ESSAYS,

PHYSIOLOGICAL AND PHILOSOPHICAL,

ON

THE DISTORTION OF THE SPINE,

THE MOTIVE POWER OF ANIMALS,

THE FALLACY OF THE SENSES,

AND

THE PROPERTIES OF MATTER.

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AND

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AT

ST. BARTHOLOMEW'S HOSPITAL.

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TO

JOHN ABERNETHY, Esq.

F. R. S.

Aſſiſtant Surgeon to St. Bartholomew's Hoſpital,

AND

LECTURER IN ANATOMY AND SURGERY,

AS A TESTIMONY OF THE FRIENDSHIP

HE HAS EVINCED TOWARDS THE AUTHOR,

THE FOLLOWING ESSAYS

ARE RESPECTFULLY INSCRIBED.

ONSLOW HOUSE,
Leiceſter Street, Leiceſter Square.

PREFACE.

I KNOW not of any work profeſſedly written on Diſtortions of the Spine, with a view of inveſtigating the ſtate of mechanical defect, and of aſcertaining the maximum of relief which may be derived from artificial contrivances.

Gliſſon, in his Treatiſe on Rickets, although he attributes diſtortion to the action of a peculiar kind of virus, yet he adopted a mode of extenſion, by ſwinging a child on an *eſcarpolette*: an infant cannot ſuffer ſuch a ſuſpenſion for more than a quarter of an hour, a time too ſhort to afford the leaſt relief. Heiſter ſuppoſed that a diſtortion might be removed by means of a continual preſſure; with this view he firſt made uſe of a back board. It requires but little knowledge of mechanics to demonſtrate the inefficacy of ſuch a mode, and ſtill leſs knowledge of

 phyſiology,

phyſiology, to point out the great impropriety of ſuch an application: ſome inſtances are recorded where the moſt excruciating tortures have been inflicted when this method has been carried to a greater extent; the caſe of Madame de Montmorenci is illuſtrative of this. Dr. Ronchin thought of reducing the diſtortion of her ſpine by means of a violent preſſure; we can no longer wonder at the mode of his treatment, when we read his proximate cauſe of the diſeaſe. "*Une luxation de deux vertébres par un*" "*catarrh tombé du cerveau ſur l'epine.*"

When the celebrated Mayou and Petit had obſerved that the moſt rational method of affording relief was to take off the weight of the head and of the ſuperior parts, ſome attention was paid to the conſtruction of machines conducive to ſuch an effect.

In the fourth volume of the Memoirs of the Royal Academy of Surgery of Paris, p. 605, there is a ſhort Eſſay *de la coubure de l'epine*, where an inſtrument is propoſed to take off the weight of the head, conſtructed in a ſimilar manner with the ſpinal machines which are made uſe of by Mr. Jones and others. I have endeavoured to prove,

prove, upon principles that are not merely ſpeculative, that the relief afforded by abſtracting the weight of the head is proportionally ſmall to what is requiſite, and few there are who can ſubmit to the continued uncomfortable preſſure of ſuch a machine; the deſtruction of all motion of the head, and the interruption to the circulation through the temporal veſſels, increaſe the languid ſtate peculiar to rachitic conſtitutions, and ultimately aggravate that complaint which it was intended to relieve.

We ſhould endeavour to remove the whole bearing on the weakened portion, by ſupporting that point where the united powers of the corporeal maſs tend. This point, uſually known by the name of centre of gravity, varies in its poſition according to the ſtate of diſtortion, to the aſcertainment of which is the principal purport of the following Eſſay.

To this point the centre of action of our inſtruments ſhould be applied, and ſuch may eaſily be effected without producing the leaſt uncomfortable ſenſation, and be permanently worn with not only eaſe to the patient, but alſo inviſible to others.

It does not appear that there is ever the leaſt neceſſity, in any caſe of diſtortion, of controlling the head by the application of inſtruments, which, in the generality of caſes, injure more than they aſſiſt. It is not merely the diſtortion to be conſidered, all circumſtances relative to the conſtitution ſhould be maturely inveſtigated; not only the aſcertainment of the deficiency of ſupport from the ſtate of incurvation, to regulate the power of our inſtrument, alſo of the cauſe from whence the diſeaſe may have originated.

How empirical would our practice be if our treatment ſhould be uniformly the ſame, whether the diſtortion is conſtitutional, or ariſing from any permanent preſſure, or external violence.

Such we find is the caſe by relinquiſhing this important branch of ſurgery to thoſe who, from their purſuits, cannot be expected to have any idea of the animal œconomy; the ſame formed inſtrument is indiſcriminately uſed, whatever may be the nature of the diſtortion; no reſpect is paid to the ſtate of the conſtitution, the robuſt and the delicate are treated ſimilar; the ſpine is acted on

like

like a piece of iron, as if it could be hammered and tempered at will.

Why this ſurgical department ſhould have peculiarly fallen into the hands of mechanics, may in ſome reſpects be owing to the abſurd practice of ſome profeſſional characters. Thus in the *Orthopedia* of Dr. Andry, we find recommended the placing the child's back on a large loaf, quite hot from the oven, and the cruſt removed, and there to remain till the loaf cools; this repeated every morning for nine times, and if pain is produced the prognoſis is good.

Such magic remedies as theſe might be admiſſible in the elegant Latin poems of the *Pædotrophia* of *Scevole de Sainte Marthe*, or the *Callipedia* of *Claude Quillet*.

In a voluminous work, profeſſedly written on diſtortions by one of the firſt Pariſian practitioners, what can we think of principles on which ſuch practice is founded?

To thoſe who have paid ſome attention to mechanical purſuits, I ſubmit the following Eſſay; if in any part I ſhould not have expreſſed my ſentiments with that perſpicuity which is neceſſary, I ſhould deem any perſonal reference an honour, and ſhould be

happy

happy in ſubmitting to any one's inveſtigation the conſtruction of thoſe inſtruments which I have, and which appear to me reconcileable to the ſubſequent theory.

The Eſſay on the Motive Power of animals would have been more correct, had I conſulted Mr. Coleman, the ingenious Profeſſor of the Veterinary College, whoſe friendly liberality I have heretofore experienced, and from whoſe extenſive information I might have derived conſiderable advantage.

The Eſſays on the Senſes and the Properties of Matter are the outlines of what I have lately preſumed to give in my Lectures on Experimental Philoſophy; they were arranged for the Student, and for ſuch are now publiſhed; they were drawn up with a view of removing any ſcepticiſm which might be founded on any ſuppoſed fallacioufneſs of the ſenſes, or on the ideal powers on which might be imagined depends the exiſtence of matter.

If by any exertions of mine the ſtudy of philoſophy ſhould any ways be facilitated, if by any explanations I have attempted the fundamental principles ſhould be eaſier

comprehended,

comprehended, my purpofe will be fully anfwered.

Some opinions, which to me appear new, I fubmit with the utmoft deference to the Public; if they are probably right, their candour will admit them; if they are erroneous, their corrections will be refpectfully attended to.

For the freedom I have indulged in with refpect to the infertion of fo many notes, will, I hope, be excufed, as it is only for the young philofopher I now write, and for whom I have ftudioufly embraced every opportunity of attempting to explain any circumftance, whether directly or indirectly connected with my fubject.

To Mr. J. Parkinfon I feel myfelf peculiarly indebted for the affiftance which his incomparable Mufeum has afforded me. If I might prefume to dictate to the Student in Philofophy, I would earneftly recommend him to devote a portion of his time to a minute examination of the valuable collection in the *Leverian Mufeum*; there he would fee Nature in her beft attire, her moft valuable productions difplayed to the greateft advantage; what he reads, he would here find exemplified; and whatever branch of Natural Philoſophy may be more peculiarly his object, he would here meet with every illuſtrative ſpecimen.

N. B. For the accommodation of Students, Mr. Parkinſon, the preſent Proprietor, has reduced the ſubſcription to Two Guineas for half a year, for which time any perſon may daily viſit the Muſeum, and remain there as long as it is agreeable. If a Student ſhould devote an hour or two daily in examining the ſpecimens illuſtrative of his ſtudies, at the expiration of ſix months he would be convinced of the value of his acquiſition.

AN

ESSAY, &c.

SPINE.

BY the Spine is meant that chain of bones which follow one another, without interruption, from the os occipitis, or the hinder part of the head, along the poſterior part of the body, forming a pillar of ſupport to the animal machine.

The bones which form the Spine are uſually known by the name of Vertebræ*, thus called, becauſe on theſe the ſeveral motions of the trunk of our bodies are performed.

The Spine ſomewhat reſembles two unequal pyramids joined in a common baſe. It is not, however, ſtraight, but ſerpentine in its direction, and is commonly divided into true and falſe vertebræ; the former conſtituting the long upper py-

* *Vertebra* is derived from *verto*, to turn.—Cervix è multis *vertebratiſque* orbiculatim oſſibus flexilis.—*Plin.* 11. 37.

ramid, which has its baſe below, while the falſe vertebræ make the ſhorter lower pyramid, whoſe baſe is above.

The *true vertebræ* are the twenty-four upper bones of the Spine: as on theſe the motions of the trunk ſolely depend, they alone will be the ſubject of inveſtigation of this little Eſſay.

The vertebræ, conſtituting ſo many different joints, muſt in their reſpective motions move the ſuperincumbent maſs, the weight neceſſarily increaſing on each vertebra the nearer it is ſituated to the baſe.

When, from any conſtitutional affections or local injury, the curvature of the Spine becomes altered, what at firſt was but a ſlight derangement, yet diſproportionate to the weight it ought to bear, gradually gives way to the ſuperincumbent preſſure, and ultimately becomes an extenſive diſtortion.

In its earlier ſtage a tendency to incurvation may in general be remedied, although this is rarely the caſe when in a more advanced period; a prevention of its increaſe becomes an object of conſideration.

This Eſſay is only intended to examine what aid artificial contrivances may afford, and to endeavour to aſcertain, on pure mechanical principles, how far we may approximate the admirably-regulated ſupport of the different vertebræ in their natural ſtate of curvature, that we may give ſtrength

ſtrength to that part which is affected, and yet interrupt no corporeal motions; that our mechanical contrivances be as ſimple and light as poſſible, neither inconvenient from their weight, nor troubleſome from their preſſure.

In the firſt point of view we ſhall regard the Spine as a pillar of ſupport, diveſted of powers of life, and ſubject to ſuch laws as are reducible to the principles of mechanics. The Spine not having thus been conſidered, is the reaſon why the machines hitherto made uſe of are inadequate to the production of any good effect. We find the ſame ill-contrived braces or collars applied alike in every caſe, whether the diſtortion be in the neck, the back, or the loins.

In an inveſtigation of any mechanical inſtrument, whoſe power we wiſh to aſcertain, that point which tends to the centre of the earth, with the united forces of all the gravitating particles of that inſtrument, muſt previouſly be determined. This common point is called the Centre of Gravity. If the ſame body varies in its figure, the Centre of Gravity varies in its poſition alſo: ſo with the Spine, the Centre of Gravity is regulated by the ſtate of incurvation. As it is to this point all the powers tend, it is here alſo our ſupports ſhould be given.

By ſuch a mode of procedure we may preſume that great practical deductions may be made; that our reaſoning may not be uncertain or vague, but deducible from incontrovertible principles; that our powers of relief may be greater, becaufe they may be more certain.

In the firft place, I fhall endeavour to point out the admirable properties of the natural-formed Spine, to fhew the convenience of its curvilinear form, although in fome refpects there appears a diminution of ftrength, and to evince that great extent of motion derived from the vertebral portions.

As in my enquiries refpecting the refiftance of bodies I fhall have frequent occafion to make ufe of the terms Centres of Gravity, and of Percuffion, it may not be deemed improper to previoufly explain what are meant by thefe terms, as this little Effay may fall into the hands of thofe whofe avocations may not admit of any attention to mechanical purfuits.

CENTRE OF GRAVITY.

IN every body there is one common point which tends to the centre of the earth, with the united forces of all the gravitating particles which compofe that body, which point is called its Centre of Gravity; and that line which this point would defcribe in falling towards the earth is called the line of direction, and always perpendicular to the horizon. Thus in every building, however

however inclined, when the line of direction falls within its base, it is necessarily supported, as is the case with the inclined tower at Bologna. In a sphere, the Centre of Gravity is the centre of the body itself, because round this point, if suspended, the whole would revolve; the spherical portion of one side not preponderating that on the other, the whole would be in æquilibrio.

In an homogeneous cylindrical body the Centre of Gravity is necessarily placed in the middle of the axis; in a cone, the centre is in the axis, three-fourths of its length from the apex.

CENTRE OF PERCUSSION.

BY the Centre of Percussion is meant the centre of the striking or percussive power of a body. When a body is thrown into motion, supposing, at the instant such motion is communicated, the body is divided into many equal portions, each portion would acquire a momentum in ratio of its distance from the centre of motion; so that one portion, situated at double the distance of another, would have double momentum; for being removed as far again from the centre of motion as the other, its velocity, or the space through which it would move in the same time, would be double; and as this, multiplied by the quantity of matter, expresses the momentum, the momenta of the different

ferent portions will neceſſarily be in the ratio of their diſtances.

By conſidering the portions as unconnected, we find each has a greater percuſſive force as it is more remote from the centre. In a walking-ſtick, in giving a blow therewith, the centre of motion is in the hand: we are very ſenſible that the part of the ſtick more remote from the hand is more powerful in a percuſſive or ſtriking effect than the part contiguous to the hand. As every particle of the ſtick is in a ſtate of mechanical union, the ſeveral powers of the reſpective portions, all united, will conſtitute, of the whole ſtick, one compound force, that will be the maximum at ſome point between the extremes, *i. e.* if we conſider the ſtick as cylindrical, the Centre of Percuſſion will be two-thirds of its length from the hand: if, like the Spine, of a conical taper, then the centre will be nearer the hand. Thus it will appear that the Centre of Percuſſion, in a moving body, is that point which, if acting againſt an immoveable obſtacle, the motion of the body would be deſtroyed. If the percuſſive forces on each ſide of the centre were not equal, the one ſide not being counteracted by an equivalent force, the ſuperior power would continue to move forwards after the ſtroke, ſo that the motion of the whole rod would not be ſpent upon the obſtacle. When we find the momenta of all the different portions are reciprocally as their diſtances from any particular

point,

point, all their forces are concentrated in that point, which is called the Centre of Percuſſion. It may, perhaps, be neceſſary to obſerve, that with vibrating bodies the Centre of Percuſſion and the Centre of Oſcillation are one and the ſame; the Centre of Oſcillation, in a moving pendulous body, being that point where, if a corpuſcle were ſuſpended, it would vibrate the ſame time as the body does.

It has been already obſerved, that the Centre of Percuſſion, in any even homogeneous body, is two-thirds of its length remote from the point about which it moves: ſo we find in a pendulum that vibrates ſeconds, being 39-2 inches long, is iſochronal to the vibration of any ſtraight even rod, whether ſquare or round, whoſe length is 58-8 inches, viz. the former being only two-thirds of the length of the latter: as in many bodies the Centres of Oſcillation and Percuſſion do not coincide, they cannot be indiſcriminately uſed.

That we may aſcertain the ratio of the ſtreſs between a perpendicular and an inclined pillar, it may not be improper previouſly to ſhew what ſupport an horizontal portion would bear; as *this cannot be known* till the Centres of Gravity and Percuſſion are given, theſe muſt previouſly be found.

In the cylinder A B C D E F put A B $= a$, and the area of the circle B E F G $= b$. and A L $= x$, the diſtance of the Centre of Gravity from

from A, $x\ b$, will expreſs the contents of that portion of the cylinder A N M and $\overline{a-x} \times b$ the content of the remaining portion. As the Centre of Gravity has equal quantities of matter on each ſide $xb = ab - bx$ $\therefore x = \frac{1}{2}a$, ſo that L is the Centre of Gravity = half A B.

TO ASCERTAIN THE CENTRE OF PERCUSSION.

If we put A B = x, the area of the circle E F = $\frac{1}{2}ap$, then $\frac{1}{2}apx^{\cdot}$, the fluxion of the weights, this multiplied by the length or velocity, will give $\frac{1}{2}apxx^{\cdot}$ = the momenta, the fluxion of the forces = $\frac{1}{2}apx^2x^{\cdot}$, whoſe fluent $\frac{apx^3}{6}$, divided by the momenta $\frac{apx^2}{4}$, will give $\frac{4}{6}x = \frac{2}{3}$ A B for the centre of force from the axis A.

Theſe being premiſed, let us put g = the Centre of Gravity, and p the Centre of Percuſſion.

Suppoſing abc is a tranſverſe ſection, and de fg are ordinates parallel to the baſe, and infinitely near each other. Suppoſing $ac = r$, $bc = s$, $af = x$, $fc = y$, $fg = z$. If this cylinder be ſupported by a block at A C D, and acted upon by a weight at D W, ſo as to break it, it muſt appear evident that the ſeparation

muſt

muſt firſt take place at the point a, (which in a fuſible body is preciſely that point of expanſion, at which it would become fluid by heat) and the nearer the fibres are towards $b\,c$, the leſs they are acted on: hence at $f = \frac{y}{r}$ and of all the fibres in $a\,b\,c\,d\,e\,f\,g = \frac{y}{r} \times e\,f$, and the ſum of all the powers in the whole ſection, equal to the ſum of all the $\frac{y^2}{r} \times e\,f$, let g and p expreſs the diſtances of the Centre of Percuſſion, and Centre of Gravity from $c\,g$ the axis of motion; therefore the ſum of all the $\frac{y^2}{r} \times e\,f = \frac{gp}{r} \times a\,b\,c$, therefore the ſtrength of the beam at $a = \frac{gp}{r} \times$ ERG. If we ſuppoſe the length $AB = l$, then $\frac{rl}{gp} \times \frac{gp}{r} \times$ ERG will expreſs the reſiſtance when drawn in direction of its length; *i. e.* ſuppoſing the tibia to be an inch in diameter, and a foot long, if ſupported at both ends, and 300lb. would break it, when applied lengthways it would require 2700lb.

N. B. In the former part it was ſuppoſed the pillar was ſupported, in an horizontal poſition, only by a block at one end: if ſupported on both ends, and the weight breaks it in the middle, the axis of motion will then be on the upper ſide, and from this the Centres of Gravity and Percuſſion muſt be meaſured, as the under part in this poſition is put to the ſtretch: in this caſe we muſt divide it into two cy-

 linders,

linders, therefore l muſt be taken for half the length, and $\frac{gp'}{r} \times$ ERG for half the reſiſtance.

It appears that a cylinder of this ſize will ſupport perpendicularly nine times more than it will horizontally; not that this is an univerſal ratio in every length of cylinders, for they may be of ſuch a length as not to ſupport their own weight, as the ſtreſs increaſes in a greater ratio than the ſtrength. It is this circumſtance that limits the magnitude of bones, and conſequently a limit to the ſize of animals: when the ſize of animals is diminiſhed, their ſtrength is not diminiſhed in the ſame proportion. We ſee a dog will carry more than its own weight, which a horſe could not do. It is upon this principle, is eaſily explained that mechanical paradox, where a part ſhall be ſtronger than the whole: a piece of wood, in the form of a triangular priſm, a portion being cut away parallel to the baſe, the remaining part will be ſtronger than the whole.

*As the Spine is of a polygonal form, having two convexities, the ſtreſs upon any particular vertebræ will be as the coſine of elevation: ſuppoſing AB to repreſent the Spine, with the curvature AE EB, if AC be conſidered as the abſciſſa,

* Quod ad figuram attinet, ea ad æquilibrium, ſingularum que partium uſus apta eſt.

Nam à ſacro lumbi primum in priora ſurgentes, curvantes que ſe retrorſum, mox rectiores, in poſteriora modice inclinant, ſinu-abſciſſa, dc and ab will be ordinates, as being perpendicular to the abſciſſa, the greateſt ordinate to the curve AE is dc, being about the ſixth cervical vertebra, and of the arch BE, ab, is the greateſt about the third lumbar vertebra. At E the ordinate is nothing, as it there touches the abſciſſa; the ſtreſs on that point is the ſame as if the bearing had been perpendicular: now as ab is ſituated $3\frac{1}{2}$ inches from AC, and AB being 18 inches, the preſſure at A acts not in the direction A c, but in the courſe AC: hence the ſtreſs upon c will be as the length of the lever dc; and at b, the ſtreſs will be expreſſed by ab, as ab is $3\frac{1}{2}$ in. and dc $1\frac{1}{4}$ in. the ſtreſs at b to that at c will be as 14 : 5. If we put E $a = m =$ 10 inches $ab = n = 3\frac{1}{2}$ in. then $\sqrt{m^2 + n^2} =$ E l, ſuppoſing from the former calculation this will bear 9 times more perpendicular than horizontal, we ſhall have $\sqrt{m^2 + n^2} : m :: 9 : \frac{9n}{\sqrt{m^2 + n^2}} = 2.97.$ that is, the Spine, if perpendicular throughout, would bear near three times more weight than it will in conſequence of this curvature; at c the

ſinu curvamnis eas in partes directo: eoque thoracem ſuſtinent commodius; neque ſurgenti eorum in priora curvamini obſtant ea, quæ in ventre repoſita ſunt.—Inde ad dorſum retrorſum inclinans, leviter à ſummo inflexa eſt curvaminis ſinu directo in priora. Ac ſic conveniens eſt ad formam capacitatis thoracis: qui ex eo etiam in priora nimium non inclinat. A dorſo ſurſum in priora cervix tendit, modice reflexa recteque caput ſuſtinens, in priora quaſi pendulum. *Albin de Ratione Spinæ.*

 preſſure

preſſure will be as much again as if perpendicular, for 14 : 5 :: 2.97 : 1 nearly.

If the curvatures of all natural-formed Spines had been preciſely the ſame, it might then have been neceſſary to have more accurately aſcertained the points of inflection and retrogreſſion, and which are eaſily determined in any ſerpentine curve: as rarely two Spines exactly agree, it becomes unneceſſary to be minutely particular. Nor indeed is it of any material conſequence whether the admeaſurements here aſſumed are very exact, as the deductions will be nearly the ſame.

Here then would appear a deficiency in the form of the Spine; it would appear that great ſtrength was ſacrificed in ſuch a deviation from a perpendicular column: ſuppoſing the ſpine was ſtraight, and divided into the ſame vertebral diviſions or joints as at preſent, in almoſt every motion of the human body the deflection from the perpendicular would be greater. In thoſe poſitions where ſtrength is more peculiarly required it would become proportionally weakened; the ſame as is daily ſeen in the conſtruction of carriage wheels, the ſpokes or radii are not made to be preſſed upon perpendicularly in their common motions, but incline towards the horizon, known by the term *diſhing*; that in a caſe of neceſſity, when the carriage inclines more on one ſide, as this inclines the radii or ſpokes become

more

more perpendicular, and more enabled to bear the requisite pressure; independent of this, the motion of the body required could not be divided among all the vertebræ; if so, they must assume a curvilinear form, and consequently the body much contracted, but the joint of any single vertebra would not admit of any extensive motion, without endangering the medulla spinalis. From the beauteous form of its double curvature it preserves nearly an uniformity of strength, admits of those motory changes, without being subject to any inconvenience. Thus, viewing the Spine posteriorly, we shall find that by inclining our head backwards, so that the cervical vertebræ bend within, the dorsal vertebræ, in a proportionate manner, lose of their curvature, and approach nearer the perpendicular: here then are great advantages derived from contrary flexures admitting of motion every way without any diminution in length: although by such an inclination the stress on the cervical vertebræ is increased, yet the power of support in the dorsal is proportionally augmented.

Having thus endeavoured to point out the great advantages that are attendant on the form of the natural Spine, I shall now attempt to shew the equally good effects that arise from its articulatory divisions.

Had the Spine been one solid curvilinear pillar, only having powers of motions at each extremity,

i. e.

i. e. the atlas or ſuperior cervical being one, and the inferior lumbar the other; if ſuch were the caſe, we ſhould have been debarred of thoſe gentle declinations, thoſe little motions we are every moment making uſe of; for in every change of poſture the whole abdominal and thoracic maſs to which it is attached would undergo an extenſive change of place. In our gentle inclination forwards, we ſhould not have that accommodating curvature of the dorſal vertebræ, but the whole maſs muſt have been unwieldly moved. If the column had been divided into two or three articulations, then the whole motion of the Spine would have been divided amongſt them, and conſequently in each would have been too great for the nervous contents. It is obſerved that each vertebra will allow of the motion of about one-eighth of an inch, without compreſſing in the leaſt the ſpinal marrow. If there had been only three vertebræ, the greateſt motion the Spine would have admitted would have been leſs than one inch; as the diviſions are greater, the ſame little motion to each in the accumulated ſum will be extenſive, ſuppoſing the Spine 24 inches long, the inferior lumbar is two inches long; if this vertebra moves one-eighth of an inch, with reſpect to its joint, it will cauſe a motion in the atlas in the ratio of their diſtances from the centre, viz. $2 : 24 :: \frac{1}{8} : 1\frac{1}{2}$ viz. one inch and a half; the ſecond lumbar vertebra being two inches from its centre of motion, which

which is 22 from the atlas, then $2 : 22 :: \frac{1}{8} : \frac{22}{16}$ $=$ one inch $\frac{3}{8}$; the third lumbar vertebra is 1 . 8 inch from its centre; then $1.8 : 20 :: \frac{1}{8} : 1.4$: ſo thus proceeding with every vertebræ, according to its length, we ſhall find the atlas, with reſpect to the loweſt lumbar, will have a motion of near 24 inches, with the motion of $\frac{1}{8}$ from the latter.

It has already been remarked, that every change of incurvation of the Spine muſt occaſion a ſimilar change in the Centre of Gravity. As this is the point where the centre of action of our inſtruments ſhould be applied, the aſcertainment of this becomes an object of great neceſſity.

The Spine will ſtill be regarded as an unconnected pillar of ſupport, as perfectly abſtracted from any other part of the body to which it is attached.

Suppoſing A B to be the Spine, as the vertebræ have nearly a regular gradation, it will be more ſimple to ſelect thoſe that are at the points of inflection and retrogreſſion, the Centre of Gravity, of which will neceſſarily be the Centre of Gravity of the whole.

If C D be a plane perpendicular to the horizon, and D E perpendicular to C D, and to the reſpective vertebræ, the ordinates ab, cd, ef, gh, ij, be drawn perpendicular to C D, and the lines ak, ek, cn, gm, jn, perpendicular to D E, then we ſhall have $\frac{a^2b + c^2d + e^2f + g^2h + j^2i}{a + c + e + g + j}$ will aſ-

certain

certain the diſtance of the point, or Centre of Gravity, from the plane C D, and $\frac{a^2k + c^2n + e^2k + g^2m + j^2l}{a + c + e + g + j}$ the diſtance from the plane D E.

In order to facilitate any calculation which may be made of the powers of any of the vertebræ, I have formed a table of eight columns, in which the meaſures, extent of motion, and ſtrength, are particulariſed. The firſt column ſpecifies the vertebræ; the ſecond, the correſponding width of each vertebra; the third column the breadth. It will be obſerved, that the breadth of three cervical vertebræ is omitted, as they are ſo thin as to be mere ſhells; I have calculated their proportionate maſs, which is added to the aggregate ſum. The column ſpecifying the extent of motion ſignifies the extent of motion of each vertebra, when a general motion of the whole takes place on the laſt lumbar vertebra. The other two columns are taken from Borellus.

The

The MEASURES of the VERTEBRÆ are as follows, by a Scale of 2 to an Inch.

	Vertebræ.	*Width.*	*Breadth.*	*Depth.*	*The Depth of each considered as perpendicular.*	*The extent of Motion on the Centre of the Vertebræ of the Loins.*	*Vires Musc.*	*Vires Cartilag.*
			Of the Brim.				In a Person carrying on his shoulders 120 pounds, the exertions of the Muscles & Ligaments are as follows:	
Cervical	1	1.5	·5	1.	.6	3·742		
	2	2	1	1.25	.8	3.7		
	3	2	Shell	1.25	1.05	3.64		
	4	2	D°	1.25	1.05	3.56		
	5	2	D°	1.5	1.50	3.47		
			Of the whole					
	6	2	2	1.5	1.3	3· 4	lb.	lb.
	7	3·5	3	1.5	1.3	3.3		
Dorsal	8	4	2.9	2.6	2.08	3.2	401	1204
	9	4	3	2.8	2.24	3.04	394	1183
	10	4	3.2	3	2.4	2.87	387	1162
	11	4.2	3.8	2.9	2.32	2.69	380	1141
	12	5.	4.	2.5	2.	2.51	373	1120
	13	4.5	4.2	2.5	2.	2.36	366	1099
	14	5.2	4.5	2.5	2.	2.21	359	1078
	15	5.3	5.	2.6	2.08	2.06	352	1057
	16	5.5	5.	3.	2.4	1.939	345	1036
	17	5.5	5.	2.9	2.32	1.75	338	1015
	18	6.	5.	3.	2.4	1.57	331	994
	19	6.2	5.	3.4	2.72	1.38	324	973
Lumbar	20	7.	5.8	3.4	2.72	1.17	413	1239
	21	7.9	5.5	3.6	2.88	.958	411	1252
	22	7.9	5.6	3.7	2.98	.78	408	1225
	23	8.	5.7	4.	3.2	.5	404	1212
	24	8.	5.8	4.	3.2	.25	403	1211
		113.2	87.5	60.9	49.09	56.049	6404	19181 6404
	mean measure	4.7	3.64	2.53			lb.	25585

If we take the ratio * of the vertebræ we ſhall have $a = \frac{1}{2}$, $c = 1$, $e = 2$, $g = 2.7$, $j = 3$, and the length of the Spine AB $= 24.545$ inches, $ab = \frac{1}{2}$ an inch, $cd = 1\frac{1}{2}$, $ef = \frac{1}{2}$, $gh = 4$, $ji = 2.5$, $ak = 26$: $cl = 23$, $ek = 19$, $gm = 9$ in. and $jn = 2$ in. then the Centre of Gravity will be 2.27 inches diſtant from the plane CD, and 11.33 from the plane DE. Having thus the Centre of Gravity of the whole, and regarding the abdomen and thorax as preſſing upon that lumbar vertebra immediately on the ſacrum, the action on this vertebra will be as half its diameter is to the diſtance between its centre and the Centre of Gravity, ſo the weight of the ſuperior part of the body is to the action on this vertebra. In a common-ſized man, the thorax and abdomen, with the contents, weigh 60 lib. the head and neck 15 lib.; a weight of 75 lib. this vertebra has to remove: the diſtance between it and the Centre of Gravity is 9.2 inches; the half diameter is 1.45 inches. Hence then, as before, 1.45 : : 9.2 : : 75 : 475.8, viz. 475.8 lib. : is = to the ſtreſs on this lumbar vertebra: the ſum of the depths of the five lumbar vertebræ is 7.49 inches, and of the dorſal 13.83; ſuppoſing the weight of the body, if cut in ſections of the vertebræ, are as the depths, then 3.2 = the cervical vertebræ, if we divide the whole weight, viz. 75 lib. into ſums of ratio = 3.2,

* The ratio of the Vertebræ means the proportion the ſolid contents of the vertebræ bear to each other.

7.49,

7.49, 13.83, will give us the proportional weight on any of the vertebræ, viz. on the cervical 9.8 lib. the dorſal 42.4, and the lumbar 22.8 lib. as the head preſſes only on the cervical, this muſt be deducted; at leaſt the weight of the head muſt be added to the cervical in calculation of their ſtreſs. Any vertebra that becomes the centre of motion, as in gently raiſing the head up, or declining down, the cervical vertebræ are ſolely in action. Suppoſing to aſcertain the ſtreſs on the ſixth cervical, the weight above is = 22 lib. the Centre of Gravity, adding the weight of the head to the atlas, is $1\frac{1}{4}$ inch from the ſixth; half its diameter is .875 ∵ .875 : 1.75 : : 22 : 44. that is, this bears the preſſure of 44 lib.

The preſſure on the lower lumbar is 475.8 lib. It ought to be obſerved, that in ſolids nearly of ſimilar ſhape, the ſtreſs is as the cube of the diameter, we ſhall find that $\overline{8}|^3$ the cube of the diameter, $\overline{3.5}|^3$: : 475.8 : 44 nearly; which ſhews that the vertebræ increaſe in their ſtrength nearly in the ratio of the ſtreſs they are to bear*, or more correctly in this calculation, the weight they are to overcome, as here we have conſidered the additional weight of the abdominal and thoracic contents.

* Generaliter ſenſim tenuiores ut ſuperiores, ad dorſi decimam uſque. Poſt nonam ſequentibus, primæque cervicis, ſenſim aliquanti craſſiores: poſt cervicis primam ſequentibus quatuor aliquanto, quam ei, tenuiores, parum differentes inter ſe. His craſſiores ſextæ, his ſummæ.

Another mode of procedure would be requifite if we wifh to afcertain the Centre of Gravity of the whole body; in fact, we might regard the thorax and abdomen as one folid, connected to the Spine, and formed by a half revolution of that curve round its axis. Apprehenfive left the inveftigation hitherto entered into fhould prove too tedious, I fhall wave for the prefent any farther confideration, and immediately proceed to an examination of thofe practical deductions that thefe principles may authorife.

In a diftorted Spine, in the collection of Mr. Abenethy, of Bartholomew's Hofpital, where five inches of height are loft by the incurvation, eight of the dorfal vertebræ project fo as to be remote from the plane AB, 4 inches; the lumbar at $2\frac{1}{2}$, and the cervical vertebræ are concave exteriorly inftead of convex, and $\frac{1}{4}$ of an inch from the plane: the Centre of Gravity would be 2.16 inches from the plane, perpendicular to the horizon, and 9.17 inches from the bafe, fo that the Centre of Gravity here would be two inches nearer the loins than in a natural Spine.

Suppofing there is a collar applied to the back that entirely takes off the preffure of the head, what particular advantages will there be gained? It is furely making the moft ample allowance, if it is regarded, that by fuch affiftance the head fhall be perfectly abftracted from the body, viz. 15 lib.; then the abdomen and thorax, with their

contents,

contents, will weigh 60 lib. hence the ratio of the vertebræ will be the cervical 8 lib. the dorſal 34, and the lumbar 18 lib. The preſſure on the moſt remote dorſal vertebra, from the plane, is 30 lib.; and the ſtreſs on this vertebra is as much greater the ſtreſs in its natural form as its diſtance from the plane is to the ſimilar diſtance in the regular-ſhaped Spine, viz. 4 in. : $\frac{1}{2}$, as 8 : 1, ſo that the ſtreſs is eight times more than in the uſual curvature. By a ſimilar mode of procedure, the Centre of Gravity, in every ſtate of incurvation, is eaſily aſcertained, as well as the ſtreſs on any of the vertebræ under any peculiar ſituation. To aſcertain what force or power this vertebra muſt exert (or which is the ſame thing, the actions of the muſcles and ligaments upon it), when it becomes the centre of motion, it will be as before, the ratio of half its diameter to the diſtance from the Centre of Gravity.

It muſt then appear evident, that an inſtrument thus applied will barely take off one-third of the preſſure acting on the Spine. If the diſtortion, as generally happens, ſhould be in the lumbar vertebræ, the effect of ſuch an apparatus would be too trivial to afford the moſt diſtant relief.

Hitherto I have ſuppoſed the inſtrument, or collar, to entirely take off the ſuperincumbent preſſure, without ſubjecting the patient to any inconvenience: when we reflect on the violent preſſure

preſſure that is made on the temples, when that interruption is given to the circulation in the temporal arteries, it can no longer be wondered at thoſe violent head-aches which are induced, that renders the uſe of them for more than an hour or two inſupportable: and ſurely no good effect can be expected from ſuch, where a permanent application is ſo impracticable. It would be abſurd to expect, that either from theſe, or the ſwing chairs ſo comparatively momentarily uſed, that a tendency to a diſtortion could be removed, or even prevented in its increaſe. Hence no good effect can poſſibly ariſe by the application of inſtruments, where only for a ſhort time the preſſure of the head can be removed, and which even when accompliſhed is ſo inconſiderable a part, that the benefit muſt be trivial. As in general, complaints of this nature are connected with a ſtate of debility, all powers of reſtoration are here checked by that motion being deſtroyed neceſſary for an invigorating circulation. The head is kept in a fixed pillory-like poſture. Still worſe are the conſequences attendant on braces, acting violently on a weakened column, or a debilitated Spine, ſo powerfully preſſing on the vertebræ, as in many caſes to have induced a lumbar abſceſs: indeed this mode of practice is not much remote from that of a ſurgeon, told us by Kerkringius, who attempted by violence to force back a diſtortion of the vertebræ, and thus

inflicted

inflicted excruciating tortures on the fuffering female, ignorantly imagining it was a luxation.

As I have thus prefumed to cenfure the principles of thofe inftruments at prefent ufed, I will curforily fuggeft the conftruction of fuch as are agreeable to the theory here laid down.

Suppofing I am applied to in a cafe of diftortion of the lower dorfal vertebræ. To merely take off the preffure of the head, the relief would be inconfiderable; although the collar is fupported on the ftays, yet ultimately there is the fame degree of preffure on the dorfal vertebræ: whatever weight may be fupported by the collar, the reaction of the fupporting inftruments is always equal. In the conftruction of an inftrument we fhould be careful that the fuperincumbent weight on the difeafed part of the Spine fhould be perfectly removed, and that there fhould be no action of the inftrument fuperior to the Centre of Gravity of the Spine. By fupporting that point which has a tendency to defcend towards the earth, we fupport the whole fyftem. From what has been previoufly obferved, the afcertainment of this point, in every ftate of diftortion, is noways difficult; and for want of this attention is entirely owing the improper inftruments that are at prefent adopted. This may forcibly be illuftrated by analogy. If a garden wall fhould be in fuch a ftate as to require fupport, fhould we not be regulated in our application of fuch fupport by the

the poſition of the weakened part. If the wall bulges ſuperiorly, in the middle, or towards the foundation, we ſhould not, in all theſe circumſtances, make uſe of the ſame ſupport. The experienced architect will immediately aſcertain that point where there is the greateſt ſtreſs, and apply his ſupport accordingly. Thus we ought to act with regard to the Spine, and not in every caſe of diſtortion uſe one and the ſame inſtrument.

I hope I ſhall hereafter have an opportunity of giving repreſentations of the different inſtruments that I may experience the moſt beneficial; I am fully aware what difficulties there are to encounter in attempting to reconcile practice to theory; yet I hope I ſhall never be ſo much warped by the latter as to prevent me adopting every improvement that may occur to me in the former.

After this little attempt of an examination of the aid that can be afforded by mechanical contrivances, it may not be improper to make a few obſervations on the different cauſes that may induce diſeaſe of the vertebræ, and which muſt neceſſarily influence our practice.

The vertebræ frequently become diſeaſed by ulcerations originating within themſelves, or in the neighbouring parts, or in conſequence of any permanent preſſure from the coagula of an aneuriſm, or from the influence of external violence. As in general a patient experiences at firſt a conſiderable rigidity ſome months before any apparent

parent alteration of the Spine, we ought then to be active in diminiſhing every internal inflammation, and in taking off the ſuperincumbent preſſure. Thus we may probably prevent any ulceration, or the formation of any lumbar abſceſs*; as well as any increaſe of incurvation.

As in general a diſtortion of the Spine is ſlow and gradual in its progreſs, and the incurvation lateral, more frequently occurring to children under ten years of age, that ſeems to ariſe from an imperfect oſſification: as we know that the baſis of bones is formed by the union of the phoſphoric acid with animal calcareous earth; hence it has been conjectured by ſome that there might be a deficiency of calcareous matter, as it is obſerved in ſuch conſtitutions that there is a conſiderable more earthy depoſit in the urine; and this in proportion to the deſtruction of the ſolids.

It has farther been ſuppoſed, that ſuch could only ariſe from a defect of phoſphoric acid, and conſequently its exhibition might prove beneficial: the ſame as has been thought by ſome to be the cauſe of the formation of the human calculi, which are found more ſoluble in phoſphoric acid than in any other.

* Vide Abenethy's Eſſay, replete with accurate and judicious obſervations.

In the Memoirs of the National Society of Medicine at Paris, Monſ. Bonhomme has propoſed another theory, replete with great ingenuity: the experiments, as well as obſervations, upon which the author grounds his inferences, preſent to view matters of fact, ſufficiently remarkable to afford a preſumption that new experiments will confirm their truth. He ſuppoſes that the nature of the rachitic diſorder ariſes, on the one hand, from the developement of an acid approaching in its properties to the vegetable, particularly the oxalic; and on the other, from the defect of phoſphoric acid.

He endeavours to prove, that the calcareous phoſphate is wanting in the bones of thoſe who are diſordered with rachitis, and that the developement of the oxalic acid is the cauſe of this alteration.

In this reſpect he is aſſiſted by an analyſis made by Hallé, and which is inſerted in the ſeventeenth volume of the Annales de Chemie.

Upon theſe principles he endeavours to demonſtrate the utility that ariſes from the topical application of alkaline lotions, and the internal uſe of calcareous phoſphate, whether alone or combined with the phoſphate of ſoda: ſuch he ſays will powerfully contribute to reſtore the natural proportions in the ſubſtance of the bones, and accelerate the cure of rachitis.

It

It ought to be obferved, the author modeftly prefents his ideas in this refpect, merely as conjectures approaching to the truth.

He feems to have no other proof of the exiftence of this oxalic acid than from there appearing in fuch children a want of bile, which corrects the difpofition to acefcence, and for want of which they are neceffarily developed, difturb the circulation, and attack and foften the bones.

When, however, it does appear that a diftortion originates from an imperfect offification; when, from want of its earthy fupport, the Spine, unable to bear the fuperincumbent preffure, bends from its ufual courfe, and becomes unnaturally incurvated, then every mode of treatment that can reftore tone to the fyftem, that can invigorate the finking frame, or ftrengthen the debilitated foundation, fhould be adopted: even if it be granted that fuch is occafioned by the union of the calcareous animal matter, and phofphoric acid, being deftroyed, it appears to me difficult to conceive how the exhibition of either the one or the other can tend to its reftoration. The operations of vital parts are not reducible to chemical laws; their functions are not explicable on the doctrine of gafes, nor are their principles to be determined by the retort or the crucible. Chemiftry, as a fcience, is great and valuable; by it the fimple operations of matter may be developed, and their various ftates of combinations unfolded.

When by ſuch, the laws of that principle, which come not under the definition of matter, are attempted to be explained, then the fallibility of this ſcience is evinced. I am apprehenſive that ſuch endeavours may ultimately involve this noble branch of philoſophy into diſgrace, and again return us to the Paracelſian period, when it was imagined by this eccentric experimentaliſt that religion was a combination of ſalt and ſulphur.

Thus it is I have but little hopes that the exhibition of phoſphoric acid could any way tend to remove the defect of it in the conſtitution. I ſhould prefer rouſing the languid ſyſtem into a ſtate of healthy action by the moſt generous liquids and nutritious ſolids; to give that ſtimulus to the powers of life, that the ſecretions may be healthy and vigorous: then, and not till then, the arterial ramification will depoſit the proper oſſific matter. In general it is obſerved, that ſuch incurvations are peculiar to children, where there is reaſon to ſuppoſe ſuch an enlargement of the meſentric glands as to prevent the chyle entering the thoracic duct: thus there is a greater quantity of ſolids removed than what is ſupplied. The bones forming cavities, containing the viſcera, not having their loſs renewed, undergo great changes: the ribs, inſtead of forming an arch, gradually bend inwards, inſtead of being curved, are flattened laterally, and conſequently more prominent anteriorly. In ſuch a caſe all our efforts would be

in

in vain till thefe obftructions are removed: gentle mercurial dofes, fea-bathing, animal food and wine, frequently will produce the moft happy effects.

When, however, there does not appear fuch a caufe, it probably may arife from thofe veffels that ufually depofit this offific matter not being in a proper ftate of dilatation. This is obfervable in the offific progrefs that takes place in the union of fractured bones; an inflammation is then neceffarily induced proper for the vafcular dilatation. When thofe veffels that are unaccuftomed to the tranfmiffion of red blood, when from any particular caufe the red globules are impelled therein, and ftimulate them to that action called inflammation, not only is there found an increafe of offific fubftance on the outfide of the bone, if long continued, the cancellated interftices fo replete as to render the bone as folid as ivory.

Thefe obfervations I have prefumed to fubmit to the public, with a view of preventing thofe injuries that fo generally enfue from ill-contrived braces, and other formed inftruments, applied by thofe who can have no knowledge of the laws of the animal œconomy. In cafes where fuch an acquifition is requifite, where the theory of mechanics fhould be combined with fome phyfiological information, where the benefit of exterior fupport fhould be united with proper interior treatment, that while affiftance is derived from the former,

the

the conſtitution ſhould be ſtrengthened by the latter: in ſuch an important branch, where more than common attention is requiſite, it is a profeſſional opprobrium that ſuch ſhould be relinquiſhed to ſtay-makers, or menial mechanics, whoſe knowledge it cannot be expected can be much more than the ſewing of dimity, or the ſcraping of whalebone. In my opinion applications to perſons of this deſcription, in caſes of this nature, are equally abſurd as a man to requeſt any of the royal phyſicians to make him a pair of breeches.

CHAP.

CHAP. II.

ON THE MOTIVE POWERS OF ANIMALS.

Lex perpetua naturæ eſt, ut agat minimo labore, mediis & modis ſimpliciſſimis, facillimis, certis & tutis, evitando quam maxime fieri poteſt, incommoditates & prolixitates.

IT is not here preſumed, upon the principles of mechanics, to aſcertain the velocity of any animal, for in ſuch, powers are concerned that come not within the ſcope of calculation. All that is here attempted is to aſcertain the maximum of extent that any animal, by any ſingle exertion, can cover.

It is here ſuppoſed, that the motion of an animal is regulated by the different angles the joints are capable of performing, but the repetition of ſuch motions which conſtitute the velocity is ſo dependant on the powers of the muſcles, and conſequently vital energy, as not to be reducible to any number.

To

To the aſcertainment of this, Borellus ſeems not to have devoted his ſuperior abilities, although he has given us five propoſitions De Inceſſu Quadrupedum, and twelve De Saltu: his enquiries went no further than to calculate the powers of muſcles in every different poſition.

Neither in the works of the Duke of Newcaſtle, Bellinger, or Bourgelat, although profeſſedly written on horſes, has any attention been paid to this. In an Eſſay by Monſieur St. Bel (on the motive powers of Eclipſe), late profeſſor of the Veterinary College, there ſeems a ſomething like a confuſed attempt. Confuſed, I ſay, becauſe I verily think the compoſer of ſuch a work could never have wiſhed its being peruſed by any one the leaſt converſant with the principles of mechanics.

In the firſt place, Monſieur St. Bel has endeavoured to prove that the flexions and extenſions of the joints of the fore parts are preciſely equal to thoſe behind, viz. the ſum of the motions of the anterior articulations equal to 360°, and ſo of the poſterior. Then he ſays, " by " examining the length and direction of his legs, " and the greatneſs and openneſs of the angles, " formed by the alternate diſpoſition of the bones " which compoſe his extremities, pronounce with " the greateſt probability that Eclipſe, free of all " weight, could cover an extent of twenty-five " feet; that he could repeat this action 2 $\frac{1}{3}$ times

" in

" in each ſecond, and conſequently could run " four miles in the ſpace of ſix minutes and two " ſeconds."

Where are the data from whence theſe inferences are made? I ſee no grounds for ſuch deductions; no other foundation, than that the author has heard *Eclipſe* could cover ſuch an extent of ground, and that he could run four miles in ſix minutes two ſeconds: hence it was very eaſy to aſcertain the number of exertions in any particular time, as it was only dividing the ſpace ran through by the extent covered at once.

For what purpoſe the diſplay of accuracy of admeaſurement, and the envelopement of Eclipſe in circles, I know not, unleſs the ingenious writer thought of eſtabliſhing his fame by a pompous attempt under the appearance of geometry

Parts of this Eſſay merit ſome attention, as far as regard the proportions of *Eclipſe*; and would have been more valuable, had the angles of extenſion and flexion been diſtinguiſhed. I am apprehenſive that in this point there has not been a perfect degree of accuracy, that it has been fancied pleaſing, that the ſums of the various circular portions the joints deſcribe ſhould anteriorly, as well as poſteriorly, form complete revolutions, and as ſuch impreſs a curſory obſerver with an idea of extenſive beauty in their formation: with ſuch a view a little truth appears to me to have been ſacrificed; in this opinion I feel myſelf ſomewhat more confirmed from the admeaſurements I have taken of Eclipſe, by the permiſſion of the gentleman in whoſe poſſeſſion he is. It might at firſt appear, that an equality exiſting between the motive powers of the joints of the anterior and poſterior parts was abſolutely requiſite; ſo with propriety it might be thought, had there been a conſonance in the lengths of the different limbs, and of the angles in which they naturally are: as theſe vary conſiderably, they never could have ultimately coincided, unleſs there was a correſponding variation in their angles; this will be evidenced by the following table:

ECLIPSE.

FORE PARTS.	Length in Inches.	HIND PARTS.	Length in Inches.
Scapula meaſured from its Spine, without the Cartilage - - -	14	Spine of the Ileum to the Acetabulum -	10
Humerus - - -	11½	Femur - - - -	14½
Cubitus, or Fore Arm	15	Patella - - - -	3½
Carpal Bones, 6 in number, being 3 in a row - - - -	2	Tibia - - - - -	15
		Hock, or Calcaneum	5½
		Five tarſal Bones -	1½
Canon - - - -	10	Canon - - - - -	12
Paſtern and Coronet -	6	Paſtern - - - -	8
Inches	58½		

The Spine of the Scapula from the fore feet meaſures 54 inches, ſo that $58\frac{1}{2} - 54 = 4\frac{1}{2}$ inches loſt by the curvature of the fore legs: from the acetabulum to the hind feet is 53 inches, ſo that nine inches are loſt by the curvature of the hind legs.

In the firſt place, I ſhall examine what extent of ground an animal formed like Eclipſe could cover with reſpect to his fore legs, ſuppoſing for the preſent that his hind legs had no flexible powers, were ſtiff ſupporting-like columns. I afterwards ſhall attempt to inveſtigate what powers are derived from the formation of the poſterior parts, regarding the fore legs as inflexible pillars. By this method of proceeding, I flatter myſelf, by ſeparately aſcertaining their powers, the effect which would ariſe from their united efforts may eaſily be determined.

The ſcapula in quadrupeds poſſeſſes a degree of motion round its centre much greater than in the human ſpecies, or thoſe animals who uſe their fore feet like hands, and conſequently have a clavicle, which horſes, dogs, &c. have not.

Thus it is, that the muſcles appertaining to the ſcapula have different attachments in theſe different animals; as in the human ſpecies the *trapezius* ariſes from the occipital bone backwards, while in horſes it originates from all the *ligamentum colli* which is below the riſe of the *levator humeri proprius*: in quadrupeds there are two elevatory

muſcles

mufcles of the fcapula, levator major and levator minor.

Thus unreftrained by a clavicle, the fcapula has a motion round its centre, in its greateft extent, of 20 degrees, and is inclined to a plane perpendicular to the horizon in an angle of 30 degrees: when the leg is extended, the angle will be 50° with the plane.

The angle the humerus forms with the fcapula towards the body is 120 degrees, and is capable of being extended 50°; hence will only form an angle of deviation of 10° from the continuation of the fcapula.

The cubitus forms an angle exteriorly, or from the body, of 130° with the humerus; and in its extenfion can be brought 40° nearer, fo as to form a right angle with that joint. The canon is nearly in a ftraight line with the cubitus, and bends inwards, fo as to make a regular curvature, in gallopping, with the cubitus.

The paftern, coronet, and foot, form an angle of 45° with a plane perpendicular to the horizon, when in motion are in the fame curvature with the canon.

A little confideration of thefe circumftances will point out many beauties in the admirable ftructure of the fore limbs. We find that alteration takes place in their direction, fo as to poffefs ftrength when ftrength is required, and freedom of motion when velocity is neceffary.

In

In the inactive ſtate of the horſe the limbs have no other weight to bear than the mere gravity of the ſuperincumbent matter. When the momentum is increaſed by the rapidity of their motion, when they bound forwards with amazing ſpeed, and ſtrike the earth with a proportionate degree of force, how admirably arranged are all the joints to ſupport the combined effects of action and re-action. The inſtant before the ground is preſſed by the foot, the cubitus relaxes of its elevatory ſtate, and falls within the line of curvature of the ſcapula and humerus. The canon and paſtern all unite, ſo as to make from the centre of motion of the ſcapula a continued kind of bony arch, except the deviation of the paſtern, which forms at the moment of preſſure an angle of 45°, nearly parallel with the ſcapula, and conſequently the beſt calculated for bearing the preſſure of the body when the whole weight is thus thrown forwards. When this angle is greater, the ſtreſs muſt be greater alſo, and conſequently an imperfection of debility in the horſe.

As then it appears that the horſe ſtrikes the ground with its fore feet in the continued degree of curvature of the ſcapula and humerus, the angle formed with the plane perpendicular to the horizon, will neceſſarily be the ſine of the extent of ground, in this point of conſideration, the animal will cover: as the vertical angle is 50°, the cathetus 54 inches, the baſe will be 67 inches,

and

and which is the ground the horſe would cover, ſuppoſing the poſterior columns or legs have no powers of flexions; ſimilar to a man being thrown forwards, the ground he would compaſs would be regulated by the extenſion of the arms.

ON THE MOTIVE POWERS OF THE HIND LEGS.

It has already been obſerved, that the hind legs in no reſpect correſpond to the fore; every articulation is not only different in length, alſo differently inclined to each other: if there was that coincidence Monſieur St. Bel has aſſerted, there would be great irregularity of motion. In the firſt place, the ilium is inclined to the perpendicular to the horizon, in an angle of 50°, while the ſcapula only inclines 30°. The femur forms an angle towards the body with the ilium of 120°. The tibia forms poſteriorly, or from the body, an angle of 120° with the femur. The calcaneum, or hock, an angle of 40° with the femur, and conſequently the canon, an angle of 140° towards the body, with the tibia and the paſtern, and 50 degrees from a line perpendicular to the horizon.

It is ſaid that Eclipſe's hind legs were ſometimes more forward than the anterior limbs: this appears improbable, that the hind feet ſhould ever advance beyond the line of direction, which

is

is ſituated 27 inches from the poſterior limbs, being the line as paſſes through the Centre of Gravity of the animal to the centre of the earth. It will eaſily be ſeen what will be the ſituation of the limb the inſtant before the motion of the body: the curve deſcribed by the hind legs will neceſſarily be reverſe to that delineated by the fore; it will in the former caſe be concave towards the horſe, while in the latter it is convex. The meaſure of this curve will be from that point of the earth where the line of direction falls, to where the curve terminates by the extenſion of the legs behind. The femur can bend forwards towards the body 30 degrees, and poſteriorly 20°. The tibia can bend backwards 60 or 70 degrees; its anterior motion is not more than 20°, in conſequence of being reſtrained by the patella. The canon will admit of 40° flexion forwards, in ſome reſpects is checked by the tarſal bones, and poſteriorly will only allow of 30° motion, in conſequence of the calcaneum.

From the above ſtatement it muſt be evident that the poſterior articulations can never fall in the ſame uniform curve as the anterior; on this account they are neceſſarily made much ſtronger: the extenſor muſcles which act upon the *calcaneum* are removed farther from the centre of motion, and conſequently act with increaſed power. The horſe, previous to his progreſſive exertion, brings his tibia forwards 20°, and the canon 40 degrees; theſe thefe actions will bring the foot to the point of direction, which falls in the middle between the centre of motion of the fcapula and the acetabulum; thefe being from each other 43 inches, fo that the line of direction is $21\frac{1}{2}$ inches from each. The angle that will be formed by the centre of motion of the acetabulum, with the point of direction, and a line perpendicular to the horizon, and paffing through the acetabulum, will be 33 degrees. From the acetabulum to the ground being 54 inches, in this flexion the horfe muft fink confiderably, as the canon is much more bent than what the tibia is ftraightened, fo the perpendicular height is confiderably lefs; this is eafily afcertained, and by the additional bending of the paftern, fo that the diftance between the acetabulum, and the point of the ground cut by the line of direction, is not more than 50 inches. This is the meafure of the hypothenufe, and $21\frac{1}{2}$ being that of the bafe, then $\overline{50}|^2 - \overline{21\frac{1}{2}}|^2 =$ to the fquare of the perpendicular, 46 inches nearly, fo that the inftant previous to the bound forwards, the horfe finks down eight inches.

In the utmoft ftate of extenfion pofteriorly the humerus will decline from the perpendicular line 10°. The tibia, forming a right angle with the humerus, will neceffarily be 80° from the perpendicular plane; the canon 20° pofteriorly, fo that the calcaneum will only form an angle of 20° with the tibia, and confequently an angle with

 the

the plane of 60°, and the paſtern, in the ſame line with the calcaneum; this will be the meaſure of the angle of extenſion, which, added to the angle formed by the acetabulum to the point the line of direction cuts, will make, with this line, nearly a right angle: hence then $\sqrt{\overline{50}|^2 + \overline{48}|^2}$ will be equal to the extent deſcribed by the hind feet, equal to 68 inches nearly; as in the extenſion backwards the diſtance from the acetabulum to the extremity of the paſtern is 48 inches, which is eaſily aſcertained, as the lengths of the articulations are known, and the reſpective angles of flexions given.

It might perhaps be here objected, that the arch deſcribed by the hind legs is a very inadequate meaſure of the progreſſive advance of the horſe, in conſequence of ſuch a motion. Surely it will be granted, that if the limbs poſſeſſed no flexible articulations, that an animal would be very limited in its tranſlatory powers, therefore in a great meaſure muſt be regulated by theſe; the muſcles can by their action overcome the weight by powerful contractions, can with great force extend the limbs, and with great velocity, for a certain time, repeat their motions.

In the fore limbs it was obſerved, that the paſtern was parallel to the ſcapula; ſo in the hind legs, when brought under the horſe's body, the paſtern is parallel to the femur. If there had not been this obliquity in the paſterns, the animal

would

would be in continual danger of falling; in the firſt motion, when the feet are brought under the body, they are little more oblique; the line of direction falls within the baſe of the legs: as the animal riſes, the Centre of Gravity changes, the obliquity of the paſtern diminiſhes, yet the ground is preſſed by the whole foot: if there had been no obliquity, the horſe, inſtead of being ſupported on all the baſe of the foot, would occaſionally be thrown on the edge, and horſes thus formed are continually tripping.

In the inveſtigation of the motive powers of the fore limbs it was deduced, that Eclipſe, without any aſſiſtance from his poſterior legs, could cover an extent of ground equal to 67 inches; and the hind legs, independent of the fore, nearly 68 inches: it appears why an animal thus formed ſhould have an equalized motion from a coincidence in the moving powers, and which could never have been the reſult of ſimilar extenſion in the fore and hind parts, when previous to the action there is ſo great a difference. Had the hind legs poſſeſſed ſtill more powers, the action of the fore legs could never have exactly correſponded, and the motion of the animal would be only a ſucceſſion of jumps, and not a regular equalized change of place.

The increaſe of motion, in conſequence of theſe being united, will be their products; ſuppoſing there were only one articulation in the fore limbs, the hind legs would have had an advantage equivalent to the power of the anterior joint; fuppofing a reprefents the power of one of the anterior joints, b the fecond, d the third, e the fourth, &c. and let p be the whole power of the hind limb, then $\overline{p \times a} + \overline{p \times b} + \overline{p \times d} + \overline{p \times e} = p \times \overline{a + b + d + e}$, as p is the power of the hind leg, and $\overline{a + b + d + e}$, the fum of the powers of the fore parts: hence the one multiplied by the other will give 31 feet, the meafure from that point where the hind feet were placed to where the fore feet fall, as the line of direction is 27 inches from the fore limbs, and which being deducted from 31 feet, will leave 28 feet 9 inches for the maximum of extent of ground an animal formed like Eclipfe could cover.

Thofe who have obferved the motion of this celebrated beaft, have well affured us, they have meafured an extent of 25 feet he has actually covered. If fo, it is not to be fuppofed, at that very inftant, his greateft powers were exerted; fo that the above deduced from calculation evinces a near coincidence of practice with theory.

It has been fuppofed by fome, that the gallopping of a horfe is nothing more but a feries of fucceffive leaps, and as fuch folely dependant on mufcular exertion, as the leap of a biped, and therefore no ways regulated by the articulations.

A little

A little enquiry will ſuffice to ſhew, that in the exertion a man makes in elevating himſelf above the ground, that the joints are principally concerned, in vain would a man attempt a leap without previouſly having his joints in a ſtate of flexion—" Saltus non fit, niſi prius articuli pedum inflectantur." This we may illuſtrate after Borellus, by the experiment of a bow; if in the bending of it, one end reſting on the ground, and the other preſſed vertically by the hand, till it has acquired a conſiderable curvature; if the hand is ſuddenly removed, not only the bow reſumes its former ſtate, alſo leaps up in the air: ſuppoſing the bow 5 feet long, and uniform in thickneſs, the Centre of Gravity is neceſſarily the centre of the bow, viz. 2½ feet from the ground; when preſſed down, the Centre of Gravity is forced downwards to be a foot nearer the ground; the re-action of the earth, when the preſſure is removed, will cauſe it proportionally to aſcend.

Thus in a man the Centre of Gravity is in the loins; in taking a leap, the thigh and legs are ſo bent, that the Centre of Gravity becomes nearer the ground by the length of the thighs; the limbs being ſuddenly extended, by the re-action of the pavement, the Centre of Gravity is cauſed to aſcend, and thus conſtitute a leap.

The leap is therefore in proportion to the length of the limbs, and the velocity to the ſpaces they move through in the ſame time. Thus alſo a leap

is

is increafed by previous running, thefe actions unite in their effects. The impetus that is acquired is no way counteracted by the neceffary declination for leaping: hence co-operating, the refult is greater. As men alfo can afcend up a declivity by running, when it would be inacceffible by attempting to mount flow.

Thus cæteris paribus, the leaps of men are in the ratio of the lengths of their limbs. With refpect to bulk, fmaller animals can leap the fartheft; a horfe can rarely rife above 8 feet perpendicular height, and a fmall dog not $\frac{1}{50}$ in bulk, will clear a gate of 4 feet: as Galilæo obferves, "Quod in corporibus animalium propor-
"tionaliter decrefcentium minuitur pondus in
"majori proportione, nempé duplicata refiftentiæ
"& roboris eorum: & ideo offa majorum ani-
"malium craffiora fieri debebant, ut fuo robore
"incrementum ponderis fuftentare valerent. Et
"hinc fit, ut animalia vafta, quæ corpus valdi
"ponderofum habent, minus vivacia, & minus
"agilia fint, quam exigua animalia."

De Motu Locali.

Thofe who wifh to be informed of the amazing power of the mufcles in a leap, may confult Borellus; where he has demonftrated, that the power of all the mufcles united in a man weighing 150lb. equal to 435,000lb. or in the ratio to the weight of the man, as 2900 : 1.

The

The leaps of frogs, grafshoppers, crickets, fleas, &c. depend entirely on what has already been obferved, viz. the greater length of their hind legs with refpect to their fore, and a fimilar investigation will eafily afcertain the extent of their leaps.

Some infects, as the cheefe maggot, have great power of leaping, without any apparent articulations; when more accurately obferved, the reafon is evident; the infect when difpofed to leap joins its head and tail together, contracts its body in a fmall compafs, and by a fudden extenfion raifes itfelf up to a confiderable height, fome will elevate themfelves 15 or 16 inches; while in this procefs, when obferved through the microfcope, they feem to have a power of fecuring their tail with their mouth, while the body is contracted. When they are difpofed to move horizontally, they lay their bodies flat on the table; when perpendicularly, the body is elevated for the purpofe.

ON THE MOTIVE POWERS OF THE ELEPHANT.

When we obferve an elephant move, it is not a contemporaneous motion of all the limbs, but fucceffive movements of different parts—not by irregular

irregular ſtarts, *non vacillans & ruinoſa, ſed firma & ſtabilis.* When inactive, he ſtands firm on his four legs, which ſupport him like pillars, forming a quadrilateral figure, the line of direction falling nearly within its centre; when he begins to move, it is with his hind leg firſt; if his left hind leg, his body is impelled forwards, ſo that the Centre of Gravity makes a proportional advance; as ſoon as this is effected, the left fore foot is raiſed, and eaſily brought forwards: then the right hind leg ſtill further impels the animal and afterwards the right fore leg.

It muſt appear evident, that the elephant, as well as all quadrupeds, in walking, the body muſt be ſupported by more than two columns; yet we often ſee repreſented in ſtatues and paintings a walking horſe, with two diametric oppoſite feet elevated.

In this caſe the motive powers of the animal will only be the ſum of the extent that can be covered by the fore and hind legs of both ſides; their motions not being ſimultaneous, the progreſſive powers of each are independent; thus uninfluenced, the velocity will only be the reſult of theſe added. By the kind aſſiſtance of my friend, Mr. John Parkinſon, I had an opportunity in his valuable muſeum (the Leverian) of taking the admeaſurements of different animals; the elephant in his poſſeſſion meaſures 99 inches from the

the withers, and 94 from the ſhoulder to the foot, and from the centre of motion of the ſcapula and femur to the ground, 84 inches. Theſe animals have very little powers of flexion in their knees, ſo that each limb may be regarded as a lever, deſcribing a ſpace proportionate to its diſtance from the centre of motion.

Each limb appears not to poſſeſs more motion than 30 degrees; no animal, not even man, deſcribes more in walking than half the radius, conſequently the progreſſion will be 42 inches* $\times 4 = 168 = 14$ feet, the extent of ground the elephant will paſs over after one motion of all his feet, being nearly twice its length: if theſe motions are repeated quick, they would be nearly equal to the gentle gallop of a horſe: if they move their limbs but once in a ſecond, will be 9 miles in an hour.

HIPPOPOTAMUS.

This animal can only walk, as its knees are nearly inflexible; its motion is ſlow, from the limbs being ſo ſhort in proportion to its ſize. In height, is 54 inches; from the centre of mo-

* As the radius or diſtance from the centre of motion to the ground is 84 inches, and always equal to ſixty degrees, conſequently $\frac{84}{2} = 42$ will be equal to thirty degrees, or half radius.

tion of the ſcapula to the fore feet, 32 inches; breadth of the foot, 6 inches; from the acetabulum to the hind foot, 32 inches. If the angle of extenſion be 30°, or half radius, the ſpace paſſed through by the motion of one foot will be 16 inches; which multiplied by $4 = 64$ inches, not much more than the length of the animal, ſuppoſing the actions of the muſcles of this and the elephant equal, the latter would go through nearly three times more ſpace than the former, about 3 miles and a half in an hour, while the elephant, by the ſame number of motions, would paſs through the ſpace of nine miles.

GREENLAND BEAR.

From the centre of motion of the ſcapula to the foot, is 24 inches; in height, 35 inches: hence, as above, in walking $12 \times 4 = 48 = 4$ feet: the whole being moved once in a ſecond, the animal would walk 2.7 miles in an hour.

ELK.

After the majeſtic walk of the elephant, and the ſlow ambulatory ſtep of the hippopotamus and Greenland bear, the motion of the elk, the ſwifteſt of animals, will come under examination: from his ſhoulder to his foot, the elk meaſures 63 inches, and

and to his knee 40; the withers to the ground, 68 inches; from the acetabulum to the hind feet, 63 inches, and the calcaneum forms an angle of 80 degrees: from these admeasurements, proceeding the same as with the horse, the extent of ground this animal can cover in one bound will be 34 feet, nearly, if repeated as often as Eclipse, about 55 miles in an hour.

THE POWER OF BIRDS IN FLYING.

Birds, from the nature of their structure, are specifically lighter than man or quadrupeds, and six hundred times heavier than the fluid in which they float; the wonderful powers they have of ascending and descending in a medium so comparatively rare, some enquiries into the cause may not prove uninteresting.

The Centre of Gravity of a bird is situated a little beyond the wings, and a small degree lower than the point of suspension, viz. that point which is the centre of a line passing through the attachments of the wings: if this were not so, the body would not be kept more in the position of the feet downwards, than the feet upwards: "Concedendum est, quod centrum gravitatis existit in aliquo puncto perpendicularis ad horizontum posito infrà punctum suspensionis;" the same as is well known to be a requisite in an accurate pair of scales, if the centres of motion and gravity coincided,

cided, the beam would remain in any given poſition, inclined as well as horizontal, becauſe the centre of gravity being then the centre of motion, any change of direction of the body could never induce any change in the centre of gravity: hence in birds it is neceſſary it ſhould be placed a little below the centre of motion, that the feet may always preſerve the downward poſition; yet not much lower, for power would be loſt in proportion to their diſtances. It muſt neceſſarily be allowed, that their wings are placed in the very beſt part, to balance their body, and to give a ſwift progreſſion; when they ſtrike downwards, they expand their wings to the greateſt breadth by the action of their large and extenſive pectoral muſcles. "Pectorales "muſculi hominis flectentes humeros, parvi & "parum carnoſi ſunt, non æquant 50am aut 70am "partem omnium muſculorum hominis. E con-"tra in avibus, pectorales muſculi vaſtiſſimi ſunt, "& æquant, imo excedunt, & magis pendent, "quam reliqui omnes muſculi ejuſdem avis "ſimul ſumpti." *Borell.*

When the ſtroke is over, the bird does not return his wings in the ſame expanded ſtate; if ſo, the action and re-action would deſtroy each other; they are contracted, and ſo inclined, that their edges only are expoſed to the aërial reſiſtance, and which muſt be comparatively ſmall. If the bird be diſpoſed to turn his courſe to the left, he ſtrikes ftrikes the air with a proportionate greater force with the right wing; when he wants to rife, his tail is raifed upwards, in order to diminifh the refiftance, and to fall, it is depreffed. Willoughby, Ray, and many other phyfiologifts, imagined, that the tail was a kind of rudder, to fteer and turn the body in the air. Borellus, however, fuppofes, that it is more to affift in afcents and defcents, and to obviate the vafcillations of the body*. "Non "negabo tamen, quod cauda in avibus reverà "ufum & facultatem temonis exerceat, fed dico "quod inferviat ad flectendum curfum volantes "furfum & deorfum."

In this calculation we will take the largeft of the hawk kind, viz. the Cuntur of Peru, erroneoufly called by the Spaniards Condor, fuppofed to be the Roc of the Arabian Nights. The fine one in the Leverian Mufeum meafures 15 feet from end to end of the wings, in weight about 60 pounds. It has been obferved by Emerfon and others, that birds of this clafs will fly more than one thoufand feet in a minute of time, about 17 feet in a fecond of time. It muft evidently

* Infects that have not the advantage of a tail, and are bipennated, have poifes joined to the body under the hinder part of their wings—fuch as have four wings, or wings with *elytra*, have none, fuch as fcarabs and ftaphilini of all forts.

The that has a very fhort tail, its head and long neck would overbalance the hinder part of the body;—their long legs are extended in flight to counterpoife the whole.

appear,

appear, that the portion of air each wing acts againſt will be a ſegment of ſphere, whoſe radius is the length of the wing: each wing moves in general through one-fourth of a circle; if the body of the animal is $1\frac{1}{2}$ foot in diameter, then the extent of each wing will be $\frac{15-1\frac{1}{2}}{2} = 6.75$ feet; as both paſs through the ſame ſpace, the aërial maſs they act againſt muſt be equal to half a ſphere, whoſe radius is 6.75 feet. If $a =$ 13.5, the diameter of the ſphere .7854 $= b$, the area of a circle whoſe diameter is unit, then we ſhall have $\frac{a^2 \times b \times 4 \times \frac{a}{6}}{2} =$ to the ſum of ſolid contents of theſe two ſegments. As the ſolidity of a ſphere is well known to be equal to the ſurface multiplied into one-third of the radius, and the ſurface four times the area of a great circle, the whole being divided, will be half the ſphere $=$ to the ſolid contents of the two ſegments, equal to 644 cubic feet; a cubic foot of air weighs near 12 ounces; ſo that 644 feet will weigh 483 lb. It is already obſerved, that the bird moves about 17 feet in a ſecond of time; the force with which the air will act againſt a body in ſuch a motion will be meaſured by that ſpace through which a body muſt fall to acquire this velocity. It is eaſily demonſtrated that a body would fall through the length of a pendulum in a period which bears the ſame proportion to a time of its vibration, as the circum-

circumference of a circle is to its diameter multiplied by the ſquare root of 2, a pendulum 39.126 inches long ſwings ſeconds; then 27.009 thirds = the time required to fall in vacuo through ſuch a length. Suppoſing the velocity, viz. 17 feet, $= a$, the time $= b$, 16.09 feet $= c$, then we ſhall have $\sqrt{c} : 2\sqrt{b^2} :: 2c : \frac{2c \times 2\sqrt{b^2}}{\sqrt{c}} = a$: hence $\frac{a^2}{4c} = 4$ feet 4 inches. It is thus by ſuppoſing in the infiniteſimals of a ſecond the velocity was thus uniform, the body would arrive at the earth at the ſame time as one would do by commencing by an almoſt infinite ſmall quantity, and gradually accelerating: hence then 483 lb. $\times$ 4 . 3 = 2052 lb.: thus we ſee how this bird is enabled to ſoar aloft with its prey, equal in weight to itſelf, although the volatile powers are diminiſhed, yet here is amply ſufficient in reſerve. It is not, however, in caſes of this nature that the maximum of its exertions is required: it is when elevated high in the air, and viewing the object of its rapaciouſneſs beneath, falls down upon it with almoſt the accelerating powers of gravitation. Let us ſuppoſe the little expanſion of its wings neceſſary to preſerve an equipoiſe, that it ſinks through the ſpace of one hundred yards in eight ſeconds, and which, were the gravitating powers not thus interrupted, would be accompliſhed in ſix moments, the uniform de-

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ſcent would be 37 feet; with a velocity ſo great, the momentum is proportionally ſo; as the weight is 60 lb. the momentum will be 2000 lb. It is here all the powers of the body* are requiſite to overcome a force that might otherwiſe daſh the animal to the earth; while, on the contrary, we ſee the hawk firſt aſſigning to himſelf the diſtance of the object, and then by precipitation darting down with an increaſing velocity: thus, were he not enabled to check at any period the impetuo-

* When we know the weight of a body, and the height from which it falls, we may eaſily know what ſtroke it will give, for the ſquare root of the ſpaces will always give the velocity, which being multiplied into the maſs or weight of the body gives us its momentum.

A body falling from the height of 300 feet, the ſquare root 17.3 will give us the velocity; when we know the momentum of the body through the ſpace of one foot, it will give us the other. To aſcertain this, I made uſe of one of thoſe iron cylinders which has a ſpring within, and according as a weight is attached to a hook at the bottom, ſuch is expreſſed by the riſe of a graduated iron plate out of the cylinder; by letting a pound weight fall through the ſpace of one foot, it extended the ſcale to the mark of three pounds: when the pound fell from four feet in height, its momentum was then equal to ſix pounds; thus their velocities are preciſely as the ſquare root of their ſpaces, 60 lb. the weight of this bird would be equal to 180 lb. in falling through one foot; through 300 feet it would be $180 \times \sqrt{300} = 3114$ lb.: as we have already obſerved, that the bird does not deſcend with ſo rapid a velocity, nearly a third leſs; its momentum at the end of ſuch a fall would at leaſt equal 2000 lb.

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ſity of his career, a fall through a ſpace of this extent muſt prove fatal.

Suppoſing he is in that ſtate as only to be hovering in the air, gently floating with a velocity not more than 4 feet in a ſecond; proceeding as above, the power of riſing will be 120lb. being double its own weight.

It has been much diſputed whether, in the rapidity of motion, birds are capable of diſtinguiſhing objects. In the Philoſophical Tranſactions for the year 1795 there is a paper on the ſtructure of the eyes of birds, by Mr. Smith, whoſe remarks being preciſely the ſame with thoſe of Dr. Derham, in his Phyſico Theology, certainly cannot merit any attention on account of novelty. Dr. Derham remarked a loricated ſtate of that part of the ſclerotica which immediately ſurrounds the cornea, acting like pulleys, over which the tendinous fibres were ſpread, and which terminated in forming the four recti muſcles. The Doctor ſuppoſed ſuch a confirmation neceſſary for the quick changes of viſion in birds, to enable them to ſee their food at their bill's ends, or to diſtinguiſh the utmoſt diſtance their high flights enable them to view, that the focal powers of the eye may be accommodated to the different refractions they muſt experience in the different aërial media in which they are immerged: to this ſuppoſition there are many objections. If all theſe muſcles act, would the eye be rendered more convex? Certainly the cornea, by ſuch an action, can never be converted into a ſegment of a leſſer ſphere. Are the ſame muſcles calculated for contrary action? Could they at one time enable the bird to view his food at his bill, and at another extend his powers of ſight over far diſtant woods and mountains; or make the globe at one time elliptical, at another like an oblate ſpheroid? Had it been recollected that the eye, although not a perfect ſphere, is yet nearly approaching to that form the moſt capacious of any, and being perfectly replete with its contents, how could it ſuffer any farther deviation from a globe, without an exudation of the aqueous humour? the ſclerotica in itſelf being ſo perfectly inelaſtic, that even a ſmall portion, by the application of a conſiderable weight, would not in the leaſt extend. In viewing a near object, the axis of the eyes is neceſſarily turned towards the noſe: how would the advocates of ſuch a doctrine attempt to explain the oblique actions of the recti muſcles which in this caſe muſt take place? "Natura ſimplex eſt & rerum cauſis "ſuperfluis non luxuriat;" thus ſays the immortal Newton. Why ſhould we think of adopting ſo complicated a ſyſtem, when all the phænomena are ſo eaſily explicable on the different curvatures of the cryſtalline lens? Had the optical properties of this beautiful medium been more philoſophically attended to by phyſiologiſts, they

certainly

certainly could never have been induced, from one solitary inſtance, where moſt probably there were ſome circumſtances not carefully attended to, to ſuppoſe it were of no uſe. With reſpect to this laminated ſtructure, if calculated for ſuch a purpoſe, it would only be found in thoſe birds whoſe motions are rapid. We obſerve the ſame in the oſtrich, the turkey, and the gooſe, as well as in the buſtard and the eagle; and, from ſome circumſtances, it appears that hawks, or birds of prey, when they dart down upon a ſmaller bird, have their eyes ſhut; the hawk generally moves horizontally to ſome diſtance, and, when he precipitates himſelf, often makes a falſe plunge: had he powers of obſerving the progreſs of the ſmaller bird, he would regulate his actions accordingly. Reaumur alſo has told us, that he has obſerved, with pleaſure, a ſparrow purſuing a butterfly, which, from the irregularity of its motion, eſcaped every attack of the ſparrow. It appears more probable, that theſe bony ſtrata are calculated for defending the eyes of birds from the danger they undergo, from their habitations on trees, &c. and thus, by the curious pectinated organs about the choroides, enabled to withdraw the eye into the bony arch.

Dr. Derham has alſo remarked another beautiful ſtructure in birds in the mechaniſm of the lungs, which are not entire, as in other animals, but communicate to many cells, both in the ſoft

 parts

parts and in the bones; as the ſternum, ribs, and vertebræ, have their internal ſubſtance divided into cells. The Doctor had obſerved a moderately thin membrane, but not regarding this as a diaphragm, he adopted the general opinion of birds having none; he imagined it might be of uſe in rendering their bodies more or leſs buoyant, and thus facilitate their aſcents and deſcents. Mr. Hunter, who has paid ſome attention to this ſubject, with more propriety thinks they are as aërial reſervoirs, when, in their rapid motions, the reſpiration cannot be ſo perfectly performed; and ſuppoſes on this alſo depends the great continuance of ſong in ſome birds. If ſuch had been confined to birds of rapid flight, or thoſe which are amphibious, ſuch would appear a proper deduction. They are obſerved more numerous in the oſtrich, a bird not intended to fly; hence the reaſon of this aërial veſicular arrangement appears not perfectly evident; it is obſerved that the animal heat of birds is five or ſix degrees greater than man; if ſuch depend on the decompoſition of oxygene gas* by carbone, perhaps this greater diffuſion may become neceſſary.

OF

* It was obſerved, in the Eſſay on the Spine, that the functions of the animal œconomy are inexplicable on chemical principles; even the favourite theory of the decompoſition of caloric from its oxygen baſe by carbone, labours under ſeveral difficulties. It is ſaid, that the heat of the body is regulated by the reſpiratory organs; the animal heat of a child is more than that of an adult,

as it is obſerved, that the young of all animated creation is hotter than the old, as with young trees. In an infant, it is ſaid, the child reſpires more frequent; in many caſes of diſeaſes man breathes much more frequent without the internal temperature being increaſed. In Greenland and Lapland, where the cold is intenſe, conſequently the generation of a greater quantity of caloric becomes neceſſary; we are then told that not only there is a greater quantity of carbone in the ſyſtem; alſo the air being in a denſer ſtate, holds a proportionate quantity more caloric. How contrary this is to the general properties of bodies, where there can be no diminution in capacity without an evolution of caloric; and, from variety of experiments, it is well known that air, as it condenſes, throws out a great quantity of heat; even with the condenſation of three or four atmoſpheres, very ſenſible effects are induced; and if we place a thermometer within the blaſt of the condenſed air reſuming its natural ſtate, the mercury rapidly ſinks; as is alſo obſerved in the exhauſted receiver: if ſo, the ſame proportionate quantity poſſeſſes leſs caloric. Birds poſſeſs more animal heat than man, even thoſe whoſe flight is very high. Sauſſure, when on Mont Blanc, demonſtrated by his eudiometer, that the air in theſe regions is very impure: we have alſo many inſtances where the greater part of the blood does not paſs through the lungs, yet no diminution of temperature. In ſome, where the foramen ovale has never been cloſed, as is the caſe with the Blue Boy, as he is called, at Rotherhithe, where the whole ſurface of the body has the venal tinge; and in many caſes of phthiſis, when Nature is interrupted in her circulation through the lungs, ſhe frequently re-opens this partition. From various authorities, we have reaſon to ſuppoſe that there are men, as pearl divers, who will bear immerſion under water for a quarter of an hour, or more, and, without more than two or three minutes interval, will dive again, and yet ſuffer no inconvenience. Surely, in all theſe caſes, if there were no other reſource for heat than in reſpiration, if the latter is checked, ſhould not there be a diminution in the former? while it is rarely obſerved, whether native of the Line, or of the frozen region, that there is the leaſt difference of temperature but what is attendant with death.

ESSAY

ESSAY

ON MATTER

AND THE

FALLACY OF THE SENSES.

As all our knowledge of external or material things depends upon the evidence of the external ſenſes, if theſe are proved fallacious, the reality of matter could no longer be ſupported. In the earlier periods of literature, in the dawn of philoſophy, we find many who have attempted to prove that our ſenſory organs are deluſive; that inſtead of acting that part for which we might ſuppoſe they were created, that they are continually leading us aſtray; that, inſtead of tending to our

our preservation and happiness, they are to be regarded as instruments of treachery and deceit.

Let any one physiologically examine the admirable structure of the eye; the beautiful and simple apparatus with which it is endowed for viewing objects at different distances; the included media so arranged as to answer the best and wisest purposes:—let him examine the organization of the sense of hearing; how calculated to concentrate the sonorous waves; how the membrana tympani regulates the percussive effect of the aërial tremors; how it increases or checks the undulatory career:—let him examine the officula, the auditory levers for transmitting undiminished the impression that has been communicated; and how the bony curve of the labyrinth is thrown into a corresponding agitation, from the impulse its included water receives:—let him attend to the olfactory organs; the exquisite sensibility and elegant whiteness of the membrana schneideriana of the ethmoidal cells, and its susceptibility of impression from the grosser effluvia:—and lastly, let him only reflect on the distribution of nervous papillæ in the tongue, the hands, &c.; how these projecting little nipples lurking under the skin, and possessing sensatory power in a concentrated degree, are admirably formed for embracing objects exposed to their action; how, in the one case, when the object is minutely divided, and directly impresses them, the sensation of taste is induced;

and

and how, in the other, when the actual contact is prevented by the cuticular cover, yet the ſenſation of reſiſtance is imparted.

Could any one, after ſuch an inveſtigation, ſeriouſly and ſolemnly believe that the wiſe and beneficent Author of Nature would thus arrange our ſyſtem to betray us; to entertain ſuch a thought is derogating from that reverence we ought to pay to our Creator; nor can I diveſt myſelf from thinking, that ſuch, in ſome reſpects, borders on impiety. We find Democritus and Epicurus maintained, that ſmell, taſte, ſound, colour, heat, are mere illuſions of ſenſe, and have no real exiſtence; even Plato aſſerted we had no real knowledge of material things, and that eternal and immutable ideas are the only objects of real knowledge: ſo all the academics endeavoured to prove, that, even in things the moſt evident, we ought to withhold aſſent. That the teſtimony of the ſenſes ſhould be ſuſpected, they inſtanced in many circumſtances; as the crooked appearance of an oar in water, objects magnified in a fog, the ſun and moon appearing about a foot or two in diameter, the different colours on a dove's neck, &c.*

The

* Quid ergo eſt, quod percipi poſſit, ſi ne ſenſus quidem vera nuntiant? quoſt tu Luculle, communi loco defendis: quod ne id facere poſſes, id circo heri, non neceſſario loco contra ſenſus tam multa dixeram: tu autem te negas infracto *remo* neque *columbæ* collo commoveri. Quid poteſt eſt ſole majus? quem mathematici

The Cartesians alſo ſuſpected falſehood in every thing the ſenſes repreſent; the celebrated Des Cartes, he who produced the greateſt revolution in philoſophy, and deſtroyed the dogmas of Ariſtotle, that he might not be led aſtray, commences his principles by a ſtate of univerſal doubt, and admits nothing as certain, until compelled by clear and cogent evidence*. But Spinoza has well obſerved, that the evidence of ſenſe ought to have been admitted as a firſt principle, as well as that of conſciouſneſs; as Des Cartes has endeavoured to prove our exiſtence from a principle of conſciouſneſs, and from hence the exiſtence of an infinitely perfect all-powerful Being; but that external objects only exiſted as images in the mind; that the ſun, moon, earth, and ſea, were only ideas, the reality of which we were not certain. Spinoza has properly remarked, that we ought to admit the exiſtence of a ſubſtance from the idea

mathematici amplius duo deviginti partibus confirmant majorem eſſe, quam terram: quantulus nobis videtur? mihi quidem quaſi pedalis. *Cic. Quæſt. Tuſc. ad Lucull.* p. 299.

* "Facile quidem ſupponimus, nullum eſſe Deum, nullum "cœlum, nulla corpora; noſque etiam ipſos non habere ma-"nus, nec pedes, nec denique ullum corpus; non autem ideo "nos qui talia cogitamus nihil eſſe; repugnet enim, ut pute-"mus id, quod cogitat non exiſtere. Ac proinde hæc cogni-"tio, *ego cogito, ergo ſum,* eſt omnium prima & certiſſima."

Des Cart. Princip.

as well as from conſciouſneſs *. This mode of reaſoning muſt neceſſarily have led Des Cartes to a ſtate of general ſcepticiſm, and ſuch would have been the reſult, had he not heen reſtrained by the terrors of the church †.

Although Des Cartes may be allowed the honour of firſt drawing a line of diſtinction between the material and intellectual world, yet it alſo muſt be granted that he has been the ſource of the doctrines of a Malebranche, a Berkley, and a Hume; although his philoſophy utterly deſtroyed the *materia prima*, *ſubſtantial forms*, and *occult qualities*, of Ariſtotle, it has alſo prevented the more uſeful part being attended to.

It would be foreign to this Eſſay, to attempt any inveſtigation of the opinions of Des

* Si quis dicerit ſe claram & diſtinctam, hoc eſt veram, ideam ſubſtantiæ habere, & nihilominus dubitare num talis ſubſtantia exiſtat, idem hercle eſſet ac ſi diceret ſe veram habere ideam, & nihilominus dubitare num falſa ſit (ut ſatis attendenti ſit manifeſtum) vel ſi quis ſtatuat ſubſtantiam creari, ſimul ſtatuit ideam falſam factam eſſe veram; quo nanc nihil abſurdius concipi poteſt: adeoque fatendum neceſſario eſt, ſubſtantiæ exiſtentiam ſicut ejus eſſentiam æternam eſſe veritatem.

Spinoz Ethic, Part I.

† "At nihilominus memor meæ tenuitatis, nihil affirmo: "ſed hæc omnia tum Eccleſiæ Catholicæ auctoritati, tum pru"dentiorum judiciis ſubmitto; nihilque ab ullo credi velim, "niſi quod ipſi evidens & invicta ratio perſuadebit."

Cartes,

Cartes, Malebranche, Norris, Berkley, Collier, and Hume; all that I intend, is to endeavour to prove, that the arguments adduced againſt the veracity of the ſenſes are not correct; that their opinions have principally aroſe from not diſtinguiſhing properly the judgment of the mind from the perception of the ſenſes.

Suppoſing a man were to exiſt, deprived of ſenſatory organs—deprived of ſeeing, hearing, ſmelling, taſting, and feeling, would not his exiſtence be merely vegetative? If ſuch be granted, it will neceſſarily follow, that all his acquiſitions muſt originate from thoſe ſenſes. We find, that when man firſt emerges into exiſtence, is likewiſe the infantine period of the ſenſes, as yet unimpreſſed, as yet unexerted; he appears, at firſt, a kind of animated maſs, without any intellectual powers; ſo it is ordained for the wiſeſt purpoſes: for could we ſuppoſe a child evolving into the world, with its underſtanding in a ſtate of maturity, all its ſenſes in a moment thrown into rapid action, it would be diſtracted with aſtoniſhment, apprehenſion, curioſity, and ſuſpenſe; its powers would be exerted with an impetuoſity which would render them unſupportable: while, on the contrary, the acquirement of ideas is ſo gentle and gradual, that we neceſſarily acquire that moderation and ſelf-government, that aptitude and readineſs in reſtraining ourſelves. As all our knowledge is derived from the external fenfes, let us examine them feparately; let us endeavour to fhew what would be the refult of a vegetative kind of mafs, endued with only the fenfe of feeing, and then fucceffively combined with the other fenfes.

SENSE OF SEEING.

To examine whether the idea of the peripatetic philofophers, refpecting the different kind of forms which bodies were continually fending off, and thus acting on the different fenfes, fince the obfervations of Des Cartes, would now be fuperfluous; it muft certainly be granted, that all bodies which are vifible either emit light, or reflect it. It might appear a matter of little confequence in this confideration, whether light is confidered as univerfally diffufed and apparent when acted on, or emanating in right lines. As, in fome refpects, the latter opinion is more agreeable to the demonftrations which hereafter will be attempted, fuch, from the following proofs, will be adopted.

Newton has fhewn, that a preffure propagated through a fluid does not act in right lines, unlefs the particles of that fluid are thus directly pofited. "Preffio non propagatur per fluidum fecundum "lineas rectas, nifi ubi particulæ fluidi in direc-"tum jacent." *Prop.* 41. *Princip.* Suppofing a room

room darkened in the fame manner as when trying prifmatic experiments, a ray of light, pervading a fmall aperture in the window fhutter, only forms on the oppofite wall a figure of the fun, fubtending an angle with the window fhutter, equal to that of the real fun; if the room had been replete with light, as with air, the firft impulfe at the aperture would caufe it to act equally all around; each particle thus acted on would conftitute a frefh centre, and thus its motion would be diffufed through every part of the room; as fuch does not take place, it is not univerfally diffufed, but "particulæ in directum jacent."

A ray of light emanates from the fun not inftantaneoufly, but progreffively, viz. eight minutes, thirteen feconds, in paffing from the fun to us; about ninety-fix millions of miles (at a medium). This has been fatisfactorily proved by the obfervations of Reaumur, refpecting the eclipfes of the jovial fatellites, as well alfo by the greateft difcovery in aftronomy in this age, the aberration of the ftars, by Dr. Bradley.

Notwithftanding thefe proofs, we find many celebrated philofophers who could not conceive how light fhould be driven off the fun's furface with the amazing velocity of 200,000 miles in a fecond of time; hence Huygens imagined that light confifted in vibrations propagated from the luminous body through fubtle ætherial medium: the great Euler fupported this, and thought that the

the ſun would be diminiſhed by ſuch a copious emiſſion. Dr. Franklin entertained the ſame opinion, and farther ſuppoſed, that the ſmalleſt conceivable particle of matter moving with ſo incredible a velocity, would acquire the momentum of a 24-pounder diſcharged from a cannon; that the ſun would diminiſh in its weight, and conſequently in its gravitating powers, ſo that the revolving planets would neceſſarily perform larger orbitary revolutions.

Newton imagined that the ſun would diminiſh, and thought the comets* were to renovate its powers, as well as their tails, to impart moiſture to the planets, and a renewal of that vital portion of empyreal air he thought were deſtroyed. Such would never have been Newton's concluſion, had he truſted a little more to his powers of calculation. If we ſuppoſe a luminous particle equal in bulk to the minuteſt volatile effluvia, the ſize of a particle emitted from aſſafœtida† does not exceed the thouſand billionth part

* Newton's Principia on the Comet of 1680. From this ſuppoſed property of moiſture in the tails, Whiſton imagined a ſudden condenſation of one when paſſing through the earth's orbit, near to this planet, might occaſion the general deluge.

† Mr. Boyle proved by experiment, that a maſs of aſſafœtida, expoſed to the open air, loſt, in ſix days time, the eighth part of a grain; therefore, in one minute of time $\frac{1}{69120}$ of a grain, ſuppoſing the flux of effluvia uniform: at the diſtance

part of a cubic inch. If we ſuppoſe light as ſpecifically heavy as gold, the force of momentum in each particle would be infinitely inferior to the momentum of the gentleſt dew, and would require more than a million of years to produce the diminution of $\frac{1}{100}$ part of a ſingle ſecond. That light has a momentum, is evident from the experiments of Homberg, Mairan, and Mitchel*, who

tance of two feet the effluvia is diſtinguiſhed by the ſmell; conſequently a ſphere, whoſe radius is two feet, is replete with this, the diviſion becomes beyond all powers of comprehenſion, viz.

$$\frac{8}{10.000.000.000.000.000} \text{ parts of a cubic inch.}$$

* One objection, among ſome others, which may be advanced againſt the concluſion of Mr. Mitchel; he ſeems not to have made any allowance for the greater proportionate decreaſe of denſity in light than in the ratio of the diſtance; that it meets with conſiderable reſiſtance in air we are well aſſured from many experiments, as from its continual refraction through all the aërial media, progreſſively increaſing in denſity, a ray of light muſt neceſſarily arrive to us in a curvilinear direction; what portion may be interrupted in its progreſs we know not. Bougouer has ſhewn, that water, more than 45 fathoms deep, reflects no image of the ſun, the whole light being loſt: from analogy the ſame may take place in air, in the ratio of its denſity, viz. 34 feet of water being equal to the weight of atmoſphere, and $45 \times 6 = 270$ feet of water, through which ſpace light becomes diſperſed; hence $270 : 1 : 34 : \frac{34}{270} = \frac{1}{8}$ nearly; ſo that we may ſuppoſe one eighth of the light is loſt by its paſſage through air; this appears farther probable, as tranſpa-

who have agitated feathers, amianthus, and delicately ſuſpended levers. Why ſhould we ſuppoſe that there is any thing afreſh created? Why may not light, when diſengaged from its terreſtrial combinations, return to that ſource from whence it originated, and thus, by a continual circulation, keep up its energiſing power without any diminution in quantity.

Light is a fluid ſui generis, and no ways ſimilar in its properties to caloric, or the matter of heat. Bodies may be heated from 540° down to 60°, without exciting any ſenſible illumination; while, on the contrary, we ſee light from the ſlow phoſphoreſcent combuſtion of the lanthorn fly and the glow-worm. Fire is diffuſible equally, and penetrates all bodies without exception, while light only produces ſenſible effects on opaque matter *. Fire is abſorbed and given out by bodies in the

tranſparent bodies of a ſimilar nature refract in the proportions of their denſities, and loſe, by reflection, the ſame proportionate degree.—Vide *Newton's Optics*, lib. 2. prop. 14.

* If in a common phial a match be placed, and this phial immerged in a glaſs veſſel filled with water, and a ſenſible thermometer applied to the fluid, the concentrated ſolar rays, through a convex lens, or from a concave mirror, being made to paſs through the water, ſo that the focus ſhall fall on the match, this will be inflamed and burnt without the water having its temperature increaſed; as would otherways be evinced by the thermometer. This ſhews light will not act on tranſparent ſubſtances.

proportion

proportion of their ſpecific gravities*, while light is regulated in its increaſe of velocity by the refracting power of the medium†; fire acts in all directions, light only in right lines; fire produces no change in the colourleſs nitrous acid, while light gives it another tinge, and renders it fuming. The experiment of Beccaria's diamond‡ even ſhews an averſion to their being united in one and the ſame body. Light has, as has already been obſerved, weight§, while no experiments have

* Iron feels colder than wood, becauſe it abſorbs and gives out heat quicker; a veſſel filled with hot water, ſuſpended in a room, and ſurrounded with wool, will preſerve its warmth 24 hours: thus the man who was placed in an oven, when ſo hot as to bake bread, yet ſuffered no inconvenience, becauſe he was only in contact with wood; and the caloric being ſo ſlowly communicated, that the powers of life prevented his temperature being increaſed.

† V. Newton's Optics, lib. 2. prop. 10.

‡ It is a well-known property of the diamond, and alſo many other bodies, that when expoſed to light they abſorb a quantity, and throw it out in the dark. Beccaria thus expoſed a diamond, which, when brought into a dark room, appeared for a time luminous; when this died away, it re-appeared by the application of ſo much warmth the mouth would give; when this diſperſed, it was renewed by immerſion in hot water; afterwards, no additional warmth ever produced the leaſt luminous appearance, till a freſh expoſure to light was made: the inference is eaſy; that the light was not produced by the caloric, but diſengaged from the body.

§ It has been ſuppoſed that light has no weight, becauſe it appears to be uninfluenced by any gravity; as darting from the

 ſun

have hitherto evinced any gravity in caloric*. Dr. Higgins fuppofes that caloric and light are one and the fame matter, their different appearances being the refult of varied directions; that caloric fubfifts by the proximity, and light by the rapid projectile motion of the fame matter. How will this be reconcileable to what is above mententioned? By what power are we to fuppofe that

fun through the immenfity of fpace, without being controlled by any of the planetary regions. The inftant a ball is fired out of a cannon, gravity has but a little fway; if, inftead of moving 4 or 500 feet in a fecond of time, it fhould move with the amazing rapidity of light, any deduction on account of gravity could even make no mathematical difference.

* Dr. Fordyce's experiments rather fhew a degree of levity than gravity in caloric. I have been attempting fome experiments refpecting the amazing difengagement of caloric by the mixture of the vitriolic acid and water. It is well known, that in fuch a mixture there is a great diminution of bulk, or, what was formerly called, a penetration of dimenfions. I have been endeavouring not only to afcertain the fpecific gravity of the compound, but alfo its relative weight; I have not as yet been enabled to prevent fome lofs by evaporation fo great a heat produces. I have been enabled to determine what quantity of ice fuch a mixture will diffolve.

It is eafy to conceive how a body expanded by caloric muft weigh lefs, as it muft difpoffefs a greater quantity of air; on this account it muft not be inferred that caloric is lefs than nothing. We know a fteel bar, when magnetifed, weighs lefs, as Whifton found one, 7 feet long, loft 14 grains: this does not evince a Stahlian principle of levity; it is owing to its gravitating tendency towards the centre of the earth being counteracted by a tendency to the magnetic pole.

one part of the ſame matter ſhall have a continued proximate action, and another portion a powerful rectilineal direction? Could any previous difference in velocity make any eſſential difference after a chemical combination? In the vegetable creation the influence of light is too evident to eſcape our attention: how pale, how languid, when expoſed even to a ſuperior temperature, without the benefit of this enlivening principle; while, on the contrary, when expoſed to a combination with this energiſing ſubſtance, it has the verdant tint of health. When caloric is diſengaged by the concentrated ſolar rays, it appears to be a ſimple chemical decompoſition, a body abſorbing light, and throwing out its matter of heat.

By the eye we are enabled to diſcriminate the colour, the diſtance, the magnitude, and figure of external objects, as well as their motion when attended with a change of place; in this order I ſhall preſume to examine them.

Colours are now well known to be owing to the different refrangibility of the different portions of a ray of light; and, according as the ſurface of a body is diſpoſed to the reflections of ſuch portions, certain correſponding colours are produced: in fact, a ray of light appears to be compoſed of portions progreſſively diminiſhing in momenta; that part which has the greateſt force is the leaſt bent out of its courſe, and impreſſing the retina with the greateſt power, produces the lively ſenſation of redneſs. According as they diminiſh in vigour, a diminiſhed vividneſs of ſenſation is induced through the priſmatic ſcale, the orange, the yellow, the green, the blue, indigo, and violet: this appears farther probable from ſtrong luminous bodies, as the ſun, when viewed through a cloudy medium, appearing red, ariſing from the momenta of the other different portions not being enabled to overcome the reſiſtance, are neceſſarily not tranſmitted: alſo, when we paint the bulb of a very ſenſible thermometer with white, it is near ten degrees lower than when covered with black; the former reflecting all the light, while in the latter the whole is abſorbed. If we paint a number of thermometers in the order of the ſpectrum, we find, that in the violet the thermometer is higheſt, while in the red it is the loweſt, and which demonſtrates, that all the rays being in action but that which is reflected, conſequently the gradation of the fall will mark the degree of force. This is contrary to the ſuppoſition of Dr. Hartley, who fancied the vibrations in the retina, from violet rays, were double to thoſe produced by the extreme red rays. If Dr. Hartley's conjecture was right, how would the nature of ocular ſpectra be explained? After looking at the ſun, we find, after the intenſity of its action has ſubſided, a red ſun appears; then

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an orange, &c. Surely, as the action diminifhes, the vibrations cannot be increafed.

It has been too generally fuppofed, that colours are entirely dependant on the mind, as if they did not originate from any external caufe. Newton, by throwing the red-making rays on cinnabar, and the blue-making rays on ultramarine, demonftrated, from their vividnefs, that their furfaces were difpofed to fuch reflections. When the experiment was reverfed, the cinnabar appeared of a faint obfcure blue, and the ultramarine of a dim red. From this it has been argued that the colours do not appertain to the body, as that light is reflected that is not congenial to it. When we view the fpectrum, we obferve no definite divifion in the colours, the one melting imperceptibly into the other; that it is only their extreme parts which can be well diftinguifhed; as the colours are more remote in the fpectrum, the lefs relation they will have to each other: thus, fuppofing the red gradually running into orange, has $\frac{1}{10}$ part of its colour in that portion; in the yellow it would be $\frac{1}{10}$ of $\frac{1}{10}$ viz. $\frac{1}{100}$ and fo on, in a decreafing feries; that in the green there would be an infinitely fmall portion; this we find confonant to experiments: the orange reflects more red rays than the yellow, and this more than the blue; fo that the faintnefs may be owing to only that

portion

portion being reflected as enters, as it were, into the compofition of that particular colour.

The colour of an external object depends upon an impreffion on the optic expanfion from the reflection of a certain portion of a ray of light. If this be granted, does it not neceffarily follow that light is material? Can we conceive impreffion without refiftance? Can we conceive refiftance without matter?

OF THE DISTANCE OF OBJECTS.

In the afcertainment of the diftance of an object, our powers are neceffarily limited, yet they anfwer the beft and wifeft purpofes of our creation; the extent of our vifual powers is fuch, as fuffice for our pleafures as well as our prefervation. It is but opening the eye, and the fcene enters; we embrace, as it were, at once an infinite number of bodies, and bring into our reach the moft remote parts of the Univerfe. When we view the conchoidal arch above, and contemplate the planetary orbs, which our powers of calculation have afcertained an immenfe difference in diftances, yet the eye is not capable of any fuch diftinction; to it the moon appears as remote as the fun; the fun as Sirius: even thofe little electrical emanations in the air, called fhooting ftars, feem as far diftanced as the conftellation

tion of Orion; and the ſmall elevation of a rocket has the appearance of being concentric, and in contact with the heavenly curve above. Nor, indeed, is it neceſſary that we ſhould ſo penetrate into the immenſity of ſpace; we are ſufficiently enabled to diſtinguiſh ſuch diſtances as are neceſſary for our exiſtence. How is ſuch aſcertained? Des Cartes fancied, that in near-ſituated objects diſtance may be known by the angle formed by the two optic axes. "Diſtan-"tiam diſcimus, per mutuam quandam conſpira-"tionem oculorum."—*Des Cartes Diopt.* If this were ſo, in remote objects, the ratio would be too little to hold good; nor could diſtance be known by perſons with one eye. Dr. Moore, his cotemporary, in an Epiſtle to that great philoſopher, has ſhewn, that ſuch could not be determined by the viſual angle, for an object, 10 feet high, and 100 yards diſtance, would form equal angle with an object 5 feet, at 50 yards. Berkley, in his ingenious Eſſay on Viſion, has endeavoured to prove, that diſtance, of itſelf, is only a line which impreſſes the retina in a ſingle point, and remains invariably the ſame, whether the diſtance be greater or leſs: he ſuppoſes that it is aſcertained by the confuſedneſs, diſtinctneſs, and faintneſs of objects. When rays, proceeding from each diſtinct point of an object, are not properly converged, a confuſion of viſion gives the idea of nearneſs; and when rays paſs

through

through a groſs medium, ſo that few arrive from the object to the eye, the attendant faintneſs produces the idea of diſtance. This theory will account for the remarkable phenomena* of converging rays, that overturned the ſyſtem of a Tacquet, and embarraſſed a Barrow, a Gregory, and a Newton. Converging rays never exiſt in Nature; in an unnatural concourſe ſuch may be requiſite. Berkley endeavours to prove, that diſtance is, in its own nature, imperceptible, therefore perceived by ſight by means of ſome other idea, for lines and angles, he ſays, are not perceived. Dr. Hartley ſuppoſes the principal criterion of diſtance is the magnitude of the picture: the obſervation of Dr. Moore, as mentioned above, demonſtrates the error of ſuch a ſuppoſition.

It appears to me, that the ſpace between the moſt viſible diverging rays and parallel are to be

* If an object be placed beyond the focus of a convex lens, and if the eye be cloſe to the lens, it will appear confuſed, but very near to its true place. If the eye be a little withdrawn, the confuſion will increaſe, and the object will ſeem to come near; and when the eye is very near the focus, the confuſion will be exceedingly great, and the object will ſeem to be cloſe to the eye. In this experiment the eye receives no rays but what are converging; and the point from which they iſſue is ſo far from being nearer than the object, that it is beyond it; notwithſtanding which, the object is conceived to be much nearer than it is, though no very diſtinct idea can be formed of its preciſe diſtance.
V. *Barrow's Optical Lectures.*

aſcertained

aſcertained by the varied action of the cryſtalline lens; as we have reaſon to believe, from its ſtructure, that there is a great ſeries of progreſſive convexities between the extremes. If the admeaſurements of the different parts of the eye, as given us by Monſ. Petit, are correct, the diſtance of perfect viſion will be near 24 inches: that the eye, in its natural ſtate, can ſee objects without any alteration; in near-ſituated objects, the diverging rays will not be united at near one tenth of an inch behind the retina, and parallel rays nearly as much before. The ſtructure of the eye will not allow of a ſufficient removal of the cryſtalline, for it is ſituated but a little more than one tenth part of an inch from the cornea; we never ſee it advancing ſo far as to force the iris forwards; nor can any alteration of any part of the eye but that of the cryſtalline ſuffice: for, to act as a ſimple lens, it certainly has a too-complicated apparatus; the different curvatures of its different ſides, the accommodating texture of the external lamina, and its ſuperior denſity to the other media, muſt evidently ſhew, that an occaſional alteration in its form will anſwer every purpoſe, without producing the leaſt derangement. If, for viewing near-ſituated objects, the anterior portion is rendered equally convex with the poſterior, diverging rays will be converged on the retina; when rays proceed from remote objects, ſo gently diverging as to be deemed parallel, the poſterior

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portion being diminifhed in its convexity, will prevent a too quick convergency. Thus, from radiants, remote and near the lens, becomes an equal double convex; fuch an alteration may be effected by its own powers. Albinus has proved to us its animal ftructure; that it is not infulated in its furrounding capfule, and has a vegetative kind of exiftence; the central artery paffing through the vitreous humour, fends off fome minute ramifications; its delicate organization is evinced by its fufceptibility of inflammation, and fubfequent opacity. If we examine the lens with a microfcope, when enveloped with its tunic, through the little intervening water a fibrous arrangement is eafily obferved, forming, as it were, three tendons, uniting in the centre, and thefe acted upon by parallel fibres, like thofe of a bipennated mufcle; as the central angles of all thefe fibres being parallel will be equal, hence equally act upon equal portions of the tendons; as the fphere is divided into fix different arranged fibrous portions, the central angles muft neceffarily be fixty degrees each. If then we fuppofe the motive power of one fibre equivalent to a fingle grain, one eighth of the power will be loft by the obliquity of the action: on the wing of each tendon we may nearly count 50 fibres; this produces 300 for the whole, whofe united actions will be more than half an ounce. If this be the power of one lamen, all the lamina combined

would

would fully effect every thing: when the lens becomes a double convex, we know its surface necessarily becomes diminished; consequently the action of the ciliary processes will prevent any corrugation of the surrounding capsule. In fishes this lens is nearly spherical; by residing in a denser medium than we, their eye is proportionally larger, as the refraction of the rays is necessarily less. It is thus, by an habitual and customary connection between an alteration of the crystalline, and the distance of the object, that when this lens becomes more convex, we associate the idea of nearness, and vice versa. From what has been observed, that our senses are gradual in their acquirements, it must be supposed, that the first impression which is made must be confused, and the object to which the eye would be directed would appear to be in contact with the visual organ, as is well known to have taken place in Cheselden's Boy.

Upon this theory we may give a probable explanation of the phenomena of the horizontal sun and moon. It has been already observed, that a ray of light is composed of seven portions, each possessing different degrees of refrangibility; consequently, when passing through any simple convex medium, they cannot concentre to one point, but form a circular space of certain dimensions. It is the different refrangibility of the heterogeneal rays which constitutes this aberration;

the ſpecific gravity of the nucleus of the lens is 1 . 346, and that of the external portion 1 $\frac{2}{9}$, and by this difference the aberration will be reduced; the lens is conſtituted to converge all the different rays: theſe horizontal luminaries loſe all the more refrangible rays, which are bent down by the ſpherical atmoſphere; while the red and orange, being leſs bent, are tranſmitted; theſe not being ſo quickly converged, an alteration is required in the lens, to make it more convex than what is neceſſary in viewing the meridian ſun, hence imagined nearer, and conſequently larger. V. *Newton*, prop. 1. lib. 1.

With reſpect to the magnitude of bodies, ſuch appear to me to depend upon a peculiar ſtructure of the expanſion of the optic nerve.

When a tranſverſe ſection of the eye has been made, we ſee the concavity lined by a ſemi-pellucid membrane, formed by the ſpreading out of the optic nerve. By being equidiſtant from the cryſtalline lens, it is properly ſituated for receiving an equal and regular impreſſion; being alſo of a white colour, it equally reflects all colours, and hence diſtinctly retains the impreſſed vibrations. On examining its texture through a glaſs which magnifies forty times, there appeared like a velvet dawn upon its ſurface; the decuſſations muſt be infinitely fine, ſince this did not render viſible the leaſt interſtice; a perfect uniformity in its appearance, except when interrupted by the minute branches of the optic veſſels. From what net-like form this has been termed *retina* I know not. By accurately examining theſe threads or fibrillæ, when thus magnified, they appeared about the ſize of a hair of the head; a hair meaſures $\frac{1}{200}$ part of an inch: hence one of theſe little threads will be equal to the eight thouſandth part of an inch.

Perhaps from this ſtructure it may be explained why our powers of ſeeing are limited with reſpect to the magnitude of objects. If we ſuppoſe that ſuch are only viſible which can impreſs two or more of theſe fibrillæ, we ſhall then find a remarkable coincidence between the ſize of the ſmalleſt viſible object, and the ſpace that two of theſe fibrillæ will occupy. De la Hire has obſerved, that he was enabled to ſee the ſail of a windmill 6 feet in diameter at the diſtance of 4000 toiſes; the picture at the bottom of the eye will be $\frac{1}{8000}$ part of an inch, and which correſponds to the interval between two of theſe nervous fibrillæ. We may thus explain why ſome men may have more extenſive powers of ſeeing, by having the fibrillæ ſtill more minute. Muſchenbrock tells us of one man he knew, who could count thirteen ſtars in the Pleiades, and could diſtinguiſh three ſatellites of Jupiter. From the angle theſe would ſubtend, the picture formed at the bottom of the

eye

eye would be $\frac{1}{17000}$ part of an inch; in fuch a man the interval between the fibrils would be lefs than half the diftance than in a common eye.

This will alfo explain the reafon why we are not fenfible to any impreffion on the optic nerve; in this part there being no fibrillæ, confequently not that fenfible arrangement as to be fufceptible of fuch impreffions.

It cannot be difficult to conceive how, from experience, we may acquire an idea of magnitude. Berkley feems defirous of diftinguifhing the magnitude of an object from that of the picture; he fays the former is invariably the fame, while the latter changes, according to the fituation of the obferver; thus he farther obferves, that when we are looking at the moon we fee a round luminous plain, about thirty vifible points in diameter: if we advance towards it 50 or 60 femi-diameters of the earth, there would be no veftige of its former appearance; the original object has long fince difappeared. This appears to me as ftrong an argument againft his own doctrine that can be advanced; the mind, he does not fuppofe, can change, it remains invariably the fame; and by the creation of a material world, he means no more than that God had decreed, from that time, to produce ideas in the minds of finite fpirits, in that order, and according to thofe rules, which we call the laws of Nature; fo that, according

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to this, it is a law of Nature, that, as we approach or recede from nothing, that nonentity ſhall vary in its appearance. How eaſily are all theſe changes explained by the ſimple theory above attempted. In whatever ſituation we are placed, the object of our ſenſes undergoes no change; ſuppoſing I am placed within a foot of an extenſive building, only part of it then becomes an object of my ſenſe, as, from the conſtruction of my eye, its powers of receiving light are neceſſarily limited. If the building is fifty feet wide, at the diſtance of one foot, it would require the bottom part of the eye to be thirteen inches long to admit all the rays of light reflected from the building. How diſproportionate would ſuch a ſtructure be; how contrary to the purpoſes of our exiſtence. As rays of light, in pervading the eye, neceſſarily interſect each other a little beyond the poſterior part of the cryſtalline lens, the diſtance between this interſection and the internal baſe is about half an inch. If we ſuppoſe the fibrillated part of the retina to be an inch in extent, it muſt appear evident that the eye, to embrace the whole object, muſt be placed at a diſtance not leſs than half the width of the building; in this caſe, to ſee the whole, we muſt be 25 feet from the building.

Why then does it vary in its appearance as we approach or recede? It has already been remarked, that a windmill ſail, 6 feet in diameter,

was

was visible at the distance of 4000 toises; had it been 3 feet only, it would not have been seen. Suppose a building divided into portions of 3 feet, at the above distance such parts could not be seen, as the picture of such would not be equal to the interval of two fibrils; but 6 feet will impress the space of $\frac{1}{8000}$ part of an inch; so that the eye is, in fact, not impressed by any of the intermediate parts of the object; as we approach, the rays of light are more diverging, and consequently the space of 6 feet will produce a picture which will cover or impress a greater number of fibrils; it is not thus the object that is changed, or the quantity of rays of light any ways altered, but a necessary consequence of our organization. A fly, we know, from its structure, from the thousands of divisions of each cornea, the radii of whose corniculæ are not more than the thousandth part of an inch, can necessarily converge rays proceeding from objects at the two or three hundredth part of an inch situated from itself, nearly two thousand times nearer than we can: insects infinitely less than a fly even this space may appear a world: the eye of a mite, how exquisitely fine, and, if there is any analogy in structure, how inconceivably delicate must the nervous fibrils be; and there may be insects to whom a mite is an elephant: we may even carry our imagination so far, as to suppose, with Male-

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branche and Valifneri, that in a fpot our vifual powers are not capable of difcriminating a world may be contained *.

Why we fee not Objects diftinctly when placed nearer than fix or feven Inches.

It muft appear evident, that all the rays of light which are thrown from any particular part of a body, or external object, unlefs they form a corresponding and proportionate part on the retina, the whole impreffion muft be confufed. If I am placed at fuch a diftance from a houfe as a fquare yard of the building will occupy upon the retina, an area of one tenth part of an inch, every other fquare yard of the building being equally reprefented in the eye, there will then be a proper ratio between the picture and the object; if, inftead of one tenth of an inch, it fhould be fpread over one fifth of an inch, the fame fibrillæ would be impreffed, at the fame time, by rays of light

* Ciò che in quefto cagiona il noftro errore, fi è, ch' effendo la noftra vifta limitata, noi penfiamo, che, anche tale fia l' eftenfione, de' corpi, ed al contrario l' eftenfione de' corpi è in um fenfo infinita, ed una piccola parte di materia, che fi nafconde à noftri occhi, è capace, *come dice l' autore della reverca della verità* di contenere un mondo, dentro il quale foffero tuttæ quelle cofe, a proporzione più piccole, che nel noftro mondo, in cui viviamo, fi trovamo. *Valifneri*, part. 1, chap. 9.

from different parts of the object; so indeterminate would the impulses be, that only a confused sensation would arise: this must be the case in both the near-sighted and the aged eye; in both the rays become dispersed, with this difference, in the former, the rays unite too soon, *i. e.* before they arrive at the retina; and in the latter too late*: moreover, the fibrillæ require that they should be impressed by the united rays, that there may be a peculiar effect resulting from the rays thus combined into a point, and each point impressing a single fibril; this appears to be the reason why Nature has so beautifully arranged the eye, that no aberration or wandering of a ray of light shall be produced†. Dr. Jurin, in his very learned Essay on distinct and indistinct Vision, supposes, that in near-situated objects all the rays do not unite, if the central part has the same proportionate

* Euler supposed the eye perfectly a chromatic, but Dr. Maskelyne has computed the diameter of the circle of the aberration upon the retina, and found it to be .002667 of an inch. He thinks some such aberration is necessary to account for the sensible diameter of some of the fixed stars.

† The circle of aberration may be thus explained: in making use of a common burning glass, it is observed, that the rays of light, in passing through the glass, are not united into an exact point, but form a circular space of some dimensions, greater than ought to arise from the image of the sun; the excess is in consequence of the aberration of the rays.

quantity of light, will only appear confufed about the extremes; if I am looking at a crown piece, placed within four inches of my eye, the middle of it I ought to fee diftinct, and only the edges confufed; as the rays of light do not imprefs the retina in united points, but form thereupon, from their conical directions, many circular portions, what ought to have been united into one point, are now diffipated over a larger fpace, and which he calls circles of diffipation. It is eafy to conceive how all thefe circles of diffipation will produce an equal intenfity of light in the central part of the image, and faint towards its bounds. To me, in practice and theory, the whole appears equally confufed; the fame fibril is impreffed by as many different rays as there are circles of diffipation; there is not that impulfe neceffary to perfect vifion. If I might be admitted to conjecture, I would fay, that the neceffary effect is that which arifes from the production of a third motion; that it is the refult of the compofition of forces, as the rays of light, before their union, are moving in different directions; at the point of union the combined power is not equal to the fum of both, but varies as the rays are inclined to each other.

Greater Impreſſions on the Fibrillæ will deſtroy thoſe which are weaker.

At the approach of day, as the morning twilight increaſes, the eye begins to be illuminated by the reflection of the atmoſphere; the ſtars grow faint, and diſappear by degrees; the moon loſes her luſtre, and, at length, her light is overpowered by that quantity which is diffuſed over the hemiſpheral regions *. All of us muſt have obſerved the duſty particles floating in a beam of light let into a darkened room, but which diſappear as ſoon as the room is enlightened. It is theſe duſty particles which produce the ſcintillation of the ſtars; in bodies placed at ſuch an immenſe diſtance, ſo infinitely ſmall the angles they ſubtend, as to be partially obſcured by ſo minute a particle; this may be illuſtrated by a very ſimple experiment: if we place a ſmall piece of looking-glaſs on the ground, ſo that it may reflect to us the ſun's light, when at about 50 yards, it has a ſteady uniform luminous appearance, as

* From theory it would ſeem, that the light of the moon would not appear to be more than 90,000 times weaker than the ſun; from experiments by the celebrated Bougouer, it was aſcertained to be 300,000 times weaker. This demonſtrates how fruitleſs the attempts of Boerhaave and others muſt be in endeavouring to produce any ſenſible heat from its concentration.

the

the planets have, when we remove one hundred yards, we perceives its twinkling.

Although we cannot ſee the ſtars in the day-time, yet either in a deep well, or by a teleſcope, we can ſee them. Mr. Ludlam has conjectured, that as a ſtar is a point, in viewing it through a teleſcope the ſurrounding ſky appears fainter, becauſe the light is diffuſed over a larger ſurface; while a ſtar hath no linear dimenſions, hence preſerves its ſame intenſity. In this explanation there ſeems many difficulties; if a ſtar is a mere ſimple thread of light, how comes it that we make it vary in its appearance, by altering the glaſſes of the teleſcope? or how would this explain its being ſeen in a well? It appears to me to ariſe from this circumſtance*: ſuppoſing a ray of light, when emanated from a luminous body, by reflection loſes one third, every ſucceſſive reflection the loſs increaſes in a certain ſeries; in the ſecond reflection, let it be granted it loſes one half, the third three fourths,

* That by every ſucceſſive reflection of light a greater proportionate quantity is loſt, according to the number of reflections, I am more convinced, from repeating ſome experiments of Buffon on reflecting mirrors; the exact decreaſe I have not yet aſcertained: by inclining ſix mirrors, ſo that the reflection from the firſt ſhall fall on the ſecond, this on the third, &c. the image of a lighted candle became ſo faint, as hardly to be diſtinguiſhed; this method will afford us ſome ratio between the intenſity of light diffuſed over the room, and the intenſity on the firſt mirror.

&c.

&c. if we ſuppoſe the light diffuſed over the hemiſphere loſes one third by being reflected to us; yet in that ſtate is equal in intenſity to the light emitted from the ſtars; the ſecond reflection of the ſky is only the firſt of the ſtars; ſo that we ſhall find the decreaſe of the former is more rapid than in that of the latter; thus $\frac{1}{2}$ of $\frac{2}{3} = \frac{1}{3}$ will expreſs the ſtate of light after the ſecond reflection; while $\frac{2}{3} - \frac{2}{9} = \frac{4}{9}$ the quantity of light in a ſtar after the firſt reflection, which being one ninth greater, is conſequently viſible.

That Impreſſions on the Fibrillæ do not ceaſe the Inſtant the Object is removed.

Sir Iſaac Newton ſuppoſed an impreſſion might laſt about a ſecond; the Biſhop of Llandaff, by a more accurate experiment, aſcertained it to be $\frac{1}{72}$ of a minute; thus, when a lighted body is turned round, it appears like one continued luminous circle; the ſucceſſive impreſſions take place before the preceding ones expire, and produce an idea of continuity. A remarkable example, illuſtrative of this, occurred in a watchmaker in Paris; when I reſided there he lived in the Quai des Auguſtins; he had a remarkable vibratory motion of the globe of the right eye in an uniform continued action. Monſ. Andravi, who had attended him, told me that, as near as he he could obſerve, a vibration correſponded to an arterial pulſation, and yet the minuteſt part of his buſineſs he could ſee without the leaſt interruption; indeed, that eye he perceived ſtronger than the other, although Borellus ſays the left eye is always the ſtronger.

How the Impreſſions are diſtinguiſhed.

From what has been already obſerved, it is almoſt impoſſible that a ray of light ſhall emerge from a body in every reſpect in ſimilar circumſtances, with the ſame degree of inclination, ſo that the reſulting momenta ſhall exactly correſpond; the ſame body will impreſs each eye in preciſely the ſame manner; when theſe impreſſions have been frequently repeated, the mind recollects the ſimilarity of the impulſe, and affixes that name which has been in general aſſumed. Some have conjectured, whether impreſſions from ſimilar objects on different men vary or not? It would produce no confuſion, as the ſame name is generally adopted. If we ſuppoſe a ſcarlet produces an impreſſion on one perſon's eye equal to two, while a blue ſhall only be equal to one, whenever he has the impreſſion two, he aſſociates the idea of ſcarlet, &c. Suppoſing this was reverſed in another perſon, ſcarlet would then be aſſociated with an impreſſion equal to one.

Although

Although the vibrations in different perſons' optic fibrillæ may not be iſochronous, yet, with reſpect to themſelves, they ſeem to preſerve the ſame proportion, as all agree that the impreſſion from ſcarlet is more vivid than from blue.

How we ſee Objects ſingle.

It would appear, that as the ſame object is repreſented twice to the mind, by being tranſmitted through two eyes, that we ought to ſee double. As the fibrillæ of each retina are in the ſame harmonious uniſon, impreſſed by ſimilar rays, the actions induced muſt correſpond; when this harmony is deſtroyed by diſeaſe or drunkenneſs, objects will neceſſarily appear double. Dr. Hepburn tells us, that the late Rev. Mr. Forſter having been blind for ſome years with a *gutta ſerena*, was reſtored to ſight by ſalivation; upon his firſt beginning to ſee, all objects appeared to him double, and the two appearances approaching by degrees till they united *. By means of two eyes we are enabled to take in a larger range, and ſee objects more diſtinctly.

It does not appear neceſſary that preciſely the ſame-ſituated fibrillæ ſhall be impreſſed by light

* This is no ways contrary to the obſervations of Cheſelden on the young gentleman he couched, as he was relieved of only one eye at once.

from

from the ſame point of an object, as in caſes of ſquinting, where the axes of the eyes are not directed to the ſame object, yet the object only appears ſingle; this diſeaſe does not ariſe from any peculiar ſenſibility in any particular part of the retina, but a vicious habit contracted by a child, when ſo improperly placed as to ſee either the light, or any other remarkable object, with one eye only *.

FALLACIES OF VISION.

From the ignorance of the ancients reſpecting the nature of colours, it is no wonder they ſhould attribute thoſe colours that are ſeen in the tail of a peacock, and which change with the poſition, to a ſpecies of deception, or, as Seneca calls it, *falſe colours* (Nat. Queſt. lib. 1. cap. 7.); while ſome ſuppoſed colour was the ſuperficies of the body; others, as Plato, imagined it was a flame iſſuing from it. It was the great Des Cartes who firſt ſuggeſted colours were only modifications of light; and had he not been biaſſed by his favourite Vortices, he would have been the Newton of the age; ſince the priſmatic decompoſition of the rays of light, and the obſervations of Newton

* See Buffon and De la Hire on Squinting.

on the reflections, refractions, and colours of thin tranſparent bodies, why they change with the obliquity of the eye, requires no farther demonſtration.

The crooked appearance of an oar in water has been adduced as another evidence of the fallacy of viſion; here is no deception; the rays of light are actually bent, becauſe they are paſſing out of one medium into another, and thus impreſs the eye in a refracted ſtate; it is rather ſurpriſing that ſuch ſhould have been adduced by the ancients, as they were acquainted with the moſt important properties of light.

So objects magnified in a fog are not, as Berkley ſuppoſes, owing to their being fainter, and conſequently imagined larger; if two ſimilar ſized objects ſhould be placed ſo as to be viewed through a fog, and the one reflected as much light again as the other, according to this theory, ought not to appear ſo large; this effect we do not find: all objects appear not only fainter, but alſo larger, from the rays of light being refracted through the miſty medium, and conſequently diffuſed over a larger ſpace; ſo that not only fewer rays enter into the eye, but thoſe which do enter are more diverging, the angle is larger, and the object muſt neceſſarily appear ſo.

Every one muſt have obſerved that a fly paſſing very near the eye has raiſed the idea of a large bird, owing to the eye not then being prepared to ſee ſo near a ſituated object; the light is diſſipated over a greater number of fibrils in that unconverged manner as to produce a confuſed idea of a larger animal.

When we ſee a man at a hundred yards diſtance, he ought to appear to us only half the ſize as when at fifty, yet we obſerve no difference; a child of three or four years of age ſeeing a man a hundred yards off, takes him for a boy; ſo we, when placed in a ſituation we have not been accuſtomed to, as at the top of a high building, or the monument, or if looking upwards at the dragon on Bow ſteeple, or at the elevated dome of a building, theſe ſufficiently ſhew that there is no fallacy in the optic powers; the number of fibrillæ that are impreſſed by the ſame object is in the ratio of its diſtance. When we have been accuſtomed to contemplate an object at the diſtance of perfect viſion, we aſſociate this appearance to the ſame object ſeen more remote. It is owing to this that a perſon, when viewing through a teleſcope a man at one hundred yards diſtance, and being told it magnifies one hundred times, is ſurpriſed that the man ſhould not appear one hundred times enlarged; not being aware that his idea of the man is only the aſſociation from the appearance of him at the diſtance of twenty-four inches, or perfect viſion; the teleſcope only enlarges the real angle the man ſubtends, ſo that he would appear no larger than if placed at the diſtance of one yard.

Berkley, in the farther ſupport of his ſyſtem, ſays, images excite the ſame ideas as real objects do; the repreſentation of a perſon in a glaſs, a picture: if I am looking at myſelf in a common looking-glaſs, I always obſerve my own face as far beyond the glaſs as I am anterior to it. By tracing the rays of light which are thrown from the face on the mirror, this muſt appear evident; the rays which are thrown on the quick-ſilvered ſurface of the glaſs are reflected to us in equal angles; the ſtate of the ſpreading rays on the glaſs mark the diſtance of the object from the glaſs, and which being added to the diſtance between the eye and the glaſs, will be the diſtance it appears to us; as conſequently the rays on the ſurface of the glaſs are juſt as diverging as the rays proceeding from an object placed at the ſame diſtance behind the glaſs.

THE MOTION OF A BODY.

Malebranche, who has endeavoured to prove the fallaciouſneſs of all our ſenſes, after attempting to ſhew that there can be no dependance on our ideas of diſtance; from this he demonſtrates the errors of our ſight with reſpect to motion; certainly he is ſo far correct, that bodies moving with

with equal velocities, their celerities will appear to us in the ratio of their diſtances. Motion produces ſucceſſive impreſſion on ſucceſſive fibrillæ; to talk of abſolute motion and abſolute magnitude is abſurd; we can only compare the ſtate of one body with that of another, and therefore all our ideas muſt be relative; as with magnitude we ſhewed that our powers were neceſſarily limited, ſo alſo is it with motion: there may be ſuch imperceptible to us, yet to ſome inſects may be as rapid as a comet in its perihelion. What may be the limits of the leaſt and greateſt viſible motions, might be a ſubject of curious inquiry; we know impreſſions continue nearly a ſecond of time; we know, alſo, that a circular card, on which are painted the priſmatic colours, being briſkly turned round, appears white, and we may eaſily conceive that a body may move with ſuch rapidity as not to be viſible; that its motion may be ſo great as to entirely change the direction of the rays of light, by imparting to them its centrifugal power.

We find all external things * which are the objects

* Could it have ever been ſuppoſed that men, after many years exercife of the ſenſe of ſeeing, ſhould have never experienced that objects vary in their apparent or viſual magnitude, according as they are diſtanced, yet ſuch has been maintained by philoſophers in no reſpect contemptible; thus Lucretius tells us Epicurus fancied the moon was no larger than what it ſeems. Lunaque

jects of the ſenſe of viſion are ſuch in conſequence of the light thrown off their ſurfaces producing certain actions within the eye; that there are ſuch extent of powers as anſwer the purpoſes of our creation; although we cannot ſee thoſe minute particles which are viſible to microſcopic inſects, we poſſeſs what they do not, a more extenſive range of viſion; thus each is admirably calculated for the ſphere he is to move in: ſuppoſing we were endowed with ſuch powers of ſight as to penetrate into the innermoſt receſſes of matter; that we could ſee the conſtituent particles of bodies, and the interſtices formed by their mechanical arrangement; or, with Dr. Highmore, behold the magnetical effluvia dancing like ſmoke in circumgyrations round their reſpective poles, ſhould we be ſo happy as we are? Could we then contemplate with ſatisfaction the ſurfaces of thoſe bodies which now afford us ſo

Lunaque ſive Notho fertur loco lumine luſtrans,
Sive ſuam proprio jactat de corpore lucem,
Quicquid id eſt nihilo fertur majore figura,
Quam noſtris oculis quam cernimus eſſe videtur.

Epicurus himſelf mentions ſuch an opinion in his Epiſtle to Pythocles.—V. *Diogenes Lucretius*, lib. 10.

So Mr. Hobbs, in his Philoſophical Elements, directly ſays the ſun and moon are preciſely of the ſame ſize they appear to us: he ſays, "if diſtance took away any of the magnitude of "theſe luminaries, they could not be ſeen ſo diſtinctly." It is rather ſurpriſing that Mr. Hobbs, who was certainly a good mathematician, ſhould have made ſuch a miſtake.

much

much pleaſure? Would our eye wander giddily along thoſe animated ſpheres on which it now delights to dwell, not knowing where to ſtop? No; to us they would be no longer beauties; they would appear like the gigantic inhabitants of Brobdinag to Gulliver; the delicate ſmoothneſs would ſink into a loricated appearance, and inſtead of a *Venus de Medicis* we ſhould have an alligator; the beauty of motion as well as of figure would be deſtroyed; what we now admire, a bird gliding gently through the air, the beauty would be loſt in the rapidity of its flight; and inſtead of the pleaſure of contemplating a ſmooth running ſtream, we ſhould behold a cataract of Niagara.

From what has been obſerved, I hope it will appear that the ſenſe of ſeeing is in no reſpects fallacious; that diſtance, magnitude, figure, motion, and colour, are regularly and properly communicated to the mind through the medium of the eye; that when we do err, it is an error of the judgment, and not of the ſenſe. The other ſenſes I ſhall only curſorily examine, and afterwards I ſhall preſume to make ſome general deductions.

SENSE OF HEARING.

In the eye the rays of light immediately impreſs the nervous organ; in the ear the elaſtic tremors of the air are never in contact with the

auditory

auditory nerve. Notwithftanding this difference in the communication, we fhall have reafon to obferve a beautiful harmony fubfifting between the two fenfes.

Whenever the air is acted on by the tremulous motion of an elaftic body, fuch an effect is induced, that when ultimately communicated to the auditory organ the idea of found is excited.

That fuch depends on the air is evident from the common experiment of attempting to produce found in an exhaufted receiver, and as the air is condenfed the found is increafed.

Varennius tells us that Fredlicus, when at the top of the Carpathian mountains in Hungary, fired a mufquet, and which feemed to him like breaking a little ftick, the air being fo rare at that height *.

Notwithftanding thefe circumftances, fome have fuppofed that found is produced by the impulfe of an ætherial nature; for Lord Verulam had remarked, that the greateft found did not agitate any flame placed near it, whilft it were affected by the gentleft breeze †.

We

* Dr. Halley alfo tells us, that a perfon in a diving bell, at a great depth, where the air would be condenfed as many atmofpheres as they were fpaces of 30 feet each deep, in attempting to blow a horn, violently ftunned himfelf and his companions.

† If we fcratch one end of a long piece of timber with a pin, the

We ought to obſerve that ſound is no ways a ſimilar motion to that of wind, the former being only the action and re-action of the aërial particles, without any change of place; while a wind is a motion of the whole maſs of air. The nature of ſound and wind may be well illuſtrated by water; when we produce that melodious tone by rubbing the tip of the finger with a gentle and equable motion along the rim of a half-filled drinking glaſs, we find the ſurface of the contained water thrown into a beautiful curdly appearance, and ſeems to move round with the rapidity equal to the finger; that there is no ſuch rotatory motion we may eaſily evince, by placing a piece of paper on the ſurface which has no ſuch motion; here the particles of the water are acting and re-acting on each other, and ſometimes with ſuch violence as to fly out of the veſſel, particularly if the water is hot; while a wind is more conſo-

the action is communicated very diſtinctly to the other end; it has been ſuppoſed ſuch could not be induced by the action and re-action of all the particles of the wood, as the effect would be greater than the cauſe; hence it has been conjectured that an ætherial principle is diſſeminated through the interſtices, and this is thrown into action. As we well know that a large glaſs receiver, by the ſlighteſt tremor, will change its ſpherical form, and become ſpheroidal, ſuch a change could not be effected without the particles of the glaſs each undergoing their reſpective action.

nant to waves where a mafs of water is moved *. Galilæo, the firft who obferved a fenfible difference between the velocities of light and found, eftimated that found moved about 400 yards in a fecond. Dr. Derham, by firing cannon on Blackheath, more accurately determined it to be 1142 feet in a moment †.

The more perfectly elaftic a body is which is ftruck, the more equally it fucceffively impreffes the air, and produces the moft mufical tones; thus glafs, the moft perfectly elaftic of any body, produces the moft perfect tones.

The number of vibrations in a certain time mark the difference of tones. Sauveur, by fome ingenious experiments on organ pipes of different lengths, has fhewn to the production of fome tones there will be 51,200 ‡ vibrations in a fecond.

A body

* When a ftone is thrown into water, we perceive many circular waves are produced, all having the part where the ftone entered as the common centre; if near to this centre the water receives another impulfe at the fame time, the circles which are formed freely and uninterrupted interfect the other circles; thefe are not waves, not a motion of any mafs of water, only the action and re-action of the particles acting from a centre; as the circles fpread, the power is more diffufed, till ultimately not being able to overcome the vis inertiæ of the water, the apparent motion ceafes.

† The fwifteft wind only moves 90 feet in the fame fpace of time.

‡ A ftring giving the deepeft mufical tones which the ear can diftinguifh

A body when ſtruck never produces a ſolitary ſingle ſound; there are certain ſecondary and ſubordinate vibrations attendant on the primary: when a fire ſhovel falls many ſounds are produced, but the parts which produced them having no muſical proportion to one another, there ariſes a jarring diſſonance; ſo the note of ſwine is made up of many others, as if proceeding from a faggot of pipes out of tune.

When ſeveral ſounds are arranged in ſucceſſion to one another in a manner agreeable to the ear, it is called melody.

The art of pleaſing that organ by the union of ſeveral ſounds, which are heard at one and the ſame time, is termed harmony.

A chord, compoſed of ſounds whoſe union or coaleſcence pleaſes the ear, is called a conſonance, and the ſounds are ſaid to conſonant one to the other; thus half a chord is the moſt perfect conſonance to the whole, and called an octave; two thirds is the next conſonance, and is called a fifth, and then a third, &c. When ſounds produced at the ſame time, each of them heard by itſelf, being no ways coaleſcent to the ear, are

diſtinguiſh vibrates $12\frac{1}{2}$ times in a ſecond; a ſecond ſtring 12 octaves higher: the moſt acute the ear could diſtinguiſh will vibrate 51,200 times in a ſecond, which is found by repeating the ratio of 2 : 1 twelve times $= 12\frac{1}{2} \times 2 \times 2 \times 2 \times 2 \times 2 \times 2 \times 2 \times 2 \times 2 \times 2 \times 2 \times 2$.

termed diſſonances; thus the ſecond and the ſeventh notes.

The ancients meaſured ſounds by numbers, and accounted for conſonances as an effect of proportion *. Galilæo was the firſt who attempted to account mechanically for the pleaſure we receive from muſical ſounds, by comparing the vibrations of a muſical ſtring with thoſe of a pendulum.

Two pendulums of the ſame length vibrate in equal times; whatever their arches may be, they will be iſochronous: a pendulum four yards long will vibrate as ſlow again as a pendulum a yard long; hence the vibrations are as the ſquare roots of their lengths. A muſical ſtring being faſtened at both ends, is to be regarded as a double pendulum; hence not neceſſary to quadruple the length, in order to make the time of a vibration twice as great, it will be ſufficient to double it.

Thus if we have pendulums of lengths correſponding to the ſubdiviſions of a monochord, the viſual conſonance in their vibrations will tell us where the auricular one is alſo.

* Pythagoras would not admit of a twelfth to be a concord, becauſe its ratio 3 : 8 neither multiple nor ſuperparticular. "Potiores rationes potioribus conſonantiis aſſignabant," ſays Dr. Wallis.

Multiple ſuperparticular proportion is when one number or quantity contains another more than once, and ſuch an aliquot part as will exactly meaſure it without any remainder.

Befides this coincidence, the monochord, by being divided into certain portions, where the moft diftinct tones are produced, are, in their lengths, in the fame proportion to each other as the divifion of the rays of light into the different colours.

As the mind judges of vifual objects by the different impreffions of light on the optic fibrillæ, fo it judges of various founds by the varied impreffions on the auditory nerves*; as, in the one cafe, by experience it determines the vifual properties of bodies, fo likewife it fimilarly afcertains the nature of the founding body when accuftomed to its impreffions.

Although there is fuch an agreement between thefe fenfes, neceffarily arifing from the harmonious arrangement of our fyftem, yet they are to be regarded as fenfes diftinct and independent; although they appertain to one and the fame foul, they are to be regarded as the different chords appertaining to one and the fame inftrument. Future obfervations may evince greater coincidence, may fhew a ftill greater alliance; they may approximate like two certain mathematical lines which can never unite †.

ON

* On compte neuf cens foixante trois mille deux cens tons différens très diftincts à l'oreille & qui peuvent encore être variés quant à la force. *Sauveur Acad. Scien.*

† Thefe are lines which may be drawn nearer and nearer the

curve,

ON THE SENSE OF FEELING.

Thofe parts of our bodies which are more peculiarly calculated for the fenfe of feeling are endued with a certain arrangement of nervous papillæ; we obferve them peculiarly feated in the large winding ridges at the ends of the fingers, regularly difpofed in fpiral folds; thefe, by the attention of the mind, are raifed and erected, and confequently more enabled to embrace a greater number of parts of external objects.

As thefe nerves are fimilarly arranged, it may appear difficult to conceive how we are enabled to diftinguifh fuch a number of different bodies by the touch*. Suppofing an impreffion was confined

curve, and yet if infinitely continued they will never meet, and are then faid to be *afymptotes* of the curve; fo alfo two curves may be afymptotical. This is eafily explained by means of a curve, called, by its inventor Nicomedes, *conchoid,* from its refemblance to the curvature of a fhell; right lines drawn from the pole to the curve are equal; if a line be fo drawn as to cut all thefe lines, and the interfected portions are equal, then fuch a line will be an afymptote to the curve: as the lines drawn to the pole increafe in their inclination to this afymptote, there will hence be a continual approximation to the curve.

* Il ne m'a pas été poffible de concevoir, que des fibres parfaitement *femblables,* puffent fuffire à recevoir et à tranfmettre fans confufion tant d'impreffions diverfes. Il m'a femblé, que chaque

confined to a ſingle nerve, the varieties would be diſtinguiſhed by force, and conſequently very limited; if we carry our ſuppoſition farther, and ſay, that from a centre ten or twelve nerves may branch from it, if a body preſſes upon any two of theſe nerves, as, for inſtance, on the firſt and ſecond nerve, a certain ſenſation would be induced; if on the firſt and third, a different ſenſation would ariſe, in conſequence of the impreſſed nerves varying in their inclinations to each other, or the angles they form, and the reſulting force varying alſo, ſo that even in twelve branches, by ſuppoſing two nerves only impreſſed at a time*, there would be 80 different impreſſions nearly. If a body preſſes upon two nerves with a certain force, the nearer thoſe nerves are to each other, the more ſtrong the impreſſion will be felt; the more diverging the nerves, the weaker the impreſſion muſt be †.

chaque fibre ſenſible feroit ainſi dans le cas d'un corps pouſſé à la fois par pluſieurs forces, qui agiroient en ſens différens: ce corps recevroit un mouvement *compoſé*, qui feroit le produit de ces forces, et qui ne repréſenteroit aucune de ces forces en particulier. *Bonnet Palingén.*

* 12 + 11 + 10 + 9 + 8 + 7 + 6 + 5 + 4 + 3 + 2 + 1 = 78.

† If they ſhould be inclined to each other in an angle of 60 degrees, one eighth of their force will be loſt; thus every degree, more or leſs, there would be a variety: this is eaſily aſcertained on the doctrine of the compoſition of forces; it is only compleating a parallelogram by two other ſides equal in length and parallel to the two nerves, and the diagonal line will expreſs their united force.

Such

Such a ſuppoſition will explain why we can diſtinguiſh ſuch an aſtoniſhing variety of impreſſions, and particularly when we conſider the almoſt infinite number of nerves diſperſed over our bodies *.

It has already been remarked, that the variety of the poſitions of the nerves may explain the variety of ſenſations of touch; when our fingers are applied to an object, there is a ſenſation of reſiſtance induced; if we apply one finger, we know ſomething muſt exiſt which produces this reſiſtance; the extent of this ſomething cannot be aſcertained but by embracing the extreme parts at one and the ſame time: as we are accuſtomed to view the ſame body we feel, we ſoon find a difficulty to diſſolve an union ſo early begun, and confirmed by ſo long a habit; when we ſee a body we have frequently felt, we immediately aſſociate the tangible ideas with the viſible; the hardneſs, ſoftneſs, roughneſs and ſmoothneſs, moiſture and dryneſs, are ſo frequently combined with our ideas of magnitude, diſtance, figure, motion,

* Some circumſtances which have occurred would induce us to ſuppoſe that other parts of the body might acquire an increaſe of ſenſibility, ſo as to reſemble the power of feeling in the papillæ; as ſome ingenious men have been born without hands or feet, and yet capable of many exertions where we ſhould think theſe limbs were abſolutely neceſſary. In the *Leverian Muſeum*, that *Repoſitory of Science*, there are the ten commandments finely written by a perſon thus deprived of both.

and

and colour of an object, ideas ſo ſimultaneouſly formed, that we are apt to ſuppoſe that in theſe two ſenſes there is a neceſſary dependance on each other *. To the farther ſupport of ſuch a ſuppoſition, it has been aſſerted that blind men have been enabled to diſtinguiſh colour by the feel. Surely it could not be imagined that the cutaneous papillæ were ſuſceptible of influence from light. That there are perſons who can diſtinguiſh colours by the touch I not only believe, but one inſtance I am well informed of; this was only in dyed ſubſtances, where there is an evident difference to the touch; let any perſon feel a white ſilk gown, and a black ſilk one after, with his eyes ſhut, and he will perceive a conſiderable difference, from the alteration of the one having undergone in dying. Surely we would not credit that the rays divided by a priſm, and thrown

* Sir Joſhua Reynolds has very elegantly deſcribed that conſonance which ſubſiſts between the ſenſations of ſeeing and hearing. " The diſtinct blue, red, and yellow colours which are " ſeen in the draperies of the Roman and Florentine paintings, " though they have not that kind of harmony which is produced " by a variety of broken and tranſparent colours, have that ef- " fect of grandeur which was intended. Perhaps theſe diſtinct " colours ſtrike the mind more forcibly, from there not being " any great union between them, as martial muſic, which is " intended to rouze the noble paſſions, has its effect from the " ſudden and ſtrongly-marked tranſitions from one note to ano- " ther, which that ſtyle of muſic requires; whilſt that which " is intended to move the ſofter paſſions, the notes impercepti- " bly melt into one another."

fucceffively on a man's hand, that he would be able to difcriminate the different colours.

A blind man can have no idea of colours, nor a deaf man of found: a man born blind experiences not the deficiency of intellect as the one born deaf does. In the former we know the mind has been capable of the greateft exertion. All muft have heard of Saunderfon, the late Geometrical Profeffor at Cambridge, and thofe prodigies of learning who now exift, a Moyfe and a Goff. With the deaf man all converfe is deftroyed; not having heard founds, he could not imitate them; he would never be able to exercife the powers of fpeech, and the acquirement of a few ideas would engage a length of time. When thefe fenfes are enjoyed till the meridian of life, then the deprivation of fight feems a greater inconvenience, although there is apparently a greater depreffion of fpirits in the deaf man, arifing from feeing all in fuch actions he cannot enter into; this, comparatively fpeaking, is a momentary inconvenience; when retired within himfelf, when man becomes a man, all the fenfes he needs he has. He who is deprived of fight is, as it were, confined within the tomb of his own body; deprived of that extenfive range he formerly enjoyed, his foul feems fettered and chained, no longer able to wing his flight, "to foar with Plato "to the empyreal fphere," his optic avenues being for ever clofed, his better part is thus for ever imprifoned*.

The arguments I have prefumed to advance to explain the fenfe of feeling, I fhould fuppofe are equally applicable to the fenfe of tafting and fmelling; I am not pretending to any phyfiological inveftigation of the fenfes; I am making only fuch enquiries as to endeavour to prove that our fenfes are faithful in the part they are to perform, are as extenfive in their powers as our exiftence requires, and are more conducive to our happinefs than any other form we could fuggeft.

By thus examining each fenfe, we find their fenfations are diftinct, and our ideas formed by their comparifons muft neceffarily be fo; if a man is blind, he can have no idea of colours†; if deaf, no notion of found; if devoid of fmelling, ig-

* ———————— why was the fight
To fuch a tender ball as th' eye confin'd,
So obvious and fo eafy to be quench'd?
And not, as feeling, through all parts diffus'd,
That fhe might look at will through ev'ry pore;
Then had I not been thus exil'd from light,
As in the land of darknefs yet in light,
To live a life half dead, a living death,
And bury'd; but O yet more miferable!
Myfelf, my fepulchre, a moving grave.

Samfon Agonifles.

† We are told of a blind man, from the defcription he had received of the colour of fcarlet, faid it muft refemble the found of a trumpet.

norant of odorous fubftances*; thus, if deftitute of all his fenfes, he would be like the nobleman of Laufanne†, in a ftate of perfect deliquium.

When the nervous fibrils are impreffed by external caufes, how is fuch an impreffion communicated to the mind? Here indeed we are involved in impenetrable darknefs, in a perfect ftate of obfcuration; the variety of conjectures ftill farther thicken the cloud which thus envelopes our mind. We fee that animated matter poffeffes powers different from inanimate: we fee that it poffeffes powers of growing from within, while common matter only increafes by the cafual aggregation of

* Monf. Prevoft, of Geneva, has endeavoured to render the emanations of odorant fubftances perceptible to the fight; when a fragment of camphor is placed on water, it is immediately moved by a fwift rotatory motion. Romieu had previoufly made this obfervation, and attributed it to the difengagement of electricity: thefe odorant fubftances evaporate 30 or 40 times more quick in water than in the open air. May not the volatile effluvia being fo quickly evolved, by meeting with fome refiftance from the furrounding medium, produce this rotatory motion?

† Monf. Croaz mentions this cafe in the Academy of Science: a nobleman of Laufanne, in giving orders to a fervant, fuddenly loft his fpeech and all his fenfes; he remained in this fenfelefs ftate fix months, and when he recovered he afked his fervant if he had executed his commiffion, not being fenfible that any interval of time had elapfed during his illnefs. Van Swieten relates the fame in his Commentaries on Boerhaave's Aphorifms; and Mrs. Bellamy, in her Memoirs, mentions a fimilar cafe of a lady remaining for a week in a ftate of this kind.

particles exteriorly. What this difference is we know not; nor, upon the leaſt reflection, could ſuch a knowledge be ſuppoſed poſſible. To comprehend any principle, requires firſt a ſuperiority; if this be granted, how can one principle comprehend itſelf? A piece of iron may as well perceive its own arrangement, as the ſoul the nature of its own conſtitution; ſuch appears to me an incontrovertible argument of the exiſtence of both: thus if I preſume to ſay I comprehend the fluxions of Newton, and the reſidual analyſis of a Landen, may I not venture to conclude that ſuch a comprehenſion implies a ſuperiority of the mind to ſuch purſuits? and ſuch a comprehenſion muſt neceſſarily demonſtrate a principle underſtanding, and a principle underſtood.

The ancients *, very ſenſible of the difficulty of explaining the action of matter on ſpirit, fancied there muſt be ſomething of a ſubtile nature, forming a line of diſtinction; they ſuppoſed the nervous fibres are fine tubes, replete with an ætherial vapour; the του πνευματος of Hippocrates; this they called animal ſpirits; while ſome have ſuppoſed them of an exploſive nature †, others

* From many parts of Cicero, it has been ſuppoſed he imagined the ſoul material, yet, after many ſuppoſitions, he confeſſes his ignorance. "Anima ſit animus, ignifve, neſcio; "nec me pudet ut iſtos, fateri neſcive quod neſciam. Illud, "ſi ulla alia de re obſcura affirmare poſſum, ſive anima, ſive "ignis ſit animus, eum jurarem eſſe divinum." *Tuſc.*

† Dr. Willis.

have

have fancied them of a ſaponaceous conſiſtence *, no ſuch tubular appearance could ever be diſcovered. Dr. Briggs conjectured that the nerves were ſolid filaments, of prodigious tenuity, and when acted on, vibrating in the ratio of their lengths and tenſions. Newton, prepoſſeſſed with an idea of æther, ſuppoſed that this pervades all bodies, and that the vibration of this medium may be propagated along the ſolid, pellucid, and uniform capillaments of the nerve. Upon this conjecture Dr. Hartley has endeavoured to deduce a very ample ſyſtem, concerning the faculties of the mind, from the doctrine of vibration, joined with that of aſſociation. By vibrations Dr. Hartley does not mean a pendulous-like motion of the whole chord, only an oſcillatory motion of the ſmall †, infiniteſimal medullary particles, ſimilar to the action and re-action of the aërial particles in the caſe of ſound. When an impreſſion is made, vibrations in the æther reſiding in the pores are excited; thus the impulſe affects both the nerves and the æther, ſo that theſe mutual actions impreſs and increaſe the denſity of the æther, which will agitate the nervous particles with ſynchronous vibrations; hence this

* Dr. Monro.

† The particles which vibrate are of the inferior, and not the biggeſt particles on which the operations of chemiſtry and the colours of natural bodies depend. Prop. IV. vol. 1.

æther

æther is to be regarded as regulating and ſupporting the vibrations of the particles, not as exciting them originally.

Theſe vibrations, he ſays, are communicated to the brain like the electric effluvia along hempen ſtrings.

However homogeneous and pellucid the nervous particles or infiniteſimals may be, they can never tranſmit an uniform equalized motion; for tremors will decreaſe from diffuſion in the ratio of their receſſion from the centre of action. Why Dr. Hartley ſhould thus have made uſe of an ætherial principle that he himſelf confeſſes he underſtood not, I cannot comprehend; although he has no direct evidence of its reality, yet he fancies he has the ſupport of indirect evidence; and comparing it to the ſcience of algebra, that we may arrive at a true concluſion from a falſe poſition. Dr. Hartley ought to have been aware, that in an algebraical analyſis we muſt have ſome data; in vain could we proceed with preciſion and certainty, if what are given to us are merely hypotheſes; in vain could we expreſs the nature of a curve, unleſs we knew the relation between an abſciſs and its correſpondent ordinate, whether, with Des Cartes*, we conſider the geometrical mode, or, with Newton, the differential method.

* Des Cartes was the firſt who geometrically ſhewed how to find the equation of a curve.

So

So alſo the ſuppoſition of a nervous meſſenger being any thing of an electrical nature is equally objectionable; the obſervations of a Galvani or a Valli do not tend in the leaſt to elucidate the ſubject. Where are ſuch actions ultimately to terminate*? To impreſs the mind they cannot; impreſſion

* Can we reſiſt a ſmile, when we peruſe the ſentiments of different phyſiologiſts reſpecting the ſeat of the ſoul. Hippocrates ſuppoſed it was in the left ventricle of the heart. Γνώμη γαρ ἡ τȣ ἀνθρώπȣ πέφυκεν ἐν τῃ λαιῇ κοιλίῃ. Such was alſo Ariſtotle's opinion, (v. Ariſtot. de Juventute et Senectute, c. 3.). Mr. Hobbs, although he reſolved ſenſe into re-action of matter, yet he here thought was the centre of action, (v. Elem. Phil. c. 25. art. 5.). Galen finding the ſtomach a faithful porter, to watch that nothing ſhould enter the conſtitution which could any ways injure it, here fancied the ſoul was ſituated; the ſame idea was afterwards entertained by the celebrated Van Helmont, in his Eſſay on the Seat of the Soul. Des Cartes, thinking the ſoul ſhould be ſeated in a central point, and obſerving the pineal gland was the only ſuch exiſting in the brain, was determined by this to make it the ſoul's habitation; here he ſuppoſed intelligence is brought of all objects which affect the ſenſes.

Bartholine, and Wharton the learned author of Adenographia, have ſeriouſly attempted to deprive the pineal gland, this conarion of Des Cartes, of this honour: they have obſerved that it is too little to repreſent all the images; that the external nerves do not here all unite, therefore could not receive the impreſſion of ſenſible objects; and laſtly, that it was ſometimes ſtony, and ſituated in a place of excrements, and conſequently *ſoil* the ſpecies of things, and *dirty* our ideas; hence they removed the ſoul to the ſpinal marrow.

Henricus Regius, the pupil of Des Cartes, maintained that there impreſſion implies reſiſtance, and reſiſtance matter. Is is not more reaſonable to ſuppoſe that the mind is not confined to any particular part of the body, but diffuſed through every fibre?

> Spiritus intus alit, totam que infuſa per artus
> Mens agitat molem et magno ſe corpore miſcet.

Hence we ſhall be relieved of the difficulty of ſuppoſing any communicating medium; the part immediately impreſſed is itſelf alive, and the portion of vitality entering into the organization of the body is proportionably influenced as the body is impreſſed.

Some phyſiologiſts have ſuppoſed that external objects may immediately influence the mind, without previouſly exciting any action on the groſſer part of our frame. To ſuch a ſuppoſition there are many objections; as in ocular ſpectra, where

there were in ſome unknown part of the body a perfectly ſolid and ſmall particle of matter, incorruptible from its hardneſs, on which the ſoul was perched, (v. Philoſ. Natural. l. 4. c. 16.); ſome have ſuppoſed the membranes enveloping the brain, others the *Septum Lucidum*, and Dr. More the fourth ventricle: more modern phyſiologiſts have not confined the ſoul to any particular part of the brain, but have ſuppoſed it may be diffuſed through a larger portion; thus Newton calls it the ſenſorium, which opinion Locke ſeems to ſupport: from the great ſenſibility of the diaphragm, Buffon conjectures its reſidence may be here; and Dr. Hartley ſuppoſes there may be an infiniteſimal elementary body intermediate between the ſoul and groſs body, but that the white medullary part of the brain is the ſeat of the ſoul. *Schol.* to prop. 5. lib. 1.

there are aſtion and re-aſtion of the nervous fibrillæ, to ſuppoſe ſuch of the mind is rendering it material. Lord Kaimes fancies the mind, when excited, aſts out of the body.

It ſeems more eaſy to ſuppoſe that each organ of ſenſe poſſeſſes a percipient power *; that matter, when ſo arranged as to be in a ſtate of organization, a ſtate into which it has been brought by the powers of life, may poſſeſs that medium of communication, as more likely to tranſmit the

* The learned Biſhop Butler, in his Analogy of a Future Life, ſays, that the matter of our bodies is as extraneous to ourſelves as any external matter whatever; that conſtant flux, continually deſtroying the identity of the corporeal part, ſhews how it may be alienated, and, in a daily courſe of ſucceſſion, changing its owners, whilſt the living agent remains one and the ſame permanent body.

During my idle hours laſt year I arranged ſome thoughts on the *circulation of vitality*; I have endeavoured to prove that animated beings could not exiſt without the aid of matter poſſeſſing life; with every portion of matter we added to our ſyſtem, a portion of vitality was added alſo; that when the matter was removed, the vitality remained, and the accumulated portions might in ſome reſpeſts account for the increaſe of living powers. Such a ſuppoſition neceſſarily renders the mind diviſible; but diviſibility is not of itſelf ſufficient to conſtitute matter; it is eaſy to conceive ſpace itſelf diviſible; nor does ſuch a ſuppoſition in the leaſt militate againſt the immortality of the ſoul.

Mind, ſoul, principle of life, or by whatever name may be termed that part of animated beings which is not material, I mean one and the ſame, in this I alſo include the *irritability of a Gliſſon*, the *vis inſita of a Haller*, and the *excitability of a Brown*.

effect of any impulse, than that external objects should immediately impress the mind.

To the sceptic, other proofs may be requisite; still he will say there is a probability of the senses' deceptions: let us endeavour to diminish such probability by mathematical reasoning: supposing he is in such a state of doubt, that the evidences for and against the veracity of his senses are equal; supposing an orange is presented to me, I see it, I taste it, I feel it, I smell it, and, when pressed, I hear the effect. Here then is a body that to each sense has the probability of existence; as the probabilities are equally against them, $\frac{1}{2}$ will express the evidence in its favour with respect to sight; so of hearing, and the other senses: this is the state of probability when independant of each other; when they all concur in the support of each other, then $\frac{1}{2} \times \frac{1}{2} \times \frac{1}{2} \times \frac{1}{2} \times \frac{1}{2} = \frac{1}{32}$; that is, the probability of our senses being correct, is as 32 : 1.

I, however, must confess that I do not much approve of the application of measure and calculation to things which do not admit of it; although, in this respect, I have the countenance of many celebrated writers, it appears to me like attempting to measure human affections and the moral worth of actions by direct and inverse ratios; or "as an eminent mathematician at- "tempted to ascertain by calculation the ratio

" in which the evidence of facts must decrease in " the course of time, and fixed the period when " the evidence of the facts on which Christia- " nity is founded shall become evanescent, and " when, in consequence, no faith shall be found " on the earth."

PROPERTIES

PROPERTIES OF MATTER.

THE opinions of the moſt ancient philoſophers reſpecting the variety of matter, were, that it originated from certain formed particles. The Ægyptians, from whom Pythagoras ſeems to have derived his knowledge, obſerved that there were only five regular ſolid figures, terminated by plane ſurfaces, which are all ſimilar and equal; viz. the tetrahedron, the cube, the octahedron, the dodecahedron, and eicoſihedron. It was ſuppoſed that all elementary bodies muſt have one or other of theſe regular figures. This ſyſtem appears to have been adopted by ſucceſſive mathematicians, till the Ariſtotelian philoſophy had fully eſtabliſhed itſelf. The Homæomeria* of Anoxagoras,

* Homæomeria amounts to the ſaying, that each totality in nature is compoſed of parts which, before their union, were already of the ſame nature as the whole; thus a bone is a compoſition of ſmall bones; a man an arrangement of little men; and a tyger an accumulated maſs of cats.

Nunc

Anoxagoras, the water-making principle of Thales*, or the fortuitous concourſe of atoms of Epicurus†, although they have had ſome partizans, yet have not been ſo generally ſupported. Pythagoras, Eudoxus, and Leon, have geometrically demonſtrated the properties of theſe bodies; their elements Euclid collected, and which conſtitute

Nunc et Anaxagoræ ſectemur Homæomeriam,
Quam Græci memorant, nec noſtrâ dicere linguâ
Concedit nobis patrii ſermonis egeſtas:
Sed tamen ipſam rem facile eſt exponere verbis,
Principium rerum, quam dicit Homæomeriam,
Oſſa videlicet ex pauxillis atque minutis
Oſſibu.

* Thales imagined water was the principle out of which every thing was formed; this he ſuppoſed from the apparent change of bodies, deſtroyed by fire, being converted into vapour, and this ultimately reſolved into water. This ſuppoſition was afterwards entertained by the celebrated chemiſt, Van Helmont, not only from the univerſality of its exiſtence, but alſo from obſerving a ſmall willow, of five pounds weight, acquiring an increaſe of 159lb. in five years by the loſs of water only.

† The Epicureans imagined the primary particles were of different forms, as crooked, ſquare, oblong, and, indeed, of every ſhape; theſe, all in motion, and ſtriving to come forwards, all deſcending and traverſing the vacuum, fortuitouſly uniting, ſome formed a heaven, ſome a ſun, others an earth, planets, and man. They tell us that the eyes of man were not made with any deſign of ſeeing, but that he afterwards thought of ſeeing becauſe he had eyes, and thus with the other parts of the body.

Lumina

conſtitute his ſix firſt books, as introductory to the eleventh and twelfth, and which are peculiarly appropriated to the inveſtigation of theſe regular ſolids. Theſe ſyſtems were all of a momentary duration, compared to the ſyſtem of Ariſtotle; with his four material elements, and occaſionally a fifth, a celeſtial quinteſſence of which he made a heaven or a ſpirit, he eaſily formed an univerſe; out of his ſtores of primitive matter his ten categories: he had ſubſtantial forms and occult qualities at will, to explain any phænomena; thus, by giving learned names to unknown cauſes, he involved the whole in a ſtill greater obſcurity. Enquire of Ariſtotle what matter is, he tells you, "*That it is what is neither* "*which, nor how great, nor what, nor any thing* "*of what being is determined by,*" (v. Phyſic. l. 1. c. ult.): in another place he ſays, "*Matter is the* "*firſt ſubject of every thing, which always ſubſiſting*

> Lumina ne facias oculorum clara creata,
> Proſpicere ut poſſimus: et ut proferre vidi.
> Proceros paſſus, ideo faſtigia poſſe.
> Surarum ac fæminum pedibus fundata plicari:
> Brachia tum poro validis ex apta lacertis
> Eſſe, manúſque datas utraque à parte miniſtras,
> Ut facere ad vitam poſſimus, quæ foret uſus.
>
> *Lucretius.*

This ſyſtem, a little more refined, has been adopted by the Archdeacon of Digne, the celebrated Gaſſendus. Epicurus fancied motion would effect every thing, while Gaſſendus requires a ſpecial providence.

"*therein,*

"*therein, makes it a being by itſelf, not by accident.*" Plutarch tells us, that when Ariſtotle publiſhed his book of *Acroamaticks*, or Select Knowledge, that his illuſtrious pupil, Alexander, was offended that he thus diſcloſed his philoſophical ſentiments to inſtruct others as he had inſtructed Alexander; he anſwered, they were written in ſuch a ſtyle as not to be comprehended by every capacity: indeed it is too true. Who can underſtand the jargon of the above definitions? yet for more than a thouſand years has this ſyſtem reigned: ſo bigotted to it were the Ariſtotelian diſciples, that Bullialdus tells us a pleaſant inſtance of a Florentine phyſician who could not be prevailed upon to look through a teleſcope, leſt he ſhould ſee ſomething contrary to the doctrines he imbibed. Ariſtotle rejected the more ſimple doctrine of the indeſtructibility of matter, which was the prevailing opinion, but endeavoured to eſtabliſh a ſyſtem of generation and corruption; with his *matter*, *form*, and *privation*, he more eaſily ſuppoſed a new creation than a different arrangement *.

I preſume

* Although it may be preſumed thus to criticiſe the Natural Philoſophy of Ariſtotle, in a collective view he muſt be admired as a ſurpriſing genius; although, with *Averrhoës*, we may not ſuppoſe him the *Limit of Human Nature*, his Eſſay on Logic, his Philoſophical Obſervations, and Natural Hiſtory, certainly merit our greateſt attention. When we reflect on Ariſtotle, we ſhould carry our mind to the period when he lived; we ſhould think

I preſume not, in this little Eſſay, to examine the ſyſtem of thoſe atomiſts who reſolved all things into the motions and modifications of matter; or the harmony* of Pythagoras; or the doc-

think of the little that was then known, from the difficulty of acquiring it. Although, with Laertius, we cannot conceive that he had written 4000 books, yet probably more than the 20 that are tranſmitted to us, as Pliny ſays he wrote 50 volumes on animals only; and Strabo tells us that Ariſtotle left his works to Theophraſtus; that they were buried for a length of time under ground, and at laſt were ſold to one Apellicon, of Athens. Scylla, on his conqueſt of this place, brought the works to Rome, and they were given to one Andronicus, of Rhodes, to reviſe: to fourteen of theſe books, which had no general title, Andronicus prefixed the words Ta Meta, Ta phyſica, that is, *the books poſterior to the phyſics,* meaning that they ſhould be ſtudied next after the phyſics; this is ſaid to be the origin of the word *metaphyſic.*

With reſpect to the elements of Ariſtotle, ſuch had been ſeparately ſuppoſed the principle of all things. Thales, as has already been obſerved, ſuppoſed water; and his ſucceſſors of the Ionic ſchool each endeavoured to overthrow what his predeceſſor had advanced; ſo ſome choſe air, a third fire, a fourth preferred earth, &c.

* In general, that any muſical chord may become in uniſon to a leſſer chord of the ſame kind, its tenſion muſt be increaſed in the ſame proportion as the ſquare of its length is greater; if, therefore, muſical chords extended from the ſun to each planet, that all theſe chords might become uniſon, it would be requiſite to increaſe or diminiſh their tenſions in the ſame proportions as would be ſufficient to render the weight of the planets equal; from this ſimilitude of proportions the doctrine of the harmony of the ſpheres is derived.

Plin. l. ii. c. 22, *Macrob. in ſomnium.*

trine of Plato*: neither do I mean to make any enquiry into the variety of fyftems which only for a fhort time have prevailed between the Ariftotelian and Cartefian period. Till the fyftem of Des Cartes arofe, the principles of Ariftotle were inculcated in every fchool. Des Cartes fhewed how inadequate to the explanation of any phænomena were the fubftantial forms and occult qualities of this philofopher of Stagira; he rejected them all. *Extenfion*, *figure*, and *motion*, were deemed by him fufficient to refolve the variety of appearances in the material world. "*Omnem materiæ variationem, five omnem ejus formarum diverfitatem pendere à motu.*"—*Princ. Philof.* So fimple a fyftem, fo reverfe to the abftrufe doctrines of the Ariftotelian fchool, was foon almoft generally adopted: the intricate labyrinth to philofophy being removed, the path became ftraight and eafy; philofophy, thus difencumbered of thorns and briars, became fo inviting in her native attire, as to be embraced by royal females.

Newton, and other philofophers, have fuppofed that Des Cartes has gone into the oppofite ex-

* Plato ftrove to raife the thoughts of men above the objects of fenfe, and zealoufly maintained the pre-eminence of active incorporeal and intellectual beings; in his Timœus he takes notice of the infenfible particles of matter which can only be conceived by the mind and underftanding, afcribing different figures to them, according to the atomical fyftem.

treme; they have thought that there are ſuch powers as *gravitation*, *attraction*, and *repulſion*, which cannot be explained on material principles. They ſay that there is a *Conatus accedendi & recedendi* in aggregate bodies, inexplicable by any known properties of matter, hence ſuppoſed to ariſe from ſome inherent active power.

We are alſo told by ſome philoſophers, that there are inherent in bodies certain powers, which are brought into action when the bodies are thrown into motion, a power Wolfius calls *vis viva*.

The author of the Eſſay on the Powers and Mechaniſm of Nature, ſays, that when a body is put into motion, a quantity of *acceſſary active ſubſtance* is received from the agent which gave it motion; this being received, it parts with it again; it moves by the preſence of this ſubſtance, and when the body is ſtopped, the active power paſſes on, and enters the obſtacle.

Ancient and modern philoſophers have ſuppoſed that there are *ſubtle media*, *ætherial principles*, *imperceptible atmoſpheres*, hovering round every particle of matter; that theſe exiſt in every body exerciſing the powers of *attraction* and *repulſion*; as it were, an enlivening agent diffuſed throughout, an impulſive action that continually impels. Other philoſophers have extended their ideas farther; they have adopted the ſentiments of the ancient Stoics, and of Spinoza; they have ſuppoſed that there is a ſpirit of life, a ſpark of divinity diffuſed through the whole material ſyſtem; that all the parts of the univerſe are vital links, which, united in one chain, conſtitute Deity * itſelf.

Theſe principles Dr. Clayton reſolved into an animation of matter; he ſuppoſed that there are certain ſouls and ſpirits reſident in all natural bodies, and commiſſioned to act in the ſeveral departments of nature.

While, on the contrary, Dr. Prieſtley has ſuppoſed that all the actions of intellectual beings may be explained by the powers of the minute particles of matter, without the aid of a ſpiritual eſſence. "A body," he ſays, "exiſts by its "powers of attraction; overcome theſe powers, "and you overcome its penetrability, and with-"out ſuch powers could no longer exiſt: theſe "powers give it energy, give it activity, that "atoms, by their exility alone, ruſh into intel-"lect †." By endowing matter with ſimple ſenſation,

* Eſt ne Dei ſedes niſi terra & aër,
Et cœlum & virtus? ſuperos quid quærimus ultra!
Jupiter eſt quodcunq; vides, quocunq; moveris.
Lucan Pharſalia, lib. 9.

† Thoſe who fancy matter may come to live, think and act ſpontaneouſly, by being reduced to a certain magnitude, would do well to diſcover to us that degree of fineneſs, that alteration in the ſituation of parts, at which matter may begin to think.
Wollaſton.

Dr.

ſation, he endeavours to deſtroy the immateria-lity of the ſoul. Although by Hartley Dr. Prieſtley is guided, yet he regards the infiniteſi-mal elementary body and immaterial ſoul, adopted by Hartley, as an incumbrance upon his ſyſtem; he ſuppoſes, that in all the bodies around us very little matter exiſts; that each minute particle be-ing ſurrounded by theſe active powers, as to dif-fuſe a ſmall quantity of matter through a large ſpace, if there had been no ſuch powers, Dr. Prieſtley ſuppoſed that all the matter of the uni-verſe might be no more than what would fill a nut ſhell.

Let us candidly and unprejudiced examine all the arguments which have been adduced in ſup-port of the exiſtence of ſuch powers. If there

Dr. Cheyne ſays, that the paſſivity of body is in proportion to the denſity, and leſſens as its denſity does; hence, to become ſpirit it muſt firſt loſe all paſſiveneſs, and conſequently all den-ſity, and paſs through the term *not matter* in its progreſſion be-fore it can arrive at ſelf-activity, and then acquire the contrary qualities; as the ſeries + 4 + 3 + 2 + 1 ÷ 0 — 1 — 2 — 3 — 4: nothing but infinite power can deſtroy its materiality, ſo as to render it an active or ſpiritual ſubſtance.

Eſſay on Philoſ. Med.

Lord Bacon has ingeniouſly conjectured that the ſpirit of ani-mated bodies is diffuſed through the whole, without any ſolution of continuity. The ſpirit of inanimate bodies, the parts of each having no degree of connection, the whole is not in a ſtate of union, conſequently the power in a divided ſtate, like, as he ſays, air is in ſnow. V. *Sylva Sylvarum*, vii century.

are

are lefs difficulties attending the belief in fuch powers, we ought not to hefitate a moment in our adoption. So, on the contrary, if all the experiments which are adduced fhould be explicable on fimple mechanical principles, we ought then to withhold our affent to powers which come not under the cognizance of our fenfes. I will venture to fay with *Bonnet**, that were I a materialift I would not fcruple at an open avowal; from principles I perfuade myfelf I am not: although I do not coincide with the fentiments of Prieftley, it is with the utmoft deference that I prefume to offer any opinions contrary to his. Every doctrine which is advanced fhould be unreftrained; it fhould be left to rife or fall according to its own merit. When civil power interferes, it is generally partial; when united with the ecclefiaftical court, almoft always cruel †.

The

* Non; je ne fuis point *Materialifte*; je ne crois point à la *materialité* de l'ame; mais je veux bien qu'on fache, que fi j'étois matérialifte, je ne me ferois aucune peine de l'avouer.
Bonnet Palingen.

It muft be confeffed that Bonnet was partly a Materialift: a l'égard de la force ou de la puiffance qui opere l'evolution des parties préformées, je ne penfe pas qu'il foit befoin de recourir à des *qualités occultes*. Il me femble que l'*impulfion du cœur* & *des vaiffeaux*, eft une caufe phyfique qui fuffit à tout.
Paling. Part 10.

† Every liberal mind muft feel a fpirit of refentment when he reflects on the unjuft treatment of Bacon, Virgilius, Galilæo, and

The arguments which have been generally advanced, in order to demonſtrate the exiſtence of certain active powers, may be reduced to the five following:

1. The tendency of light bodies floating on the ſurface of water contained in a veſſel towards the ſides of the veſſel.

2. The riſe of fluids in capillary tubes.

3. The force with which two poliſhed leaden ſpheres cohere.

4. Reflection and inflexion of light.

5. Expanſion of bodies by heat, and contraction by cold.

and Vanini; would he not exclaim, I am for no Pontifex Maximus, as in Rome; nor high prieſt, as in Judæa; no Patriarch of Egypt; no Dairos of Japan, or Lamas of Tartary? In vain, under the cloak of religion, does the human heart endeavour to conceal its paſſions; they are invariably the ſame: the conqueror differs not from the prieſt; both are alike actuated by ambition and the luſt of power; the pride of pre-eminence diſplays itſelf even in the exceſs of humility.

The

The Tendency of light Bodies floating on the Surface of Water contained in a Veſſel towards the Sides of that Veſſel.

When a glaſs veſſel is nearly filled with water, a thin glaſs bubble, or a piece of cork, placed on the ſurface, moves with an accelerated force towards the ſide of the veſſel, is this tendency to be attributed to the power of attraction? When we examine the ſurface of the water, it is perceived higher towards the ſides of the glaſs than towards the centre; as bodies ſpecifically lighter than the fluid on which they float muſt neceſſarily riſe to the ſuperior part, the glaſs bubbles muſt approach the ſides of the veſſels. If we cauſe to float a body which is ſpecifically heavier than water, but whoſe gravity is not ſufficient to overcome the *vis inertiæ* of the fluid, as a needle ſwimming on water, we ſhall always obſerve a contrary effect; the needle will avoid the ſides of the glaſs, and tend towards the centre: that this cannot any ways originate from a peculiar repulſive power between the glaſs and needle, may be demonſtrated by placing the needle on a ſmall piece of cork; it then tends towards the ſides. If the glaſs veſſel be entirely filled with water, theſe effects are reverſed; the central part of the

the water becomes the higheſt; the glaſs bubble flies from the edges, and moves with rapidity towards the middle; the floating needle in this caſe does not retain its central ſituation, but moves with an increaſing velocity towards the ſides. If in the firſt experiment it be ſuppoſed that the bubble is attracted by the glaſs, in the ſecond experiment we muſt ſay it is repelled: it is extremely difficult to conceive how ſuch contrary powers ſhould be exerted, merely by a little difference in quantity of the ſame fluid. I have already obſerved, that in the firſt caſe the water is higher towards the edges, and in the ſecond caſe towards the centre; it will then only remain to enquire the cauſe of this. A fluid acts equally in every direction, as all its component parts are equally obedient to the general preſſure; ſo long as theſe are uninterrupted, the ſurface is even and regular. When a body is interpoſed, a reſiſtance is induced, and the preſſing action of the whole fluid is limited by the ſurface of the body. It is eaſy to conceive how, by ſuch a general determination, the fluid where interrupted will be the higheſt; as the fluid tends towards the centre of the earth, it meets with leſs reſiſtance in its central portion. When the veſſel is, as it were, more than filled, we find the fluid higheſt in the centre; in this caſe the fluid hangs over the edge of the veſſel, the gravity of the fluid not overcoming the combinatory union of the particles; ſo that, in fact, the fluid is only depressed about the edges, in consequence of a portion being thus in a suspensory state; the same quantity swelling over the edges, when interrupted by a resisting surface, would render the same part the highest.

The Rise of Fluids in capillary Tubes.

When a tube of a very small bore is immersed in water, the water rises in the tube considerably above its surface; the increase of its rise has been found to be in the inverse ratio of the diameters of the tubes: this is observable in capillary or hair-like tubes of every kind, as in lump sugar, &c.

This rise has been generally attributed to a power called *attraction of cohesion*, a power inherent in the tube of drawing the water upwards.

When we immerse in a fluid a tube of a narrow bore, we find the fluid rises to a certain height above the level. If a tube, twelve inches long, and whose bore does not exceed the twentieth part of an inch, be divided into twelve parts, when one part is immersed in the fluid, the water rises near one inch and a half in the tube above the level; when two parts of the tube are immersed, the ascent of the fluid is not much more than one inch and a quarter; when a third part is immersed, the difference is still less; so that when ten parts of the tube are immerfed in the water, the rife is not more than a quarter of an inch; when the whole tube is immerfed, the afcent is nothing.

If the fides of the tube caufed the fluid to rife by virtue of any attractive power, why fhould there be this gradation in the afcent of the fluid?

It appears to me that this is explicable on principles more comprehenfible than thofe which arife from the fuppofition of unknown powers.

It feems to depend on the different elafticity of the air; the elafticity of the air is always a counteracting balance to the general preffure of the atmofphere; as a diftended bladder preferves its diftenfion, becaufe the elafticity of the included air is equal to the preffure externally. If by any means the elafticity of the air is diminifhed, no longer a counteracting force, the atmofpheric preffure will then evince its power. Bodies of many kinds, we obferve, that are very elaftic in a larger mafs, which are not proportionally fo in a fmaller ftate, as glafs, the moft elaftic of all bodies, is not confiderably fo when in a filamentous ftate, as in glafs feathers: fo with air, its elafticity being the action and re-action of its particles; in a minute column we cannot expect the fame elafticity as in the furrounding unconfined air. By fuch a fuppofition every circumftance of the capillary tube is eafily explained. When the tube is immerfed in water, the water meets with lefs refiftance in the tube, confequently the preffure of the outer air will caufe the water to rife. When the tube has more of its parts immerfed, then the afcent is not fo great; becaufe the air in the tube out of the water being nearer the atmofpheric air, neceffarily increafes in its elafticity, and proportionally refifts the rife of the water; this refiftance increafes the lefs portion of the tube there is out of the water, till ultimately the refiftance is equal to the atmofpheric preffure.

That the air in the tube lofes its elafticity may be farther demonftrated, by obferving that the fluid will rife to a certain degree when the upper end of the tube is not open. I have attempted fome experiments to afcertain what ratio there may be in the deficiency of elafticity in different tubes.

It may be objected to this fuppofition, that the fluid will rife in tubes placed within an exhaufted receiver; but the ratio of the elafticity of the air in the tube to that of the receiver will be the fame as above. I have not as yet obferved the effects which would take place in the highly-exhaufted ftate that can be produced by the valuable air pump of Mr. Cuthbertfon's invention; I purpofe to afcertain this with the affiftance of this Gentleman, who, as an experimentalift, is fecond to no one.

The Force with which two polifhed leaden Hemifpheres cohere.

When two polifhed leaden or other foft metallic hemifpheres are rubbed together with a rotary motion, they cohere with fuch power as to require a weight for their feparation confiderably more than what would be requifite for the feparation of exhaufted Magdebourg hemifpheres of the fame fize.

Two leaden hemifpheres, of about an inch and a quarter in diameter, will require 150lb. to feparate them.

This cohefion has been fuppofed to arife from the influence of a certain attractive power when the furfaces are brought nearly into contact.

Two hemifpheres, well polifhed, and their planes placed upon each other, in this pofition, preffed with ever fo great a weight, there is no particular cohefion produced.

No fuch effect is induced by the application, in any mode, of brafs or iron plates.

When a leaden hemifphere is accurately examined by a glafs after the cohefion has been produced, the furface appears covered with fpiral lines and ridges where particles of the lead are raifed up.

From

From this circumſtance the power with which they unite is eaſily explained.

The reverſe rotary motion round the axis of each hemiſphere raiſes up on each plane particles of the lead in contrary directions, ſo that all the particles of the one being locked with thoſe of the other, will reſiſt ſeparation in proportion to the number of particles thus entangled. This is rendered probable from the following reaſons:

However ſtrong the hemiſpheres were united, they do not in the leaſt reſiſt the ſame rotary motion which induced the union.

When the hemiſpheres have thus been uſed two or three times, the ſurfaces become ſo irregular, that no union can be induced till the ſurfaces are ſcraped.

Reflection and Inflection of Light,

Newton, in the eighth Propoſition of his ſecond Book of his Optics, ſays, that the reflection of a ray of light is not effected by a ſingle point of the reflecting body, but by ſome power evenly diffuſed over its ſurface, and by which it acts upon the ray without immediate contact; for the parts of bodies act upon light at a diſtance. Thoſe rays which do not impinge on ſolid parts are neceſſarily ſtifled, or elſe there would be a double reflection; this fine ſubſtance thrown upon the

ſurfaces

furfaces of bodies he calls *æther:* he fays that mirrors are only produced by rubbing away their protuberances, as none to us may be vifible, yet from their inequalities would reflect light differently, and fcatter the rays.

If matter has the power, under any circumftances, of forming to itfelf, or as matter neceffarily connected with it, an atmofphere capable of reflecting light, this atmofphere muft neceffarily be regulated in its extent by certain properties of the body. In fuch a fuppofition each little portion muft have a feparate atmofphere, which muft alfo produce a correfponding inequality in the ætherial medium, and a neceffary fcattering of the rays.

If we take a mirror of the moft perfect reflecting powers, this property is loft by having the furface ground. Could an operation of this kind be fuppofed to impart or remove an ætherial atmofphere?

Newton fuppofed it was this medium which admitted of refraction as well as reflection; that it operated in the cafe of the fingle refraction as well as the double reflection, which occur in every looking-glafs, where we always find a refraction produced by the rays of light pervading the medium of the glafs; alfo an image formed by the reflection from the quickfilver furface, and a fecond image from the parts of the glafs itfelf.

Inflection of Light.

When a ray of light paſſes by the ſharp edges of bodies, it bends from its rectilineal courſe, and is divided into a number of coloured fringes.

This is called the inflection of light.

Grimaldi, who was the firſt that paid any particular attention to this ſubject, made uſe of theſe circumſtances as proofs of the Ariſtotelian ſyſtem, that light is not a ſubſtantial but an accidental quality: while, on the contrary, Newton ſuppoſed that light was not only material, but that there were ſome powers diffuſed over the ſurface of the body that produces this inflection, before the light can arrive at the body itſelf.

Mairan conjectured, that round every body thus inflecting light there is an atmoſphere of a variable denſity; while Monſ. du Tour ſuppoſed it an atmoſphere of an uniform denſity.

To the ſupport of ſuch a ſuppoſition, it has been aſſerted that the light is inflected before it arrives at the body; conſequently by the influence of ſome power connected with the body.

It is obſerved, that the greater the intenſity of light, the leſs the inflection.

The diſtance that is aſſigned between the inflection of the ray of light and the body is too ſmall to be aſcertained.

Probably this may admit of explanation on ſimple mechanical principles.

The fineſt edges of any cutting inſtrument which can be made, when viewed through a microſcope, appear replete with inequalities.

If a ray of light be regarded as a maſs of material particles, moving with that amazing velocity which is generally aſſigned, and ſo inconceivably minute in themſelves, they muſt be diverted from their uſual courſe in conſequence of ſtriking on the little projecting parts of the fineſt edge.

In the Eſſay on Viſion it was obſerved, that probably light conſiſted of portions whoſe momenta were different; that theſe, when divided, produced, by their different impulſes, different actions on the retina, and conſequently the ſenſations of the different colours.

When a ray of light, compoſed of portions of different momenta, ſtrike upon any body, the impulſes will be different; ſo that the portion with the leſs momentum will be more diverted from its courſe than the portion with a greater momentum.

The portions, by being differently bent, will fall ſeparately on any opake ſubſtance; being reflected to the eye ſeparately, will thus produce the different coloured fringes.

The ſame muſt take place on a ſcratch of a poliſhed mirror, or of a lens; the inequalities produced by ſuch a ſcratch will act in the ſame manner.

In viewing a candle with the eyes nearly cloſed, the inflection of light in paſſing through the eye-laſhes is very evident, forming luminous trains, like unto comets' tails; as the inflections by every hair of the eye-laſh run into one another, the coloured fringes are deſtroyed, ſo that only a luminous diffuſion of the whole appears.

When on reflection one circumſtance was omitted, which has been adduced as a proof of the exiſtence of ſome kind of power acting at a diſtance from the body itſelf, a drop of water on a vegetable leaf appears opake in the inferior part, if it had been in contact with the vegetable, the green colour of the leaf would have been tranſmitted; hence it has been ſuppoſed that the watery drop is kept ſuſpended by ſome kind of repulſive power. When we view the leaf with a microſcope we find it covered with an infinite number of fine fibrillæ; it is upon theſe the drop is ſuſpended, and owing to ſuch ſupport it preſerves its ſpherical form.

Expanſion of Bodies by Heat, and Contraction by Cold.

It has been ſuppoſed difficult to conceive how the ultimate particles of bodies could be in contact, as they are expanded by caloric, and contracted by cold; that if they are in contact, and their union depended on ſuch contact, they could not admit of the leaſt expanſion without ſeparation.

If they are in actual contact, an approximation could not be induced by the application of cold.

As we do obſerve bodies ſuffer expanſion without ſeparation, and likewiſe admit of condenſation, it has been thought more eaſy to ſuppoſe that the ultimate particles are not in any contact, but that each particle is ſurrounded with an atmoſphere of a repulſive nature, which acts powerfully at a very minute diſtance from the particle.

This repulſive power being increaſed by caloric, and diminiſhed by cold, would explain the different ſtates.

Every particle being ſurrounded by a ſphere of repulſion, would neceſſarily prevent that union we obſerve in bodies, were not ſome other power ſuppoſed to be interpoſed; hence it is ſaid that ſpheres of attraction extending farther than the ſpheres of repulſion, prevent any ſeparation.

By what circumſtances are theſe principles regulated? They do not depend upon the quantity of matter, as gold is eaſier ſeparated than iron.

I muſt confeſs I cannot carry my mental powers to ſuch an extent, as to conceive the exiſtence of two contradictory elements exiſting in one and the ſame body.

If ſuch powers did actually exiſt, if equal in their influence, they muſt deſtroy each other; if different, only the exceſs could prevail.

It appears to me that theſe different ſtates of bodies may be more ſimply explained.

I will illuſtrate my meaning by water: we find, by abſtracting a certain quantity, or imparting a certain quantity of caloric * to or from water, ſo that its temperature be at 32°, it changes its fluid appearance, ſhooting out into cryſtals, forming a ſolid ſubſtance called ice.

The figure of the integrant parts of ice is an equilateral triangle, which, by ſucceſſive unions,

* Although ice has been deemed the more native ſtate of water, yet a certain portion of caloric is requiſite to its formation. Water, at the temperature of 20°, may be in a fluid ſtate; when raiſed to 32°, may congelate; we are informed, that in the icy cavern of Szelice, near Mount Carpathus, the water freezes in the ſummer, and melts as the winter approaches: ſo Wolfius has obſerved the ſame in Germany, *(Elem. Aerom.* 1203.) and Reaumur in France, *(L'Hiſt. de l'Acad. Roy.* 1730.)

form

form little octohedrons, whose aggregation produces that beautiful arborisation we observe on our windows.

Mairan tells us, that these little icy crystals are inclined to each other in an angle of 60° or 120°.

The ice we find specifically lighter than water; here is a substance losing $\frac{1}{14}$ part of its specific weight, and consequently a proportionate increase in bulk, by abstracting that principle which always expands *.

1. I believe it will be granted me, that in fluids the particles are perfectly spherical, evident from their free and easy motion; that this sphericity is acquired by the combinatory union of caloric with their ultimate particles; those bodies not capable of such a combination cannot be liquefied.

It

* That ice is only water separated from a portion of caloric seems to have been an opinion entertained by the most ancient philosophers. Cicero, who ascribed animation to fire, has particularly noticed that congelation is owing to the abstraction of this principle. "Atquæ *aquæ* etiam admistum esse *calorem*, "primum ipse liquor, tum aquæ declarat effusio: quæ neque "conglaciaret frigoribus, neque nive, pruinaque concresceret, "nisi eadem se admisto calore liquefacta, et dilapsa, diffun-"deret." (*Cic. de Nat. Deor.* lib. 11.) Galilæo was the first who observed that ice is specifically lighter than water; he attributed this increase of bulk to a quantity of air bubbles disengaged from the water in the act of freezing, and of this opinion were the Florentine philosophers, Boerhaave, and many others. (*Exp. Acad. del Cim.* 25. 3.).

Des-

It is no difficult matter to conceive how the ultimate particles which compofe a body may admit within each particle a certain quantity of caloric, which tending equally every way, may induce this fphericity.

2. That fluid fpherical particles, when converted into a folid, is effected by abftracting that portion of caloric which rendered the particles fpherical, and then they refume their native form.

3. A fpherical particle is eafily demonftrated to contain the greateft quantity of matter in the leaft fpace, and when changed in form, may occupy a greater fpace, more than adequate to its own increafe by its union with caloric.

4. According as the change is more or lefs deviating from a fphere, the difference in bulk will be greater or lefs.

Des Cartes, as attached to his three elements, as Newton was to his æther, whimfically fancied, that when the globules of his fecond element were inactive in air, the air was converted into water; and when inactive in water, the water was changed into ice. "Ut cum ifti globuli paulo minus folito agunt, aquam "in glaciem mutent, et particulas aëris in aquam."

Prin. Philof.

Muffchenbroek fuppofed that water could not be converted into a folid by the mere abftraction of caloric; he thought the particles of the fluid muft be fixed by wedges of fubtle bodies out of the atmofphere, mingling with water, and entering into the pores of the particles. V. *Elem. Philof.*

If in any cubic veſſel we calculate the number of octahedral pyramids, ſimilar in content to an equal number of ſpherical particles, and inclined to each other in an angle of ſixty degrees, we ſhall find that the ſaid veſſel will only contain three fourths of the pyramids, as it would of the ſpheres.

From hence we may eaſily explain the increaſe in bulk of ice by the change in form of the ultimate particles, and allowing ſufficient for the expanſion of the fluid from caloric.

By one particle being in actual contact with another, each is wedged in by its neighbour, and thus the whole is mechanically retained*.

* Some idea may be formed of the power with which one particle is wedged with another, when we reflect on the power of reſiſtance in the aggregated maſs. The Florentine philoſophers included water in a golden ball, cloſed it up, and accurately meaſured its greateſt circle by means of a wheel of metal. The water, when converted into ice, ſwelled the golden ball very conſiderably, ſo that it would not paſs through the ſame wheel; the expanſion was ſo violent, as to extend the whole maſs of gold. (*Tent Florent.* p. 142.). Veſſels of glaſs, earth, ſtones, and even metals, have been burſt; trees have been cleft, and houſes razed from their foundation. Huygens has obſerved, that an iron cannon has been burſt by the congelation of water included therein. The Rev. Mr. Jones ſays, that in a ſmall box, holding about ten inches of water, which being converted into ice, raiſed up a weight equal to 2296lb. This is in no reſpects equal to the experiments of the Florentine Academician, who, by including water in thick ſpheres of braſs, eſtimated the expanſive force of the icy cryſtals to be in every ſpherical inch equal to 27,720lb. (*Tent Flor.* p.)

The

The force with which they refift feparation will be regulated by the form of the particles, and angles of inclination they form with each other.

If we fuppofe four cubical particles lying with their fides parallel to each other, were feparated, fo as to touch only at their corners, the fpace they would then occupy would be double, what intervals of expanfion between thefe two ftates, and which eafily explain how a body may be expanded by heat without the particles being difunited *.

All thefe circumftances which have been adduced as proofs of the exiftence of certain pow-

* When the particles are of an irregular or polygonal figure, the expanfion will take place in fome parts before the whole particle is rendered fpherical, and confequently produce an expanfion of the whole mafs. If the form of an ultimate particle be a cone or pyramid, any caloric that may be admitted would firft fwell out the part near the apex, as there meeting with more refiftance.

How fimply this explains that firm union which exifts in metallic bodies; when melted they occupy lefs fpace than when in a folid ftate: the external furface is the firft portion which is cooled, afterwards a contiguous ftratum or layer: the exterior lamina, when cooled, refift the fwelling of the interior, fo that each particle becomes fo finely impacted with one another, as to render their feparation fo very difficult; while thofe bodies which formed, as it were, from a centre to a circumference, their adhefion is neceffarily not fo ftrong; the gradual arrangement of the particles gradually infinuating into each other, will ultimately form a folid fubftance, whofe refiftance to feparation will be regulated by the figure of its conftituent particles.

ers,

ers, we find are reducible to pure mechanical principles. By rejecting ſuch ſuppoſitions in our ſyſtems of philoſophy, we ſhall ſimplify much; the ground work will be clear and evident, when the fundamental principles are cognizable to every mind. A ſtudent feels diſcouraged in his purſuits when embarraſſed by crowds of *powers, ætherial atmoſpheres, attractive and repulſive influences*; not being enabled to conceive their exiſtence, he is apt to attribute to his own inability what is in fact incomprehenſible to all.

Notwithſtanding the great authorities of a Boyle, a Newton, a Boerhaave, and a Prieſtley, whom no one can revere more than I do, with reſpect to the ſimple properties of matter, I muſt give my vote of preference to the plain and eaſy doctrine of Des Cartes.

If I ſhould hereafter be induced to trouble the Public with a ſecond volume of Eſſays, I purpoſe to attempt the ſame mode of reaſoning with reſpect to chemical affinities, electricity, magnetiſm, and gravitation.

Of the Homogeneity of Matter.

That the primary particles of matter are homogeneal, or of the ſame kind, is an idea which has been entertained by philoſophers in the moſt diſtant periods, as well as in modern times.

It has already been obſerved, that Thales ſuppoſed water as the element out of which every thing was formed; that all the variety of matter was owing to the different arrangement of the watery particles: it has been ſuppoſed that the hemp ſeed expanded and unfolded its vegetable by the addition of water only; that the hemp was formed into threads, the threads into cloth, and the cloth into paper; through all theſe different ſtates the water paſſes, aſſuming in each diſtinct appearances, from the diverſity of its arrangement. The Pythagoreans imagined there were five elements; the Ariſtotelians four; the Carteſians three*. Newton and his diſciples have ſup-

* The ancient chemiſts ſuppoſed there were three principles; *tria prima*, viz. *ſalt, ſulphur*, and *mercury:* ſubſequent chemiſts added earth and water. Paracelſus imagined that the ſtars are cucurbits, in which meteorical ſalt, ſulphur, and mercury, are contained; and that the winds, which are made of theſe by the ætherial volcanos, are blown forth out of theſe emunctories; that the ſtars are the pots in which the Archæus, or heavenly Vulcan, prepares pluvious matter; that hail and ſnow are the fruits of the ſtars. The ſtars eat and are nouriſhed, and that falling ſtars are their excrements. *Tract. de Meteor. Parac.*

poſed

pofed that God, in the beginning, formed certain hard, impenetrable particles, out of which every thing has been formed; he imagined it might be-fome fuch matter as light; as he fays, upon the authority of Mr. Boyle *, that water, after 200 diftillations, was converted into earth, and earth, by ignition, may be converted into light.

To change one matter into that of another, only a frefh arrangement of its primary particles were deemed neceffary; thus the laboured attempts of alchemifts, in the tranfmutation of metals, to change iron into gold, it was thought only requi-fite to increafe the denfity of the former, to ren-der its primary particles in the fame ftate of ap-proximation as the latter; even Boerhaave ima-gined fuch was only neceffary in converting glafs into diamond. Infinite are the experiments which have been tried; however they may have failed in their attempts, their accidental difcove-ries have contributed much to the increafe of fci-ence. The Pythagorean fyftem, revived by Co-pernicus, was not admitted till the wild doctrine of Des Cartes eftablifhed it.

So to that mad enthufiaft, Paracelfus, the torturer of mercury, are we indebted for the principal preparations of this valuable metal.

* Mr. Boyle did not try the experiment himfelf, but took it upon the credit of another, that an ounce of water, after 200 diftillations, produced 6 drachms of a whitifh earth. Boerhaave has fhewn the fallacy of this.

We obſerve, that gold in the ingot is gold in the powder, and, however varied in form, is ſtill gold; ſo iron is the ſame, whether in the bar, or united with an acid in the form of green vitriol, in ochre, or in vegetable recrements. Bodies of this claſs have their conſtituent particles of exactly the ſame principle as the body formed by their union.

It has been ſuppoſed by ſome chemiſts, that metals are not elementary bodies, for that iron may be generated by vegetables; we certainly do obſerve the production of iron from the decompoſition of vegetables. Waters oozing from all moraſſes are chalybeate, and depoſit their ochre on being expoſed to the air; the iron acquiring a calciform ſtate from its union with oxygene, or vital air. This formation of iron from vegetable recrements is farther evinced by the fern leaves, and other parts of vegetables, ſo frequently found in the centre of the nodules of ſome iron ores. Kirwan ſays that all the leaves conſiſt of one fourth of iron. If iron is ſo univerſally diffuſed as to conſtitute ſo great a portion of vegetables, do they ſeparate it from the ſoil? from the air, as Prieſtley ſays iron there exiſt, or create it themſelves? Although our chemical analyſes can no ways reduce metallic bodies to a more ſimple ſtate, are ſuch bodies to be deemed perfect elements? May not they ariſe in conſequence of certain combinations which may be

 effected

effected by living powers? We daily see the power of vegetables in decomposing water, in absorbing light, &c. and hence may we not suppose that one important purpose they are to answer is to form an union of certain principles for the advantage of mankind? Thus to one simple vegetable, a solitary fern, we may be indebted for all the iron we possess, as well as to a single and small polype, the island we inhabit*.

It

* Polypes, the species which form the coral, were formerly deemed marine minerals; afterwards, by La Pluche, the Comte de Marsylles, and others, were supposed to be vegetables; and some curious theories were formed respecting their being always attached to rocks: it was fancied they were formed as shelters and support to tortoises and other shell fish. When the celebrated Naturalists, Ellis and Peyssonel, had proved they were animals, then enquiries were made respecting the nature of the stony incrustration in which they are embedded, and which is usually known by the name of coral. Reaumur had supposed, that in snails the shell was formed by a tartarous moisture transuding through the pores of the animal, and that the body was only the mould. "Qu'il a des coquilles qui croissent par *juxta* "*position*, qu'elles se forment des sucs pierreux qui transudent des "pores de l'animal; que son corps en est re-ellement le moule." Had such been the case, the snail could never have had that free and easy motion. The coral, he says, is a mere nest for the polype: "Le corail est un polypier, comme on nomme un nid de "Guêpes in Guêpier." This same error Bomare, in his valuable Dictionary, has imbibed. Monf. Trembley, whose observations on the polype are well known, has not paid any particular attention to the coral. Monf. Herissant, in his ingenious Observations on Madrepores and Corals, demonstrates, that the

coral

It appears more eaſy to conceive that there ſhould be more elements than one, as we could not from any analogy imagine how, by any poſſible arrangement of the ſame particles, that diverſity of bodies we ſee, poſſeſſing ſuch different properties, unleſs by ſuppoſing that there are binary,

coral is to the polype what the ſhell of a ſnail is to the ſnail; that before any incruſtration takes place, a quantity of coagulable lymph is thrown out, ſo as to form a membranous envelopement of a parenchymatous nature; into this the calcareous depoſit is made, ſo that in a coral each polype is ſecured by its own membranous envelopement, and which increaſes by ſucceſſive layers. The polypes multiply by ſhoots; one planted upon another, and the whole riſing from one general trunk, which was formed by the firſt polype, by thus branching out has been ſuppoſed a marine plant. This is an admirable inſtance of the powers of life forming an union of thoſe principles that conſtitute aëriated lime. When we ſee thoſe large maſſes which are formed by theſe animals, is it unreaſonable to ſuppoſe, that after they have anſwered the purpoſes of the polype's exiſtence, they may, by ſucceſſive unions, form an iſland? and we might extend our ideas ſtill farther, and ſuppoſe that all bodies, where there is a firm degree of union in their conſtituent parts, that ſuch have been formed by the influence of living powers. We may thus be enabled to conceive why there ſhould be in particular places particular kinds of firm united maſſes of matter; unleſs by ſome ſuch influence it would be difficult to explain why in ſome parts there ſhould be ſuch quantities of ſilver, in others gold, diamonds, &c.

We may thus form ſome idea of the utility of the myriads of inſects embowelled within the earth; they may be at work in forming theſe decompoſitions and unions, and thus conſtitute neceſſary links in the chain of creation; that they are all performing nary, ternary, quaternary combinations, &c. and beyond which no bodies by any analyſis can be reduced.

We may ſay a primary particle poſſeſſes a certain property; two of theſe particles to us inſeparably united a ſecond property, ſo three particles a third combination, &c.

Such, perhaps, may appear more ſimple than to ſuppoſe the primary particles of matter heterogeneous.

May we not imagine that the powers of life may have more influence on theſe combinations than

forming their ſeveral functions in obedience and ſubmiſſion to the divine will.

——— Tota concors fabrica perſonat
Dei tuentis cuncta potentiam,
Non voce quæ pancorum ad aures
Perveniat ſtrepitu maligno.

Buchanan, Pſ. xviii.

They may be regarded as agents, the reſults of whoſe tranſactions are conducive to the happineſs of mankind; they tend to prevent that ſtate of apathy, that vegetable kind of exiſtence into which we ſhould fall, were we not ſtimulated by the value affixed to their productions; they rouze us to exertions, they incite us to rifle the dark caverns of the earth, and purloin from thence theſe different treaſures. Not with the poet can we conceive that it is a kind of ſacrilege to diſcloſe to view what the Deity had thought proper to conceal from our ſight.

——— Itum eſt in viſcera terræ,
Quaſq; recondiderat, ſtygiiſq; admoverat umbris
Effodiuntur opes, &c. *Ovid Metam.* 1.

our

our retorts and our crucibles? and that to their influence may be owing the nature of thofe fecretions which are fo different from the principles of which they were formed, as the poifon of venomous animals, the bitternefs of bile, &c.

We may thus form fome idea how the living powers, when difturbed in their action, may, by decompofing thofe bodies which are deemed chemical elements, form thofe unions which may conftitute contagious miafmata, and infectious fecretions.

In atonic ftates of the ftomach air is in abundance fecreted; in diabetes fugar, in large quantities, will be formed; and in every morbid affection of a gland its natural fecretion is entirely changed.

OF THE

SYMMETRIC ARRANGEMENT

OF THE

CONSTITUENT PARTICLES OF BODIES.

IN various minerals we obferve that there is a fomething more than a mere fortuitous concourfe of the conftituent particles; there is a fymmetric affemblage, a beautiful arrangement appropriate to particular bodies. When thefe prefent themfelves under any regular form whofe faces may be reprefented by geometrical figures, fuch are called cryftals *.

* The ancients knew only the rock cryftal and fome other tranfparent ftones, thinking they were congealed water, becaufe principally found on mountains whofe temperature is intenfely cold; called thus cryftals, from χρυςαλλ☉, ice.

That they are found plentifully in high mountains is becaufe thofe in Italy are of granite, of which quartz, or rock cryftal, is the principal ingredient.

It would ſeem that there was ſome power influencing the conſtituent particles of theſe minerals, while floating in the fluid in which they are diſſolved; as we perceive the integrant particles, although ſeparated by the interpoſition of a liquid, are determined to unite and form a ſolid maſs of regular and conſtant figures.

If we dip a thread into a ſolution of alum, we find the thread will be covered with little cryſtals of an octohedral form; if we again immerſe the thread, we do not find an accidental ſcattering of the ſame cryſtals in different parts of the thread. The ſucceſſive layers are determined to the firſt cryſtals, increaſing their ſize with the ſame octohedral form.

It has been thought that this regular arrangement is effected by the influence of a power a degree inferior to vegetable life; thus Haller obſerves that animal life is a degree above vegetables, and vegetable life a degree above cryſtalization. Von Linnæus ſays, "Lapides creſcunt; "vegetabilia, creſcunt et vivunt; animalia cre- "ſcunt, vivunt et ſentiunt." Monſ. Metherie, and others, have ſuppoſed that there are ſeeds of cryſtalization, that there is a ſpontaneous generation in the mineral kingdom; they have extended this doctrine ſo far, as to ſuppoſe animals or vegetables are produced by the cryſtalization of the ſeed.

That

That minerals poſſeſs ſome powers equivalent to life is an idea that has been entertained by Theophraſtus, Tournefort*, Plott, Liſter, and the learned Biſhop of Llandaff, and no doctrine can be abſurd which is eſpouſed by ſuch characters as theſe; they ſaw that there was a ſomething which influenced this arrangement that could not then be referred to any known principle.

Since Mr. Lichtenberg has ſhewn us what beautiful configurations may be produced on an electrophorus, and the ramifications influenced by the ſtate of electricity, with ſome degree of reaſon it has been thought that cryſtalization may be owing to the influence of the ſame principle.

As the principle of electricity is ſo univerſally diffuſed, in every action the moſt minute its

* Tournefort, in his Deſcription of the Labyrinth of Candia or Crete, obſerves that the ſtones there evidently grow; an increaſe which cannot take place from their ſituation by the accidental accretion of matter externally. Perſons who have cut their names on the perpendicular walls of this labyrinth, the ſtrokes of the chiſel are not only filled up, but even raiſed two or three lines above the ſurface of the ſtone, ſo that what at firſt were indented, are now ſo many baſſo relievos, formed of a matter much whiter than the general maſs.

This notion is not entirely new, as Pliny informs us that Mutianus and Theophraſtus believed the ſame; and Gregory Nazianzen aſſures us that there were ſome authors who maintained that ſtones made love; and a learned living writer imagines that the various ſtreaks of ſtones are an arrangement of calculous veſſels.

agency is difplayed. The evaporation of a drop of water, the agitation of a few dufty particles, the contact of two different metals, the change of temperature in any body, even the wafture of any part of our apparel, can no ways be effected without unfolding a certain portion of this energizing power.

As it is well known that fome bodies, when united, have their capacities for caloric increafed, while others, when entering into combinations, will impart a confiderable quantity. So it is with bodies with refpect to electricity; fome, upon the leaft difturbance, will appear to have a fuperfluous quantity, and freely impart it to the furrounding medium; while other bodies appear as if they cannot enter into any altered ftate without an additional quantity of this principle.

It is no difficult matter to conceive that the conftituent particles of different minerals poffefs different degrees of power; and as they are influenced in their arrangement by this power, each mineral muft have its own refpective arrangement.

This arrangement can only take place when the conftituent particles are in a fluid ftate, and running gradually into a folid form.

When the combination of the fame elementary principles operate in fimilar and exactly proportionate circumftances, the fame formed body refults ſults with the ſame denſity, the ſame hardneſs, taſte, &c.

When the proceſs is ſlow, we find a ſymmetrical and regular arrangement of the cryſtaline moleculæ; the electric principle which is diſengaged operates equally from the fluidity and temperature of the body being preſerved in nearly an equal ſtate, ſo that each particle, equally influenced, ſhoots out in equal directions.

When the proceſs is hurried, inſtead of cryſtals with determinate formed faces, we have only curved ſurfaces, dendrites, and maſſes, ſometimes ſo ill formed, with an appearance lamellated, ſtriated, granulated, or cellular, and at other times an aſſemblage of almoſt imperceptible moleculæ.

Such is the difference between a rhomboidal calcareous ſpar, and a block of ſtalactites, or white marble; between a regular cryſtal of ſelenite, and the common gypſum or alabaſter; between a quartz or rock cryſtal, the hexagonal ſpecies with iſoſceles, triangular planes, and the unformed quartz, as freeſtone, agate, or flint.

If we have three hot ſaturated ſolutions of marine ſalt, if we cryſtalize the ſalt in one ſolution by a quick evaporation over the fire, and put the ſecond ſolution in a cool ſituation, and the third placed within a large medium of its own temperature, as in a veſſel of hot water, ſo that its cooling ſhall be very gradual, we ſhall have three different ſtates of cryſtalization produced.

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The firſt ſolution, hurried by a rapid evaporation, produces only an irregular precipitation of a confuſed ſaline maſs, without any regularity of form. The ſecond ſolution being more gradual, the ſalt ſhoots out into the form of little cubes, or by the union of two or three cubes, parallelipipedons * are formed. In the third, where the cryſtalizing proceſs is conſiderably ſlower, then cryſtals of a more perfect form are produced. In the firſt ſolution the interpoſed fluid being ſo ſuddenly removed, the ſalt is diſengaged with too great a rapidity to ſubmit to any influence from this principle of regularity; when the proceſs is gentle and ſlow, the liquid in which the ſaline particles float being mildly removed, unreſiſting they obey this arranging electric power. If the time is much longer in the formation of theſe cryſtals, the more perfect they are.

Formerly ſalts were only diſtinguiſhed from ſtones, by being ſoluble in water; and of a certain taſte; ſo metals were diſtinguiſhed from minerals by the degree of fuſibility. The inaccuracy of ſuch a ſyſtem immediately appears, when

* Dans le ſel marin, par exemple, dont les molécules intégrantes ſont eſſentiellement cubiques, les petits cubes, en ſe réuniſſant pour former un autre cubes plus conſidérable, ne s'appoſent pas toujours en nombre ſuffiſant pour former des cubes parfaits, de ſorte qu'il ne réſulte très ſouvent de leur agrégation que des parallélipipédes rectangles plus ou moins larges, plus ou moins epais. *Romé de l'Iſle.*

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we find that gypſum is ſoluble in water, and ſchorl fuſible by fire.

Linnæus was the firſt who thought of aſſociating cryſtalization to the ſcience of mineralogy, and of rendering it one of the principal baſes of his lapidary ſyſtem. In the firſt edition of his Syſtema Naturæ, he only particulariſed 18 ſpecies; in a ſucceſſive edition he increaſed them to 40. Some mineralogiſts reject this mode as illuſory and frivolous; they ſay the form of cryſtalization is not a conſtant character, and more equivocal and variable than any other to characteriſe minerals: thus we find Buffon, in his Natural Hiſtory, thinks there is more dependance on the imperfections of a cryſtal than the perfections, and hence divides them into three ſpecies, viz. *laminated, filamentous*, and *granular*.

The accuracy of Linnæus's ſyſtem is now demonſtrated by the valuable obſervations of Romé de l'Iſle. This celebrated Cryſtalographiſt, in his firſt work, enumerated 110 ſpecies; in his laſt edition he has increaſed them to 438*. He has ſhewn,

* At preſent it can only be expected that this ſcience is in its infancy. The gypſum, the calcareous ſpar, ſelenite ſpar, rock cryſtal, granite, and mica, are the only ſpecies which are perhaps tolerably well known. The ſchorls, metallic and ſaline cryſtals, perhaps not 100th part is yet aſcertained. I am informed that Monſ. Bournon, a gentleman reſident at Paddington,

ſhewn, that in cryſtals of the ſame kind their faces form with each other the ſame correſponding angles; that even when the faces or planes vary in their relative figure and dimenſion, yet the reſpective inclination of the ſame planes are conſtant and invariable in each ſpecies *.

When the principal angles, and the regular and diſtinctive forms of a cryſtal are known, the intermediate varieties are eaſily aſcertained †.

Bergman, Abbé Haüy, and others, have attempted to demonſtrate, by geometrical calculations, the mechaniſm peculiar to ſome cryſtals, which are eaſily divided by a cutting inſtrument; they have ſuppoſed that all the different forms under which the ſame cryſtaliſed ſubſtance may appear, that there is one which may be regarded

ton, and very eminent in this branch of Natural Hiſtory, has enumerated 2,000 diſtinct ſpecies.

From his attention, Dr. Babbington, and others, we have reaſon to hope that this ſcience will be ſoon conſiderably improved.

* Les faces d'un cryſtal peuvent varier dans leur figure et dans leur dimenſions relatives; mais inclinaiſon reſpective de ces mêmes faces eſt conſtante et invariable dans chaque eſpece.

Romé de l'Iſle.

† Thus Romé de l'Iſle ſhews that feld ſpars yet unknown will have right angles, as well as of 65°, 115°, 130°, or of 150°; if there ſhould be any new angles, they will always be found with ſome of the afore-mentioned angles, ſo that the ſpecies may be known.

as the primitive form, the other forms only being modifications; that the rhomboidal form of the iſland ſpar is the primitive form of all the calcareous ſpar. If in a cubic cryſtal it is attempted to divide it by a ſection parallel to any of its ſides, there would be conſiderable reſiſtance, and only irregular fragments broke off; if cut parallel to the diagonal, and the cutting inſtrument inclined about $54\frac{1}{2}$ to the ſide, without any trouble a pyramidal piece will be detached; it will be ſeparated in a laminated ſtate, with that poliſh which Nature gives; and hence, by gradual ſmall ſections, equilateral triangular lamina will be ſeparated, increaſing as approaching the centre, ſo that if the diviſions be ſucceſſively continued on the eight angles, in equal correſponding ſections, as theſe ſections approach the centre they will mutually interſect each other; ſo that the corners of the triangles being cut off, the planes will then become hexagonal; continuing the ſections, the laſt-formed nucleus will prove to be an octahedron, with equilateral triangular planes.

Abbé de Haüy does not aſſert that a cubic cryſtal is of itſelf formed of an octahedron proportionate to the whole maſs, and rendered cubic by hexagonal and triangular lamina; for the ſmalleſt particles perceptible by a microſcope have already a cubic appearance, he ſuppoſes theſe minute particles may envelope a nucleus of the above-mentioned form *.

* Abbé Haüy farther obſerves, that the granite of 24 ſides ariſes from the juxta poſition of decreaſing rhomboidal lamina upon the twelve ſides of the dodecaedral granite with rhomboidal planes; hence he concluded that the laſt reſulted from the juxta poſition of four rhomboidal parallelipipedons. In order to prove the errors of a geometric theory, De l'Iſle ſays that the ſame granite may as well reſult from the juxta poſition of ſix *octaèdres ſurbaiſſés*, ſimilar to the figure of the ſuppoſed primitive of the cryſtals of tin. As there are many dodecaedral granites with rhomboidal planes, whoſe ſtria, far from being in a ſeries of decreaſing rhombs, are ſeen in the 24 ſided granite, with trapezoidal faces, but a ſeries of continually diminiſhing ſquares; ſo that the above theory is only applicable to certain varieties.

OF

OF THE

CRYSTALLIZATION OF BODIES

RENDERED

FLUID BY HEAT.

WE have already ſeen that the conſtituent particles of minerals, when ſeparated by an interpoſed liquid, and allowed gradually to unite, arrange themſeves in perfect ſymmetric order, commencing at a centre, and gradually increaſing themſelves equally all around.

When the conſtituent particles undergo that change we have already obſerved in becoming fluid by fire, if they are placed in ſuch a ſituation as to ſlowly loſe their caloric, they are ſubject to the ſame influencing principle, and arrange themſelves in perfect order; inſtead of acting from a centre, they terminate here, and commence from the circumference.

This is the reaſon why the conſtituent particles of bodies rendered fluid by heat are more firmly united than the arrangement of thoſe held in watery ſolutions. In the cryſtallizations of ſalts, each particle acts uncontrolled by any ſurrounding medium; not ſo with melted metals; the ſurface is firſt cooled, and which neceſſarily prevents the expanſion of the interior portion, ſo that the conſtituent particles are gradually more and more wedged with each other.

Glaſs, when fuſed and left gradually to cool, inſtead of forming a ſolid tranſparent maſs, ſhoots out into figured cryſtals, the conſtituent particles being rendered ſpherical by caloric; by ſlowly loſing this expanding principle, they gradually recover their native form, and conſequently in a more perfect ſtate of union.

If the glaſs is ſuddenly cooled, then the deviation from the ſpherical ſtate of the integrant particles muſt be leſs; and the gradual arrangement which otherways would take place being thus deſtroyed, are cauſes why their union is ſo inconſiderable.

In order to have a perfect, regular, and even ſurface of a glaſs, that it may equally and properly reflect the rays of light, the circumſtance of its cooling gradually is particularly attended to. This we ſee in the manufactories for plate glaſs; after the plate is caſt, it is placed in an an-

nealing

nealing oven for nine or ten days, and the fire gradually diminiſhed.

So with glaſſes for common uſe; they break with the leaſt agitation if they have not been expoſed to the annealing ſtate.

This is the reaſon why thoſe glaſſes, which are known at the glaſs-houſes by the names of proofs, although ſome of them are three eighths or half an inch thick, break with the ſlighteſt tremor.

This experiment excites at firſt a conſiderable degree of ſurpriſe; a piece of lead, or any other inelaſtic ſubſtance, of an ounce or two weight, dropped within one of theſe veſſels, no effect is induced; the minuteſt ſhiver of flint or glaſs, or any thing that by its own electricity will excite a tremor, the bottom of the glaſs in the thickeſt part immediately breaks.

When a glaſs, or any elaſtic body, is thrown into a tremulous ſtate, ſuch is induced by the action and re-action of every conſtituent particle of the body. It is eaſily ſhewn how a large and thick glaſs receiver loſes its circular ſtate, and becomes elliptical * by the ſlighteſt tremor; the

* If a glaſs receiver, as is uſed for the air pump, be well ſecured in a frame, if two ſcrews be covered with ink or any marking ſubſtance, be applied on the outſide of the receiver in oppoſite parts, ſo as to be one eighth of an inch from being in contact with the glaſs, on ſtriking the receiver there will be obſerved on each ſide a black ſpot, which could not have been affected in both places without a change in form of the receiver.

amount of this altered ſtate is equal to the ſum of all the actions of the integrant parts of the glaſs. When the glaſs is annealed, there is the more intimate union of the particles, from their native form being thus reſumed. When the cooling is hurried the union is ſo imperfect, that the ſlighteſt tremor produces a ſeparation: the fracture takes place in the thickeſt part from the ſame cauſe, viz. the tremor not being equally diffuſed, the part which is thrown into agitation is additionally reſiſted by the diſſonance of the contiguous lamina.

So unannealed glaſſes, in the form of a bell, will not admit of that expanſion which is induced by the warmth of a hand, without a ſolution of continuity.

A common glaſs goblet ſome people will break with their voice, by applying the mouth to its edge, and bringing their voice to a pitch in uniſon with the glaſs, and gradually increaſing the ſame note, the glaſs will break; the action and re-action of the conſtituent particles being increaſed, till the accumulated powers cauſe a diſunion.

This action and re-action of the minuter particles cannot be reduced to any numbers: it is on this account we muſt never expect a true eſtimate of the mechanical power of the wedge; we find a wedge will not penetrate a body when a thouſand weight is laid upon its back, and which can

be

be effected by a gentle percuffive force; a little agitation throws the conftituent particles into a tremulous motion, and at the inftant of relaxation the wedge penetrates.

The Batavian, or Prince Rupert's Drops.

These glafs drops are in England commonly known by the name of hand crackers, of a pear-like form, with a long tail; when a fmall part of the tail is broke off, the whole drop is reduced into powder; this appears the more furprifing, as it is with difficulty that the larger part can be broke by a hammer.

They are made by letting drops of melted glafs fall into a veffel of cold water.

The tails are afterwards drawn out by means of a lamp; the glafs is very rapidly cooled, and confequently in a very unannealed ftate; the external furface of the glafs is firft cooled, and, as before obferved, the conftituent particles in a very imperfect ftate of union; the interior portions of the drop are flower in their cooling, as they approach the centre, fo that every fucceffive portion will have their conftituent particles in a more perfect ftate of union, and confequently in a ftate of greater approximation; as fuch every interior portion will recede from the exterior, forming involucra, like the concentric partitions

of

of an onion. All theſe ſpaces muſt be in the moſt perfect ſtate of exhauſtion, free from every particle of air.

When the glaſs is intermixed with any extraneous matter, the regularity of theſe involucra is neceſſarily deſtroyed, and in that point we ſee a little bubble; as theſe drops are made of the moſt inferior ingredients, there are many of theſe bubbles.

That there are intervals of ſpace in a ſtate of exhauſtion may be farther proved by rendering the drops ſoft by heat; the bubbles diminiſh from the glaſs by the preſſure of the atmoſphere being compreſſed.

When a portion of the tail is broke off, a communication is formed between the atmoſphere and theſe concentric vacua; the air ruſhes in with violence into all the exhauſted intervals; each vitreous involucrum yielding to the tremulous impulſe, the conſtituent particles ſeparate, and the whole falls into ruins.

GENERAL

GENERAL CONCLUSION.

That the conſtituent particles of any body may arrange themſelves in ſymmetric order, it is previouſly neceſſary that they ſhould be in a liquid ſtate, either rendered fluid by caloric, or held in ſolution. By what means ſuch large cryſtalliſed maſſes* which are obſerved arranged in the Alpine mountains, where regular-formed quartz is found in abundance, is a ſubject which has been much diſputed. The Scheuchzers who ſtudied among the ſteep mountains of Switzerland, amid rocks of granite, petroſilex, and jaſper, had recourſe to the power of the Almighty, who broke in pieces theſe ſtrata, and elevated the ſplinters into the form of mountains. While Stenon, Hamilton, Buffon, and others, who only contemplated burning mountains, and traces of volcanic productions, imagined the earth to have been liquefied by fire; and Woodward, from obſerving ſhells and remnants of animals buried in the earth, remote from the ſea, ſuppoſed the

* Hottinger ſays, that in the country of Valais there are perfect cryſtalliſed quartz, 60lb. in weight. Kircher aſſures us he had met with ſome above 100lb. The Scheuchzers had ſome in their collection 250lb. In the Leverian Muſeum there is the fineſt and largeſt ſpecimen in Great Britain.

globe was in a fluid ſtate by water; he thought the ſtrata were regulated by their ſpecific gravities.

Romé de l'Iſle thinks primitive mountains are the effects of cryſtallization, the ſecond in order from ſub-marine depoſitions, and the more modern volcanic.

That the earth has been in a fluid ſtate is farther demonſtrated from the globe being flattened at the poles, a circumſtance which could not have been induced by any centrifugal power, had not the earth been in a liquid ſtate.

If the whole had been liquefied by caloric, there are many ſubſtances, as quartz, &c. would not have been cryſtalliſed; and even baſaltes have been obſerved enveloping watery cryſtals of zeolite, which could not have exiſted had the baſaltes been fluxed by fire.

Throughout the whole material world we ſee diverſity of arrangements, and combinations of the conſtituent particles; the diſengagement of one principle giving energy to another, reciprocally changing their ſituations, to give activity to the whole. If we admire theſe mutual influences, how exalted muſt our admiration be when contemplating the effects of living powers. If we are pleaſed with viewing the proceſs of cryſtallization, what muſt we feel in ſeeing the ſtate of organization. In the minuteſt part of animated nature, diſcernible by our ſenſes, what resources, powers, and motions, are enclosed in the small portion of matter which composes the body! What properties, what harmony, and what correspondence between these parts! How many combinations, arrangements, and principles concurring to one end! When to these reflections we add those which arise from a contemplation of the powers of succession and reproduction, how lost we are to all conception of this spiritual part.

"Behold this midnight glory, worlds on worlds!
"Amazing pomp! Redouble this amaze;
"Ten thousand add; and twice ten thousand more;
"Then weigh the whole; *one soul* outweighs them all,
"And calls th' astonishing magnificence
"Of unintelligent creation poor."

FINIS.

MEDICAL ELECTRICITY.

THE beneficial effects which have been experienced by the application of electricity in variety of diseases, render it necessary for every practitioner to medicinally examine this pervading principle.

As our knowledge of this branch of philosophy is yet in its infancy, it requires the united observations of many individuals before its influence on our organization can be well ascertained. Every complaint in which it may be advantageously employed should be accurately characterised, and its effects in every stage of the disease carefully stated.

With such a professional consideration, C. WILKINSON has fitted up a spacious apartment at his house, with an appropriate and extensive apparatus; by employing electricity on an extensive scale, he flatters himself he may be hereafter enabled to make some useful inferences.

Every case, to the utmost of his power, he purposes to accurately mark down, to observe the stated periods when any effects are induced, the degree of power employed, and the requisite time for its application particularised.

To

To apply electricity to every diſeaſe indiſcriminately, with the ſame degree of force, &c. would be as empirical as to preſcribe any particular medicine as an univerſal remedy.

To accommodate thoſe who prefer the adminiſtration of electricity at their own houſes, C. Wilkinson has arranged a number of portable electrical machines, which he equally ſuperintends.

Thoſe medical Gentlemen who favour him with any directions of the mode in which they wiſh it ſhould be applied, may depend upon the moſt punctual attention.

Every year C. W. propoſes to make a ſelection of thoſe caſes which may come under his immediate care, and ſubmit them to the Public.

ANALYSIS

OF A

COURSE OF LECTURES

ON

EXPERIMENTAL PHILOSOPHY,

By C. H. WILKINSON, Surgeon,

ONSLOW HOUSE, LEICESTER-STREET, LEICESTER-SQUARE,

AND LECTURER ON EXPERIMENTAL PHILOSOPHY AT
ST. BARTHOLOMEW'S HOSPITAL.

INTRODUCTORY LECTURE.

MECHANICS.

LECT. I. THE properties of matter explained—That matter, in a ſolid or fluid ſtate, has its ultimate particles in actual contact—The increaſe of ſpecific gravity of bodies going from a ſolid into a fluid ſtate explained on mechanical principles, without the neceſſity of adopting the incomprehenſible ſyſtem of ſpheres of attraction and repulſion—That fluid matter, when entering into a ſolid ſtate, having its particles diſpoſed in a certain arrangement, ſhewn to probably ariſe from the influence

of

of ſome active principle as electricity, according as the capacities of bodies may be increaſed or diminiſhed—The effect ſhewn of electrified ſolutions in the conſequent cryſtallizations—The genera of cryſtals, and the ſpecies ariſing from each genus, ſhewn and explained.

LECT. II. On the laws of motion and compoſition of forces, with the doctrine of centripetal and centrifugal powers.

LECT. III. Mechanical powers illuſtrated by machines.

LECT. IV. The mechanical power of the animal economy as muſcular action—The powers of the heart—The theories of Borelli, Lower, Bellini, Harvey, Keil, Hales, and Wilſon examined, and the great utility of a mechanical knowledge to the ſurgical practitioner, illuſtrated in a variety of caſes.

OPTICS.

LECT. V. Of the properties of light, and the doctrine of the priſm.

LECT. VI. Of lenſes and mirrors—Reflection, refraction, and inflection, ſhewn to moſt probably depend on a certain arrangement of the ſmaller particles of matter, and not from ætherial atmoſpheres, as Newton conjectured.

LECT. VII. Of the eye—The denſities of the different media determined on hydroſtatical principles—The decuſſated ſtructure of the cornea of thoſe inſects that are deprived of any rotary motion of the head, hence enabled to ſee all around—The loricated ſtate of this part in birds ſhewn to be admirably calculated for viewing objects in the different aërial media in which they are immerged—The uſe of the aqueous humour—The exquiſite ſenſibility of the iris, accommodating itſelf ſo as to admit nearly an equal intenſity of light—The cryſtalline lens—Its laminated ſtate, conſiſting of ſtrata of different denſities, ſhewn to be admirably contrived for correcting the aberration of the rays of light—The different convexities of its different ſides, the actual fibrous appearance that can be ſhewn, render it probable that the power of the eye, in accommodating itſelf to objects at different diſtances, is veſted in this lens—Geometrically demonſtrated that it cannot be in the cornea, and that the ciliary zone ſeems calculated by occaſional contraction to prevent any corrugation of the ſurrounding capſule, when the ſurface of the lens is diminiſhed on account of its aſſuming a more ſpherical form—The fibrillated texture of the retina ſhewn, and the remarkable coincidence of theſe delicately-formed fibres with reſpect to the angles the leaſt viſible objects ſubtend—The theories of Kepler, Des Cartes, Newton, Le Cat, De la Hire, Pemberton, Smith, Porterfield, Reid, Hunter, and Home, examined.

Lect. VIII. On the ſimple, compound, and ſolar microſcopes—The method of arranging the glaſſes, calculating their power, and preparing objects; and how the preſent ſtructure might be improved—Of refracting, achromatic, and reflecting teleſcopes—Of many optical deceptions.

PNEUMATICS, HYDROSTATICS, AND METEOROLOGY.

Lect. IX. An examination into the different gaſes, as far as relates to experimental philoſophy—Their production, different gravities, properties, &c.

 Lect.

Lect. X. On ſound—Why its propagation exceeds thirteen times the velocity of the moſt violent wind—Shewn to ariſe from no other change of place in the aërial particles, than their tremulous actions and re-actions—The effect of an undulatory percuſſion on the auditory organ—The admirably contrived ſtructure of the exterior portion of the ear—The analogy between the membrana tympani and the cryſtalline ſhewn—The The mechanical advantage derived from the oſſicula, not only determining the action to the membrana feneſtræ ovalis, but acting as ſo many levers increaſing its powers—Euſtachian tube, formed for preſerving a proper tenſion of the membrana tympani—The labyrinth—The aqueous fluid with which it is replete, producing an extenſive impreſſion on the nervous expanſion with which it is lined—Its greater ſenſibility than the retina ſhewn by its retaining, in a given time, a greater number of impreſſions.

Lect. XI. Harmonics—The monochord—The analogy ſhewn by Newton ſubſiſting between its diviſion and the priſmatic decompoſition—Of the nature of ſonorous bodies—Of the production of muſical ſounds, conſonances, and diſſonances—The Galilæan compariſon of the vibrations of a muſical ſtring with thoſe of a pendulum—On echoes, whiſpering galleries, &c.

Lect. XII. On the weight of the atmoſphere, ſhewn by the air pump, with a variety of miſcellaneous experiments—The barometer, pumps, fire engines, condenſing machines, &c.

Lect. XIII. Of fluidity—The action of fluids on bodies immerſed in them—The method of eſtimating their ſpecific gravities—The method at preſent adopted by ſuch means of diſcovering the proportion of a known alloy mixed with gold or other valuable metal, ſhewn not to be perfect.

Lect. XIV. On the Hydrometer—Syphon—Reciprocating ſprings, fountains, rivers, and ſeas—Diving bell—Hook's explorators, winds, thermometers, &c.

MAGNETISM.

Lect. XV. Iron, the only ſubſtance ſuſceptible of being influenced by it; others, as Nickel, &c. being only ſo in proportion as they are combined with it—Of the action of the magnetic poles—How to render iron magnetic—An enquiry into its directive powers—Of the variation, inclination, &c.—The hypotheſes of Halley, Whiſton, Æpinus, Wargentin, Van Swinden, Dalton, and Lorimer—The coincidence of the line of no variation with the vertex of thoſe irradiated electrical emanations in the air, called Aurora Borealis—Various magnetic deceptions.

ELECTRICITY.

Lect. XVI. An inveſtigation into the nature of this fluid, by comparing its properties with thoſe of light—Caloric, magnetiſm, and the æther of Newton—Shewn to be none of theſe—That from ſome of its effects it may be the reſult of a binary combination of light and caloric—Its production by the excitement of various ſubſtances by the hand—Its extrication by the contact of two bodies, or its diſengagement by the application of caloric, as produced by the immerſion of the tourmaline, topaz, &c. in boiling water.

Lect. XVII. On the conſtruction of electrical machines—The various forms in which they are made examined—A compariſon between the beſt cylindric forms of Nairnes, and the plate machine of Dr. Ingenhoufz, as at prefent fuperiorly conftructed by Mr. Cuthbertfon—On Conductors—How far it is advantageous to have an extenfive furface—Shewn to be injurious in charging a battery—On the cufhions, infulations, points, &c.

Lect. XVIII. On the Leyden phial—The theories of Franklin, Eeles, Symner, De Luc, Bennet, Morgan, Reid, &c. fhewn to be inadequate to its folution—The various ideas refpecting pofitive and negative electricity—Cavallo's explanation of the repulfion between negative electrified balls unfatisfactory.

Lect. XIX. On electrofcopes, electrometers, electrophori, doublers, collectors, &c.

Lect. XX. On atmofpherical electricity—The phenomena of thunder and lightning—The theory of Lord Stanhope refpecting the returning Stroke, and the opinion of Morgan examined—The production of fire-balls, fhooting ftars, Northern lights, comets' tails, hail, fnow, and rain; how far dependent on electricity—The theories of conductors, whether points or balls are more eligible—The opinions of Franklin and Wilfon thereupon.

Lect. XXI. An examination into the properties of the electric fluid in different gafes, and the increafe of fome and diminution of others in their bulk—The production and decompofition of water by electricity—The calcination of metals—The beautiful appearance of the oxyds when thrown on paper—The opinions of Van Marum—An examination whether light appertains to the electric fluid, or elicited from the bodies through which it paffes—Whether apparent in a good Torricellian vacuum.

Lect. XXII. On animal and medical electricity—The great fenfibility in the mufcular fibres of fome of the imperfect animals, as frogs, &c. being thrown into action by the application of two different metals, on forming a connection between them, fhewn to moft probably arife from the different capacities of the metals for giving out or abforbing electricity by the clofe contact of fome fubftance, and hence the evolution may imprefs parts endued with the remnants of life, although its exiftence not afcertainable by the moft delicate electrofcopes—This rendered probable by fhewing that the mufcles of a frog are thrown into action at a much greater diftance from an excited machine, than any electrofcope—That it is not fimilar to the torpedo, gymnotus, or filurus—Thefe electric organs examined—How probably the electricity may be generated, and how evolved—Why thefe animals, however irritated, never throw themfelves into a ftate for its accumulation, till a previous circuit is formed—The theories of Galvani, Valli, Monro, and Fowler examined—The effects of electricity on an animal body medically confidered.

ASTRONOMY.

Lect. XXIII. The fituation and fize of the fun, and his double motions—The faculæ that appear on his difk—The primary and fecondary planets, their orders, revolutions, magnitudes, and diftances, with their reciprocal gravitating power explained.

Lect. XXIV. The fituation of the earth, and its triplicate motion—The difference of feafons—The moon and her various phafes explained.

Lect.

Lect. XXV. The method of calculating ſolar and lunar eclipſes—Tranſits of the inferior planets—An examination into the various ideas of fanciful aſtrologers reſpecting planetary influence, how far ſuch a power may probably exiſt—The wonderful action of the ſun and moon in producing tides, &c.

Theſe Lectures are illuſtrated by a great variety of Philoſophical and Aſtronomical Inſtruments: other particulars may be known by application to Mr. Wilkinſon. Perſons preferring private inſtructions in any of the above ſciences may receive ſuch by attendance on Mr. W.

NOTE.

In the algebraical demonſtrations, I have not thought any illuſtrative figures were requiſite; they could not be neceſſary to the mathematical reader, nor of any uſe to one unacquainted with the principles of geometry. It may be proper to obſerve, that in the aſcertainment of the centres of gravity and percuſſion, A B is ſuppoſed in both to be the length of the cylinder, and E F the diameter of the circular end. In order to determine the ſtrength of a cylinder, it is ſuppoſed one end A faſtened to a block C D, and a weight D W acting on the other end B, the weight increaſed till the cylinder is broke: the tranſverſe ſection is expreſſed by E R G, which muſt be ſubſtituted for *a b c*, which by miſtake was placed as expreſſing the tranſverſe ſection.

In the demonſtrations of the ſpine, and not being of a ſerpentine form, only the points of inflection and retrogreſſion are particulariſed.

In the calculation of the powers of birds the decimal has been omitted; inſtead of a cubic foot of air weighing 12 ounces, it ſhould be expreſſed 1 . 2 ounces, and ultimately the ſum of the powers 200lb.