluid, may contribute in fome other way towards fupporting life; yet fince a *fœtus* can live a confiderable time without refpiration, when feparated from its mother and involved in its fecundines, its dying fooner for want of air, after it has once breathed, cannot be owing folely to the defect of any thing which this fluid might communicate to the blood in the lungs, but muft be deduced from the change made in the pulmonary veffels by re-fpiration, as has been above explained. And this reafoning is confirmed from the obferva-tion, that animals, through whofe lungs a fmall fhare only of the blood circulates, can fuftain the want of air much longer than man and the other more perfect animals, in which the whole mafs of blood paffes through the pulmonary veffels: as likewife that new-born animals, which have breathed only for a fhort time, don't die fo foon in the air pump as others do *.

HAVING thus, at large, fhewn the vital and other involuntary motions of animals to be all owing to a *ftimulus* of one kind or other, acting either immediately upon the organ moved,

* Philofophical Tranfact. abridged, vol. 2. p. 217. & 218.

moved, or on ſome neighbouring part with which it ſeems to have a peculiar ſympathy; it remains that we next inquire, whence this power of a *ſtimulus* over the muſcles of animals muſt be derived?

SECT. X.

Of the reaſon why the muſcles of animals are excited into contraction by the application of a ſtimulus.

THE muſcular fibres of animals are ſo framed, as to contract whenever a cauſe proper to excite their action is applied to them, or, in defect of this, always to remain at reſt. This cauſe is either an effort of the will *, or a *ſtimulus* of ſome kind or other †: to the former are owing the voluntary motions; and to the latter all ſuch as we call vital and ſpontaneous.

How or in what manner the will acts upon the voluntary muſcles, ſo as to bring them into contraction, is a queſtion wholly beyond the reach of our faculties; and indeed, were it otherwiſe, the anſwer would be of no great importance

* Sect. 1. N° 7. above.

† Ibid. N° 8.

importance, it being ſufficient that experience convinces us the will is really poſſeſſed of this power. But, in this our endeavour to trace the vital and other involuntary motions up to their firſt ſource, it ſeems to be a matter of no ſmall moment, to inveſtigate the cauſe or cauſes which enable *ſtimuli* of various kinds to excite the muſcles of living animals into contraction. And here,

1. SOME have contented themſelves with aſcribing the contractions of muſcles conſequent upon pricking, tearing, ſtretching, or otherwiſe ſtimulating them, either by the application of ſolid bodies, or acrid fluids, to the elaſtic power of their fibres *; but without informing us particularly, whether by this they only underſtood that remarkable power of reſilition belonging to many bodies, and from which they are named elaſtic, or ſomething different from, or ſuperadded to this. However, theſe would have done well to conſider,

* *Bagliv.* opera, 4to, lib. de fibra motrice, cap. 11. p. 335. & Differt. de anat. fibrar. & motu muſcul. p. 403. *F. Hoffman.* ſyſtem. med. lib. 1. ſect. 1. cap. 3. N° 17. & 18.

confider, that an elaftic body, of whatever kind it may be fuppofed, is no more than a piece of dead inactive matter, without any power of generating motion; and that tho' it ever recoils with a force proportional to that which bent or wound it up, yet it does this only in confequence of its being acted upon, and not from any proper agency of its own.——That the fharpeft needle does not produce ftronger vibrations in the fpring of a watch, than a blunt one acting upon it with equal force; and that fpirit of wine, or oil of vitriol, dropt upon the moft highly elaftic body, difturb not its ftate of reft, any more than the mildeft milk, or oil of almonds: whereas the contrary of all this is true with refpect to the action either of ftimulating folid bodies or acrid fluids upon the mufcular fibres of animals; whence it follows, that the motions they produce are not to be explained by any elaftic powers, which, it may be imagined, thefe fibres are endued withal.

2. OTHERS, giving fcope to a lively imagination, have fancied the animal fpirits lodged in the cavities of the mufcular fibres, to

confift

confift of a number of little fprings wound up, which, by the application of ftimulating bodies, being put into vibratory motions, dilate thefe fibres, and fo render the whole mufcle fhorter *. Not much different from this is the opinion of the learned Dr. *Senac*, who tells us, in his accurate Treatife upon the heart †, that this mufcle is brought into contraction by the returning venous blood, which dilates its ventricles, and ftretches their conftituent fibres in fuch manner, as to excite an ofcillation in the animal fpirits lodged in them, and confequently to make the mufcular fubftance of the heart fwell and become hard.

BUT, waving the objection, that as the nature of the animal or vital fpirits, as they are called, is altogether beyond our ken, every account of mufcular motion from a *ftimulus* which depends on their peculiar energy or manner of action, muft therefore be merely hypothetical and precarious at beft; may it not well be afked, why, if mufcular contraction from a *ftimulus* were owing to the animal fpirits excited into an ofcillatory motion,

* *Lieutaud*. element. Phyfiolog. p. 71. 72. & 261.
† Vol. 1. lib. 2. cap. 8.

tion, ſhould preſſing the belly of a muſcle with a ſmooth body cauſe a weaker oſcillation than the pricking of a pin, which is applied with leſs force, and affects only a very few of its fibres? or why ſhould one and the ſame irritating cauſe acting on the tendinous fibres of a muſcle, raiſe a much more violent oſcillation of the nervous fluid, than when applied to its carnous ones?—— Beſides, ſuppoſing the animal ſpirits lodged in the muſcular fibres to be ever ſo elaſtic, would it not be in vain to go about deducing the motions of muſcles conſequent upon a *ſtimulus* from this property, ſince elaſtic bodies, as was obſerved above, never, of themſelves, generate motion, but recoil only with a force proportional to that wherewith they are acted upon. If it be pretended, that the animal ſpirits differ from other elaſtic bodies, or owe their oſcillatory motion to ſome other cauſe*, no ſatisfaction, ſurely, can ariſe from ſuch a refuge in ignorance; for theſe ſpirits muſt either act entirely as a mechanical power, or not: if the affirmative be admitted as true, it muſt alſo at the ſame time be confeſſed, their reaction,

 like

* Senac. Traité du coeur, vol. 1. p. 452.

like that of other elaſtic bodies, can never exceed the power acting upon them and putting them in motion: but if their action, inſtead of being properly mechanical, be aſcribed to ſome unknown active properties, this will be found to be not only a mere *hypotheſis*, but ſuch a one as will hereafter be proved utterly irreconcileable with the *phænomena* of muſcular contraction from a *ſtimulus*.

3. IT may be thought, that muſcular contraction is owing to ſome kind of exploſion, ebullition or efferveſcence, occaſioned by the mixture of the nervous and arterial fluids, or perhaps to the peculiar energy of ſome very ſubtile ethereal or electrical matter reſiding in the nerves; and that as theſe cauſes may be brought into action by the power of the will, in order to voluntary motion, ſo, in the caſe of involuntary motion, they may be neceſſarily determined to exert their influence, by the mechanical action of heat, ſharp inſtruments, or other *ſtimuli* applied to the fibres or nerves of the muſcles *.

BUT,

* Dr. *Robinſon* has aſcribed muſcular contraction from heat, punctures, &c. to their exciting a vibrating motion in the *æther* within the nerves and membranes of the muſcles;

BUT, without inquiring how far the contraction or intumeſcence of a muſcle may be owing, or not, to any of the cauſes now mentioned, it will be no difficult matter to ſhew that they cannot, without the intervention of ſome other agent, be excited to exert themſelves by the various *ſtimuli* which are obſerved to bring the muſcles of animals into contraction: for a fluid lodged in the nerves or muſcular fibres, though of a nature fit to produce exploſions, efferveſcences, *&c.* is by no means ſufficient for any of theſe purpoſes, unleſs a cauſe peculiarly adapted to excite ſuch motions be applied to it. Thus gunpowder

ſcles; and thinks that the exploſion of the electrical vapour brings the muſcles into a ſtrong and ſudden contraction, by raiſing a ſtrong vibrating motion in the *æther* lodged in their nerves and membranes. Animal Œconomy, prop. 8. and Diſſertation on Sir *Iſaac Newton's æther*, Appendix, p. 140.——Dr. *Langriſh* alſo is of opinion, that warmth and pricking with a needle renew the contraction of the heart, by putting in motion the ethereal matter of the nerves. Cronean Lectures, ſect. 127. and 151.—— And as of late years there has appeared a fondneſs in ſome, to explain almoſt every hidden operation in nature by electricity, I thought it might not be improper to ſhew, that the electrical *aura*, even ſuppoſing it were the MATERIAL cauſe of muſcular contraction, will not enable us to account for the motions of muſcles, whoſe fibres or membranes are pricked, torn, or otherwiſe ſtimulated.

powder produces no explofion without the affiftance of fire; nor are electrical *effluvia* excited into action, but by the attrition of certain bodies. Alcalies then only raife a commotion when mixed with acids; and no effervefcences or fudden ebullitions can be produced, without the mixture of fubftances difagreeing in their qualities. Fire applied to a glafs globe will not produce electricity, any more than friction will make an alcaline liquor effervefce, or the mixture of an acid fet gunpowder in a flame. If therefore mufcular motion were owing to any of the caufes above mentioned, it might reafonably be expected that it would only follow upon the application of certain kinds of *ftimuli* to the mufcular fibres: but we know from experience, that inftruments of different metals, provided their fharpnefs and figure be the fame, have an equal power of bringing the mufcles of animals into action: — that it makes no odds whether the ftimulating fubftances be electrics *per fe*, or *non*-electrics: — that acrid liquors of quite oppofite natures have much the fame effect, if their degree of pungency be equal: — that acids, alcalies, neutral falts, heat,

pricking,

pricking, tearing, and in ſhort every kind of irritation, excite the muſcles of animals into contraction; and that there is no difference in the motions they produce, except what ariſes from their acting as ſtronger or weaker *ſtimuli*, *i. e.* from irritating the part more or leſs.

FURTHER, no violent motion is produced by any bodies in nature, however active, unleſs the peculiar cauſes neceſſary to produce this be applied to them: but in order to the contraction of a muſcle, it is not neceſſary that the *ſtimulus* ſhould be applied to its fibres; it is enough that the common membranes covering them are irritated, the ſame effect being hence produced as from wounding the very fibres of the muſcle. This is evidently fact, in the caſe of the heart, ſtomach, guts, and bladder; nay, many times muſcles are excited into action by a *ſtimulus* affecting a remote part with which they have no immediate connexion, or ſo much as even a communication by means of nerves, unleſs it be that general one ſubſiſting between all the parts, as their nerves are derived from the ſame brain. Thus any thing which affects the

the interior membrane of the ſtomach after a diſagreeable manner, brings the diaphragm and abdominal muſcles into convulſive contractions: the action of light, as a *ſtimulus*, upon the tender *retina* is followed by the contraction of the orbicular muſcle of the *uvea*, and according to the various impreſſions made by ſounds upon the auditory nerves, the muſcles of the internal ear are contracted variouſly.

LASTLY, As the electrical *effluvia*, excited by friction of certain bodies, are not emitted by fits and ſtarts, but in a continued equable ſtream, ſo neither do the exploſions or efferveſcences produced by the mixture of ſubſtances of diſagreeing natures exert themſelves, like irritated muſcles, by alternate efforts. As little will the oſcillations of an elaſtic *æther* (ſuppoſing the animal ſpirits to be of this nature) ſerve to explain this *phænomenon*, ſince theſe muſt always follow the laws of vibration obſerved in other elaſtic bodies, which yet are utterly inconſiſtent, as we ſhall have occaſion of proving below, with the alternate and vibratory-like contractions of muſcular fibres from an irritation. Upon

the

the whole then, we may fairly conclude that the contraction of an irritated muſcle cannot be owing to any efferveſcence, exploſion, ethereal oſcillation, or electrical energy excited in its fibres or membranes, by the mechanical action of the *ſtimulus* upon them.

4. SEVERAL Phyſiological writers have ſuppoſed ſome latent power or property in the muſcular fibres of animals, to which their motions, in conſequence of an irritation are to be referred *.

BUT this opinion ſeems to be no more than a refuge of ignorance, which nothing, but the deſpair of any ſucceſs in their inquiries into this matter, can have driven them into. For, if they here mean ſome unknown active powers reſulting from the peculiar conſtitution or mechanical ſtructure of a muſcular fibre, it may be ſufficient reaſon with us for denying there are any ſuch latent cauſes, that the aſſertors of them have hitherto been as

* *Peyer*. Parerg. anatom. 7. p. 198.
Haller. not. in Boerhaave inſtitut. med. vol. 4. p. 615. & 617. Comment. *I. G. H.* in Boerhaave inſtitut. med. vol. 5. p. 101. & 104.

as unable to vindicate their exiſtence by *phænomena*, which cannot be explained without them, as to ſpecify their true nature; beſides that it muſt appear greatly unphiloſophical to attribute active powers to what, however modified or arranged, is yet no more than a ſyſtem of mere matter; powers I ſay, which are not only confeſſedly ſuperior to the utmoſt efforts of mechaniſm, but contrary to all the known properties of matter.

FURTHER, the influence of a *ſtimulus* in exciting even muſcles, to which it is not applied, into contraction, plainly argues ſuch motion not to ariſe from any hidden power in the muſcle being called into action by the mechanical effect or operation of the *ſtimulus*. Every attempt, therefore, towards explaining the motions of irritated muſcles, from properties which their fibres, conſidered as mechanical inſtruments, ever ſo exquiſitely framed, or nicely adjuſted, can be ſuppoſed endued withal, muſt be vain and fruitleſs: for as well might we pretend the eye ſees objects, and the ear hears ſounds, purely by virtue of their being material organs, as imagine the motions of animal fibres from a *ſtimulus*,

ſtimulus, to be owing ſolely to their mechanical ſtructure, or to the peculiar arrangement and diſpoſition of their parts.

5. SOME may, perhaps, be of opinion, that the all-wiſe AUTHOR of nature hath endued the muſcular fibres of animals with certain active powers, far ſuperior to thoſe of common matter, and that the motions of irritated muſcles are owing to theſe. And indeed we cannot but readily acknowledge, that he has animated all the muſcles and fibres of animals, with an active ſentient PRINCIPLE united to their bodies, and that, to the energy of this PRINCIPLE, are owing, the contractions of ſtimulated muſcles. But if it be imagined that he has given to animal fibres a power of ſenſation, and of generating motion, without ſuperadding or uniting to them an active PRINCIPLE, as the SUBJECT and CAUSE of theſe, we preſume to ſay, that a ſuppoſition of this kind ought by no means to be admitted; ſince, to affirm that matter can, of itſelf, by any modification of its parts, be rendered capable of ſenſation, or of generating motion, is equally as abſurd,

as to afcribe to it a power of thinking. Matter, fo far as we can judge of it by all its known properties, appears to be incapable either of fenfation or thought: and the whole *phænomena* of the mere material world evidently fhew, that it acts invariably according to certain laws prefcribed to it, and without any feeling, inclination or choice of its own; nor is there any thing more refembling will, felf-determination, or real active power in the moft refined and fubtile parts of matter, than in the groffeft and moft fluggifh.

IF then the effects of *ftimuli* upon the mufcular fibres of animals, cannot be deduced from any property or powers belonging to them, as mere MATERIAL organs, it remains, that they are owing to an active fentient PRINCIPLE animating thefe fibres. But this will more evidently appear from the following confiderations.

1. A *ftimulus* applied to the mufcles of animals when laid bare produces, inftead of only one contraction lafting for a confiderable time, feveral contractions and relaxations alternately fucceeding each other, which become

come gradually weaker, and are repeated after longer intervals, as the force of the irritating caufe is diminifhed *. Now, thefe alternate contractions are eafily accounted for, if we fuppofe them to proceed from a fentient PRINCIPLE, which, in order to the getting rid of the pain or uneafy fenfation that arifes from the irritation of the mufcle, determines the influence of the nerves into its fibres more ftrongly than ufual. For, if by one or two contractions the irritating caufe be thrown off, and, together with it, the difagreeable fenfation removed, the mufcle will return to its former ftate of reft; if otherwife, it will continue for a longer time to be agitated by alternate convulfive motions, which will be more or lefs forcible, and repeated after fhorter or longer intervals, in proportion as the *ftimulus* and painful fenfation hence enfuing are ftronger or weaker. The titillation of a flighter *ftimulus* will be fo much weakened by the firft contraction of the mufcle, that fome fpace of time muft intervene before it will be able to produce a fecond: whereas the fmart pain, which follows a ftrong

* Sect. I. N° 10. and 11. above.

ſtrong irritation, affects the ſentient principle ſo powerfully, that no ſooner is the muſcle relaxed, than a new contraction neceſſarily comes on. Thus a gentle irritation of the left orifice of the ſtomach cauſes only a ſlighter hiccup or convulſive contraction of the diaphragm, which too is not repeated till after conſiderable pauſes; while a greater irritation, not only excites ſtronger convulſions of this muſcle, but alſo a quicker repetition of them.

WHY the ſentient principle, in conſequence of a painful ſenſation, does not keep irritated muſcles in a continued ſtate of contraction, but allows them to be alternately relaxed, ſhall be afterwards explained.

IF the contraction of an irritated muſcle were owing to the action of the *ſtimulus* upon it as a mere mechanical organ, then, ſo long as the *ſtimulus* continued to act equably, the muſcle ought to remain equally contracted, and, upon its ceaſing, the muſcle ought to be relaxed, or rather the muſcle, upon the firſt application of the *ſtimulus*, ought to be ſuddenly contracted; which contraction ſhould become weaker by ſlow degrees, till at length the

the mufcle had returned to its natural ftate of relaxation. If a few drops of any acrid liquor let fall on a bare mufcle, or the pricking with a needle, excites it into contraction, as a mechanical caufe acting upon a mechanical organ; then, fo long as the caufe acts on the organ, the effect muft continue to follow; and if the caufe becomes gradually weaker, fo alfo muft the effect, till it ceafes altogether, *i.e.* the mufcle ought not to be agitated with alternate convulfive motions; but, after its firft and ftrongeft degree of contraction, it fhould begin to lofe fome of its force, and continue to do fo, till it came again to its natural ftate.

WHAT moft refembles mufcular contraction from an irritation, is the falling or clofing of the leaves of the fenfitive plant after being touched: but this equally happens, whether thefe leaves be touched with the fharp point of a penknife, or the blunt end of a pencil, with a piece of fmooth wax or rough iron, with brandy or with water. Here there are no alternate contractions and relaxations, as in the mufcular fibres of animals; no indication of feeling or of being peculiarly affected

affected by ſtimulating things; but all is effected by mere contact or mechanical impulſe. I cannot help obſerving in this place, though foreign to my preſent purpoſe, that the cloſing of the leaves of the ſenſitive plant upon their being touched, cannot be owing, as ſome have lately imagined, to the electrical matter iſſuing from them; ſince the touch of wax, which repells this matter, makes them cloſe as remarkably, as that of *non*-electric bodies: nay, a piece of wax ſtrongly electrified by rubbing, made the leaves of this plant quickly cloſe, by attracting them to it with a conſiderable force.

IF it be ſaid, that the elaſtic fibres of the muſcles, or the nervous fluid contained in their cavities, are excited by a *ſtimulus* into ſtrong oſcillations, which are repeated till the irritation ceaſes, or even for ſome time after; I anſwer,

α THAT it is not eaſy to conceive how ſuch *ſtimuli* as don't act by any mechanical force, but merely by their acrimony, ſhould excite an oſcillatory motion in the ſuppoſed elaſtic fibres of the muſcles, or in the animal ſpirits lodged in them. But not to inſiſt on this,

β IF

β IF the motion of our muſcles from a *ſtimulus* were owing to elaſtic vibrations of any kind whatever; how could the *ſphincter pupillæ* and the muſcles of the internal ear, continue uniformly and equably contracted for a conſiderable time, which they never fail to be, when the *ſtimuli* affecting them act with unvaried force? And why ought they not rather to be agitated by a number of quickly repeated contractions? Nay the continued, uniform and equable contraction of the voluntary muſcles would be impoſſible, if their motion was owing to any elaſtic oſcillations.

γ IF muſcular motion from a *ſtimulus* were the effect either of the vibrations of the nervous fluid, or of the ſolid elaſtic fibres of the muſcles themſelves, the alternate contractions of an irritated muſcle, like the vibrations of elaſtic bodies, ought to follow one another at equal intervals, nor would they be more ſlowly repeated as they become weaker, and were about to ceaſe; which however is the caſe.——A muſical chord, a bell, or any other elaſtic body, performs its vibrations in equal times, whether it be acted upon by a ſtronger or a weaker force; and its oſcillati-

ons

ons follow one another; from firſt to laſt, with an equal degree of ſwiftneſs: In like manner the elaſtic pulſes which theſe bodies communicate to the ambient air, ſucceed each other as quickly in diſtant places, where the ſound is faint, as in thoſe near the ſonorous body, where it is ſtronger. Since therefore the alternate contractions of irritated muſcles do not follow the law of the vibration of elaſtic bodies, but become remarkably ſlower when they decreaſe in ſtrength, and before they ceaſe altogether; it follows with all the force of demonſtration, that they cannot be owing to any elaſtic vibrations excited in the muſcular fibres, or in the nervous fluid contained in them. But of this more fully afterwards *.

2. If it were conſtantly obſerved, that ſuch muſcles only as had their fibres immediately acted upon by a *ſtimulus*, were excited into contraction, then indeed it might be ſuſpected with greater ſhew of reaſon, that ſuch motions were no more than a neceſſary conſe- quence

* Vid. ſect. xiii. below on the motion of the muſcles of animals when ſeparated from the body.

quence of the mechanical action of the *stimulus* upon the muscular fibres: but as we find the muscles of animals brought into action without any irritation of their fibres, whenever a *stimulus* is applied to the coats or membranes covering them, or to some neighbouring or even distant part, it seems absurd to imagine such motion owing to the mechanical action of the *stimulus* upon the fibres of the muscle, and not to the impression it makes on the sentient principle. Thus the contraction of the *sphincter pupillæ* arising from the action of light on the *retina*, with which it has no communication of nerves, cannot possibly be explained mechanically, but must be owing to some sentient principle in the brain, which, excited by the uneasy sensation, determines the influence of the nerves more copiously into that muscle. The same thing is also true of the various motions of the muscles of the *malleus* and *stapes* from different sounds striking upon the auditory nerve; and of the motions of the eye-lids as often as any thing irritates the *cornea*, be it ever so gently.—The contraction of the diaphragm and intercostal muscles, in consequence of an uneaſy ſenſation in the lungs, muſt alſo be owing to the mind or ſentient principle acting at the origin of the nerves, and not to any change wrought mechanically upon the fibres of theſe muſcles, by the difficult paſſage of the blood through the pulmonary veſſels. The violent action of the diaphragm and abdominal muſcles in a *teneſmus* or ſtrangury is to be explained in the ſame way.—— If a ſpark from the fire, or a drop of boiling water, falls upon one's foot, the leg is inſtantly drawn in towards the body; but as the muſcles employed in this action are thoſe which run along the thigh, and are inſerted about the head of the *tibia*, it is manifeſt that this *ſtimulus* cannot excite the muſcles into contraction in conſequence of any mechanical action upon them: and if ſympathy of nerves, or continuation of membranes, ſhall be alledged as the cauſe of this motion, it may be juſtly demanded, why the muſcles which run along the leg, and are inſerted into the foot, are not more remarkably moved than thoſe of the thigh, ſince they have a nearer connexion with the part to which the *ſtimulus* is applied; or why the extenſors of the leg are not brought

equally

equally into action with its flexors. It remains therefore that the motion of the leg, in this cafe, be attributed to the pain or uneafy fenfation excited by the fire or boiling water, for avoiding of which the fentient principle is inftantly determined to put the flexors of the leg in motion, and fo to remove the member from the offending caufe. Nay, where the *ftimulus* is applied to the membranes or teguments covering the mufcles, it feems highly probable, that the fubfequent contractions are not owing to any change firft made on their fibres: thus the convulfive motions of the intercoftal and other mufcles of the trunk of the body, which are excited by tickling the fides, muft undoubtedly be afcribed to the mind, which, in order to avoid the difagreeable titillation, puts thefe mufcles in action, and not to any immediate influence the tickling can have on their fibres; otherwife why fhould the fame mechanical action of our own, and of another perfon's fingers, affect us fo differently?— Tincture of *ipecacuan* applied to the internal furface of the ftomach, does not feem to produce the convulfive contractions of that bowel in vomiting, by immediately affecting

affecting its muſcular coat, which is defended by the nervous and villous ones, but by irritating its nervous *papillæ*, and thence affecting the mind or ſentient principle.

SINCE, therefore, *ſtimuli* applied, not only to remote parts, but alſo to the membranes or coats immediately covering any muſcle, excite it into contraction by the intervention of the mind; is it not reaſonable to think, that even when the muſcles themſelves, or a few of their fibres, are irritated, the ſubſequent motions are owing to the mind's being excited, from a diſagreeable ſenſation, to determine the influence of the nerves more ſtrongly into them? This, however, will ſtill further appear, if,

3. WE conſider, that not only an irritation of the muſcles of animals, or parts nearly connected with them, is followed by convulſive motions; but that the remembrance or *idea* of things, formerly applied to different parts of the body, produces almoſt the ſame effect, as if they themſelves were really preſent. Thus the ſight, or even the recalled *idea* of grateful food, cauſes an uncommon flow of ſpittle into the mouth of a hungry perſon;

ſon; and the ſeeing of a lemon cut, produces the ſame effect in many people.—The ſight of a medicine that has often provoked vomiting, nay the very mention of its name, will in many delicate perſons raiſe a *nauſea*; and they are affected much in the ſame manner when they behold any one under the violent operation of an emetic.—The apprehenſion or fear of having one's ſides tickled, cauſes almoſt the ſame motions in the trunk of the body, while another perſon threatens or attempts it, as tickling itſelf would do, though in a leſs degree.

FURTHER, That many very remarkable changes and involuntary motions are ſuddenly produced in the body by the various affections of the mind, is undeniably evinced from a number of facts. Thus fear often cauſes a ſudden and uncommon flow of pale urine. Looking much at one troubled with ſore eyes, has ſometimes affected the ſpectator with the ſame diſeaſe.—— Certain ſounds cauſe a ſhivering over the whole body.—The noiſe of a bagpipe has raiſed in ſome perſons an inclination to make urine.—The ſudden appearance of any frightful object, will, in delicate

delicate people, cauſe an uncommon palpitation of the heart.—The ſight of an epileptic perſon agitated with convulſions, has brought on an epilepſy; and yawning is ſo very catching, as frequently to be propagated through whole companies. In theſe caſes, the motions produced in the veſſels of the eyes or eye-lids, in the heart, ſtomach and bladder, in the ſecretory tubes of the ſalivary glands and kidneys, in the muſcles employed in yawning, *&c.* cannot be owing to the mechanical action of the cauſes above mentioned upon the fibres of the parts moved: for what particular connexion is there between the optic and auditory nerves, and thoſe which ſerve the heart, ſtomach, bladder of urine, mouth, ſalivary glands, and the muſcles which depreſs the lower jaw and move the trunk of the body? All the nerves don't at laſt terminate in a point, but in a large ſpace of the brain; wherefore the conſent between them cannot be deduced from their contiguity, but muſt be owing to a ſentient PRINCIPLE, which is preſent AT LEAST whereever the nerves have their origin, and which, accordingly as it is variouſly affected, produ-

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ces motions and changes in different parts of the body.

IF then external caufes affecting the brain, do, by the intervention of the mind or fentient principle, produce remarkable changes in the mufcles of fpontaneous as well as of voluntary motion; and if the *idea* of a *ftimulus* has in many cafes almoft the fame effect as the thing itfelf; is it not highly reafonable to think, that ftimulating things applied to the mufcles of animals excite them to contract, not by any immediate mechanical action upon their fibres, not by caufing an unintelligible explofion or effervefcence, or exciting ftrong vibrations in any ethereal or electrical matter fuppofed to be lodged in thefe fibres or their nerves; but by difagreeably affecting the fentient PRINCIPLE, in confequence of which it determines the influence of the nerves more copioufly into the fibres of the mufcle ftimulated. And there is the lefs reafon to hefitate in admitting this doctrine, fince the various *phænomena* juft now recited feem undoubtedly to prove the prefence, agency and very extenfive influence of SOMETHING in the bodies of animals, of a nature different

different from, and of powers ſuperior to mere matter, however modified, compounded or arranged.

IF *ſtimuli* excite the muſcles of animals into contraction by acting upon them, rather as ſentient than mere mechanical or material organs, it is eaſy to ſee, why the mildeſt aliment is apt to excite vomiting when the coats of the ſtomach are inflamed, and why the heart is agitated with violent convulſions and palpitations as often as itſelf, or even the *pericardium*, is affected with any degree of inflammation. In theſe caſes the ſtomach and heart are rendered extremely ſenſible and impatient of any irritation; whence the *ſtimuli* which were in uſe to affect them very gently, now excite them into violent convulſions.

IT has been obſerved above, that muſcles whoſe fibres have a *ſtimulus* applied to them, don't remain contracted for any conſiderable time, but are agitated with alternate contractions and relaxations. Thus any of the muſcles of the eye, by irritating their tendinous fibres with the point of a file, are ſet a beating almoſt like the heart of an animal

mal affected with ſtrong palpitations *. But in muſcles whoſe contraction is owing to the action of a *ſtimulus* upon ſome diſtant or neighbouring part, there is a diverſity obſerved; ſome of them being uniformly contracted while the irritating cauſe laſts, others alternately contracted and relaxed: thus the action of light and ſound upon the *retina* and auditory nerves, produces an equable conſtant contraction of the *ſphincter pupillæ* and muſcles of the internal ear; while an irritation of the membrane of the noſe and *trachea* is followed by alternate convulſive motions of the muſcles of reſpiration, and a titillation of the inferior extremity of the gullet, by repeated contractions and relaxations of the diaphragm.

* Dr. *Senac* has fallen into a great miſtake with reſpect to this matter, when he affirms that an irritation makes the muſcles of living animals only perform one contraction, although the ſame cauſe produces many repeated contractions in the muſcles of thoſe that have been newly killed †; for, beſides the inſtance of the muſcles of the eyes here mentioned, the heart of an animal is obſerved to be agitated with violent and quickly repeated convulſions when it is pricked with a ſharp inſtrument immediately upon opening the *thorax*; and, if any other muſcle of a living animal be laid bare, it will, by irritating its fibres or

† Traité du coeur vol. I. p. 453.

THESE very different effects of *ſtimuli* on different muſcles and organs of the body, which I may venture to pronounce altogether inexplicable upon any mere mechanical theory, are eaſily accounted for from the principles already laid down: for if the contraction of an irritated muſcle be owing to the uneaſy ſenſation excited by the *ſtimulus*, as often as the firſt contraction does not remove this, the muſcle will be agitated with alternate convulſions, as being moſt proper to throw off the irritating cauſe. If indeed, by the firſt contraction, the diſagreeable ſenſe of irritation be quite removed, no further motion follows; but

or membranes, be brought into alternate contractions. A *ſtimulus* therefore applied to the muſcles of animals excites them, if it be any way conſiderable, into alternate repeated contractions, whether the animals be alive or newly killed; only the convulſions in the former caſe are ſtronger and more remarkable than in the latter. Nay, it will be difficult to reconcile this ſuppoſed difference in the effect of an irritation on the muſcles of living and newly killed animals, with the principle which the Dr. himſelf lays down, namely, that the contraction of an irritated muſcle is owing to the reaction of the animal ſpirits lodged in its fibres, in conſequence of the action or impreſſion of the *ſtimulus* upon them; for there does not appear any reaſon why the reacting power of the animal ſpirits ſhould continue to exert itſelf longer or more remarkably in the muſcles of dead animals, than in thoſe of living ones.

but if it ſtill remains, new convulſive contractions ſucceed, and continue to be repeated alternately, till the *ſtimulus* either ceaſes entirely, and is no longer felt, or becomes too weak to produce a new contraction. But where the contraction of any muſcle cauſed by the action of a *ſtimulus* on a neighbouring part, would, if it was alternate, neither tend to remove the irritation, nor render the mind leſs ſenſible of it, there no ſudden relaxation follows, but the muſcle remains equably contracted as long as the ſtimulating cauſe continues the ſame. Let us now ſee how this general doctrine can be applied to the different ſpontaneous motions of animals.

THE alternate contractions and relaxations of the muſcles of reſpiration in ſneezing, are moſt wiſely adapted to remove the irritating cauſe from the membrane of the noſe, and to leſſen the uneaſy ſenſation ariſing from it: if, by the air firſt ſtrongly inſpired, and immediately after more forcibly expelled through the noſe, the *ſtimulus* affecting its nerves be removed, no new contraction enſues; if not, the action of ſneezing is ſtill repeated, till the titillation in the noſe ceaſes, or becomes too weak

weak to produce a new convulſion. In ſneezing, inſpiration is only performed in order to make way for the ſucceeding violent expiration, which moſt effectually removes the uneaſy ſenſation or irritating cauſe; at the ſame time the ſtrong and ſudden contraction of the inſpiratory muſcles, acts partly as a kind of *ſtimulus* in exciting the ſubſequent convulſive motion of the expiratory ones.——The alternate contractions of the diaphragm in the hiccup, and of the muſcles of reſpiration in coughing, evidently tend to remove or leſſen the uneaſy ſenſation in the gullet and *trachea*, and are therefore not continued, but interrupted by alternate relaxations. On the other hand, a ſtrong irritation of the *inteſtinum rectum*, from too great a quantity of excrement, cauſes a continued contraction of the abdominal muſcles and diaphragm, becauſe in this caſe the contraction of theſe muſcles has no effect to leſſen the uneaſy ſenſation, till the *fæces* are expelled. 'Tis true indeed that when one is coſtive, ſeveral efforts of the diaphragm and abdominal muſcles are required before any of the excrement is expelled; but the action of theſe muſcles is in this caſe interrupted,

rupted, not on account of the irritation in the *rectum*, but in order to carry on reſpiration, which cannot long be interrupted without cauſing a moſt uneaſy ſenſe of ſuffocation in the lungs, by which we are more ſtrongly affected than by the *ſtimulus* of the *fæces*.

THE cauſes which produce the erection of the *penis* *, though they be generally excited into action by the *ſtimulus* of the ſeed, yet do not act by alternate fits, becauſe the erection has no immediate effect to leſſen the ſtimulating cauſe: but the contraction of the *muſculi ejaculatores ſeminis* is alternate, becauſe by each convulſive motion, the *ſemen*, *i. e.* the irritating cauſe, is expelled.——The orbicular muſcle of the *uvea*, and the muſcles of the *malleus* and *ſtapes*, remain equally contracted, while the ſame degree of light and ſound is applied to the eye and ear, becauſe their contraction does not hinder theſe cauſes from acting uniformly and equably upon the *retina* and auditory nerve; but no ſooner is more or leſs light applied to the eye, or a ſtronger or weaker ſound to the ear, than theſe muſcles are more contracted or ſomewhat relaxed.—

With

* Sect. vi. N° 4. above.

With refpect to the heart, as the returning blood or irritating caufe is alternately received into its cavities and expelled out of them, it is eafy to fee why it fhould, like the *ejaculatores feminis*, be agitated with regular alternate contractions. And as by the *fyftole* of every fmall portion of the guts, the air, aliments, *&c.* are pufhed into the fucceeding ones, the motion here muft alfo be alternate; only not fo equable and regular as in the heart, where the alternate action of the irritating caufe is more uniform and unvaried.

WHEN the fibres of a mufcle are irritated, by tearing them with a fharp inftrument or otherwife, a ftrong convulfive contraction inftantly enfues; which is fuddenly followed by a relaxation, becaufe an uniform continued contraction would not be fo well fitted to drive off the offending caufe from the mufcle as alternate contractions and relaxations: and we are fo framed by the all-wife AUTHOR of nature, as fpontaneoufly, and without any previous reflexion, to perform thefe motions and actions which tend moft effectually to the prefervation of our bodies. It is probable, however, that the alternate relaxa-

tions

tions of irritated mufcles may be owing to the uneafy fenfation's being fome way leffened by each contraction *, on account of which, the fentient PRINCIPLE, as being now lefs affected, immediately allows the mufcle to be relaxed. This is manifeftly the cafe in the hiccup, where the convulfions of the diaphragm weaken or fufpend, for fome little time, the fenfe of irritation in the inferior extremity of the gullet. The relaxations, however, of ftimulated mufcles do not laft for any confiderable time, but are quickly fucceeded by new contractions, becaufe the painful fenfation foon begins again to affect the mind more ftrongly: but as the irritation becomes gradually weaker, thefe alternate contractions will not only grow feebler, but fucceed one

* If any one doubts that the difagreeable fenfation, excited by the irritation of a mufcle, will be lefs fenfibly perceived during its contraction, let him confider that brutes, by the motion of their *panniculus carnofus*, not only drive off moft effectually flies and other infects which vex them, but, by the very action of this mufcle, feem to be rendered lefs fenfible of the tickling.—That friction of a part leffens, in the mean time, any itching or painful fenfation in it. And that people, whofe bodies are uneafy, often change poftures, becaufe during the motion of the parts neceffary to this change they are lefs fenfible of the uneafinefs.

one another more flowly; for while the irritation is ftrong, the mufcle is no fooner relaxed, than its contraction is immediately renewed: whereas a weaker *ftimulus* requires a longer time to operate, before it caufes fuch an uneafy fenfation as is required to produce a convulfive contraction of the part. Thus when the *thorax* of a living animal is laid open, and the heart is pricked with a fharp inftrument, its contractions are greatly quickened; nay, they return fo frequently, that, during their remiffion, very little blood enters the ventricles. Hence the fides of the heart make very fmall motions at firft, nor are ever fully dilated, their contractions being repeated almoft as foon as their *diaftole* begins; but when the impreffion of the *ftimulus* begins to be weakened confiderably, the contractions and relaxations of the heart being performed more flowly, the blood has time to dilate the ventricles more, whofe fides, therefore, now make larger and more fenfible motions. From what has been faid, it is eafy to fee, why, if the blood be rendered acrid, or the heart much more irritable than ufual, the pulfe becomes fmall, fluttering and quick.

WHILE

WHILE therefore the voluntary mufcles, which are contracted in confequence of an effort of the will, remain in that ftate as long as the will continues to determine the influence of the nerves into their fibres; irritated mufcles, whofe contraction is owing, not to will or choice, but to an uneafy fenfation, are entirely regulated by this; and as each contraction tends to leffen the difagreeable perception, they will be agitated with alternate convulfions.

UPON the whole, as nature never multiplies caufes in vain, it feems quite unphilofophical to afcribe the motions of the mufcles of animals from a *ftimulus* to any hidden property of their fibres, peculiar activity of the nervous fluid, or other unknown caufe; when they are fo eafily and naturally accounted for, from the power and energy of a known fentient PRINCIPLE.

SECT. XI.

Of the ſhare which the mind has in producing the vital and other involuntary motions of animals.

THAT all the motions of animals were by ſome of the antient philoſophers aſcribed to the energy of a living principle wholly diſtinct, as to its nature, from the body, the paſſage of *Cicero* prefixed to this Eſſay clearly ſhews. And it was the difficulty of accounting for the motion of the heart from mechanical principles alone, which made no leſs a Philoſopher among the moderns than *Borelli* doubt, whether it were not rather owing to the mind, than to any natural neceſſity ariſing from the ſtructure of this organ or its nerves *. The great Mr. *Leibnitz*, in a letter to *Michelloti*, goes ſtill further, and ſuppoſes that the natural motions may be owing to ſome impreſſions made on the mind, although we are no way conſcious of

* De motu animal. part. 2. prop. 79. & 80.

of these *. It is true Dr. *Stahl*, by extending the influence of the soul, as a rational agent, over the body a great deal too far, and thus carrying this doctrine beyond all reasonable bounds, has been the occasion, why it has rather for many years been looked upon as a subject of ridicule, than deserving a serious and rational answer. However, that the motion of the heart and circulation of the blood, are altogether inexplicable upon principles purely mechanical, there are arguments *à priori* which seem to demonstrate †. But, as this kind of reasoning is apt to render us too presumptuous, and frequently betrays us

* *Michellot*. de separatione fluidor. p. 351.

Indeed, strictly speaking, it is inconsistent with Mr. *Leibnitz*'s principles to ascribe any of our motions, either voluntary or involuntary, to the mind; since, according to his pre-established harmony, the soul neither acts on the body, nor is affected by the impressions of external objects. This ingenious fable, however, which novelty, I suppose, at first recommended, has been so fully refuted by Mr. *Bayle* and others, as to make it needless for us to attempt to shew its weakness: but we cannot help observing, that it is matter of wonder how a doctrine, which explains nothing, and is loaded with so many difficulties, should still have any advocates.

† See *Edinburgh* Medical Essays, vol. 4. art. 14. where an argument of this kind is proposed with great strength and perspicuity by my ingenious friend Dr. *Porterfield*.

us into error and miſtakes, we ſhall further endeavour to vindicate this opinion from the moſt plauſible objections which may be brought againſt it; and at the ſame time ſhew by a variety of arguments *à poſteriori*, chiefly of the analogical kind, that the vital, as well as the other involuntary motions of animals, are directly owing to the immediate energy of the mind or ſentient principle.

THE chief power propelling the blood through all the veſſels of the body, is the contraction of the heart. But from Dr. *Hales*'s experiments it appears, that, in every circulation, the blood loſes $\frac{9}{10}$ of the *momentum* communicated to it by the left ventricle of the heart *; wherefore, there muſt be in every animal ſome cauſe, which repairs this loſs of motion ariſing from friction, *&c. i.e.* a cauſe generating motion: but, as has been obſerved above, matter, in its own nature inert, is incapable of this. Further, ſuch animals as lie in a dead inactive ſtate during the cold winter-ſeaſon, and whoſe blood has loſt all its motion, may at any time be reſtored to life by warmth, which rarifying their

* Statical Eſſays, vol. 2.

their ftagnating fluids, and communicating to them a fmall degree of inteftine motion, excites the heart into action; whofe motion, though it be at firft very languid, yet gradually gains ftrength, till at laft it arrives at its wonted vigour. As, in this cafe, the renewal of the heart's motion, and its gradual increafe, cannot be explained from any mechanical principles; fince we have not only a caufe producing an effect greater than itfelf, but alfo an effect increafing by degrees, and, as it were, of its own accord: it follows, that there is in thefe animals fome living principle, which being, by the *ftimulus* of warmth, roufed, as we may fay, out of a ftate of indolence, brings into gentle contractions the *finus venofi*, auricles and ventricles of the heart; which are parts of the body moft fenfible of the irritation of the fluids when rarified and agitated by heat.

The contraction of the heart, fo far as it is owing to a material caufe, feems to proceed from the derivation of the nervous influence into its fibres: but as, perhaps, $\frac{1}{100000}$ part of the blood thrown out by the left ventricle of the heart, does not return to it again in the

the form of vital ſpirits, as they are called; and as the motion of this fluid muſt be incredibly diminiſhed by its paſſage through the vaſtly ſubtile veſſels of the *cerebellum, &c.* there can be no force in theſe ſpirits derived from the laſt *ſyſtole* of the heart ſufficient to produce a new contraction of this muſcle, ſince no cauſe can generate an effect greater than itſelf.

AGAIN, The human body, in which there is no mover that can properly be called FIRST, or whoſe motion depends not on ſomething elſe, is a ſyſtem far above the power of mechanics. The contraction of the heart is indeed the cauſe of the blood's motion, and conſequently of the ſecretion of the ſpirits (as is ſuppoſed) in the *cerebellum, &c.*; but without theſe ſpirits, this action of the heart could not be performed: theſe two cauſes, therefore, truly act in a circle, and may be conſidered mutually as cauſe and effect. Whence it is incumbent on thoſe Philoſophers who aſcribe the heart's motion to mechanical cauſes alone, to demonſtrate the poſſibility of a *perpetuum mobile*, ſince, as long as life laſts, an animal is really ſuch. But as a perpetual motion is, in the opinion of the ableſt Philoſophers,

losophers, above the powers of mechanism, and inconsistent with the known laws of matter and motion *, we must be allowed to conclude, that the contraction of the heart, and the propulsion of the blood through the body, and consequently the continuance of life, are not owing to any mechanical or even material causes alone, but to the energy of a living principle capable of generating motion.

How far the mind is really concerned in the motion of the heart, may easily appear from what has been already offered in the preceding Sections; where, I hope, it has been shewn, beyond all doubt, that the contraction of the heart is owing to the returning venous blood acting as a *stimulus* upon it, as well as made highly probable, both from reason and analogy, that a *stimulus* excites our muscles into motion, only as they are animated by a sentient principle. Whence it must follow, that the alternate contractions of the heart are in no other sense owing to the irritation of the returning blood, than as the

* "Ex calculo mechanico liquet omnem de motu perpetuo quæstionem eò redire, ut inveniatur pondus seipso ponderosius, vel vis elastica seipsâ fortior." *Clarkii* not. in Rohault. physic. § 1. cap. 22.

the mind or ſentient principle is, by this, excited to determine the influence of the nerves more copiouſly into its fibres.

THIS doctrine of the alternate contraction of the heart being owing to the power of the mind, excited into action by the *ſtimulus* of the returning venous blood admitted into its cavities, is greatly ſtrengthened by the account we have given of the alternate motions of reſpiration, of the contractions of the muſcles of the internal ear and of the pupil. Theſe we have clearly ſhewn to proceed from the mind, as affected by a *ſtimulus*, and to be altogether inexplicable upon principles merely mechanical. The firſt of theſe motions (*viz.* reſpiration) agrees with that of the heart, in being performed whether we attend to it or no, and whether we ſleep or are awake; though it differs from the heart's motion, in being partly under the dominion of the will. The motions of the *iris* from light, and of the muſcles of the ear from various ſounds, differ from thoſe of the heart, both as they are not vital, nor continually and alternately excited by cauſes within the body, but owing to external cauſes acting at particular times

on

on the organs of ſight and hearing: theſe muſcles, however, exactly agree with the heart in this, that their motions are altogether involuntary, and cannot be controuled by any immediate effort of the will. Since then, in the muſcles of reſpiration, we have an inſtance of a vital, though not altogether involuntary motion, proceeding from the mind; and, in the muſcles of the *uvea* and ear, examples of motions, which, though not vital, are yet wholly involuntary, owing to the ſame cauſe; may we not, if it be in the leaſt allowable to argue from analogy, ſafely conclude, that the contraction of the heart, which is both vital and involuntary, is ultimately to be referred to the ſentient principle excited to put this muſcle in motion by the irritation of a material cauſe acting upon it alternately? What has been ſaid of the motion of the heart, as proceeding from the mind, is equally applicable to the periſtaltic motion of the ſtomach and inteſtines, and to the reſt of the vital or involuntary motions.

ALTHOUGH what has been already offered, might be ſufficient to ſhew, that all the motions of animals, involuntary as well as voluntary, are ſome way owing to the mind; yet as this doctrine may appear to ſome, who have always been uſed to think in a different way, as beſet with many difficulties; and as there may not be wanting thoſe, who are unhappily more tenacious of received opinions than willing to embrace ſuch as are true; we ſhall briefly obviate ſome of the ſtrongeſt objections, which, at firſt ſight, ſeem to lie againſt it; and this we ſhall do the more willingly, as an opportunity will hence be afforded us of illuſtrating, ſtill further, the nature and cauſe of the involuntary motions of animals.

Objection I. IT may be ſaid, that, while we aſcribe the vital and other involuntary motions of animals to the mind, we, in fact, attribute them to a power, whoſe nature and manner of acting we are ignorant of *.

Anſwer. THAT there is united to the bodies of men and animals an active, living, ſentient principle, which is the cauſe of voluntary motion, it may be hoped there are few Philoſophers, now a-days, ſo MINUTE as

* *Senac* Traité du coeur, vol. I. p. 441. & 445.

as to deny: and, if it be thought no abſurdity to aſcribe voluntary motion to the energy of the mind, though we do not underſtand its nature or manner of operation, why ſhould it be reckoned ſuch, to derive the vital and other involuntary motions from the ſame ſource; eſpecially, when a variety of *phænomena* and the ſtrongeſt analogy concur in ſupporting this opinion? That there is ſuch a thing as gravity, or attraction betwixt the parts of matter, is a thing not to be doubted of, becauſe we ſee its effects, though its cauſe be unknown: and, if Philoſophers make uſe of this power every day, with the greateſt juſtice, in order to explain the *phænomena* of nature, why ſhould it not be thought equally reaſonable to have recourſe, in accounting for the motions and actions of an animated body, to the power and energy of the mind, which we are ſure is always preſent with it, and in numberleſs inſtances operates upon it? In an attempt to account for the ſurpriſing operations and effects of an inanimate machine, it would be thought highly ridiculous to have recourſe to the agency of an immaterial living principle: and muſt it not be equally ſo, to baniſh banifh the confideration of mind in explaining the *phænomena* of an animated fyftem; or to endeavour to deduce its moft remarkable motions from the mere material part?

THERE is no need of underftanding the nature of the foul, or the way in which it acts upon the body, in order to know that the vital motions are owing to it: it is fufficient, if we know from experience, that it feels, is endued with fenfation, and has a power of moving the body *.

EVERY attempt hitherto made towards deducing the vital motions of animals from powers wholly material, has been unfatisfactory; and, I may venture to fay, will be for ever vain: fince it has not only been proved, that they are above the force of mechanifm, but alfo that the fuppofition of any mere material

* The reader will eafily perceive, that the objection againft deriving the vital motions from the mind, becaufe we are not fully apprifed of its nature and manner of acting, may be retorted with double ftrength upon thofe, who afcribe the contraction of the heart to fome latent power in it, or to the ofcillations of an unknown fluid fuppofed to be lodged in its fibres and nerves *.

* *Senac* traité du coeur, vol. 1. p. 434. & 452.

terial power's being their cauſe, is by no means ſuitable to the *phænomena* we obſerve. Nor can I conceive the reaſon why Phyſicians have laboured ſo long in accounting for the action of the heart and other vital motions of animals, from the powers and properties of body independent of mind: if it be not, that in ſome, the leaven of Carteſianiſm ſtill continues to work; in others, a too great fondneſs for mechanical reaſoning in Phyſiological matters; and in both, a contempt of the extravagant flights of *Stahl* and his followers, with regard to the manner in which the mind regulates all the actions of the body *.

MANY

* I have not met with any author, who has embraced the STAHLIAN doctrine with leſs reſerve, or carried it to a more ſurpriſing height, than Dr. *Nicholls*, in his elegant Prælection *de Anima medica*. According to him, the ſoul at firſt forms the body, and governs it ever after, carrying on and regulating all its vital and natural motions; diſtributing the fluids with greater or leſs force to its ſeveral parts, and exciting in them, from time to time, ſuch commotions and changes, as ſhe ſees moſt proper for removing their various diſorders.—He aſcribes it to the prudence of the ſoul, that the *ſemen* is not perfected in males, till the body hath acquired ſtrength and vigour ſufficient for the work of generation: and he finds a wonderful inſtance of her ſagacity, in the flow and gradual eruption of the ſmall-pox; as the force of the diſeaſe is hence divided, and its danger greatly leſſened.—When the body is diſordered, or

MANY Philofophers have fuppofed two diftinct principles in man; one of which has been called the *anima*, or foul; the other, the *animus*, or mind: by the former, they underftood

or exhaufted with fatigue, the foul frequently hides herfelf in fleep, and retires from external things, in order that fhe may be more at leifure to recruit the body, or to rectify what has happened amifs in it; and hence the inclination to fleep after child-bearing: hence, alfo, the frequent fleeping of infants; whofe *anima*, it feems, is fo taken up with directing and governing the vital motions, that it has little time to attend to any thing elfe.—— The foul, however, feems to neglect, in a great meafure, this province, as often as fhe is too much diftracted with external things; and hence it is, that health is fo much impaired by fear, forrow, love, and other more violent paffions: nor is fhe without her wilful and froward fits; as appears from her fending the milk back into the blood from the breafts of pregnant women, whofe *fœtufes* fhe had only fancied were fuddenly dead, and from her not deriving into them again thofe nourifhing ftreams, when living children are really born; as if, for her part, fhe had rather they were ftarved, than that fhe herfelf fhould feem to have been under miftakes.——In fevers, the fudden failing of the ftrength and pulfe ought, we are told, to be regarded by us as figns of the defpairing foul's difcontinuing her care of the body, and being foon about to relinquifh it: nay, fometimes, like a mean and filly coward, fhe finks even under fuch difeafes, as, in their own nature, are not at all deadly; and, through falfe alarms, fhe is either thrown into a great hurry and trepidation, which urges her to make wild work of it, and to do much mifchief; or elfe fhe becomes very backward and remifs in her endeavours to preferve the body, and, as if it were a FIELD not worth keeping, foolifhly deferts it: though, were fhe but always wife enough, ſtood the principle of life and ſenſe influencing the vital motions; and by the latter, the ſeat of reaſon or intelligence. According to them, we have the *anima*, or vital and ſentient

enough, and, neglecting things of leſs moment, were ſolely intent on the preſervation of the body, ſhe could, if we may believe the Doctor, not only prevent diſeaſes, as far, at leaſt, as they proceed from internal cauſes, but protract alſo the life of man, it may be, to a thouſand years: a TERM greatly beyond what the ADEPTS promiſed themſelves from their *aurum potabile*, or UNIVERSAL REMEDY!

But, as this account of the agency of the ſoul, and of its power over the body, ſcarcely ſeems to demand a ſerious anſwer, I ſhall only obſerve, that to imagine the ſoul ſhould, with the wiſeſt views and in the moſt ſkilful manner, at firſt form the body, (a work far above the utmoſt efforts of human art and contrivance!), and afterwards, when it is diſordered, ſhould, with the ſame ſkill and wiſdom, often remedy the evil, and reſtore it to a ſound ſtate; but finding it in the end, or ſometimes ſuſpecting it only, to be no longer tenable or comfortable, ſhould, inſtead of repairing, either whimſically or wiſely deſert it: to conceive, I ſay, of the ſoul as performing all this, without, in the mean time, being conſcious of ſuch intentions, or of the exertions of its power in purſuance of them, is at leaſt as great a ſtretch of fancy, as to ſuppoſe, that an able architect might raiſe a ſtately edifice, in which nothing ſhould be wanting that could contribute either to its uſefulneſs or ornament; that he might frequently make good ſuch damages as it ſuſtains from the weather, or from the decay of any of its materials; and at laſt, apprehending it to be in danger of falling, might abandon it; without being at all aware of ever having once exerciſed, either his ſkill in contriving, erecting, and repairing it, or his prudence in quitting it, when, as he thought, it was ready to bury him in its ruins.

tient ſoul, in common with the brutes; but the *animus*, or *mens*, which is of a more exalted nature, is proper to rational creatures alone *.

SOME modern Materialiſts have imagined the *anima* to be no other than a more ſubtile kind of matter lodged, chiefly, in the brain and nerves, and circulating with the groſſer fluids. But ſuch ſpirits, or ſubtile matter, can no more be acknowledged the vital principle or ſource of animal life, than the blood from which they are derived; and ſtill with leſs reaſon can this material *anima* be ſuppoſed endued with ſenſe, ſince matter, of itſelf, and unactuated by any higher principle, is equally as incapable of ſenſe or perception, pleaſure or pain, as it is of ſelf-motion. Indeed, a few authors have run even ſuch lengths, as to ſuppoſe the very *animus*, or rational ſoul itſelf, material: but ſurely the powers and faculties of the mind are not to be found in matter, or in any of thoſe principles, or elements, whereof either the antients or mo-
derns

* —— *Indulſit communis conditor illis*
Tantum animas, nobis animum quoque.
JUVENAL. Sat. 15. lin. 148. & 149.

derns have imagined it to confiſt: fire itſelf, the moſt ſubtile and active among theſe, being as incapable of thought and reflexion, as water or earth, the moſt ſluggiſh *: and in what manner ſelf-motion, ſenſe or reaſon can poſſibly reſult from the figure, connexion, ſituation or arrangement of the various parts of the body, (without ſuppoſing a mind) is a point which the abettors of Materialiſm, to their confuſion, will never be able to clear up †.

As I cannot therefore agree with thoſe, who, in aſcribing all our powers to mere matter, ſeem willing to deprive us wholly of mind; ſo neither, at the ſame time, do I ſee any reaſon for multiplying principles of this kind in man: and, therefore, I am inclined to think the

N n *anima*

* "Animorum nulla in terris origo inveniri poteſt. "Nihil enim eſt in animis mixtum atque concretum, aut "quod ex terra natum atque fictum eſſe videatur: nihil "ne aut humidum quidem, aut flabile aut igneum. His "enim in naturis nihil ineſt, quod vim memoriæ, mentis, cogitationis habeat, quod et præterita teneat, et "futura provideat, et complecti poſſit præſentia". *Cicero* in Tuſculan. diſput. lib. I.

See alſo, in proof of the immateriality of the ſoul, Dr. *Sam. Clarke*'s defences of his letter to Mr. Dodwell, where Perſpicuity, Metaphyſics, and ſound Philoſophy, are happily united.

† "Membrorum verò ſitus et figura corporis, vacans "animo, quam poſſit harmoniam efficere non video". *Ciceron.* Tuſculan. diſput. lib. I.

anima and *animus*, as they have been termed, or the ſentient and rational ſoul, to be only one and the ſame principle acting in different capacities. Nay, *Epicurus* himſelf, according to *Lucretius*, did not look upon theſe two as ſeparate beings, but regarded the mind as a kind of *mouvement* produced by the *anima* or ſoul *.

THAT the involuntary motions in man are not owing to a principle diſtinct from the rational mind, ſeems evident, from the muſcles and organs, whoſe action has been generally aſcribed to the *anima*, being, in many caſes, ſubject to the power of the *animus* or rational principle; as well as, on the other hand, from the motions of the voluntary muſcles often becoming involuntary, or independent upon the will. Thus the diaphragm, whoſe motions in the hiccup are altogether involuntary, and in ordinary reſpiration go on without our conſciouſneſs of them, is nevertheleſs ſubject to the immediate influence and direction of the mind; ſince its motions in breathing can, by an effort of the will, either be augmented or

* *Nunc* animum *atque* animam *dico conjuncta teneri*
Inter ſe, atque unam naturam *conficere ex ſe.*
LUCRET. lib. 3. verſ. 137. & 338.

or leſſened, retarded or accelerated.——The evacuation of the *inteſtinum rectum* and urinary bladder, which, when the *ſtimulus* is gentle, is in part voluntary, becomes altogether involuntary and convulſive, when the irritation is greater.—The eye-lids, which the mind ſeems to have a full power over, move, commonly, not only without our attention but, in ſome caſes, even againſt every effort of the will to the contrary.—The action of the *acceleratores urinæ* is voluntary in expelling the laſt drops of urine; but in expelling the *ſemen*, it is involuntary.—The contraction of the pupil, which, in order to diſtinct viſion, is voluntary, becomes altogether involuntary when owing to the light. In ſhort, there is not a voluntary muſcle in the body, whoſe motion does not become involuntary, as often as it is either directly, or from its conſent with ſome neighbouring part, affected by any conſiderable *ſtimulus*: if the irritation be very gentle, we ſtill retain a greater or leſs power over the muſcle; but when it becomes ſtronger, we loſe all this power.

FURTHER, in man the ſentient and rational principle muſt be acknowledged to be one; ſince

ſince we are all conſcious that what feels, reaſons, and exerts itſelf in moving the body, is one and the ſame, and not diſtinct beings. It is the mind, therefore, that feels, thinks, remembers and reaſons; which, though one principle, is nevertheleſs poſſeſſed of theſe different powers, and acts in theſe different capacities: nay, ſince memory is as widely different from the preſent perception of ideas, or the exertion of the will in order to action, as ſenſe is from reaſon, it might with equal propriety be maintained, that we are endued with four ſouls, namely, with a rational, a reminiſcent, an active, and a ſentient one, as that we have two. In brutes of the loweſt kind there is evidently a ſentient principle; but it ſeems to be wholly devoid of reaſon or intelligence: in thoſe, however, of a higher claſs, we can perceive faint traces of ſomething like what we call reaſon and reflexion in man. Why, therefore, may not the human mind, which enjoys all the powers belonging to the ſouls of the inferior creatures, and has alſo reaſon ſuperadded to thoſe powers, be allowed ſometimes to act as a ſentient, and at other

times

times as a rational being, *i. e.* in different capacities?

BUT, if any one yet contends, that the ſentient principle, governing the vital motions, is different from the rational, I ſhall not think it much worth while to diſpute the matter with him: ſince whatever is advanced, in the preſent ESSAY, upon the ſubject of the involuntary motions of animals, will hold equally true, whether the ſentient and rational ſoul be ſuppoſed diſtinct, or otherwiſe.

HOWEVER, although we conceive it to be the moſt probable opinion, that the ſentient and rational principle in man are one and the ſame; yet we think it a very clear point, that the mind does not, as Dr. *Stahl* and others would perſuade us, preſide over, regulate, and continue the vital motions, or, upon extraordinary occaſions, exert its power in redoubling them, from any rational views, or from a conſciouſneſs that the body's welfare demands her care in theſe particulars: for infants, ideots, and brutes of the loweſt kind, (which laſt are certainly deſtitute of reaſon), perform theſe motions in as perfect a manner as the wiſeſt Philoſopher; and the mind, when

when life is endangered by the too violent circulation of the blood, neither does, nor can moderate the heart's motion. If the contraction of the heart were owing to any previous deduction of reafon, or conviction of its being neceffary to the continuance of health or life, the mind ought to have a power of reftraining the uniform motions of its auricles and ventricles, or of repeating them at fhorter or longer intervals, notwithftanding their having become, like thofe of the eyes, in a manner neceffary through long habit: for though we cannot, indeed, move our eyes in every different direction, yet we can reftrain or vary their uniform motions as we pleafe.

FURTHER, if there were any exercife of reafon neceffary to the continuance of the vital motions, the mind certainly ought to be confcious of this; fince, in every ratiocination refpecting action, there muft firft be a comparifon of things, and then, in confequence of this comparifon, a preference or election: but, I believe, few Philofophers will be found hardy enough to maintain, that the mind can compare two, or more ideas, and thence form certain conclufions and determinations, without

out being ſo much as conſcious, in any degree, of what it has been all the while employed about: for though, when we are ſolicitouſly engaged in any action, deeply involved in any thought, or ſtrongly hurried away by any paſſion, we may often be unconſcious of the impreſſions made by material cauſes on the organs of ſenſe *; yet we cannot but be ſenſible of the ideas formed within us by the internal operation of our minds, becauſe their very exiſtence depends upon our being conſcious of them, and is at an end, as ſoon as either we attend not to, or forget them: to ſay therefore that ſuch ideas may be formed and exiſt in the mind without conſciouſneſs, is, in effect, to ſay that they may, and may not exiſt at the ſame time; than which nothing can be more abſurd.

FURTHER,

* To avoid all metaphyſical diſputes about different degrees of conſciouſneſs; I deſire it may be underſtood, that here and in other parts of this Eſſay, when I ſay we are not conſcious of certain impreſſions made on the mind by the action of material cauſes on the organs of the body, I mean no more, than that we have no ſuch conſciouſneſs or perception of them, as either convinces us of their exiſtence when preſent, or enables us, by the help of memory, to recall them when paſt.

FURTHER, the motions excited by any pain, or irritation, are ſo inſtantaneous, that there can be no time for the exerciſe of reaſon, or a compariſon of ideas in order to their performance; but they ſeem to follow as a neceſſary and immediate conſequence of the diſagreeable perception. And as the DEITY ſeems to have implanted in our minds a kind of SENSE reſpecting *Morals*, whence we approve of ſome actions, and diſapprove of others, almoſt inſtantly, and without any previous reaſoning about their fitneſs or unfitneſs; a FACULTY of ſingular uſe, if not abſolutely neceſſary for ſecuring the intereſts of virtue among ſuch creatures as men! ſo, methinks, the analogy will appear very eaſy and natural, if we ſuppoſe our minds ſo formed and connected with our bodies, as that, in conſequence of a *ſtimulus* affecting any organ, or of an uneaſy perception in it, they ſhall immediately excite ſuch motions in this or that organ, or part of the body, as may be moſt proper to remove the irritating cauſe; and this, without any previous rational conviction of ſuch motions being neceſſary or conducive to this end. Hence, men do not eat, drink, or propagate their kind,

kind, from deliberate views of preferving themfelves or their fpecies, but merely in confequence of the uneafy fenfations of hunger, thirft *&c.*

THE mind, therefore, in producing the vital and other involuntary motions, does not act as a rational, but as a fentient principle; which, without reafoning upon the matter, is as neceffarily determined by an ungrateful fenfation or *ftimulus* affecting the organs, to exert its power, in bringing about thefe motions, as is a balance, while, from mechanical laws, it preponderates to that fide where the greateft weight prevails.

THE general and wife intention of all the involuntary motions, is the removal of every thing that irritates, difturbs, or hurts the body: hence, thofe violent motions of the heart, in the beginning of fevers, fmall-pox, meafles, *&c.* when frequently the blood, from its being affected by the mixture of fome peculiar *miafma*, acts as a ftronger *ftimulus* than ufual upon this organ. Neverthelefs, as, in many inftances, the very beft things may, by excefs, become hurtful; fo this endeavour to free the body, or any of its parts, from what is noxious, is unhappily, ſometimes, ſo ſtrong and vehement, as to threaten the entire deſtruction of the animal fabric. But, in the main, this FACULTY muſt be confeſſed highly uſeful and beneficial; ſince, without it, we ſhould conſtantly have cheriſhed in our bodies the lurking principles of diſeaſes, ſlowly indeed and by imperceptible degrees, but not leſs ſurely, ruining our health and conſtitutions.

UPON the whole, there ſeems to be in man one ſentient and intelligent PRINCIPLE, which is equally the ſource of life, ſenſe and motion, as of reaſon; and which, from the law of its union with the body, exerts more or leſs of its power and influence, as the different circumſtances of the ſeveral organs actuated by it may require. That this principle operates upon the body, by the intervention of ſomething in the brain or nerves, is, I think, likewiſe probable; though, as to its particular nature, I preſume not to allow myſelf in any uncertain conjectures; but, perhaps, by means of this connecting *medium*, the various impreſſions, made on the ſeveral parts of the body either by external or internal cauſes, are tranſmitted to, and perceived by the mind; in in confequence of which it may determine the nervous influence varioufly into different organs, and fo become the caufe of all the vital and involuntary motions, as well as of the animal and voluntary. It feems to act neceffarily, and as a fentient principle only, when its power is exerted in caufing the former; but, in producing the latter, it acts freely, and both as a fentient and rational agent.

THE bodies of brute animals are actuated by a principle of a like kind with what is placed in man, but greatly inferior with regard to the degrees of reafon and intelligence which it poffeffes: in the more perfect brutes, this principle is plainly intelligent as well as fentient; and their actions fo evidently fhew them to be endued, not only with a ftrong memory, but with reflexion and fome degrees of reafon, that it is really wonderful to find *Defcartes* and his difciples fo far impofing upon themfelves, as ferioufly to believe thefe were machines formed entirely of matter, and, as it were, fo many curious pieces of clock-work wound up and fet a-going. Nor is it lefs furprifing that the generality of Theological writers fhould, till of late, have been fo far

miftaken

miſtaken in this matter, as not to have perceived, that, after once admitting all the actions of the moſt perfect brutes to reſult from mere mechaniſm, the aſcribing every thing in man to no higher a principle, would be a natural and eaſy conſequence.

IN the inferior orders of brutes the appearances of reaſon and reflexion are more obſcure; and, in the loweſt ſpecies of animals, there are no marks of intelligence, nor do we obſerve them to differ otherwiſe from vegetables, than as they are endued with ſome degree of ſenſation and ſelf-motion.

Obj. II. IT may be alledged, that the vital motions cannot be owing to a *ſtimulus* affecting the ſentient principle, in the manner above explained, ſince we are not conſcious of any ſuch thing.

Anſwer. THIS may either be owing to the gentleneſs of the irritation, or to our having been long accuſtomed to it, perhaps from the beginning of our lives.

« WE all know, that ſuch ideas as but ſlightly

ſlightly affect us, and ſoon give place to ſucceeding ones, are quickly forgot; nay, that impreſſions, which are very faint in themſelves, or loſt amidſt far ſtronger ones, are frequently neither attended with conſciouſneſs when preſent, nor remembered when paſt. In walking the ſtreets, how many perſons of one's acquaintance are every minute preſented to the mind, as their pictures are painted on the *retina*; yet if we be alone, having our thoughts ſtrongly turned upon a particular ſubject, or elſe be deeply engaged in converſation with a friend, we are often not conſcious of the preſence of theſe people when before our eyes, nor remember their having been ſo, when they have left us.—If we turn our eyes towards the azure ſky at noonday, we cannot, by the utmoſt attention, obſerve any of the ſtars; and yet it is certain, that, at that time, there are images of every ſtar in the viſible hemiſphere formed upon the bottom of our eyes: for the ſtellar light muſt run through the ſame torrent of ſun-beams to reach us in the night as in the day, allow-

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ance being only made for the inconfiderable depth of the earth's atmofphere *.

THE fenfation arifing from the impetuous courfe of the blood through the pulmonary veffels, is, ufually, fo very flight, as not to be

* In this particular cafe, we muft either fuppofe, that the impreffions, made by the ftars on the *retina*, are fuffocated and loft in thofe ftronger ones made by the illuminated atmofphere, fo as never to reach the *fenforium* in order to excite any *idea* in the mind, or that if they do reach the fenfory, and create correfpondent ideas, yet they are fo drowned, as it were, in the ftronger idea, as to efcape our attention and memory. I am not infenfible, that there is a real difficulty in this matter, and even fome appearance of contradiction in the laft fuppofition: for it may well be afked, what is an idea drowned in another, but a perception unperceived? Without pretending to decide, therefore, in this fo very fubtile a queftion, I fhall only take notice of a fact, which, if duly weighed, would perhaps go as far towards clearing it up as any other confideration whatever. It is well known Sir *Ifaac Newton* has proved, by a beautiful variety of experiments, that, from the union of fimple-coloured rays, are formed compound-coloured ones; for example, that a red and yellow ray mingled make an orange, blue and yellow a green one, and fo of the reft; and that all the fimple-coloured rays combined form a white one. But this difcovery is by no means confined to colours as they exift out of the mind, either in the rays of light, or furfaces of bodies; but is equally true of the ideas of colours in the mind itfelf: for it appears, by experiments, that the *idea* of red and the *idea* of yellow, confounded in the mind by co-exiftence or rapid fucceffion, make the *idea* of orange; the ideas of blue and yellow, that of green. *&c.* and thofe of the feven fimple colours that of white.

be felt or attended to. But this is far from being the cafe in afthmatic diforders, or after refpiration has been fuppreffed for fome time; for, then, it is very remarkable, being accompanied with the moft painful anxiety.—The action of the air, aliments and bile, upon the inteftines, which is the caufe of their periftaltic motion, is commonly altogether unperceived by us; but let this *ftimulus* be increafed by purgative medicines, or by fharp humours lodged in the *primæ viæ*, and it will be felt very fenfibly.—The *ftimulus* of light upon the *retina*, which makes the pupil contract itfelf, is feldom perceived or regarded, unlefs it be, when the degree of light is much ftronger than what the eye, immediately before, had been expofed to.—The action of the returning blood upon the heart, though it be ufually quite imperceptible, feems, in fome cafes, plainly to be felt: for people, efpecially fuch as have weak nerves, after a fudden fright, which makes the blood return more haftily, and in greater quantity, than ufual to the heart, are fenfible of a particular feeling, not eafy to be defcribed in words, from the heart's being more than ordinarily affected

by

by a furcharge of this fluid.—In various parts of the body, pulfations, or fmall alternate convulfions, are fometimes perceived; which, as they keep not time with the beating of the heart, cannot be arterial vibrations, but muft be the alternate contractions of mufcles, or, rather, of a fmall parcel of their fibres. There is no fenfation of a *ftimulus* in the part before thefe motions begin, or while they continue; and yet, as they frequently happen to people in good health, whofe brain and nervous fyftem are found, it is more than probable that they are owing to fome obftructing matter, which diftracts the fibres of the fubtiler veffels, or to acrid particles in the fluids coming into contact with the tender nerves of the convulfed part. But,

β The *ftimulus* caufing the vital motions is unperceived by us, not only on account of its gentlenefs, but alfo becaufe we have been accuftomed to it from the earlieft period of our lives. The force of cuftom is prodigious and unaccountable; what we have been long ufed to, we become fcarcely fenfible of, while things which are new, though much more trifling, and of weaker impreffion, affect us remarkably.

markably. Thus he who is wont to ſpend the greateſt part of his time in the ſilent retirements of the country, is ſurpriſingly affected, upon his firſt coming into a populous city, with the noiſe and buſtle which prevail there: of this, however, he daily becomes leſs and leſs ſenſible, till, at length, he regards it no more than they who have been uſed to it all their life-time.

THE ſame ſeems to be the caſe alſo with regard to what paſſes within our bodies. Few perſons in health feel the beating of their heart, though it ſtrikes againſt the ribs, and that too with a conſiderable force every ſecond or oftener; whereas the motion of a fly upon one's face or hands, occaſions a very ſenſible and uneaſy titillation.—The pulſation of the great *aorta* itſelf is wholly unobſerved by us; yet the unuſual beating even of a ſmall artery in any of the fingers, from an obſtruction of its veſſels, becomes very remarkable.—Although the blood ruſhes into the ventricles of the heart with a conſiderable velocity, and is thence expelled into the arteries with a much greater force; yet we are not conſcious of ſo much as one drop of this fluid paffing that way; otherwife the circulation of the blood could not have remained fo long a fecret to mankind. And if we are not fenfible of the *ftimulus* of the air, aliment and bile upon the inteftines, which, however, all allow to be the caufe of their vermicular motion; nor are immediately confcious of the action of *opium* upon the nerves of the ftomach, which yet produces furprifing effects over the whole body; why fhould it be thought ftrange that we don't feel the *ftimulus* of the blood upon the internal furface of the ventricles of the heart, which is much more gentle than the laft, and which, as well as the firft, cuftom, that fecond nature, prevailing from the very beginning of our lives, has rendered quite familiar and unheeded.

UPON the whole, from what has been faid, it may fully appear, that there is no good reafon for denying the vital motions to proceed from a *ftimulus* affecting the mind, becaufe we are not confcious of this; or for imagining that the blood does not gently irritate the heart, becaufe we don't feel a particular fenfation in this mufcle immediately preceding every contraction of it.

Obj.

Obj. III. IT may be ſaid, that although we are inſenſible of the *ſtimuli* affecting the organs of vital motion, either from their ſlightneſs or from cuſtom; yet we ought to be conſcious of the exertion of the mind's power in cauſing theſe motions.

Anſwer. « THAT a man may in general, and with propriety, be called conſcious of any action, it is not only neceſſary he ſhould perceive it during the time in which it is performed, but alſo that he be able to recollect it after it is paſt: for though one be ſenſible, while a viſible object is before him, that he ſees it; yet if he retains not the leaſt memory of it after it is removed out of his ſight, he can neither ſatisfy himſelf nor others that ever he ſaw it. In like manner, we cannot be called conſcious of an action or volition that is not adverted to when performed, or, as ſoon as it is over, is entirely forgotten by us: for as there are ſome ſenſations, either ſo ſlight in themſelves, or ſo much weakened by the diverſion of our attention, that they leave no traces in the memory; ſo there may be actions and volitions, that are either ſo faint, ſo habitual,

bitual, or ſo much leſſened amid ſtronger and more important exertions of the mind, that they may not only be entirely and for ever forgotten, but never ſo much as taken notice of or reflected upon.

β SETTING aſide, however, all metaphyſical conſiderations, we may find arguments *a poſteriori* ſufficient to prove that the mind does perform actions, which yet are unattended with conſciouſneſs. Thus we are not conſcious of any effort of the mind in cauſing thoſe motions of the body, which tickling the ſides or the ſoles of the feet excites; yet it appears they in fact do proceed from the mind, from the like motions being produced, though in a leſs degree, by the fear only or apprehenſion of being tickled.—Duſt, as well as flies and ſeveral other inſects paſſing before our eyes, make us ſhut the *palpebræ*; and yet theſe motions, which certainly proceed from the mind, are not often attended to, and ſeldom remembered by us.—The contraction of the pupil from light, and of the muſcles of the internal ear from ſound, has been ſhewn to ariſe from an exertion of the mind's power, of which, however, we are in no degree ſenſible.—

ſible.—As the erection of the *penis* often proceeds from laſcivious thoughts, it muſt be aſcribed, in theſe caſes at leaſt, to the mind, notwithſtanding our being equally unconſcious of her influence exerted here, as in producing the contraction of the heart.——The ſight, or lively idea of grateful food, is accompanied with a ſudden and copious excretion of ſpittle into the mouth of a hungry perſon: certain ideas excited in the mind are the occaſion of an uncommon flow of tears, from the lachrymal veſſels: and a nurſe's breaſt pours out its milk when a child is brought only near it. The extraordinary motions of the veſſels of theſe parts cannot in any other way be accounted for, than by aſcribing them to the mind; of whoſe action, however, we are no way conſcious.

FURTHER, ſince, in conſequence of certain ideas being excited in the mind, the ſtomach is immediately affected with a *nauſea* and vomiting, it cannot be denied that this is owing to an unuſual determination of the nervous influence, by means of the mind, into the muſcular fibres of this bowel; yet we are not at all more ſenſible of an exertion of the mind's

power

power in this cafe, than we are when vomiting is excited by fwallowing a doze of ipecacuan or emetic tartar. The want of confcioufnefs, therefore, can be no fufficient argument againft the motion of the ftomach, whether natural or perverted, being owing to the active power or energy of the fentient principle, which is varioufly affected by the different *ftimuli* applied to the delicate nerves of this bowel; and if the *idea* only of a difagreeable fenfation in the ftomach, can bring about, through the influence of the mind, fuch irregular motions in it, why fhould not the real feeling of fuch a fenfation in this organ, more remarkably affect the mind, and fo excite it to produce fimilar motions.

WHAT has been faid with regard to the motions of the ftomach, may readily be applied to thofe of the heart: for no fooner are certain ideas prefented to the mind, than the motion of the heart is increafed and accelerated; which muft, therefore, undoubtedly be the effect of an extraordinary determination of the nervous power into its fibres confequent upon the emotion raifed in the foul: yet of this effort of the mind we are not in any degree con-

fcious.

ſcious. If, therefore, the mind can thus influence the heart's motion, and we, at the ſame time, not be ſenſible of its power being directed to that end, it can by no means appear unreaſonable to ſuppoſe, that the *ſtimulus* of the returning blood may excite the ſentient principle to bring this muſcle into contraction, although we are not in the leaſt conſcious of any ſuch exertion of its power.

BUT, the objection againſt the mind's being concerned in effecting the vital and other involuntary motions, drawn from our not being conſcious of its interpoſing for this end, is quite overturned, by conſidering that great variety even of voluntary motions are many times performed, when we are inſenſible of the power of the will exerted in their production. Thus, while in walking we either meditate by ourſelves, or converſe with others, we move the muſcles of our legs and thighs, without attending to, or knowing any thing of the matter.—We are not ſenſible of the eye-lids being kept open by the immediate action of the mind; but yet, when drouzineſs and ſleep ſteal upon us, we find it requires a conſiderable effort to prevent the falling down of of the ſuperior *palpebræ*. The ſame thing is true of the action of the muſcles which ſupport the head. The true account of our ignorance in theſe things, which, as they are tranſacted within the ſphere of our own bodies, it might be expected we ſhould be well acquainted withal, ſeems to be this, *viz.* that we not only acquire, through cuſtom and habit, a faculty of performing certain motions with greater eaſe than we were wont to do them, but alſo, in proportion as this facility is increaſed, we become leſs ſenſible of any ſhare or concern the mind has in them. Thus a young dancer, or player upon the harpſicord, is very thoughtful and ſolicitous about every motion of his fingers, and every ſtep he takes; while the PROFICIENTS or MASTERS in theſe arts perform the very ſame motions, not only with greater agility, and more dexterouſly, but almoſt without any reflexion or attention to what they are about.

SOME indeed have gone ſo far, as to deny that even the voluntary motions are owing to the mind, as their proper cauſe, and have thought the direction of the ſeveral voluntary muſcles, in order to perform the various motions

tions of the body, to be an office which its faculties are by no means equal to *. But if theſe motions be not owing to the mind, from what cauſe, I pray, external or internal, do they proceed? They cannot be owing to the powers of the body alone; and it is in vain to attribute them to any LAW which it may be pretended the DEITY has eſtabliſhed †; ſince a law can produce no effect of itſelf, and, without ſome agent to execute it, is only a mere name or empty ſound: they muſt, therefore, be aſcribed either to the immediate agency of the SUPREME BEING, or to that of ſome general inferior NATURE, which HE has conſtituted for this purpoſe, or to the energy of a particular active PRINCIPLE united with the body. The firſt two ſuppoſitions are poſſible indeed, but not at all probable, as is the laſt; whence it may be inferred, that not only the voluntary motions, of which we are immediately conſcious, but thoſe alſo which we don't advert to, proceed from that SENTIENT and INTELLIGENT PRINCIPLE with which the AUTHOR of nature has animated our bodies;

Q q whoſe

* *Haller*. not. in Boerhaav. Inſtitut. vol. iv. p. 588.

† Id. ibid.

whofe powers and operations, it muft be owned, are, in many inftances, as much above our knowledge, as is the nature of its union with the body, or the manner of their reciprocal action upon each other.

Obj. IV. IF the vital motions were owing to the mind, they fhould be under its dominion or controul; and we ought at any time to be able to fufpend or vary thefe motions at pleafure.

Anfwer. IN all actions which are the refult of reafoning and deliberation, man evidently appears to be a FREE AGENT: he has it in his power, after weighing all motives and circumftances, to prefer this or the other action, or to abftain from acting altogether. But there are actions, towards the performing of which we are in no ways determined by reafon, and where the mind is a neceffary agent, even in the very ftrongeft fenfe of the word: of this kind are the involuntary motions of mufcles, whofe fibres have a *ftimulus* applied to them; for the application of external objects to their proper organs, does not more neceffarily or im-

mediately

mediately excite correfponding ideas in the mind, than certain uneafy fenfations produce confequent motions of the body. As we cannot therefore hinder ourfelves from feeing every object which is painted on the bottom of the eye, nor from hearing every found which affects the ear; fo neither can the mind refrain from exerting its power of moving a mufcle, whofe fenfible fibres are ftrongly affected by a *ftimulus*. And as no body ever went about to deny that it was the mind which fees colours and hears founds, becaufe, whenever the external caufes exciting thefe, are applied to their proper organs, we can, by no effort of the will, prevent ourfelves from feeing or hearing, nor can fee and hear objects or founds different from what thefe impreffions naturally reprefent; fo it muft be wholly unreafonable to pretend the vital and other involuntary motions cannot arife from the energy of the mind, becaufe the will has no immediate power over them.

AN action is denominated free, from the agent's having willed or chofen it, when he had a phyfical power of doing otherwife; thus the action of fwallowing poifon is faid to be free,

free, when a perſon chuſes it, and might have refrained from it; but the convulſive motions of the ſtomach and diaphragm which ſoon enſue upon taking it, are ſtrictly neceſſary; ſince the mind cannot, by any effort or exertion of its power, prevent them, being as neceſſarily determined to move theſe parts violently, from the diſagreeable ſenſation which the poiſon excites, as a ſtone is in falling to the ground, or a balance in inclining to the ſide where there is the greateſt weight, from the principle of gravity. The only difference in theſe caſes is, that the cauſe acts upon a living ſentient principle in the firſt; and in the laſt, upon inert and lifeleſs matter.

As the actions which neceſſarily follow an irritation of our muſcles, or any uneaſy ſenſation in the body, are not performed by the mind, in conſequence of any previous ratiocination, or from any views of their being immediately neceſſary, or conducive to the welfare of the body; ſo neither do they flow from cuſtom or habit; ſince new-born children perform them as well as the oldeſt and moſt experienced man. Infants, as ſoon as they come into the world, perform the action of breathing, tho'

quite

quite unaccuſtomed to it before; they ſhut their eye-lids upon the approach of light, vomit when their ſtomach is oppreſſed, ſuck when hungry, ſneeze, or cough, upon any irritation of the membrane of the noſe or wind-pipe, and void their *fæces* and urine, when theſe excite an uneaſy ſenſation in their inteſtines or bladder. Cuſtom may enable us to perform ſome actions with ſurpriſing facility, and little or no attention, but will not render the motions of muſcles abſolutely involuntary, which were originally voluntary: Thus, as *Haller* has well obſerved againſt the followers of *Stahl*, the muſcles of the eye-lids, and thoſe which ſerve to erect the back, though they are almoſt conſtantly employed, except in time of ſleep, nevertheleſs continue to be ſubject to the will *.

IT remains, therefore, that the motions performed by us, in conſequence of an irritation, are owing to the original conſtitution of our frame, and law of union eſtabliſhed by the all-wiſe CREATOR between the ſoul and body, whereby the former, immediately and without any exerciſe of reaſon, endeavours by all means and

* Not. in *Boerhaave* Inſtitut. med. vol. iv. p. 588.

and in the moſt effectual manner, to avoid or get rid of every diſagreeable ſenſation conveyed to it by whatever hurts or annoys the body *.

WHEN the organ is not extremely ſenſible, or the *ſtimulus* is very ſlight, or is applied to ſome diſtant part, and not immediately to that which is to be moved, we can reſtrain the motions, which otherwiſe would follow, by an effort of the will: but if the nerves of the part be more delicate, and ſuſceptible of the ſmalleſt impreſſion; if the *ſtimulus* be ſtronger and applied immediately to the organ which is to be brought into action; then the motions which follow, are neceſſary, and cannot be controuled by the power of the will, becauſe the mind is more ſtrongly affected by the irritation, than by any arguments or ideas it can preſent to itſelf. To illuſtrate this matter by a few examples.—In voiding the excrement and urine, the contraction of the abdominal muſcles and diaphragm is uſually in ſome meaſure voluntary, and can be reſtrained at pleaſure, becauſe the *ſtimulus* is not only ſlight, but applied to a diſtant part; but in a violent *teneſmus* or ſtrangury, the motion of

* See page 288. & 289. above.

of theſe muſcles becomes altogether neceſſary and convulſive, not becauſe the mind is leſs concerned in this laſt caſe than before, but becauſe the painful ſenſation compells it to act whether it will or no.—If the internal membrane of the wind-pipe be ſlightly irritated, we can reſtrain coughing; but if the tickling be ſtrong, we loſe this power.—When the *tunica cornea*, or *conjunctiva* of the eye, are gently ſtimulated, we can, by an effort of the will, prevent the ſhutting of the *palpebræ*; but when any thing very acrid is applied to theſe parts, the eye-lids are moved neceſſarily.—Although the contraction of the pupil ariſes from the action of light upon the *retina*, and not upon the fibres of the *iris*; yet this motion is altogether involuntary, on account of the extreme ſenſibility of the irritated part.—The motions of the heart and alimentary tube are wholly neceſſary, becauſe the nerves of theſe organs are highly ſenſible, and the *ſtimulus* is immediately applied to them. Nor can the mind leſſen the violent contractions of the heart in a fever, however conſcious it may be of the danger ariſing from too impetuous a motion of the blood; becauſe the

the heart being more ſtrongly ſtimulated than uſual by the blood, the ſentient principle, in order to expel the irritating cauſe, is neceſſarily excited to contract this muſcle with proportionably greater force.—The motions of the reſpiratory muſcles can be accelerated, retarded, or altogether ſtopt, as often as we pleaſe; becauſe the *ſtimulus* exciting them, is not immediately applied to their fibres, but to the lungs, a part not very ſenſible, and with which they have little or no connexion. However, as often as the *ſtimulus* is greatly increaſed, by the difficult paſſage of the blood thro' the lungs, and there is an immediate danger of ſuffocation, the motion of theſe muſcles becomes more neceſſary, and almoſt ceaſes to be under the power of the will.—In a fever, when, from an obſtruction or perverted motion of the fluids in the brain, or its membranes, the patient talks of ſeeing and hearing things which are neither preſent nor ſpoken, he may be readily convinced of his error, provided the *delirium* be of the ſlighter kind; if otherwiſe, we endeavour in vain to correct his wrong judgment by reaſon or argument, ſince the diſordered ſtate of the brain makes a ſtronger im-

preſſion

preffion upon the mind, than any arguments or external confiderations whatever: yet acrid cataplafms applied to the foles of the feet, as they give great pain, and fo make a remarkably ftrong impreffion on the fentient principle, will often leffen, and fometimes entirely remove fuch a *delirium*. But,

β THE objection againft the mind's producing the vital motions, drawn from their being involuntary, muft appear extremely weak; fince there are a variety of motions equally independent upon our will, which yet are certainly owing to the mind. Thus, as has been already obferved, the contraction of the pupil from light, and the motions of the body from tickling, or the apprehenfion of it, undoubtedly flow from the mind, notwithftanding their being involuntary.—The fhutting of the eye-lids, when a blow is aimed at the eye, is another inftance of a motion performed by the mind in fpite of the will; for as the threatened blow does not, by any corporeal contact, affect the orbicular mufcle of the *palpebræ*, its contraction muft neceffarily be deduced from the mind, moved to perform this action from the apprehenfion of fomething ready to hurt the eye: and if there are ſome who, by an effort of the will, can reſtrain this motion of their eye-lids, yet this does not proceed ſo much from the mind's making no attempt, in conſequence of the apprehended danger, to cloſe the *palpebræ*, as from the ſuperior eye-lid's being kept up by a ſtrong voluntary contraction of its *levator* muſcle.——We cannot, by an effort of the will, either command or reſtrain the erection of the *penis*; and yet it is evidently owing to the mind; for ſudden fear, or any thing which fixes our attention ſtrongly and all at once, makes this member quickly ſubſide, though it were ever ſo fully erected. The titillation, therefore, of the *veſiculæ ſeminales* by the *ſemen*, laſcivious thoughts, and other cauſes, only produce the erection of the *penis*, as they neceſſarily excite the mind to determine the blood in greater quantity into its cells *.—A ſhocking ſight, or a diſagreeable ſound, will often, in an inſtant, excite a *tremor* or ſhivering over the whole body; which cannot be owing merely to the mechanical action of light upon the eye, or of ſound upon

* Vid. Sect. vi. N° 4. above.

upon the ear; ſince, when the external organs are unaffected by theſe things, their idea, recalled by the mind, can of itſelf produce a ſimilar effect: this motion, therefore, though it be involuntary, and can neither be performed nor ſtopt at pleaſure, muſt neceſſarily be owing to the mind or ſentient principle.

IF, therefore, we have found various involuntary motions ariſing from the mind, it can be no proof againſt the vital motions flowing from the energy of the ſame principle, that they are involuntary: and if the motions of the voluntary muſcles themſelves become involuntary, as often as they are excited into action by a *ſtimulus* applied to their fibres, it can be no wonder that the motions of the heart and alimentary canal are neceſſary, and independent on the will, ſince theſe organs are perpetually expoſed to the alternate action of a *ſtimulus*.

IF it be aſked, why, when neither light nor ſound affect the muſcles of the *uvea* and internal ear, we cannot at pleaſure move them; or why we cannot at any time, by an effort of the will, produce an erection of the *penis*; it may be anſwered, that as mankind, by by having their ears tied down when young, loſe the power of moving them, though there are muſcles deſtined by nature for this purpoſe; ſo the mind, through diſuſe, may have loſt its power of moving the above mentioned muſcles at pleaſure, even when they are not acted upon by a *ſtimulus*; or why may we not, for wiſe purpoſes, be ſo framed by the AUTHOR of nature, that the mind, while it can at pleaſure contract the greateſt part of our muſcles, may have no power over others, whoſe motions are to be regulated only by certain ſenſations, ſince theſe will never fail to excite the ſentient principle into action, when it is neceſſary or proper? whereas, if they were ſubject to the will, it is probable, that men, by a perverſe effort of this, would in many caſes greatly prejudice their health, or endanger their lives. And I imagine, that the mind's want of power over the motion of the heart; is not only owing to its being continually acted upon by a *ſtimulus* *, but in part to an original conſtitution †; and that tho' we

* Sect. i. N° 12. & 13. above.

† By an original conſtitution, I here mean no more, than that we are ſo formed, that the mind, which can at pleaſure

we ſhould ſuppoſe theſe organs for a little while free from every degree of irritation, yet the mind, by an effort of the will, could not move them. Thus, although the mind remains preſent with the body, and ready to actuate it in a *ſyncope*; yet it can neither directly renew the heart's motion after it has ceaſed, nor communicate a ſtronger contraction to it when it is juſt going to fail: and there is no reaſon to think, that theſe animals which lie in a death-like ſtate during the winter-ſeaſon, have, when they begin to revive in the ſpring, any more power over the motion of their heart, than thoſe in whom its motions continue without any ſuch interruption from the beginning to the end of their lives.

WE need not, therefore, with Mr. *Lieutaud*, have recourſe to any croſſings or *entrelacements* of the nerves of the vital organs, or to their proceeding from different parts of the brain, in order to account for their not being ſubject

to

pleaſure move moſt of the muſcles of the body, has, from the beginning of life, no power to move the heart and other involuntary muſcles, unleſs when it is excited to do this by a *ſtimulus* acting upon them, or upon ſome neighbouring part with which they have a peculiar ſympathy.

to the power of the will *; eſpecially ſince we ſee that the motions of the *uvea* and muſcles of the internal ear, notwithſtanding their nerves are deſtitute of the above conditions, are equally involuntary with thoſe of the heart; that the muſcles of the arm, whoſe nerves have theſe croſſings, are yet ſubject to the will; and that, in ſhort, even the voluntary muſcles, when affected by any remarkable *ſtimulus*, ceaſe to be under the controul of the will †.

Obj. V. THE mind can only perceive diſtinctly one idea at once; and therefore muſt be incapable to attend to and govern all the vital and involuntary motions, which are ſo numerous ‡.

Anſwer. THIS objection is chiefly levelled againſt the opinion which ſuppoſes the vital motions to be regulated and carried on by the mind as a rational agent, and does not at all affect our theory: for whether the mind can diſtinctly apprehend more ideas than one at a time,

* Eſſaïs anatomiq. p. 702. & Element. Phyſiolog. p. 72.
† Sect. i. N° 12. & 13. above.
‡ *Haller*. not. in Boerhaave inſtitut. med. p. 589.

time, or no, yet furely it can and does feel various fenfations in different parts of the body at one and the fame time; and we know that it can move many of the voluntary mufcles in the fame inftant. Why, therefore, may it not, in confequence of the perception of various *ftimuli* affecting the different vital organs, move them alternately?

BUT further, when *Mahomet Caratta*, the famous equilibrift, ftood with one foot on the flack wire, toffing, with his hands, fix or feven balls up into the air, and catching them again, was he not attentive to more than one thing at once? In this cafe, the *equilibrium* of the body was to be preferved, the balls were to be taken out of his girdle, they were feverally to be thrown up into the air, to be caught as they came down, and toffed up again; and thefe motions, which followed each other with furprifing quicknefs, were continued for fome confiderable time. Any man can hear a found and perceive a particular colour at the fame time; and though ever fo attentive to thefe, he will not fail, if a fly happens to run along his face, to drive it off

with

with his hand, that he may avoid the tickling ſenſations which it excites. In like manner, how much ſoever the mind may be buſied with its own thoughts, or the ideas of external objects; yet is it ever ready to perceive and feel the various *ſtimuli* which alternately affect the vital organs, and, in conſequence of this, to continue their motions. Nor is there any need of an infinite wiſdom in the mind, as ſome have objected, to enable it to perform the ſeveral vital and other involuntary motions, with different and always varying degrees of force and quickneſs, according to the different circumſtances of the body; ſince, in doing this, the mind has no particular wiſe ends in view; nor is it influenced by any rational motives, but merely by the ſtimulating cauſes affecting the ſeveral organs; *i. e.* it acts as a SENTIENT, and not as a RATIONAL principle. In the AUTHOR of nature, however, who has framed both the ſoul and body, and thus adapted them to each other, we ought, as upon many other accounts, ſo alſo upon this, to acknowledge a wiſdom that is infinite and unſearchable!

IN

IN contemplating the various motions of animals, we obſerve a ſtriking analogy; a remarkable agreement in ſome things, and a diſagreement in others.

1. SOME of the voluntary motions, by the force of cuſtom and habit, come at length to be performed with little or no attention of mind; and, though we have full power to begin or ſtop them when we pleaſe, yet they become ſo far independent of the will, that we can only perform them in a certain way. Of this the uniform motions of the eyes are an example.

2. NEARLY a-kin to theſe are the mix'd motions, or thoſe of a middle nature between the voluntary and involuntary; ſuch as reſpiration, and the motions of the eye-lids when any thing ſlightly irritates the *cornea*. Theſe agree with the motions from habit, in being often performed without conſciouſneſs; but in this they differ, *viz.* that the former proceed from a *ſtimulus*, and become altogether involuntary when this is increaſed; while the latter owe their beginning to an effort of the will, and are always ſubject to its controul.

3. THE involuntary and mix'd motions, in general, agree in proceeding from a *ſtimulus*, and in being moſtly performed without conſciouſneſs; but differ, in the latter's being partly, and the former not at all under the power of the will. Some of each of theſe motions never ceaſe, but go on alternately through the whole of our lives; while others are only excited on certain occaſions: among the former kind are the motions of the heart, lungs, and alimentary tube; of the latter are the contraction of the pupil, eye-lids, and muſcles of the internal ear.

4. IN ſome of the involuntary motions, we are neither conſcious of the *ſtimulus*, nor of the effort of the mind in conſequence of it; as is the caſe with the motion of the heart, and the ordinary vermicular contraction of the ſtomach and guts. In others, we are ſenſible of the irritation, or diſagreeable perception exciting them, but not of any exertion of the mind's power: ſuch are the convulſive contractions of the ſtomach, diaphragm, and abdominal muſcles in vomiting, of the diaphragm in the hiccup, of the inteſtines in purging,

ging, and of the *acceleratores urinæ* in expelling the *ſemen*.

5. WITH reſpect to the mix'd motions: in thoſe of the eye-lids, ſo far as they are of this kind, we are ſenſible of the irritation, or cauſe exciting them, though rarely ſo of any effort of the will.—In that of reſpiration, neither the *ſtimulus* affecting the lungs, nor effort of the mind in conſequence of this, are uſually perceived; yet, as often as we pleaſe, we can ſuſpend or vary this motion, as freely as thoſe of the eye-lids.—In the motions of the diaphragm and abdominal muſcles, in expelling the excrement and urine, which are alſo of the mix'd kind, we are perfectly ſenſible of the *ſtimulus*, and frequently of an exertion of the mind's power in conſequence of it; yet when the irritation is very great, theſe motions become altogether convulſive and involuntary.

6. FURTHER, it appears, that as in all the works of nature, there is a beautiful gradation, and a kind of link, as it were, betwixt each ſpecies of animals, the loweſt of the immediately ſuperior claſs, differing little from the

the higheſt in the next ſucceeding order; ſo in the motions of animals ſomething ſimilar may be obſerved; the mix'd motions, as they are called, and thoſe from habit, being the link between the voluntary and involuntary.

Laſtly, FROM what has been advanced in this and the preceding ſections, with a deſign to ſhew what concern the mind has in producing the vital and other involuntary motions, it clearly follows, that the human body ought not to be regarded (as it has too long been by many Phyſiologiſts) as a mechanical machine, ſo exquiſitely formed, as, by the mere force of its conſtruction, to be able to perform, and continue, the ſeveral vital functions*; things far above the powers of mechaniſm! But as a ſyſtem, framed indeed with the greateſt art and contrivance; a ſyſtem! in which the peculiar ſtructure of each part is not more to be admired than the wiſe and beautiful arrangement of the whole; nevertheleſs, as a ſyſtem whoſe motions are all owing to the active power, and energy, of an immaterial ſenti-
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* See *Heiſter's* Differt. de præſtant. medicin. mechanic. p. 22. 25. 51. 69.

ent principle, to which it is united, and by which every fibre of it is enlivened and actuated.

IN accounting for the vital and other involuntary motions of animals, we have ſhewn, that they are all owing to a *ſtimulus*; and have pointed out the particular *ſtimuli* applied to the ſeveral organs, and exciting them into action; we have further ſhewn, that theſe *ſtimuli* can only produce their effects by the influence they have upon the mind or ſentient principle. But what way the mind puts the muſcles into motion; what is the material cauſe in the brain, nerves, and muſcular fibres, which it employs as its inſtrument for this purpoſe; what the intimate ſtructure of a muſcular fibre, or the preciſe manner in which the nervous influence acts upon it, when it produces its contraction: theſe are queſtions we have wholly avoided, being perſuaded that whatever has been hitherto ſaid on theſe ſubjects, is mere ſpeculation; and that to offer any new conjectures on matters ſo greatly involved in darkneſs, and where we have neither *data* nor *phænomena* to ſup-

port

port us, is to load a ſcience already labouring under *hypotheſes* with a new burden.

To complete our account of the ſpontaneous motions, it now only remains, that we inquire into the reaſons why the vital motions continue in time of ſleep, and why muſcles, or a few of their fibres, are often obſerved to move for ſome time after death or their ſeparation from the body.

SECT. XII.

Of the reaſon why the vital motions continue in ſleep.

THE reaſon why the vital organs are continually agitated with alternate contractions, while the other muſcles of involuntary motion are contracted on certain occaſions only, may fully appear from what has been already offered; for we have ſeen that the former are expoſed to the action of a *ſtimulus* always, the latter only at particular times. But ſince, during ſleep, the organs of ſenſe are, as it were, lock'd up, and the voluntary muſcles become more relaxed and unfit

unfit for action, on account of the brain's difpenfing its influence more fparingly than ordinary, it may be afked, why the vital motions don't at this time either ceafe, or at leaft fail confiderably?

To fay here, that the vital motions muft therefore go on without diminution or difturbance, becaufe their organs are equally acted upon by their proper *ftimuli*, both when we are awake and fleeping, would be an incompetent anfwer to this queftion; for though the ftimulating caufe be granted to continue the fame, yet if the organ's aptitude for motion be leffened, the effect muft be the fame, as though the *ftimulus* were weakened or entirely wanting. The difficulty, therefore, which we are to endeavour to remove, is, why the vital organs fhould not, like the organs of fenfe and mufcles of voluntary motion, be fo far affected by fleep, as to become lefs fit or able to perform their ufual functions?

SLEEP feems to be owing to fome change produced in that part of the body which Anatomifts, diftinguifhing it from the *cerebellum*, call the BRAIN.—The proof of this is plainly

plainly ſeen, in the inſtances of people who, having loſt part of their ſkull, were immediately ſeized with ſleep, whenever their brain was gently preſſed ; and, from the experiments which ſhew, that, inſtead of ſleep, death itſelf, or at leaſt a *ſyncope*, is the effect of a like compreſſion upon the *cerebellum*. If, therefore, it can be made appear, that the vital organs have their nerves chiefly from the *cerebellum*, and not from the brain, it will be evident alſo, that the reaſon why their motions continue unimpaired in time of ſleep, muſt be this peculiar circumſtance attending the *cerebellum*, that its nerves are not, like thoſe proceeding from the brain, affected by ſleep, but are at all times fitted for actuating the parts to which they are diſtributed.

Now there are many experiments of *Vieuſſens* *, *Ridley* †, and others, ſhewing, that reſpiration and the motion of the heart are quickly ſtopt upon wounding the *cerebellum*, but that wounds in the brain produce little or no change in theſe motions. On the other hand, ſeveral authors of great reputation and unqueſtioned

* Neurograph. lib. I. cap. 20.

† Anatomy of the brain, chap. 17.

unqueſtioned veracity aſſure us, that, in their experiments, the vital motions continued for ſome conſiderable time after the *cerebellum* had been cut in pieces. However, it does not, by any means, appear from other experiments of theſe very authors, that the wounding or cutting in pieces of the brain, affected the vital motions more, or even ſo much, as the ſame treatment of the *cerebellum*. Are we then to conclude, from theſe experiments, that neither the brain nor *cerebellum* are neceſſary to the motions of the vital organs? By the like kind of reaſoning, it would ſeem, that the nerves alſo, and the influences they may have, are unneceſſary in the producing of theſe motions, ſince that of the heart has been known to remain a conſiderable time after the intercoſtals and eight pair of nerves have been cut *. Do theſe experi-

T t ments,

* I ſhall here take occaſion to obſerve, what indeed would have come in more properly under Sect. i. p. 6. that there are related by *Molinelli*, in the *Comment. acad. Bonon. vol.* 2. *part* 2. the hiſtories of two patients, who, though they had, in the operation for the aneuriſm in the arm, the nerve tied along with the artery, yet recovered, after about three months, the entire uſe of that member; whence ſome have not ſcrupled to conclude, that

ments, therefore, which prove too much, prove nothing at all? Far otherwife. The true inference is this; That, fince various experiments concur in fhewing the *cerebellum* to be more concerned in the vital motions than the *cerebrum*, while none at all can be adduced in proof of the *cerebrum* being more immediately

that the nerves are not neceffary to motion or fenfation. But in this they have rather been too hafty; for *Galen* informs us, that as often as a nerve has been quite cut through, the mufcles to which it belonged were deprived both of fenfe and motion †: and many later examples might be produced, where the fame confequence attended the deftroying of a nerve. I fhall only mention one, which is confiftent with my own knowledge. *J. F.* who had the nerve tied along with the artery in the operation for the aneurifm eighteen years ago, continues, to this day, to have a numbnefs and feeblenefs of the mufcles of the thumb and forefinger, which are alfo a good deal fhrivel'd.—But further, it appears, even from the hiftories now mentioned, that the immediate confequence of a ligature made upon the nerves was a total lofs of motion and fenfation in the parts below; and this happened notwithftanding that the blood continued, by two pretty large arterial branches, to be diftributed to them: which is fuch a direct proof of the neceffity of the nerves to motion and fenfe, as is not to be overturned by the parts recovering afterwards their power of motion, fince this might happen without any inconfiftency to the former conclufion, and in a way unknown to us.——In the hiftory found by *Morgagni* among *Valfalva*'s papers, and related in the fame volume of the *Comment. Bonon.* we are told, the patient did not recover the full ufe of his arm till

† De motu mufculorum, lib. 1. cap. 1.

immediately neceffary to thefe than the *cerebellum* *, it follows, that the vital organs have their nerves, either wholly or principally, from the latter.

BUT though the *cerebellum* be the chief fource of the vital nerves, yet its deftruction does

till eight or nine months after the operation for the aneurifm was performed. When *Molinelli* diffected this arm, thirty years after, he found the nerve not wanting in the place where the ligature had been made, as were the artery and vein, but of a much greater thicknefs than ufual, and not unlike a *ganglion*. From this obfervation, I think, we have reafon to believe, that, in *Molinelli*'s two patients above mentioned, the nerve was not deftroyed by the ligature, but perhaps acquired a greater thicknefs in that part, and fo became, after fome months, fit to perform its functions.

Upon the whole, the hiftories of the operation for the aneurifm related in the Bononian tranfactions, though they may perhaps confound a fuperficial inquirer, will never incline an accurate and impartial one to reject the doctrine of the nerves being neceffary to motion and fenfation.

* In the accurate Dr. *Kaau*'s experiments, the vital motions continued in a dog, above eight hours after the medullary part of the brain was broken down into a pulp; but when the medullary fubftance of the *cerebellum* was treated in the fame way, though they did not ceafe inftantly yet they began to fail in a few minutes †. When the *cerebellum* was wounded, without touching the *cerebrum*, the heart's motion failed fooner than when the brain alone was wounded ‡.

† Impet. faciens. N. 325.

‡ Ibid. N. 326.

does not put an immediate ſtop to the vital motions, for the ſame reaſon that cutting off the head, or tying the intercoſtal and eight pair of nerves, does not produce this effect; *i. e.* becauſe the branches from the ſpinal marrow which join the intercoſtals, together with the ſpirits (if I may be allowed to call the influence of the brain by that name) remaining in the trunks of the nerves and fibres of the heart, are ſufficient to keep up theſe motions for ſome time: in man, perhaps, only for a few pulſations, in young dogs or cats for ſeveral hours, and in a tortoiſe for ſix months; which laſt animal, not to mention other differences, has its ſpinal marrow remarkably large: nay, the motion of the hearts of many animals, after they are taken out of their bodies, affords us ocular demonſtration of the nervous influence, lodged in the fibres of the heart and in the ſmaller filaments of the nerves, being ſufficient to continue the motions of this muſcle for ſome time, or to enable it to perform a great number of contractions.

THE inſtances given us of animals, whoſe *cerebella*, upon opening them, were found ſcirrhous,

ſcirrhous, corrupted, or otherwiſe diſeaſed, avail no more, towards proving that the vital organs don't derive their nerves chiefly from this part, than do the hiſtories of oſſified and petrified brains, or of monſters born with no brain at all, towards making it a clear point that the brain and nerves are, in fact, not the ſource of ſenſe and motion *.

BUT further; did not the vital organs receive their nerves chiefly from the *cerebellum*, and thoſe of ſenſe, and voluntary motion, theirs from the *cerebrum*; why ſhould the latter, in time of ſleep, be affected with a languor and relaxation, while the former continue to act with undiminiſhed vigour? Why, in a deep apoplexy, when the muſcles of voluntary motion are ſcarcely excited into action by the ſtrongeſt *ſtimulus*, and when the organs of ſenſe are loſt to their proper objects, does the heart move with its wonted force? Why in ſuch a caſe ſhould the *ſphincter* of the pupil, and muſcles of deglutition, refuſe to obey their uſual *ſtimuli*, and the heart be almoſt as ſenſible as ever of the irritation of the returning blood? If the heart derived its nerves equally

* See Sect. 1. N° 1. above.

ly from the brain and *cerebellum*, why, in apoplexies, when feveral other mufcles of the body are convulfed, is it not itfelf affected with ftrong palpitations? And why in animals newly dead is not the heart's motion renewed by irritating the brain, as well as by irritating the *cerebellum* or *medulla oblongata?*

THE longer people have wanted fleep, or the greater fatigue they have endured, a recruit of fpirits becomes the more neceffary for the free ufe and exercife of the organs of fenfe and inftruments of voluntary motion: and whence is the cafe different with regard to the vital organs, unlefs it be that their nerves differ, either as to their origin or nature, from the animal ones? Why the *cerebellum* fhould not be affected in time of fleep, as well as the *cerebrum*, and why, without any intervals of reft, it fhould at all times furnifh fpirits fufficient for the purpofes of vital motion, I will not pretend pofitively to determine; only I think it pretty evident that the medullary fubftance of the *cerebellum* is by far lefs liable to various degrees of compreffion, than that of the *cerebrum*, as well on account of

its

its firmer texture and want of cavities, as of the different diſtribution of its arteries.

DRINKING largely of ſtrong ſpirituous liquors cauſes not only ſleep, but a *ſtupor* alſo, and ſometimes a real apoplexy; now, if theſe be in a good meaſure the effects of a rarefaction of the blood, and conſequent diſtenſion of the veſſels in the brain, as is probable from diſſections, it follows, ſince the vital motions continue after all the animal functions are ſuſpended, that the *cerebellum* is not ſo ſoon affected as the brain, either becauſe of its firmer ſubſtance, or of its differing in ſome other circumſtances from the brain. But, as a deficiency of ſpirits is allowed to be one general cauſe of ſleep, as well as a compreſſion of the medullary ſubſtance of the brain, it may ſtill be aſked, why the vital ſpirits ſhould never, like the animal, be ſo much exhauſted as to require intervals of reſt for their recruit. In anſwer to this, we can only ſay that, it may be, there is not ſo great an expence of nervous power in carrying on the vital motions, which are very gentle and equable, as is required for the exerciſe of the ſenſes and the motions of the voluntary muſcles, whoſe contractions, though

though not ſo frequent, are yet much more violent; or elſe there may be a quicker ſecretion or ſupply of it by the *cerebellum* than by the *cerebrum*. If both or either of theſe ſuppoſitions be true, the vital organs which, whether we be awake or ſleeping, are equally acted upon by their uſual *ſtimuli*, muſt neceſſarily continue their motions uninterrupted and undiminiſhed as long as we live; or at leaſt ſo long as the *cerebellum* and its nerves, together with the organs themſelves, remain ſound, and the cauſes ſtimulating them into action are the ſame.

THAT muſcles, which have their nerves from the brain, may, even in time of ſleep, be excited into action by a *ſtimulus*, is moſt certain: I ſhould, therefore, have no doubt, that the vital organs might be kept continually in motion, by the efficacy of the *ſtimuli* acting upon them, even though there were no difference between their nerves and thoſe ſerving the other muſcles of the body, provided their action were obſerved to be ſenſibly weaker in time of ſleep, and to become more remarkably languid in proportion as this was deeper: but, as no ſuch thing has hitherto

been

been diſcovered, I cannot but be of opinion, there is ſome difference between the vital and animal nerves, as to their nature and origin, to which, as well as to the conſtantly repeated action of their *ſtimuli*, it is owing that the vital motions continue undiminiſhed in time of ſleep.

IF it be ſaid, that the vital organs are ſo extremely ſenſible of the *ſtimuli* applied to them, or ſo peculiarly adapted to motion, as that their action muſt be continued in time of ſleep, while other parts, equally furniſhed with nerves, are then, upon account of their leſs ſenſibility and fitneſs for action, more languid and ſluggiſh; I would deſire to be informed, what part of the body is endued with a more exquiſite ſenſe than the *retina*, or what muſcle in it can be found capable of more various degrees of motion than the *ſphincter* of the pupil? and yet we well know, that, in an apoplexy, the former loſes its ſenſibility, and the latter all its power of contraction; at the ſame time that the action of the heart is in no degree weakened. But, be the vital organs ever ſo ſenſible, or well fitted for motion, they muſt neceſſarily act with leſs vigour during

U u ſleep,

ſleep, or in a fit of the apoplexy, if it be true, that in theſe circumſtances the nervous influence is more ſparingly tranſmitted to them, than when we are awake and in health.

THE induſtrious *Haller* is of opinion, that there is no difference, as to their origin or nature, between the vital and animal nerves; ſince the intercoſtals, the nerves from the ſpine which unite with theſe, and the eight pair of nerves, give off branches to ſome of the organs of ſenſe and voluntary motion, as well as to thoſe parts whoſe motions are vital and involuntary; and ſince, he is unable to conceive how, in the ſame nerve, the vital part can remain undiſturbed and without action, while the animal part is violently agitated, and *vice verſa**. But this reaſoning proceeds upon a double miſtake, as it ſuppoſes, 1*ſt*, That the organs and muſcles of voluntary motion have no need of vital nerves; and, 2*dly*, That if two kinds of nerves be diſtributed to any part, they muſt always act both together.

1. As to what concerns the firſt of theſe ſuppoſitions, we have formerly obſerved that as

* Not. in Inſtitut. Med. *Boerhaave*, vol. 4. p. 585.

as the heart is excited into alternate contractions by the *ftimulus* of the returning blood, fo the larger arteries owe their *fyftole* in part to the fame caufe, while the fmaller veffels, in which no alternate *fyftole* and *diaftole*, arifing from the force of the heart, regularly takes place, are ftimulated into alternate ofcillatory contractions, by the gentle irritation of the fluids as they glide along their fides *. Since therefore all the veffels of animals, fmaller as well as larger, are, like the heart and alimentary tube, continually agitated with a vital motion; it is highly probable, that not any even of the organs of voluntary motion are wholly deftitute of nerves derived from the *cerebellum*. So that the objection brought againft Dr. *Willis* and his followers, who allow the third, fourth, fifth, and feventh pair of nerves to receive fome fibres from the *cerebellum*, *viz.* that, in this, they muft be miftaken becaufe thefe nerves affift not in the performance of any vital motion, is extremely ill founded; for, as we have juft now faid, there is no mufcle in the body whofe veffels are not agitated with a vital fpontaneous motion;

* Sect. vi. N° 1. & 2. above.

tion: and the opinion that all the nerves have fibrils both from the brain and *cerebellum*, which was firft embraced by *Ridley*, and afterwards gone into by *Boerhaave*, is far from being improbable *. However, it may be fuppofed, that while the mufcles of voluntary motion have the largeft fhare of their nerves from the brain, or from the fpinal marrow confidered as arifing from thence, and only a few fibrils ferving for the ofcillations of their veffels from the *cerebellum*; the organs of vital motion, on the other hand, are fupplied more plentifully, if not wholly, with nerves from the *cerebellum*, as well for the ofcillatory contractions of their veffels, as for their motions as mufcular organs.

BUT further, fince no body can pretend to affirm, that the intercoftals and eight pair of nerves proceed wholly from the *cerebellum*, without having any fibres at all from the *cerebrum*, it were an eafy anfwer to *Haller*'s objection to fay, that the branches which thefe nerves

* The olfactory nerves indeed feem wholly to be derived from the brain; but the membrane of the nofe is furnifhed with a branch from the fixth pair of nerves, to which the vibratory motions of its veffels are owing.

nerves give to the organs of ſenſe or voluntary motion, are ſuch only as they receive from the brain.—If it be ſaid, that the fifth pair of nerves, which is diſtributed to the organs of ſenſe and voluntary motion, is chiefly or wholly derived from the *cerebellum*; it may be anſwered, that to diſcover from diſſection, with any tolerable degree of certainty, how far this is fact or otherwiſe, is an extremely difficult matter: but as this nerve ſeems to aſſiſt in the formation of the intercoſtal, and may give branches to the noſe and other parts, upon which it is beſtowed, for the vital oſcillations of their veſſels, we may very well allow it to be derived in a great meaſure from the *cerebellum*.

WHERESOEVER in the preſent argument I have ſpoken of nerves being derived from the brain or *cerebellum*, I deſire to be underſtood as including the ſpinal marrow, ſo far as it can be reckoned a continuation of the medullary ſubſtance of theſe parts, or to agree with them in its ſtructure and uſe; for the ſpinal marrow does not ſeem altogether derived from the brain and *cerebellum*, but probably prepares a fluid itſelf; whence it is enabled

bled to keep up the vital and other motions for ſeveral months, in a tortoiſe, after the head is cut off.

2. ALTHOUGH two ſorts of nerves were diſtributed to the ſame organ, it would by no means follow, that the one could not act without the other: for if the mind can determine the ſpirits through a few fibrils of a nerve, without diſturbing others which are contiguous to it; and if the impreſſions of external objects are tranſmitted to the brain by the nerves deſtined for feeling, without affecting any of the fibrils which are included in the ſame coats with them; why may not the gentle irritation of the fluids, contained in the veſſels of a muſcle, excite their circular fibres into alternate contractions, by means of the nerves derived from the *cerebellum*, without affecting the nerves from the brain, in ſuch manner, as to make the muſcle itſelf contract? Although the nerves from the *cerebrum* and *cerebellum* be contained in the ſame common ſheath, yet they are quite diſtinct; ſo that there can be no reaſon for ima-

imagining the one may not be acted upon without bringing the other into consent.

BUT as the real and intimate structure, and the distinct uses of the brain and *cerebellum*, as well as the particular distribution of their medullary fibres, are things which we are much in the dark about, it is no wonder, if we frequently lose and bewilder ourselves and readers, when we attempt to push our inquiries deeply into these matters. Far, therefore, from expecting, that what has been advanced in this Section concerning the difference between the vital and animal nerves, should give every one full satisfaction, or be thought quite clear of all difficulties; I have only offered, in a few words, what seems most probable to myself, being ready to give up my opinion, as soon as further experiments or observations shall lead us to a better and more consistent account of this matter. *Sequimur probabiliora; nec ultra quam id quod verisimile occurrit progredi possumus, et refellere sine pertinacia, et refelli sine iracundia, parati sumus**.

* CICERON, disput. Tusculan. lib. 2.

SECT.

SECT. XIII.

Concerning the motions observed in the muscles of animals after death, or their separation from the body.

SINCE the hearts of many animals continue their alternate contractions for some time after they are taken out of their bodies; and as this is a circumstance which possibly may be mistaken for an unanswerable objection to the account we have given of the vital motions, * we shall here inquire particularly into the nature and cause of those motions which are so frequently seen in the muscles of animals after death, or their separation from the body; and

* "Sed manifesto falsum est motus omnes ab anima "oriri, et absque ea materiem fore immobilem segnem- "que massam. Nam vis contractilis ad stimulum quem- "cunque, ad quam motus cordis, intestinorum, et forte "omnis motus in homine pertinet, ne requirit quidem ani- "mæ præsentiam, superest in cadavere, suscitatur me- "chanicis causis, calore, flatu; neque deserit fibram, quam- "diu nondum refrigerata riguit, etsi dudum animam abe- "gerit destructio cerebri cordisque, etsi, ex ipso corpore "revulsus musculus, ab omni imaginabili animæ sede se- "paratus sit." *Haller*. Prim. lin. Physiolog. N° 562.

and we flatter ourſelves much, or it will hence appear, that inſtead of being inconſiſtent with our theory, they ſerve rather to illuſtrate and confirm it.

SEVERAL authors (ſome of them indeed of conſiderable name) have aſcribed the motions of the heart after death, or its ſeparation from the body, to ſome peculiar property, not found in the other muſcles, wherewith they ſuppoſe this to be endued *: but with what reaſon, will appear from the following experiments and obſervations.

1. AN eel, which I diſſected, moved the muſcles of its body with great force, for more than half an hour after the removal of its heart and the other *viſcera*; and though I had not leiſure to obſerve them, I doubt not but it continued theſe motions a much longer time; for Dr. *Harvey* has long ago informed us, that not only the heart, but alſo the fleſh of eels continues to move after being cut in pieces.

2. I have often obſerved a frog turning from its back to its belly, and leaping about

* *Van Swieten* comment. in aphor. *Boerhaave*, vol. 1. p. 1. & 2.
I. H. G. comment. in *Boerh.* Inſtit. med. vol. 5. p. 101. 104.

for an hour after the heart and other *viſcera* were cut out; and when its muſcles were at reſt, they have been brought into convulſive contractions, by pricking them with a pin or a ſcalpel: nay, a frog's limbs ſeldom fail to move for ſome time after they are ſeparated from its body.

3. A tremulous motion has been obſerved in the muſcles upon the *ſternum* for a quarter of an hour after it was cut out of the body; and, when it had ceaſed, it was renewed by pricking the fibres of theſe muſcles with the point of a knife *. The like tremulous motions have continued for an hour in the muſcle of an ox ſeparated from its body immediately after it had been killed, and, upon their ceaſing, have been recalled, by pricking its fibres with a ſharp inſtrument †.

4. In a young pigeon, which I killed, by ſeparating its head from the *vertebræ* of the neck, the divided muſcles of the left ſide of the *thorax* (upon which ſome of the blood thrown

* *Swencke* Hæmatolog. p. 28.
† Ibid.

thrown out of the heart had been ſpilt) were agitated with alternate contractions for about ten minutes. Theſe contractions were very quickly repeated at firſt, but, like thoſe of the heart, became much ſlower before they ſtopt altogether.

WERE not the alternate contractions of theſe muſcles more remarkable, and of longer continuance, on account of the *ſtimulus* of the blood which was ſpilt on them? This ſeems not at all improbable, ſince, as has been obſerved above *, the motions of the *vena cava* ſeem to continue longer than thoſe of the heart, becauſe it is longer ſupplied with blood. Beſides, the alternate contractions which happened to the muſcles of the *thorax* in other pigeons which I opened, and where no blood was ſpilt, were much leſs remarkable, and laſted but a very ſhort time.

5. *Swammerdam* tells us, that, in diſſecting animals alive, he obſerved contractions, not only in every muſcle ſeparated from the body, but alſo in every muſcular fibre †. And the ſame

* Sect. vi. N° 3.

† Tractat. de reſpirat. cap. 7. p. 67.

ſame kind of motion has been remarked in the muſcular fibres of men, which had been cut away in the extirpation of tumors.

6. THE vermicular motion of the inteſtines remains for a conſiderable time after both them and the ſtomach are taken out of the body.

α HENCE it appears, that all the muſcles of living animals, whether they be of the voluntary or involuntary kind, are agitated with alternate contractions, after being diſſected from their bodies; and, conſequently, that the vibrations performed by the hearts of animals, when divided from their bodies, beſpeak not any latent power reſiding particularly in the fibres of this organ, or which they do not ſhare in common with thoſe of every other muſcle.

β IF the voluntary muſcles, which in a healthful ſtate remain at reſt when the will interpoſes not to the contrary, are alternately contracted and relaxed, as well as the heart, when they are ſeparated from the body; it cannot be concluded, that, becauſe the heart beats after ſuch ſeparation, it muſt therefore move

move alfo while in the body: on the contrary, it follows, that the alternate motions of the heart in living animals muft be owing to its being acted upon by fome particular caufe, which does not affect the voluntary mufcles.

7. THE heart of an eel, which I cut out of its body, and divided into two, continued its vibrations above twenty minutes.

8. WHEN the heart of an eel inclofed in an exhaufted receiver, after beating about an hour, had become very languid, and almoft ceafed from motion, Mr. *Boyle* renewed its pulfations, by breathing on that part of the glafs where it lay *.

9. I have obferved the hearts of frogs beat 12, 15, 18, or 30 minutes, after being feparated from their bodies; and when their motions begin to languifh, or are juft about to ceafe, they may be increafed or renewed, by heat or pricking them with a pin.

10. THE

* Philofophic. Tranfact. abridg'd, vol. 2. p. 222.

10. THE hearts of frogs, which, when firſt ſeparated from their bodies, beat from 64 to 68 times in a minute, performed from betwixt 90 to 100 pulſations in the ſame time, when expoſed a little to the heat of the fire; but, after being removed from it, their vibrations became gradually ſlower and ſlower, till they were no quicker than at firſt. While warmth thus increaſes and renews the motion of the heart, even in thoſe animals whoſe blood is cold, too great heat deſtroys it both in hot and cold animals, by producing ſuch a change in the muſcular fibres, and their fluids, as renders them unfit for motion. Hence the heart of a pigeon or frog immediately loſes its motion when immerſed in boiling water.

11. THE hearts of vipers continue their alternate motions for ſeveral hours after they are ſevered from their bodies *.

12. A viper's heart, which beat only 25 times in a minute, when Dr. *Langriſh* firſt took it from its body, was, by the warmth of

* *Boyle's* Uſefulneſs of Experimental Philoſophy, part 2. p. 16.

of his hand, ſoon made to perform 48 vibrations in that time; and, being afterwards put in water a degree or two warmer than human blood, it repeated its pulſations 87 times in a minute *.

13. UPON ſtretching a cock's neck ſo as to ſeparate the head from the *vertebræ* of the neck, ſeveral violent convulſions enſued, and in leſs than five minutes he ſeemed to be quite dead. At this time laying the *thorax* open, I obſerved the heart performing its alternate motions, but much more faintly than that of a frog or eel when ſeparated from the body. Three minutes after, when the heart's motion was become yet weaker, I cut it out of the body, and found its veſſels and cavities had been filled with blood; which was no ſooner evacuated, than the tremulous motions of this organ ceaſed; nor could they be recalled by breathing upon it, or pricking it in ſeveral places with a pin; but, by touching it two or three times with a red-hot iron, a vibrating contraction was obſerved, which ſcarcely laſted for a ſecond.

14. THE

* Cronean Lectures, N° 150.

14. THE heart of a chick taken out of the ſhell, beat an hour after its head and breaſt-bone were clipp'd away with a pair of ſciſſars, and the auricle retained its motion ſome time after the heart. The motion of the other parts ſeemed only to ſurvive the loſs of the head for a few moments: the heart's motion, when about to ceaſe, was frequently renewed by pricking it with a pin. In another chick the heart was kept beating, by the influence of warmth, above two hours after its head was cut off *.

15. I laid open the *thorax* of a young pigeon, four minutes after ſeparating its head from the *vertebræ* of the neck, and found the heart, with its right auricle, which was greatly diſtended with blood, without any motion. I let a few drops of warm *ſaliva* fall from my mouth on the heart; upon which its right auricle began to move, and continued repeating its alternate contractions with remarkable vigour and quickneſs for three minutes, when they became gradually both weaker and ſlower.

* *Boyle*'s Uſefulneſs of Experimental Philoſophy, part 2. p. 15. & 16.

flower. At eleven minutes from the beginning of the experiment, the motions of the auricle were ftill flower, but were quickened fomewhat by pricking it with a pin. After eighteen minutes, the contractions of the auricle were much more feeble, and not repeated till after the interval of 7, 8 or 9 beats of my pulfe; whereas, at firft, they fucceeded each other much more quickly than the vibrations of my heart. Before the twentieth minute was expired, the motions of the auricle ceafed entirely; but were fo far renewed afterwards, by filling the *thorax* with water of the fame warmth with the human blood, as to laft about two minutes. During all this time, no motion was obferved in the body of the heart; nor were its fibres excited into contraction by pricking them with a pin feven minutes after the *thorax* was opened.

16. I opened the *thorax* of another pigeon three minutes after I had pulled off its head and made a ligature about its neck: the right auricle, with part of the *vena cava inferior* adjoining to it, ftill continued to beat, but the body of the heart was at reft; fometime

after, when the motions of this auricle were about to ceafe, they were renewed with their former vigour by drawing afunder the fides of the divided *thorax*, and confequently ftretching the great veffels leading to the heart. When the auricle's motions were become very languid and flow, the *vena cava inferior* made feveral contractions before the auricle contracted once; and it continued to palpitate for fome time after the auricle had ceafed altogether.

17. IMMEDIATELY after feparating from the *vertebræ* of the neck the head of a pigeon fomewhat younger than either of the two former, I laid open the *thorax*, and found the heart beating pretty ftrongly, and at every *fyftole* throwing out the blood with a confiderable force by a wound which I had accidentally made in it. When, after a few contractions, its motion had become much more feeble and irregular, it was made to recover its vigour and propel the blood through the wound as before, by drawing the fides of the divided *thorax* a little afunder. Sometime after this, when the heart was become much more

more languid, its contractions were renewed with double force as often as I raiſed the point of it with my finger. About ſix or ſeven minutes after opening the *thorax*, the motions of the heart could be perceived only in its right auricle and *apex*, but were by far moſt remarkable in the former. In three minutes more, when no motion could be ſeen in the body of the heart, this auricle ſtill continued to vibrate, and its motions were very ſenſibly quickened by raiſing the point of the heart, and of conſequence ſtretching the great veſſels adjoining to its baſe. At this time a few weak palpitations were excited in the heart by dividing it with a ſharp knife.

18. SOME young Gentleman having hanged a cat till ſhe was quite dead, opened the *thorax*, and obſerved only a tremulous motion in the heart which ſoon ceaſed, but was renewed by pricking it with a ſharp inſtrument; after this, by ſqueezing the cardiac nerves downwards, or otherwiſe irritating them, the heart was made to perform two or three pulſations; which it continued to do for a conſiderable time,

time, whenever the cardiac nerves were thus ſtimulated.

19. THE heart of a cat, which had been dead for four hours, was excited into alternate contractions by blowing warm air into its cavities through a tube fixed in the *receptaculum chyli* *.

20. THE motion of the heart was renewed in the ſame manner, by *Brunnerus*, in a dog which had been a good while dead †.

21. EVEN in man, the heart retains a power of motion for ſome little time after its ſeparation from the body; as appears particularly from the well known ſtory of Lord *Verulam* concerning a malefactor, whoſe heart, having been cut out of his body, and thrown immediately into fire, leapt ſeveral times upwards to a conſiderable height ‡.

22. IT is obſervable, that after the convulſions, which animals ſuffer at the time of death,

* *Wepfer.* hiſtor. cicul. æquat. p. 89.
† Experiment. circa Pancreas, p. 21.
‡ Hiſtory of life and death, ſect. ix. N° 31.

death, have ceafed, their mufcles remain at reft, unlefs they are ftretched, cut, expofed to the air, or otherwife ftimulated.

FROM the above experiments it follows,

α THAT the feparated hearts of fome animals, vibrate more ftrongly, and for a much longer time, than thofe of others. N° 9. 11. 13.

β THAT animals of the amphibious kind, which have either no lungs or very imperfect ones, which bear the air-pump long, and whofe blood is cold, as well as languid in its motion, fhew figns of life, not only in their hearts, but alfo in their other members, for a much longer time after they are feparated from their bodies, than animals which have more perfect lungs, hotter blood, and a quicker pulfe. N° 1. 2. 4. 14.

THOSE animals whofe parts preferve motion and appearances of life longeft after being feparated from their bodies, feem to have both their fluids and folids a good deal different from thofe of other animals: their blood is not only colder but perhaps more vifcid and lefs diffipable; and their fibres are fo conftituted, that

that neither conſtant ſupplies of this fluid from the heart, nor of the influence of the nerves from the brain, are neceſſary to keep them in due order for motion : thus frogs, eels, vipers and tortoiſes live and move ſeveral hours after their heart is cut out, and the various parts of their bodies continue to move for a great while after all communication between them and the brain is cut off.

γ THAT, *cæteris paribus*, the heart preſerves its motions longer in young animals, after its communication with the brain is intercepted, than in older ones, N° 13. 15. 16, compared with 14. 17.

δ THAT, *cæteris paribus*, the hearts of thoſe animals which continue to beat longeſt, after being ſeparated from their bodies, perform their vibrations at the greateſt intervals, N° 9. 10. compared with 11. 12. The reaſon of this is eaſily underſtood; ſince, as has been juſt now obſerved, in thoſe animals, whoſe hearts beat longeſt after ſeparation from their bodies, the blood is coldeſt and its circulation moſt languid.

ε THAT the motions of the heart, after death or ſeparation from the body, are generally ly more confpicuous, and laft longer, than thofe of the other mufcles. N° 14.

ζ THAT the right auricle continues to move, after the heart appears quite dead. N° 14.——17.

η THAT the *vena cava* and *finus venofus dexter* preferve their motions ftill longer than the right auricle. N° 16.

θ THAT the motions of the heart and other mufcles, when feparated from the body, are not only at all times increafed, but even renewed, when they are juft at an end, by heat, wounds, ftretching their fibres, or any thing elfe that fhall gently irritate them. N° 2. 3. 4. 8. 9. 10. 12.—17.

ι THAT, after the heart has entirely, and for a confiderable time, ceafed to move in dead animals, it may be excited into action by ftretching or ftimulating its fibres or nerves. N. 18. 19. 20.

κ THAT as in living animals the voluntary mufcles are not convulfed, except when a *ftimulus* is applied to them; fo in animals newly dead, no convulfive contractions happen, provided the fkin be not fo cut as to lay them bare,

bare, and expoſe their fibres to ſome kind of irritation. N° 22.

λ WHENCE it follows, that the vibrating contractions of the muſcles of animals after death, or their ſeparation from the body, cannot be owing to any innate power, whereby, independent of all external cauſes, they move themſelves alternately, but muſt be aſcribed to the action of a *ſtimulus* of one kind or other upon their fibres.

WHEN the heart is taken out of the body in animals newly dead, the cutting alone muſt be a very remarkable *ſtimulus*, and therefore, muſt not only excite or increaſe its motions, but alſo make them continue for a conſiderable time. When the *thorax* and *pericardium* are only laid open, the vibrations of the heart will be increaſed and continued by diſſecting and ſtretching theſe parts with which it is nearly connected, (N° 16. 17.) and even by the external air acting as a *ſtimulus* upon its ſenſible membranes; for the particles of this fluid are never at reſt, but agitated with inceſſant vibrations. This undulatory motion of the air is ſo remarkable, as to be obſerved by the aſſiſtance of good teleſcopes, and is clearly enough ſeen

ſeen in the conſtant whirl of duſty atoms, and other light ſubſtances, perceived in the ſtilleſt room, where-ever the ſun beams play.

THE motions of the heart, therefore, in animals newly dead, or after it is ſeparated from the body, are owing to the *ſtimulus* of the blood remaining in its cavities, to the contact of the external air, or to the irritation which is communicated to it, by ſtretching or cutting its own fibres, or thoſe of ſuch parts as happen to be immediately connected with it.

IN a *ſyncope*, and in animals newly dead, the inteſtines continue their periſtaltic motion after the heart has ceaſed to vibrate, which cannot be aſcribed to their being more fitted for motion, ſince the heart, when ſeparated from the body or otherwiſe irritated, moves more remarkably than they; but is ſolely owing to their being acted upon by their uſual *ſtimuli*, even after the heart is deprived of that regular and alternate ſupply of venous blood which was wont to keep up its motion: as therefore the bile, air, and aliment, remain in the guts equally after death as before it, they will continue to excite the fibres of the various portions of this canal into alternate contractions, till at length they become quite dead and rigid with cold.

MR. *Boyle* tells us that an eel's, heart being placed in a ſmall receiver, became very turgid when he exhauſted the air, and beat as manifeſtly, and more ſwiftly than it had done before*; the reaſon of which *phænomenon* is abundantly evident from what has been ſaid; ſince the diſtraction of the fibres of the heart thus ſwelled, muſt have had the ſame effect in quickening its vibrations, as any other *ſtimulus*.

DR. *Harvey* obſerved, that in time of incubation, the chick's heart, whoſe motion languiſhed, and at length ceaſed in the cold air, quickly recovered its vigour by heat, and contracted with greater force and frequency as often as it was touched with the point of a needle or any thing elſe that could irritate it †; from which it follows that the ſame cauſes excite the motion of the heart in living animals and thoſe newly dead, in the body and out of it.

THE concluſion to be drawn from what has been ſaid is, that there remains in the muſcles of

* Philoſoph. Tranſact. abridged, vol. 2. p. 222.

† De generat. animal. exercitat. xvii.

of animals and their nerves, for ſome time after death or their ſeparation from the body, the immediate cauſe of motion, which may be excited into action, as in living animals, by any *ſtimulus* or irritation. How or by what means this happens, ſhall be the ſubject of our next inquiry.

SOME have aſcribed the motions of the heart out of the body, and conſequently of other muſcles ſeparated from it, to the ſpirits remaining in their nerves, which, by the capillary attraction of theſe tubes, or the cold conſtringing them, continue for ſome time to be derived into the muſcular fibres. But from ſuch an equable derivation of the ſpirits, it will be difficult to account for the regular alternate contractions and relaxations of theſe muſcles, or for their being excited and renewed by *ſtimuli* of very different kinds.

OTHERS have been inclined to deduce the vibrations of the heart, when out of the body, from the elaſtic power of its fibres *, or of

* *Hoffman.* ſyſtem. med. tom. 1. lib. 1. ſect. 1. cap. 3. N° xviii.

of the ſpirits lodged in them *; which are excited into oſcillations by any impulſe or irritation, and which, obſerving the ſame laws with other elaſtic bodies, muſt perſiſt in theſe tremulous motions for a conſiderable time.

BUT if the motions of the heart, or other ſeparated muſcles of animals, were owing to any ſuch cauſe, how could their vibrations be excited by bringing a red hot iron near them, after the impulſe and tearing of a pin or point of a knife had ceaſed to have any effect? (N°. 13.) Will warm water heighten and increaſe the elaſtic powers of any body? Does it not rather weaken and relax animal fibres? And how can acrid liquors, which communicate no impulſe at all, excite vibrations in an elaſtic machine?

FURTHER, as the times of the vibrations of a *pendulum* in a cycloid would be exactly equal, however unequal the arches which the body deſcribes, may be, were it not for the ſmall inequality that the reſiſtance of the air neceſſarily occaſions; ſo the vibrations of a *pendulum* in a ſmall arch of a circle which coincides with the

* *Lanciſi* de corde, prop. 58. *Lieutaud* element. Phyſiolog. p. 71. 72. *Senac* traité du coeur vol. i. p. 434. & 452.

the cycloid, and the oſcillations of elaſtic bodies, would follow one another at equal intervals of time, were it not for the air, which, as it reſiſts a great vibration of a *pendulum* or elaſtic body more than a ſmall one, muſt conſequently retard it more; whence, ſtrictly ſpeaking the firſt and greater vibrations of ſuch bodies muſt follow each other more ſlowly than the laſt and ſmaller ones. But as this difference is too inconſiderable, eſpecially in ſmall vibrations, to be perceived by us; ſo, in a phyſical ſenſe, we may be allowed to ſay, that the vibrations excited in elaſtic bodies by any external cauſe, though they be always decreaſing in greatneſs and force, are yet performed from firſt to laſt at equal intervals of time. Let us now ſee how far the ſeparated hearts of animals obſerve the ſame law, in their motions.

23. THE hearts of frogs, when firſt their *thorax* is laid open, generally beat from 64 to 66 times in a minute; but after they are ſeparated from the body, and have been in motion for ſome time, their vibrations begin to grow ſenſibly ſlower, ſo as only to be renewed

ed after an interval of 2 or 3 feconds; and, a little before their motion ceafes altogether, I have counted 7, 10, 13, 15, 16, or more beats of my pulfe * between their pulfations, each fucceeding pulfation following the former not till after a longer paufe, which at laft ended in a final ftop. In the feparated heart of a frog (into whofe ftomach I had forced, about an hour and a half before opening it, a fmall quantity of *opium* diffolved in water) I obferved the intervals between the fix laft pulfations to increafe nearly in the following proportion, 11, 13, 16, 19, 23, 30; which numbers denote how many beats of my pulfe intervened betwixt each of thefe vibrations. From which it appears, that, before the laft pulfation of this frog's heart, there was a paufe of 24 feconds.

WHAT is here faid of the motions of the feparated hearts of frogs becoming remarkably flower as they grow weaker, is alfo true of the hearts of eels; and holds not only in the pulfations of the right auricle of a pigeon's heart, which remained in the body after death,

* The motion of my pulfe was at the rate of 75 in a minute.

death, (N° 15.), but in the contractions alſo of the muſcles of its *thorax* after diſſection, N° 4.

SINCE, then, the motions in the hearts of animals after death, or after they are ſeparated from their bodies, decreaſe gradually in quickneſs, as well as in ſtrength, and become, at laſt, ſo ſlow, that, before they ceaſe altogether, the heart repoſes itſelf, as it were, for a conſiderable time, and, after appearing to have been quite dead, performs yet another contraction ſlowly, and with much ſeeming difficulty; it evidently follows, that they are regulated according to laws wholly different from thoſe of elaſtic bodies; and that every attempt to account for theſe motions, from elaſtic powers of whatever kind, ſuppoſed to reſide in the heart, muſt be vain and fruitleſs; and can only ſerve to ſhew, that the authors or ſupporters of ſuch opinion were either ignorant of the nature of elaſtic vibrations, or unacquainted with the *phænomena* recited above, (N° 23.).

WE may alſo ſee, from what has been ſaid, with how little reaſon the motion of the heart, after its ſeparation from the body, has been

been ascribed to the alternate action of its distending fluids and contracting solids; and compared to the *follis lusorius*, which being let fall from a height, does not lie still upon the ground, but is immediately thrown off from it, and continues to rise and fall alternately for some time *.

IT appears, from the experiments already recited, compared with N° 8. 9. 10. and 11. of Sect. I. and with what has been advanced Sect. X. p. 242. 243. and 256.—258. that the motions of the heart and other muscles after death, and when separated from the body, are owing to a *stimulus*; that where no *stimulus* is applied, they either happen not at all, or soon cease; that, when failing, they are excited a-new by any irritation; and that, in the laws they observe, and the *phænomena* they exhibit, they agree exactly with the motions which a *stimulus* excites in the muscles of living animals. But we have fully shewn, in Sect. X. that the contractions of the muscles of living animals, arising from any thing that tears, distracts, or otherwise irritates their fibres, are not owing merely to the

* *Santorini* de structura & motu fibræ, sect. 73.

the peculiar ſtructure and arrangement of their parts as mechanical organs, or even to the ſole efficacy of any material powers; but to their being endued with feeling, and animated by a ſentient principle. Whence it follows, that the motions of the heart and other muſcles, after death, or their ſeparation from the body, muſt proceed from their ſenſibility. As long as this ſentient power remains, or is but little impaired, they are impatient of any irritation, and are, therefore, alternately contracted and relaxed; but when it becomes conſiderably weaker, ſtronger *ſtimuli* are required to rouſe them into action, and even then their motion is more languid.

DR. *Harvey*, whoſe mind was neither blinded by prejudice, nor prepoſſeſſed with any favourite theory, but who formed his judgment of things, not as imagination might ſuggeſt, but from repeated experiments and obſervation, aſcribes, without the leaſt doubt, the various and irregular motions of the chick's heart, when irritated by different *ſtimuli*, to its being endued with ſenſe *; and therefore

* De generat. animal. exercitat. 17.

compares it to an animal which lives, moves, and feels.

THE motions of the heart from a *ſtimulus* greatly reſemble the alternate contractions of the *panniculus carnoſus* of brutes, when their ſkin is tickled or ſtung by inſects: and as this muſcle cannot properly be conſidered as a mere mechanical organ, but as ſomething animated, which endeavours to throw off whatever affects the ſurface of the body with any diſagreeable ſenſation; ſo the motions of the ſeparated hearts of animals, are not to be aſcribed to any property they can be poſſeſſed of as mere material organs, but to their being ſtill endued with ſome kind of life and ſenſe, which makes them ſhew an impatience of whatever hurts them, and endeavour, by their alternate contractions, to throw it off.

24. AT eleven o' clock in the forenoon, I injected a ſolution of *opium* in water into the ſtomach and guts of a frog, both by the mouth and *anus*. In leſs than a quarter of an hour, it had loſt a good deal of its vivacity and power of motion, and, when touched or pricked, it dragged its limbs as though their muſcles

muſcles had been in ſome degree paralytic. In little more than half an hour, it ſeem'd to have loſt all power of motion. At two in the afternoon, when I opened it, I found the auricle of the heart, with the large veſſels attached to it, greatly diſtended with blood; but there was not the leaſt motion either in the heart or its auricle: nay, ſo very inſenſible were theſe parts become of any *ſtimulus* or irritation, that neither tepid water, nor pricking or tearing their fibres, had any influence in exciting them into motion. Hot water, indeed, being poured into the *thorax* and *abdomen*, made the heart and inteſtines ſuddenly ſhrink and contract, in the ſame manner as the fleſh of any dead animal does when immerſed in boiling water; but produced no alternate contractions like thoſe which follow the action of a *ſtimulus* upon the muſcles of living animals, or of ſuch as are newly dead. Afterwards, I cut off this frog's head, and with the point of a probe preſſed and broke down the ſpinal marrow into a pulp; but did not obſerve the leaſt motion or convulſion in any part of the body.

25. At

25. AT half an hour paſt one in the afternoon, I injected a ſolution of *opium*, as above, into another frog, and opened it an hour after. The auricle and great veſſels leading to the heart were more than uſually filled with blood, but not ſo much as in the laſt experiment. The heart ſtill continued its motions, but much more ſlowly than in a ſound ſtate: its pulſations followed each other after an interval of about $3\frac{1}{2}$ ſeconds: the diſtended auricle always contracted firſt, and, after it, the ventricle. No convulſions happened in any part of the body from irritating the ſpinal marrow, nor were any of the muſcles of the limbs or trunk brought into contraction by pricking or tearing their fibres.

26. I forced down into the ſtomach of another frog a ſmaller quantity of a ſolution of *opium*; and, upon opening its *thorax* an hour and three quarters after, I found its heart beating regularly, but as ſlowly as in the laſt experiment: when I cut it out of the body, and laid it on a plate, it renewed its pulſations faſter, *viz.* once in two ſeconds; but, after five or ſix minutes, they became as ſlow as at firſt.

α SINCE,

α SINCE, from theſe experiments, it appears, that *opium*, internally applied, ſoon renders the motion of the heart in frogs three or four times ſlower than it naturally is, and, at length, puts an end to it entirely, ſo that the cauſes which uſe to renew it, prove quite ineffectual for that purpoſe; and ſince *opium* received into the ſtomachs of animals, is well known to deſtroy the ſenſe of feeling, either in the whole, or in part, as its doſe is greater or leſs; is it not highly probable, that *opium* ſtops or retards the motions of the heart, only as it renders it wholly, or in a great degree, inſenſible to the *ſtimulus* of the returning venous blood; and that the contractions of the heart, both in the body, and after it is ſeparated from it, are owing to the ſentient power of its fibres, by which it is made capable of being properly affected by various *ſtimuli*?

β As the heart continued to beat after the muſcles of the trunk and limbs were no longer affected by any irritation; it follows, either that its fibres are endued with a higher degree of ſenſibility than the fibres of other muſcles, or, at leaſt, that its ſenſibility is not ſo ſoon deſtroyed by the *laudanum*. *Opium* ſeems

to

to affect the brain fooner and more remarkably than the *cerebellum*; if therefore the heart is chiefly fupplied with nerves from the latter, its fenfibility will not be fo foon deftroyed by this poifon, as that of the voluntary mufcles whofe nerves are derived from the brain.

γ Dr. *Kaau* has obferved, that the convulfive motions which were excited by irritating or breaking down the brain of a dog to whom he had given fix grains of *opium*, were an hundred times lefs remarkable than thofe he had been in ufe to obferve in other dogs who had got nothing to lull their fenfes *; and experiment 25. above, fhews, that no convulfive contractions are produced, either by irritating the mufcles themfelves, or the fpinal marrow of a frog, an hour after a folution of *opium* is injected into its ftomach and guts: from which this inference is obvious, *viz.* that convulfions excited in dying animals, or fuch as are newly dead, by diffecting the fpinal marrow, preffing it with a probe, or breaking down the brain, are folely owing to the fenfibility of thefe parts to irritation, and not to the fpirits being mehanically propelled through

* Impet. faciens. N° 435.

through the nerves into the mufcles, either by the cut veffels of the *medulla*, or brain retracting themfelves * ; or by the preffing power of the probe or diffecting inftrument applied to them.

IT has, for many years, been the prevailing opinion, that *opium* produces its moft remarkable effects on the body, not by mixing with the blood, but merely by its immediate action on the nervous *papillæ* of the ftomach, whence the brain and whole nervous fyftem are affected in a very furprifing manner. In fupport of this opinion, many arguments have been advanced, fome of greater, others of leffer weight: but the following experiments compared together, put the truth of it beyond doubt.

27. A frog continued moving its limbs, turning from its back to its belly, and leaping about for above an hour after I had cut out its heart; and was not quite dead after two hours and a half.

* *Kaau* impet. faciens N° 333.

28. FIVE

28. FIVE minutes after taking out the heart of another frog, I injected a ſolution of *opium* into its ſtomach and guts. In leſs than half an hour it ſeemed to be quite dead, and neither pricking, tearing, nor cutting its muſcles, cauſed any contraction in them, or any motion in the parts to which they belonged. A probe puſhed into the ſpinal marrow, after cutting off its head, made its fore legs contract feebly.

SINCE, in this frog which was deprived of its heart, the parts of the *opium* could not poſſibly be mixed with the maſs of blood, or be conveyed along with it to the brain, their effects muſt neceſſarily be deduced from their direct action upon the nerves and fibres of the organ to which they were immediately applied. But to return from this digreſſion.

SINCE the ſenſibility of our fibres is owing to their being animated by a living principle different from matter, and of powers ſuperior to it (Sect. x.), it may be objected, that if we aſcribe the motions of the muſcles after death, or their ſeparation from the body, to their being endued with ſenſe, we muſt not only ſuppoſe the ſoul to continue preſent with the body

body after death, but alſo to be extended and diviſible.

BUT, though theſe objections, as they are founded in our ignorance of the nature of the ſoul, and its union with the body, and of the manner of their mutual action upon each other, ought to have little or no regard paid them in a Phyſical inquiry; yet, to clear our ſubject, as much as poſſible, of all difficulties, we ſhall conſider them particularly.

α I think it is not only probable, but even demonſtrable, that the ſoul does not immediately leave the body upon a total ſtoppage of the heart's motion, and, conſequently, of the circulation of the blood, *i. e.* upon what we uſually call DEATH *, but continues for ſome time at leaſt preſent with it, and ready to actuate it. Thus, a variety of inſects, bats, hedge-hogs, and ſeveral other animals, which continue in a death-like ſtate in the cold winter-ſeaſon, are reſtored to life by the kindly warmth of the returning ſpring, which, as it ſtimulates the ſolids into contraction, as well

B B b as

* By death is here meant the general death of the body as a ſyſtem, and not the particular death of the ſeveral parts, which does not happen for ſome time after.

as rarifies and agitates the fluids, gives the latent ſoul an opportunity of ſhewing itſelf by its effects: yet, in theſe animals, during the cold weather, there is no circulation of the blood; they are quite deſtitute of feeling, may be torn and cut in pieces, without ſhewing that they have any ſenſe of pain, and cannot be diſtinguiſhed from ſuch animals as are really dead, except in this ſingle circumſtance, that, by the aſſiſtance of warmth, they may at any time be brought to life.

IN the Northern countries, magpies and other ſmaller birds, after being frozen by the exceſſive cold, have been ſoon brought to life again by warmth *; nay, ſeveral of the human kind have been recovered by agitating their bodies, blowing into their lungs, or expoſing them to heat, after having been for hours, nay ſometimes days, to all appearance, dead, without pulſe, breathing, or any degree of natural heat. Had not the ſoul been preſent with ſuch bodies, and ready to actuate them, is it to be imagined, that blowing air into the *anus* or lungs, that heat, friction, or any other *ſtimuli*, could, as it were, by ſome

* Flora Siberica, præfat. p. 73.

ſome magic charm, have called it back from diſtant regions? Upon the whole, it ſeems certain, that after death, or an entire ſtop of all motion in the bodies of animals, the ſoul ſtill remains preſent with them, and can be again brought to exert its influence, by various kinds of *ſtimuli* applied to their different parts. May not then the ſame principle continue preſent with the ſeveral muſcles after they are ſeparated from the body, and be the cauſe of their motions when irritated? And is it not reaſonable to think, that the renewal of life in a frozen magpye, and of motion in the frozen heart of a ſalmon *, by expoſing them to the heat of a fire, was owing to the ſame cauſe, *viz.* to the ſoul or ſentient principle, which being preſent with the body of the magpye, and the ſeparated heart of the ſalmon, was excited by the *ſtimulus* of heat to put them in motion? But here it will be ſaid, that, not only contrary to the opinion of many Philoſophers, we ſuppoſe the ſoul to be extended, but alſo, in oppoſition to them all, ſeem to make it diviſible; which is the ſecond objection

* *Peyer* Parerg. anatom. 7. p. 200.

objection mentioned above, and to which we now proceed to give an anſwer.

β As the ſchoolmen ſuppoſed the DEITY to exiſt in every *ubi*, but not in *any place*, which, as a learned and acute writer has well obſerved, is to ſay, in *Latin*, that he exiſts *every where*, but in *Engliſh*, *no where*; ſo they imagined the ſoul of man not to occupy ſpace, but to exiſt in an indiviſible point. Yet, whoever conſiders the ſtructure and *phænomena* of the animal frame, will ſoon be convinced that the ſoul is not confined to an indiviſible point, but muſt be preſent at one and the ſame time, if not in all the parts of the body, yet, at leaſt, where-ever the nerves have their origin; *i. e.* it muſt be, at leaſt, diffuſed along a great part of the brain and ſpinal marrow. Nay, while, in man, the brain is the principal ſeat of the ſoul, where it moſt eminently diſplays its powers; it ſeems to exiſt ſo equally through the whole bodies of inſects, as that its power or influence ſcarce appears more remarkable in one part than another: and hence it is, that, in ſuch creatures, the ſeveral parts of the body live much longer after being ſeparated from each other, than they do in man

and

and the other animals more nearly refembling him, where the foul feems chiefly to act on the different parts by means of their connexion with the brain and fpinal marrow; or, at leaft, where the cutting off fuch connexion, foon renders the parts unfit to be any more acted upon by it. The amphibious animals feem to hold the middle place, between man and the infect tribe, as to the diffufion of the foul through the body, and its power of moving the various parts independently of the brain.

IT was not, therefore, altogether without reafon, that fome of the greateft Philofophers of the laft and prefent age, fuppofed the foul to be extended *.

BUT

* *Gaffendi*, Dr. *Henry-More*, Sir *Ifaac Newton*, Dr. *Sam. Clarke*.

Gaffendi argued for the foul's being extended in the following manner. If it be faid, that the foul refides in a point of the brain, this is either phyfical or mathematical; if phyfical, the difficulty ftill remains, becaufe this is extended, and confifts of parts, and confequently the foul muft be extended which occupies it: if mathematical, which has no dimenfions, how can the nerves, which are not mathematical lines, all terminate in that which hath neither length, breadth, nor thicknefs. *Gaffend. object. contra meditat. Defcartes, p.* 32. 33.

BUT if the ſoul, without extenſion, be preſent at one and the ſame time in different places of the brain; and if in many animals it can act along the ſpinal marrow for a great while after the head is cut off, why may not it alſo actuate parts ſeparated from the body, without being extended? On the other hand, if we allow the ſoul to occupy ſpace, I don't ſee why it may not continue to be preſent with the parts of its body after they are ſeparated, as well as when they were united. And with reſpect to the diviſibility of the ſoul, which is generally thought to follow from the ſuppoſition of its being extended; why may it not be a ſubſtance ſo perfectly and eſſentially one, as that a diviſion or ſeparation of its parts would neceſſarily infer a deſtruction of its eſſence? Further, if the ſoul can be preſent in all or in any conſiderable part of the body at one and the ſame time without being diſcerpible, its ſphere of exiſtence being ſo much increaſed, as to enable it to act upon the parts when ſeparated, will not infer its diviſibility. As the DEITY is every where preſent, and, in the infinitely diſtant parts of ſpace, actuates at the ſame time a vaſt variety

variety of different syſtems, without any inconſiſtency with his UNITY or INDIVISIBILITY; ſo, may not the ſouls of animals be preſent every where in their bodies, actuating and enlivening at the ſame time all their different members? Nay, further, when the fibres and threads connecting ſome of theſe parts are divided, may not the ſoul ſtill act in the ſeparated parts, and yet be only ONE mind?

IT muſt be owned, there is a great deal of difficulty and obſcurity in theſe matters. But what *hypotheſis* can we embrace that will clear us of them, or to what part of nature can we turn our inquiries where we ſhall not find ſomething to puzzle us, ſome myſtery at laſt which we cannot unfold? Nor is this to be wondered at; ſince, in the preſent ſtate, our knowledge is very much limited, and we have only acceſs, as it were, to the ſurface of things! But becauſe we cannot explain fully, are we therefore in noways to attempt explaining the operations of nature? Becauſe, in accounting for the ſpontaneous motions of animals, and ſhewing their dependence on the ſoul, there occur ſome difficulties with reſpect to the nature of an immaterial ſubſtance,

ſtance, its manner of exiſting, and way of acting upon, or being preſent with the body; are we therefore to deny the reality, influence and action of this principle, which, from a variety of arguments, appear undeniable? At this rate, we ought to give up all inquiry into the works of nature, and, with our arms a-croſs, ſit down contented in ignorance!

BUT, not to perplex ourſelves any longer with metaphyſical difficulties, we ſhall recite a few experiments and obſervations, from which we are led, by the moſt obvious analogy, to conclude, that the motions of the ſeparated parts of animals are owing to the ſoul or ſentient principle ſtill continuing to act in them.

29. A frog lives, and moves its members, for half an hour after its head is cut off*; nay, when the body of a frog is divided in two, both the anterior and poſterior extremities preſerve life and a power of motion for a conſiderable time.

30. A young cock, whoſe head Dr. *Kaau* ſuddenly cut off with a ſharp razor, as he was running

* *Kaau* impet. faciens. N° 331.

running with great eagerneſs to his food, went on in a ſtreight line 23 Rhinland feet, and would have gone farther, had he not met with an obſtacle which ſtopp'd him *. The ſtory, therefore, mentioned by Lord *Verulam*, of an oſtrich running along the ſtage after its head was ſtruck off with a forked arrow by one of the *Roman* Emperors, is no way improbable †.

31. A viper, after being deprived of its head and intrails, moved towards a heap of ſtones in a garden where it uſed to hide itſelf ‡.

32. THE bodies of vipers not only move two or three days after they have been deprived of their ſkin, head, heart and other bowels, but are alſo manifeſtly ſenſible of punctures, by means of which they may be made to move with greater vivacity ‖.

33. THE female butterflies into which ſilk worms have been metamorphoſed, not only

* Impet. faciens, N° 331.
† Sylva ſylvarum, on the word *life*.
‡ *Kaau* impet. faciens, N° 331.
‖ *Boyle*'s Uſefulneſs of Experim. Philoſ. part 2. p. 16.

admit the male, after loſing their heads, but alſo lay eggs *.

34. *REDI* informs us, that a land tortoiſe, whoſe brain he extracted by a hole made in its ſcull, in the beginning of *November*, lived till the middle of *May* following. Immediately after the loſs of its brain, it ſhut its eyes, nor ever opened them any more, but continued to move and walk about until the time of its death. When the ſcull was opened, its cavity appeared quite clean and ſmooth, and nothing was found in it except a ſmall dry clot of blood. The ſame experiment he repeated on various other tortoiſes, ſome of which lived a longer, others a ſhorter time, but none of them leſs than fifty days †.

35. A large tortoiſe, whoſe head *Redi* cut off, allowing the blood to flow freely from the open veſſels of its neck, lived after this twenty three days; and though it did not walk about like thoſe which were deprived of their brain, yet as often as its fore or hind feet

* *Boyle's* Uſefulneſs of Experiment. Philoſoph. part. 2. p. 16.

† Obſervation. circa animal. vivent. p. 209. & 210.

feet were pricked, it moved them with great force, and was otherwife convulfed. In two tortoifes which he opened fifteen days after decollation, he faw the heart beating as in a living animal, and the blood circulating through it *.

HERE, we are naturally led to obferve, that while thofe animals who have a fmall brain and large fpinal marrow, live long after decollation; man, and moft quadrupedes, which have the brain remarkably large, furvive the lofs of it only for a few moments.

« IF the motions of a tortoife, after decollation (35.), or the lofs of its brain (34.), cannot proceed from mere mechanifm, but muft be undoubtedly afcribed to the living principle which caufed its motions in a found ftate; and if the fame thing is true of the actions performed by butterflies after the lofs of their heads (33.); it muft follow, that the motions and other figns of life which are obferved in the trunk and limbs of a frog for above half an hour after its head is cut off (29.), are to be attributed to the fentient principle, to which its motions and actions were owing, when in an

* Obfervat. circa animal. vivent. p. 212. 213.

an entire ſtate; and if ſo, then the motions of this body, when divided into two parts, muſt alſo be referred to the ſame cauſe, ſince they are of a like kind, although of ſhorter duration. Shall we then deny that the motions of its ſeparated heart and limbs, which are ſimilar to theſe, and are increaſed and renewed by the application of the ſame cauſes, proceed from the ſentient principle ſtill acting in theſe parts? This would be to neglect the ſtrongeſt analogy; and muſt be the more inexcuſable, as no other cauſe can be aſſigned, which accounts ſo well for the appearances.

β WE have no other way to ſatisfy ourſelves that an animal is alive, or endued with feeling, but by obſerving, whether it ſhews an uneaſineſs when any thing hurts, or tends to deſtroy any of its parts, and an endeavour to remove or avoid it. Since therefore the bodies of vipers make juſt the ſame kind of motions when pricked with a ſharp inſtrument, two or three days after loſing their head, heart, and other bowels, as if they were entire (32.); we are naturally led to conclude, that they are ſtill, in ſome ſenſe, alive and endued with feeling, *i. e.* animated by a ſentient principle.

And

And as the muſcular parts of theſe creatures move after being cut in pieces, and are ſenſible of punctures, it alſo follows, that they continue ſtill to be animated.

7 *Laſtly*, IF the motions of the muſcles in a cock's limbs after decollation (30.), are, without diſpute, owing to its ſoul; may we not alſo aſcribe to the ſame principle, the like, but leſs remarkable, motions, in men and quadrupedes, after their heads are ſtruck off, and, conſequently, the tremulous motions and palpitations of their hearts too, after death or ſeparation from their bodies.

To ſum up all in a few words; from what has been ſaid, it appears undeniable, that the involuntary motions of living animals, and the alternate contractions of their muſcles, after the general death of the body, or their being ſeparated from it, are owing to one and the ſame cauſe; *viz.* an irritation of their fibres or membranes, or of ſuch parts as are nearly connected with them. If then, as we have ſhewn (Sect. x.), the motions of animal fibres, from a *ſtimulus*, moſt certainly beſpeak a feeling, and cannot be explained unleſs we admit it; and if feeling be not a property of matter,

but

but owing to a ſuperior principle, it muſt follow, by neceſſary conſequence, that the motions of the heart, and other muſcles of animals, after being ſeparated from their bodies, are to be aſcribed to this principle; and that any difficulties, which may appear in this matter, are owing to our ignorance of the nature of the ſoul, of the manner of its exiſtence, and of its wonderful union with, and action upon the body.

CONCLUSION.

As Philoſophical inquiries, howevèr agreeable and entertaining they may be to the mind, become ſtill more intereſting when they can be applied to practice; I intended to have ſhewn, how far the theory of the vital and other involuntary motions, which we have endeavoured to eſtabliſh, may be uſeful towards explaining the nature of ſeveral diſeaſes, and conſequently towards pointing out the moſt proper method of curing them. But, as this *Eſſay* has ſwelled to a much greater bulk than I at firſt expected, I ſhall now,

now, omitting that part of my defign, conclude with a reflexion of a different nature.

FROM what has been offered, then, in the preceding pages, it may appear, how unjuftly the ftudy of Medicine has been accufed of leading men into Scepticifm and irreligion. A little Philofophy may difpofe fome men to Atheifm; but a more extenfive knowledge of nature, will furely have the contrary effect. If the human frame is confidered as a mere CORPOREAL fyftem, which derives all its power and energy from matter and motion; it may, perhaps, be concluded, that the IMMENSE UNIVERSE itfelf is deftitute of any higher principle: but if, as we have endeavoured to fhew, the motions and actions of our fmall and inconfiderable bodies, are all to be referred to the active power of an IMMATERIAL principle; how much more neceffary muft it be, to acknowledge, as the Author, Suftainer, and Sovereign Ruler of the univerfal fyftem, an INCORPOREAL NATURE every where and always prefent, of infinite power, wifdom, and goodnefs; who conducts the motions of the whole, by the moft

moft confummate and unerring reafon, without being prompted to it by any other impulfe, than the original and eternal benevolence of his nature!

Nam quis non videt, finitæ fi breve corpus
Subjicitur menti, mens quanta fit illa fupremo
Quæ regit arbitrio vaftum quem condidit orbem?
Non poterit fine confilio tam parva moveri
Machina, tam fragilis; te judice, tanta regetur
*Mentis inops! Credant Epicuri de grege porci**.

THE true Phyfiology, therefore, of the human body, not only ferves to confute thofe Philofophers, who, rejecting the exiftence of IMMATERIAL BEINGS, afcribe all the *phænomena* and operations in nature to the powers of matter and motion; but, at laft, like all other found Philofophy, leads us up to the FIRST CAUSE and fupreme AUTHOR of ALL, who is ever to be adored with the profoundeft reverence by the reafonable part of his creation.

* Polignac. Anti-Lucret. lib. 5. lin. 1376. &c.

FINIS.