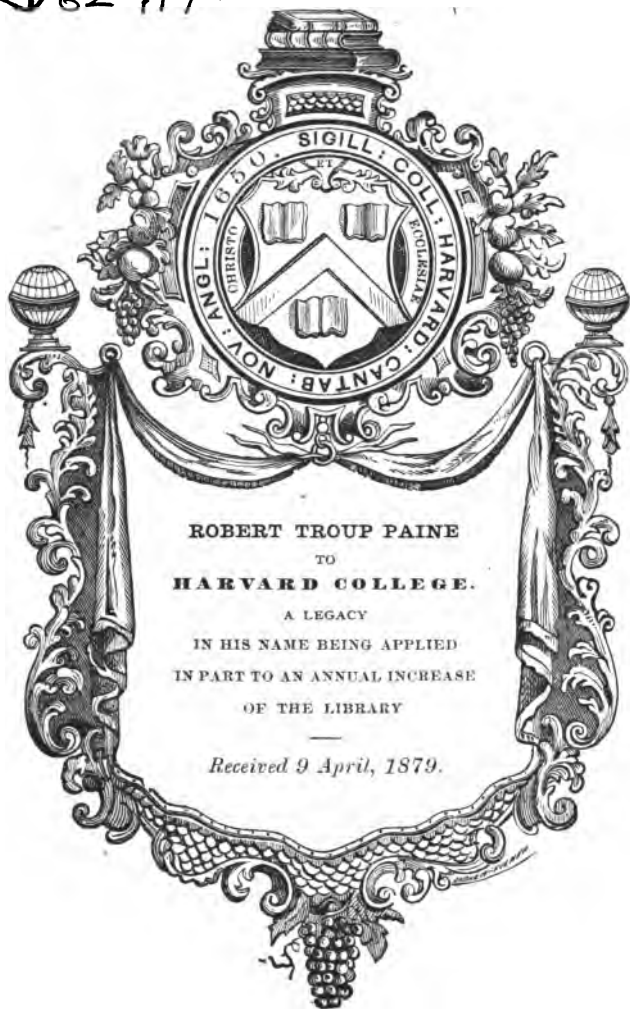


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An EXPERIMENTAL
I N Q U I R Y
On some PARTS of the
Animal Structure.



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 Group Piece
to Harvard College
AN EXPERIMENTAL

INQUIRY

On some PARTS of the
Animal Structure.

By CLIFTON WINTRINGHAM, junior.

— *Ex iis, quæ Experimentis constant, ducere tentemus quicquid potest, antequam in Hypotheses liberiores expatiemur: Non male cæperunt Sanctorius, Jungius, Redius, Borellus, Stenonius, Wepferus, Brunnerus, Bellinus, Spoletus, Thirnaufus, Bernoullius, Listerus, Pitcarnius, aliique etiam in Gallia, & alibi egregii Viri; sed adhuc in primis Viis hæremus, optandumque est, ut ab iis Initium fiat, quæ Praxi Medicæ sunt proxima.*

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THE
INTRODUCTION.



THAT the Theory of Physic
has been much improved,
and many truths discovered
by the industry of the Mo-
derns, of which the Ancients were in-
tirely ignorant, is a position nobody,
I believe, will dispute. But that a
great many more relating to every
branch of this most useful Art lie still
buried in obscurity, is equally cer-
tain.

INTRODUCTION.

tain. And what is yet more to be lamented than real ignorance itself, is, false maxims and positions are many times introduced as facts, and assumed as Data, whereon to build future inquiries. Anatomy itself, tho' it has been more cultivated, and received greater improvements, than any other branch, as lying most obvious to our senses, is not free from this error, no not even the largest vessels ; what then shall we think of such as are more remote ?

The fatal spring from whence most of the errors in the Theoretical part of physic have flowed, is, the deducing general conclusions from a few particular Experiments, and on this foundation erecting some pompous plausible Hypothesis, which like *Descartes's* Vortices may indeed shew how the one would have framed the Universe,
and

INTRODUCTION.

3

and the other the Animal body ; but give us very little light into the real structure of either.

This can only be obtained by a laborious search, and the strictest examination imaginable, and that too by a vast variety of Experiments ; as any one may be convinced by the few methods of trial here made use of, wherein only the different Densities, Strengths and Thicknesses of some few of the Solids are considered ; but much more so, if he will give himself the trouble of such a variety of Experiments, as are requisite fully to illustrate any branch of this complicated Machine, or thoroughly explain any one particular Secretion ; wherein it is impossible to advance one step without error, unless we be supported by undeniable matters of Fact.

INTRODUCTION.

The ingenious Dr. *Hales*, has given us a few Experiments of the remarkable strength of some animal vessels; but no one, that I know of, has attempted their Comparison, or afforded us any light towards a discovery, on what foundation their different degrees of action on the contained fluids must depend.

The Experiments here related are mostly made on the vessels of Brutes; but they are all on such parts as are similar to those of human bodies; and that not only because it was scarce possible to procure a competent number of the latter; many of them, tho' not here mentioned to avoid confusion, being repeated ten, nay, twenty times over, as well on different Animals of the same kind, as those of a different Species, in order to the greater certainty, where that was required; but

INTRODUCTION.

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but chiefly, because it is necessary in Experiments of this nature, that the Animal should die in perfect health. The vessels of Morbid bodies being so altered by the force of different diseases, whose effects are often quite contrary to each other, and the various changes introduced by the Humours, that no certainty could be derived from trials of that kind. For what is more common in Dissections of this nature, than to find many vessels so extended, that not only their Capacities vastly exceed their proper size and dimension, but the Coats themselves are become so thin and dilated, as not to equal one-half of their natural Thickness? whilst others, in different cases, vary from their natural proportion in the contrary extreme, not to mention their Rottenness and Corruption, occasioned by the violence of the diseases, and

effects of the Humours upon them,
www.libgen.org a circumstance not less frequent than
either of the other.



AN



A N

Experimental INQUIRY

On some PARTS of the

Animal Structure.

EXPERIMENT I.

§ I.



ART of the Aorta descendens of a young man, taken out of the body after it had been dead forty hours, was found to weigh in air by a very nice balance, whose beam turned with the two-

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hundredth

hundredth part of a grain, 5 pennyweights, 16 grains, 75 mites, which name I shall use for a weight, a hundred of which make up but one grain. Then weighing it in water, its gravity was 7 grains, 75 mites.

§ 2. The weight of part of the Vena cava in the same person was in air 1 pennyweight, 4 grains, 63 mites; and the same counterpoised in water, 2 grains, 66 mites.

§ 3. Hence the specific gravity of the great Artery in a man will be to water, in the proportion of 13675 to 12900, that is, nearly as 106 to 100.

§ 4. Hence also the specific gravity of the corresponding Vein will be to water, as 2863 to 2597, that is, in the proportion of 1102 to 1000 nearly.

§ 5. Hence by comparing the specific gravities in § 3, 4. together, it is evident, that the Vena cava of this young

young man exceeded the Aorta of the same person in density in the proportion of 36932700 to 35513975, that is, in the proportion of 26 to 25 nearly.

EXPERIMENT II.

§ 1. Part of the Aorta descendens of a calf, taken fresh out of the body, which I always understand, if not expressed otherwise, was found to weigh in air 7 pennyweights, 10 grains, 25 mites. The weight of this in water was 9 grains, 62 mites.

§ 2. Part of the Vena cava of the same calf weighed in air 2 pennyweights, 5 grains, 95 mites, and afterwards in water 4 grains, 75 mites.

§ 3. Hence the specific gravity of the Artery to water will be in the proportion of 17825 to 16863, that is, as 1057 to 1000 nearly.

§ 4.

§ 4. Thus also the specific gravity of the Vein to the same fluid will be in the proportion of 5395 to 4920, that is, as 1096 to 1000 nearly.

§ 5. Hence by comparing these specific gravities together, it appears, that the density of the great Artery was to that of the corresponding Vein in this animal a calf, in the proportion of 87699000 to 90975885, that is, as 27 to 28 nearly.

EXPERIMENT III.

§ 1. I found the weight of part of the Aorta of a lamb to be in air 2 pennyweights, 14 grains, 44 mites; and afterwards in water it counterpoised 3 grains, 23 mites.

§ 2. The weight of part of the Vein corresponding to the preceding Artery was in air 13 grains, 69 mites, and
the

the same being weighed in water, its gravity was 1 grain, 16 mites.

§ 3. Hence the specific gravity of the Aorta in this lamb was to water in the proportion of 6244 to 5921, or of 1054 to 1000 nearly.

§ 4. Thus also the specific gravity of the Vena cava in the same animal was to water in the proportion of 1369 to 1253, or of 1092 to 1000 nearly.

§ 5. Hence comparing the specific gravities of the Vein and Artery in § 3, 4. together, it appears, that the density of the great Artery in the lamb was to that of the great Vein in the same, in the proportion of 7823732 to 8105849, that is, in the proportion of 250 to 259 nearly.

EXPERIMENT IV.

§ 1. The Aorta of a young boar weighed in air 6 pennyweights, 12 grains

grains, 15 mites, and in water 9 grains, 49 mites.

§ 2. The Vena cava of the same boar weighed in air 1 pennyweight, 13 grains, 27 mites; the same in water counterpoised 3 grains, 55 mites.

§ 3. Hence the specific gravity of the great descending Artery in this animal was to water, in the proportion of 15615 to 14666, that is, nearly as 1064 to 1000.

§ 4. Hence also the specific gravity of the Vein corresponding to the preceding Artery, will be to water, as 3727 to 3372, that is, in the proportion of 1105 to 1000 nearly.

§ 5. It appears therefore from § 3, 4. that the density of the Vena cava in the boar exceeded that of the corresponding Artery in the proportion of

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54660182 to 52653780, that is, in the proportion of 519 to 500 nearly.

In order to obtain the Thickness of such Vessels or Membranes as were wanted with the greatest exactness, I took the following method.

Having first carefully cleared the part, whose Thickness I was seeking, of all fat, or any other adhering substance, I carefully spread it upon a smooth surface; and then cutting off by an instrument made for that purpose, an exact inch square, or some determinate portion of it, where so much could not be obtained, I let it down into water; hence as bodies immersed in that fluid, from a principle of Hydrostatics, possess spaces equal to themselves in bulk, I found by comparing these bulks together, that a quantity of water having the same base,
and

and equal to the solid content of the part immersed, was of such a precise Thickness, equal to that of the part before unknown.

EXPERIMENT V.

§ 1. I found by the preceding method, that the Aorta descendens of the man mentioned in § 1. Exp. I. was $\frac{1}{5}$ of an inch thick, and the corresponding Vena cava was $\frac{1}{7\frac{1}{4}}$ of an inch thick.

§ 2. The Aorta descendens of the calf mentioned at § 1. Exp. II. was $\frac{1}{11}$ of an inch in Thickness, and the Vena cava ascendens of the same animal was $\frac{1}{17\frac{1}{8}}$ of an inch thick.

§ 3. The Aorta of the boar, whose Density was found by Exp. IV. was $\frac{1}{15}$ of an inch in thickness, and the Vena cava of the same was equal in Thickness to $\frac{1}{16\frac{1}{2}}$ of an inch.

§ 4. Hence by comparing the Thicknesses of the vessels found in the preceding sections of this experiment, it is evident, that as Ratios having the same antecedents, are reciprocally as their Consequents, therefore the Thickness of the Aorta of the young man was to that of its corresponding Vein, in the proportion of 154 to 9, that is, nearly as 17 to 1. And the Aorta of the calf is in like manner to its corresponding Vein, in the proportion of 158 to 11, that is, nearly as 14 to 1. Lastly, the Aorta of the boar exceeds the Thickness of the Vena cava ascendens in the same animal in the proportion of 262 to 16, or of 33 to 2, that is, nearly as 16 to 1.

§ 5. From § 5. EXP. I. § 5. EXP. II. § 5; EXP. III, IV. it is observable, that this less degree of Density in the coats of the Arteries to their corresponding Veins

Veins is sufficiently recompensed by the Thickness of their coats (a), and is indeed necessary in continuing the life of the animal to its present natural period. For the blood in the Arteries being constantly impelled from the base towards the apex of a Cone, their coats, especially those near the heart, must in a much shorter time have become bony, had they been as close wrought as those of the Veins, and consequently the animal would not have lived to the term it now does; the Aorta, and sometimes even those at a greater distance from the heart, being in old animals frequently found ossified.

§ 6. This greater Density, and more compact Texture, of the coats of the Veins, in proportion to their Thickness, than in the Arteries, furnishes us also

(a) See § 4. EXP. V.

with another instance of the infinite wisdom used in the animal structure. For, as there is here no pulsation, the fluid moving from the apex of a Cone, there was no danger of their becoming bony, tho' the texture of their coats be so closely wrought. But then a sufficient strength was here likewise necessary to support the lateral pressure consequent upon such an altitude of fluid, which would otherwise distend their coats, and render them varicose, as we see it actually does, whenever their coats are weakened by accidents.

§ 7. It may be objected, that the Valves placed in them, by dividing them, as it were, into so many cells, are a great preservative against this distention; but this is rather a proof, that they necessarily required the strength and density before-mentioned, since

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where

where these are not placed, and the coats lie naked, and less supported by the surrounding parts, as in the Uterus, &c. varicose swellings and hæmorrhages frequently ensue. How great then the disorders must have been in almost every part of the body in a short time, will appear to every one conversant in Anatomy, had the coats of the Veins been of so lax and weak a texture, as they are generally supposed, nay, are frequently defined by Anatomists to be; and not had that degree of density and firmness, which the experiments above cited at § 5. EXP. V. as well as several succeeding ones, no way depending on these, actually shew they have. Nay, it might easily be demonstrated, that had their texture been otherwise, polypous concretions must necessarily have been formed in almost every Vein, and
thence

thence the circulation of the blood have been soon obstructed, and not only so, but the Heart could not have been supplied with a sufficient quantity for the animal life, when so great a proportion of it remained in the distended Veins, as must inevitably have ensued on an universal weakness of their coats, even though we should suppose the force of the Heart and Arteries increased to any degree of strength and thickness, that can be imagined consistent with the size and shape of the animal.

EXPERIMENT VI.

§ 1. I took part of the descending Aorta from an old man two days after his death, and having carefully removed all the adhering fat from it, which in these as well as the preceed-

ing experiments I always suppose done, I weighed it in air, and found it equivalent to 8 pennyweights, 5 grains, 43 mites ; and in water to 17 grains, 66 mites.

§ 2. The weight of part of the Vena cava ascendens in the same person, was in air 2 pennyweights, 18 grains, 7 mites ; and the same, counterpoised in water, no more than 6 grains, 34 mites.

§ 3. Hence the specific gravity of the great Artery in this old man, was to water, in the proportion of 19743 to 17977, that is, of 1098 to 1000 nearly.

§ 4. The specific gravity also of the great Vein in the same man, will be to water, in the proportion of 6607 to 5973, that is, nearly as 1106 to 1000.

§ 5.

§ 5. From the foregoing experiment we learn, that the great Artery in this old animal was so altered by age, and the course of a longer circulation, that notwithstanding the density of the like Artery in a young one of the same species, was less than that of its corresponding Vein by $\frac{1}{25}$, nearly (*a*), yet in the old one the specific gravity of the same vessel is so increased as to make it bear to its proper returning Vein, the proportion of 117924939 to 118774039; and consequently the Vein in the old man exceeds the density of its corresponding Artery in no greater proportion than that of 140 to 139.

EXPERIMENT VII.

§ 1. I took part of the descending Aorta from an ox 15 years old, and

(*a*) See § 5. EXP. I.

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having

having removed the fat, as in the preceding experiment, I found its weight to be in air 16 pennyweights, 12 grains, and in water 1 pennyweight, 7 grains, 37 mites.

§ 2. The weight of part of the corresponding Vena cava was in air 5 pennyweights, 10 grains, 25 mites, and the same, counterpoised in water, 12 grains, 2 mites.

§ 3. Hence the specific gravity of the great Artery in this old ox, was to water, in the proportion of 29600 to 36463, that is, of 1086 to 1000 nearly.

§ 4. The specific gravity also of the great Vein in the same ox, will be to water, in the proportion of 13025 to 11823, that is, nearly in the proportion of 1101 to 1000.

§ 5. It appears therefore, that the density of the Aorta in this animal,
was

was to that of its corresponding Vein, in nearly the proportion of 500 to 507.

§ 6. By comparing § 3, 4. of this Exp. with § 3, 4. of Exp. II. it is evident, that the density of the descending Aorta in this old ox, is to that of the like Artery in a calf, as 1027 to 1000 nearly ; and that the density of the Vein here does not exceed that of the like Vein in the calf, in scarce so great a proportion as that of 1005 to 1000.

EXPERIMENT VIII.

§ 1. The Aorta of a large old boar, being weighed in air, was equal to 5 pennyweights, 9 grains ; and the same, counterpoised in water, 10 grains, 1 mite.

§ 2. The Vein corresponding to the preceeding Artery, weighed in air

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1 penny-

1 pennyweight, 11 grains, 9 mites, and
in water 3 grains, 33 mites.

§ 3. Hence the specific gravity of the Aorta in this old boar, was to water, in the proportion of 12900 to 11899, that is, nearly as 1084 to 1000.

§ 4. The specific gravity of the Vein, will be to water, in the proportion of 3509 to 3176, that is, nearly as 1105 to 1000.

§ 5. It appears therefore, that the density of the descending Aorta in this animal, was to that of its corresponding Vein, in the proportion of 40970400 to 4175359, that is, nearly in the proportion of 52 to 53.

§ 6. Hence, by comparing § 3, 4. of this experiment with § 3, 4. of EXP. IV. it appears, that the density of this Aorta in the old boar, exceeds that of the like Artery in a young one,

one, in the proportion of 54 to 53 nearly; and further, that the Vein has not in the same time increased its density at all.

EXPERIMENT IX.

§ 1. Part of the great Artery of a young greyhound weighed in air 2 pennyweights, 16 grains, 98 mites; and afterwards in water 3 grains, 62 mites.

§ 2. The corresponding Vein weighed in air 14 grains, 43 mites; and in water it counterpoised 1 grain, 30 mites.

§ 3. Hence the specific gravity of the Aorta in this greyhound, was to water, as 6498 to 6136, that is, nearly as 1059 to 1000.

§ 4. Hence also, the specific gravity of the Vena cava in the same animal, was to water, in the proportion

www.libt~~o~~ EXPERIMENT XI.

§ 1. The great Artery of the boar, whose density we found in EXP. IV. was 0.0625 of an inch thick, and the great Artery of the great old boar, mentioned in EXP. VIII. was 0.094 of an inch in thickness. The great descending Artery of the greyhound, mentioned in EXP. IX. was 0.046 of an inch in thickness, and the Aorta of the old dog, mentioned in the preceding experiment, was 0.07 of an inch thick.

§ 2. It is evident, that the canals in an animal body, may be considered as so many cylindrical receivers, filled with a fluid. If now we compare the fluid in the cavity of the Aorta of the boar, whose diameter was 0.34 of an inch, with the thickness of the coat that contains it, it follows,

follows, that as cylinders of equal altitudes are directly as their bases, therefore the fluid contained within this Artery, will be to its coat, as 1156 to 1006 nearly ; and by using the same method of comparison with the Aorta of the greyhound, whose diameter was 0.26 of an inch, it appears, that the fluid contained within this, is to the solid part of the Artery, as 676 to 563 very nearly.

§ 3. By comparing the fluid in the cavity of the Aorta of the old boar and the old dog, with their thicknesses respectively, as they are given in § 1. of this experiment, it is evident, that the fluid contained in the cavity of the first, is to its respective Artery, whose diameter was 0.45 of an inch, in the proportion of 202 to 204 nearly ; and the fluid contained in the Aorta of the old dog, whose diameter

diameter was 0.33 of an inch, and its thickness 0.07 of an inch, will bear to the coat of its respective Artery, the proportion of 1089 to 1120 nearly.

§ 4. It is therefore evident from the two preceeding sections, that the fluid contained in the cavity of the Aorta of the young boar, and of the greyhound, bear a larger proportion, with respect to the coats of those Arteries, than those circulating in the cavity of an Aorta of the old animal of the same species, bear with relation to theirs; these last being to the former, with regard to the bulk of their containing coats, in the proportion compounded of the direct ratio of the fluids, and the reciprocal one of the solids they act upon; which proportion appears from computation to be, that of 203212 to 235824, and 613107
I. to

to 757120 respectively, that is, nearly as 1000 to 1160, and 1234, for each particular ratio.

§ 5. It appears highly probable, that the densities of the Arteries, being changed by age, to the very reverse of what they were in young animals (*a*), may well be esteemed as the principal cause in limiting their growths, and confining them to their natural size and proportion. For the impulse of the blood being much greater in such vessels, as spring immediately from the Aorta, than those more remote, these must be first distended, and that too in length, in a greater proportion than in their diameters, as is manifest from the nature of the cone, through which they circulate, whose small diminution in its trunk between each ramification,

(*a*) See § 5. EXP. VI. § 5, 6. EXP. VII, VIII, X.
joined

joined with the quantity of blood drawn from the trunk by each branch, must diminish the lateral impetus in a greater ratio than the longitudinal, as is evident not only from the doctrine of Conics and Hydraulics, but appears, even to our senses, in such vessels, as are partially compressed, or obstructed, in all which the lateral impetus is increased, and thereby tumors produced.

This then being the structure of the animal vessels, it is evident, that these must grow both in length and diameter, though in a greater proportion in the former, than the latter, till such time as their coats have acquired such a degree of firmness, as to put them in æquilibrium with the impetus of the fluids upon them ; at which state when the animal is once arrived, it can grow no taller.

But

But though the vessels immediately springing from the Aorta, where the impetus upon them is greatest, have acquired this degree of firmness and density, it is manifest, that the collateral vessels, which derive their juices, as it were, at second-hand, must remain much weaker, and more easily distensible ; and consequently the proportion of blood, which was required to the distention of the former, must pass into these, and that too with greater force than before, by reason of the increased strength of the primary vessels ; these then must be next distended in their destined proportion, till their acquired strength push on the juices to exert their force to all succeeding ramifications, in their natural order and proportion ; which done, the animal has acquired the full strength and proportion its vessels

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are

are capable of. Consonant to which, we see, that young animals, though equally tall with those of the same species which are older, are always more weak, lax, and slender, than such as are full grown, where every part has acquired its due firmness and density, and is sufficiently replenished with its proper juices.

The solids and fluids being thus reduced to a just æquilibrium through the whole body, the animal will remain in this state, or at least be less liable to changes than before, till such time as, by the continued action of the solids and fluids upon each other, the case become considerably altered, as it necessarily must be from the increasing density of the solids. Hence the coats of the arterial vessels will be contracted, and resist the fluids more strongly ; and if the same quantity
5 of

of nourishment be continued, the redundant quantity must be thrown off upon such parts as are most lax and distensible, of which kind are the Abdomen and adipose Cells, as daily experience confirms in this state of the animal life, both in men and brutes.

The same cause, *viz.* the increasing rigidity and density of the solids, still continuing (*a*), its effect must do so likewise, and consequently all the solids of the body become more rigid and contracted.

But this increasing density and rigidity of the Arteries, is not the sole effect produced by age. For the proportion of the coat to the cavity of the Vessel is considerably altered, as appears by § 4. *Exp. XI.* wherein the thickness of the coat of the Aorta in

(*a*) See § 5, 6. *Exp. VII. to Exp. X.*

the old dog, bears a much greater proportion to the contained fluid, than in the young one, and that without any allowance for the greater moisture, and more supple texture in the coats of the latter; and consequently whatever force is necessary to excite any degree of motion in the Fibres of the younger animal, must be increased, if we would produce an equal effect on the Fibres and Vessels of the old one.

Hence then, a greater influx of spirits must be necessary to actuate an old animal, than one that is younger; but this being impossible to be supplied from a less proportion of blood, and that too not equally elaborated, through the same defect in the secretory organs, the animal must of necessity grow torpid and unactive; the force exerted by the muscles,
must

must be more weak and feeble, and instead of that steadiness in the limbs, which arises from a regular and sufficient derivation of the nervous fluid, a tremor ensue, the antagonist muscles being stimulated to frequent ineffectual contractions, by an insufficient and irregular derivation in the old, which are firmly braced, and sufficiently supplied in the younger animal. Hence the muscular parts must become shriveled, be less fit for their proper functions, and the animal unable to perform its accustomed motions and exercises, a state of life most elegantly described by the poet (a):

——— *Quam continuis & quantis longa senectus
Plena malis! deformem & tetrum ante omnia vultum,
Dissimilemque sui, deformem pro cute pellem.
Plurima sunt juvenum discrimina, pulchrior ille
Hoc, atque ille alio, multum hic robustior illo:*

(a) JUVENAL, Sat. X.

Una senum facies, cum voce tremantia membra,

Et jam leve caput, madidique infantia nasi.

Præterea minimus gelido jam corpore sanguis

Febre calet solâ, circumfilit agmine facto

Morborum omne genus—

§ 6. Hence also appears the reason of the different diseases incident to young and old animals, as also why many of the former shall gradually wear off, and frequently disappear, as the animal approaches to its greatest strength and maturity, without any assistance from art; many vessels, before too weak to perform their destined offices with proper vigour, daily acquiring more strength and firmness.

Nor is it less apparent, why those incident to age should constantly increase, even where the greatest skill is applied to prevent it. For these consisting mostly of obstructions, arising primarily

primarily from the contraction and rigidity of the canals, must keep pace with the increasing cause, and prove incurable by the most skilful physician.

§ 7. I might here also shew the fallacy of an assertion of the late ingenious Dr. Keil, which is still adhered to by most Anatomists, viz. that Accretion and Nutrition consist only in the distention of vessels; which is manifestly false from their increasing density and firmness. Nay, it might easily be made appear, that was this the case, the animal must daily grow weaker, the nearer it approached to maturity; and not only so, but considering the size of an embryo, with regard to that of a full grown animal of the same species, its most firm and compact parts would not exceed the cohesion of the thinnest gelly.

'Tis true, indeed, that the coats of the Vessels consist of others that are smaller, and these again of others, to the minutest ramifications imaginable, and that by the distention of these, the coats of the largest increase in thickness; but this alone will not account for their increasing density, which necessarily supposes an addition of matter in the same bulk; and consequently must arise not solely from distention, but likewise from the apposition of fresh particles into such pores and interstices, as by the distention of the coats are qualified to receive them, which are there fixed and consolidated by the constant impulse of the fluids upon them; and that more especially during sleep, when the circulation is equable and regular, and not disturbed by the action of the muscles.

It

.It were easy hence to shew the vast difference betwixt Nutrition properly so called, and Repletion, or such a distention of the vessels, which apes it, were it not digressing too far from my present design.

§ 8. Hence appears the unreasonableness of that practice, which forbids the use of bleeding in distempers of old persons, though recommended and practised with great advantage to younger ones in diseases of the same species. For though the coats of the Arteries bear a greater proportion to their contents in these than young animals (*a*), and consequently the quantity of fluids be proportionably less in the first, than in the latter ; yet, as the Arteries, in which obstructions are principally formed, are apparently more dense and rigid, and cannot be

(*a*) See § 4. E x P. XI.

so dilated, as in many cases is requisite; it follows, that where either Revulsion is absolutely necessary, or inflammations to be resolved, whose continuance or suppuration would be destructive of the life or well-being of the sick, this inconvenience must be dispensed with.

'Tis true, indeed, a less quantity will generally suffice; but that is no reason, why an evacuation, so necessary, should be totally omitted.

§ 9. Nor is it less apparent from hence, that the quantity of nourishment taken by old persons, should be less than in those that are younger; and that too, gradually diminished in very old age, consonant to the advice of HIPPOCRATES, and the practice of the famous *Venetian* CORNARO; the expence by perspiration, and several other Emunctories, being not only less, and
thence

thence a less recruit necessary, but the cavities of the containing vessels diminished, and withal so rigid, as not easily to yield either to the receipt or discharge of an unnecessary quantity; and which, if retained, will sooner or later produce fatal obstructions, particularly shortness of breath and suffocations, the constant harbingers of death in old age. A just sense of these, and some other ill attendants shewn in the preceeding sections, necessarily incident to this last period of frail life, has drawn from a *Roman* poet, the following beautiful and exact description (a):

*Hæ sunt primitiæ mortis, his partibus ætas
Defluit, & pigris gressibus ima petit.
Non habitus, non ipse color, non gressus euntis,
Non species eadem, quæ fuit ante, manet.
Contrahimur, miroque modo decrescimus ipsi:
Diminui nostri corporis ossa putes.*

(a) CORN. GALLUS.

Nec

Nec cælum spectare licet, sed prona senectus
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Terram, a qua genita est, & reditura, videt:

*Fitque tripes prorsus, quadrupesque, ut par-
 vulus infans,*

Et per sordentem flebile serpit humum.

Ortus cuncta suos repetunt, mortemq; requirunt,

Et redit ad nihilum, quod fuit ante nihil.

§ 10. From the consideration of
 § 5. EXP. VI. § 5, 6. EXP. VIII. § 5, 6.
 EXP. X. § 2, 3, 4. EXP. XI. we may
 be furnished with the true reason of
 that well-known maxim in Physic,
 that true original and habitual Con-
 sumptions seldom spontaneously arise
 after a person is turned forty. This
 is generally imputed to the greater
 strength of the Vessels, and abundantly
 confirmed by the preceeding experi-
 ments. For though the juices of the
 body grow naturally more acrid and
 pungent by their constant attrition on
 each

each other ; yet being daily supplied with a considerable quantity of fresh and mild chyle, must suffer a less degree of alteration, than the coats of the Arteries, on which the impulse is perpetually repeated, without any such supply, as is sufficient to preserve them in a continued equal state; and consequently the arterial coats will, by this gradual increase of strength and firmness, prove so strong, as not easily to be affected by the included fluid, or be so readily lacerated by coughing, as to produce a hæmorrhage, or have their coats so distended, as to produce tubercles and obstructions in those, as in younger persons.

There are indeed other reasons besides these I have enumerated, why Consumptions should begin before the age above-mentioned, rather than later ; but as they flow not from these experi-

experiments, I shall not trouble the reader with them.

EXPERIMENT XII.

§ 1. I took part of the great Artery in a calf, where the radius of its Curvature was the greatest; and having first marked the limits of its most Convex surface, I divided it lengthways from the opposite side, which was the Concave surface of the same Artery; then weighing both in air, I found the weight of the Convex part to be 2 pennyweights, 22 grains, 94 mites; and that of the Concave was 2 pennyweights, 18 grains, 4 mites. I afterwards weighed them in water, and found the first to counterpoise 4 grains, 38 mites; and the second, when immersed in the same fluid, to weigh 3 grains, 27 mites.

§ 2.

§ 2. Hence it appears, that the Convex side of the Aorta in the preceding calf, was, with respect to the density, to that of the Concave side of the same Artery, in the proportion of nearly 82 to 81.

§ 3. After the same manner I found the Convex part of the great descending Aorta in an old ox, to be in density to that of the Concave side of the same vessel, nearly as 50 to 49; and the Convex part of the great Artery in a young boar was to that of the Concave in the same respect, nearly as 78 to 79; lastly, the analogous parts in a six years old ram, and a lamb, bore nearly the proportion of 57 to 56, and 88 to 89 respectively.

EXPERIMENT XIII.

§ 1. The thickness of the Convex side of the Artery taken from the calf,

calf, was 0.16 of an inch, and that of the Concave was 0.14. The Convex side of the ox's Artery was $\frac{2}{7}$ of an inch thick, and the Concave part of the same was $\frac{1}{4}$ of an inch in thickness. The Convex part of the Artery in the lamb was $\frac{1}{14}$ of an inch thick, and the Concave part was $\frac{1}{17}$. The thickness of the Convex part of the Aorta in the ram was $\frac{1}{9}$ of an inch, and the opposite Concave side of the Artery was $\frac{1}{12}$.

§ 2. Hence 'tis evident, that the Convex part of the calf's Artery exceeded the other side in thickness in the proportion of 8 to 7.

§ 3. Hence also we learn, that the Convex side of the Aorta in the old ox was in thickness to that of the opposite part of the same Artery, as 8 to 5; and the analogous parts in the lamb and the sheep, bore the same propor-

proportion in this respect to each other, as 17 to 14, for the two different sides of the same Artery in the Lamb; and as 11 to 9, for those in the latter, *viz.* the six years old sheep.

EXPERIMENT XIV.

§ 1. I filled an iron Syphon, that had a free communication with my condensing Syringe, with a sufficient quantity of Mercury; into which I screwed a glass Gage, above double the length of those commonly used, that the different Altitudes of the Mercury in it might be taken with more ease, and greater exactness. I then took part of the Aorta descendens of a young man, whose diameter was half an inch, and having firmly fixed it to a Tube issuing out of the Syphon, I compressed the air in the sealed top of the Gage, with a force equal to 4.7

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Atmo-

Atmospheres, with this Pressure the
www.history.com.cn
 coats of the Artery burst.

§ 2. Now the Area of an inch in length of this Artery, being so many parts of a square inch, as correspond to the tabular Logarithm 0.1962947, and the Altitude of the incumbent column of Mercury (taking 29 inches, the mean height of the Quicksilver in the Barometer for the weight of one Atmosphere) being likewise expressed by the Logarithm 2.1344959, it is evident, that the pressure required to break this portion of the Artery, was equivalent to a column of Mercury, having the preceeding Area and Altitude for its base and height. Hence a cubic inch of Mercury weighing 7.384 z. troy, its Logarithm is 0.8682917; and consequently the Logarithm 3.1990823 will express in ounces troy the force the Artery was compressed

pressed with, at the moment of its bursting, which by reduction appears to be equal to 131 pounds, 10 ounces, 0 pennyweight.

EXPERIMENT XV.

§ 1. The Aorta of the same man, upon an area of an inch in length, where the diameter was 0.3 of an inch, being tried in the same manner as the preceeding vessel, bore the pressure of 4.26 Atmospheres, ere its Fibres gave admittance for the air to pass through.

§ 2. Now the area of this Artery an inch in length, being expressed by the Logarithm .9.9745117, it is evident, that the weight of a column of Mercury upon this area, and whose Altitude is equal to 4.26 Atmospheres, will be expressed by the Logarithm 2.9346110 ; which, by computation from its value in ounces troy, we find

E 2

equal

equal to 71 pounds, 8 ounces, 4 pennyweights, 14 grains.

§ 3. As the areas of an inch in length of this Artery in the young man, where the diameter was half of an inch, and where it was 0.3 of an inch, are denoted by the Logarithms 0.1962947. 9.9745117 respectively; consequently, by comparing these areas with the Logarithms of the weights, that each of them required to burst their Fibres afunder, it is evident, that the inferior part of the same Artery, upon an equal surface with the upper, would not have yielded to the compression, till the weight was equivalent to 119 pounds, 5 ounces, 10 pennyweights.

§ 4. The thickness of the Aorta mentioned in the preceeding experiment, was 0.097 of an inch; and that part of it, whose strength was found
here

here in this, was 0.049 of an inch.
Hence comparing the Logarithms of
these thickneſſes, *viz.* 8.9867717,
8.6901961 with the Logarithms of
the weights ſuſtained upon equal areas
of the veſſels, as given in the pre-
ceeding ſection, it appears that the
narrower part of the Aorta deſcendens
in this young man differed ſo much
in the texture and coheſion of its Fi-
bres from that of the ſame Artery, at
a conſiderable diſtance above it, as to
render a portion of the former, ſtronger
than one of equal bulk of the latter,
in the proportion of nearly 1794 ad
1000.

EXPERIMENT XVI.

§ 1. Part of the Aorta deſcendens
of a young boar cut off ſome diſtance
above the Cœliac branches of the Ar-
tery, being fixed to the Condenſer,

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the

the air was compressed in the top of the Gage with a force equal to 3.58 Atmospheres ; with this the Artery broke.

§ 2. The diameter of this part of the Artery was 0.27 of an inch, and consequently its area an inch in length, will be expressed in parts of a square inch by the Logarithm 9.9294189. Now the weight of one Atmosphere upon an inch square being equal to 214.136 ounces troy, it is evident, that the weight of 3.58 Atmospheres upon this area of the Artery, will be equal to 54 pounds, 2 ounces, 14 pennyweights, 9 grains.

EXPERIMENT XVII.

§ 1. Part of the same Aorta of the young boar cut off nearer the Iliac, than Emulgent branches, bore the pressure of 3.2 Atmospheres, before it
was

was able to break the Artery, or produce any leakage through its coats.

§ 2. The diameter of this part of the Artery was 0.17 of an inch, and consequently, its area an inch in length will be expressed in parts of a square inch by the Logarithm $\bar{9}.7277852$, and the weight of the column of Mercury incumbent on it at the time of its bursting, by the value of the Logarithm 2.5636249 taken in ounces troy, equal, as appears from computation, to 30 pounds, 6 ounces, 2 pennyweights, 9 grains.

§ 3. Comparing the areas of the preceeding vessels in the Boar together, and likewise the weights required to break them, as delivered above (*a*), it will be found, that the inferior part of the Artery between the Emulgent and Iliac branches, upon an area equal

(*a*) See § 2. EXP. XVI. and XVII.

E 4

to

to the superior part of the same Artery above the Cœliac branch, would have born a weight equal to 48 pounds, 6 ounces, 9 pennyweights.

§ 4. The thickness of the Aorta, whose strength we found by EXP. XVI. was 0.046 of an inch, and that part of the same vessel made use of in this experiment, was 0.024 of an inch. Now the Logarithms of these thicknesses are $\bar{8}.6627578$, $\bar{8}.3802112$ respectively, which being compared with the Logarithms of the weights sustained upon equal areas of these vessels, *viz.* with 2.8139936 , 2.7652586 , it is manifest that the Aorta descendens of this Boar, at a little distance from the Iliac branches, was composed of Fibres differing so much from the texture and cohesion of those, which composed the superior part of the same Artery above the Cœliac branches, as
to

to render a portion of this narrower part of the Aorta of equal area and thickness with another of the upper, where it was 0.27 in diameter, stronger than this last, in the proportion of nearly 1713 to 1000.

§ 5. It is evident, from the preceeding experiments that the superior thickness of the Aorta at its Curvature is not merely the effect of age, and the repeated strokes of a long-continued circulation, as has frequently been assigned for the cause of this difference; but that even in young animals, where no such effect can reasonably be expected, from the duration of the impetus upon this, more than in the opposite Concave surface of the Artery, we yet find that its Convex side, is by nature, formed with a superior degree of density and thickness,

ness (a). Nor is the reason of this contrivance far to seek : For since that power by which the Arteries contract, is wholly owing to some peculiar make and constitution of the Fibres which compose them, it is evident, that the *momentum* of this contraction must, *cæteris paribus*, be always in proportion to the number of Villi, that is, their thickness. Now, as we learn from Anatomy that this remarkable Curvature of the Aorta, was highly requisite for the due conveyance of the blood to the two different extremes of an animal body ; and also admirably serves to a regular and sufficient secretion of the nervous fluid, so it is no less manifest from the laws of Hydraulics, that the blood thrown out at each Systole of the heart, must im-

(a) See E X P. XII, XIII.

pinge

pinge upon this Convex part of the Artery with its full force; and consequently, not only a much greater contracting power was necessary to prevent the dangers and inconveniences, which would unavoidably arise from too great a dilatation of this part; but also, that the motion of the propelled fluid, might be communicated to the opposite side of the same Artery, with as little loss as was possible, after its impulse on a surface so elastic and contractile.

§ 6. Anatomists have in general represented that force with which the Arteries contract, by the number of circular Fibres lying in parallel directions from the base of the Cone to the Apex; and in conformity to this opinion, have ventured to presume, that as the coats of the Arteries diminish in thickness at every branching
from

from the trunk, their resisting power must decrease in the same ratio, and consequently be in all cases proportionable to the circumference of the Artery, and the thickness of its coats.

But this conclusion is by no means true, as appears from the preceeding experiments (*a*) which being compared with the former already mentioned in the foregoing section, manifestly shew, that such a general notion in no-wise quadrates with the workmanship of nature, who is so far from observing any such law in that complicated series of vessels, which make up an animal body, that not only the cohesion of the Fibres in different vessels admit of the greatest latitude and variety (*b*) but that even the Villi, which compose the opposite

(*a*) § 4. EXP. XV. § 4. EXP. XVII.

(*b*) § 4. EXP. XV. § 4. EXP. XVII.

fides of the same Artery, differ very considerably both in their thickness and density (a).

Nor is such a structure of an animal canal any-ways disagreeable to that precise and rigorous exactness, which we find in all the works of nature, but was really necessary. For since the blood is a very heterogeneous fluid, and compounded of particles very different from each other in their relations, and specific gravities, it is evident, that in their motion they will be endowed with very different centrifugal forces, and on that account require a different repelling force, in different parts of the same vessel, both to keep up a due mixture of the fluid, and also to propel it into the lateral canals, according to their various An-

(a) § 2, 3. EXP. XII, XIII.

gles and Curvatures. But even this, in the larger vessels we find always performed, and no doubt is so in the smaller, could we equally take a measure of their angles, coats, and proportions. Thus we find, that in all those parts of the vessel, where its Curvature was necessary, the Convex side of the Artery is much the strongest, densest and thickest, which was really necessary with regard to those particles, whose nifus at the tangent is much the strongest, which will be carried in greater proportion against that side of the Artery where it is Convex, and thence be determined into such vessels and in such proportions, as are requisite for the performing the various functions for which they are designed, whilst those endowed with a less *momentum*, will in a proportional manner be determined

by the weak and thinner side of the
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Artery.

Besides as the blood is an imperfect fluid, and can by no means be brought under the definition of one whose parts give way to the least pressure, but must be considered as endowed with a considerable degree of tenacity and cohesion, and even as borrowing part of its fluidity from its progressive motion, therefore many of its particles, would be in a perpetual danger of adhering to the sides of the membranous canals, through which they pass, were not their points of contact, as well as their impetus perpetually altered by the various angles and flexures of the containing vessels; and consequently neither its due fluidity could have been preserved, nor the requisite secretions performed, had not the different strength in various
parts

parts of the containing vessels, as well as their different flexures and angles, contributed thereto.

EXPERIMENT XVIII.

§ 1. Part of the Aorta descendens of an ewe sheep near the heart, which weighed in air 2 pennyweights, 18 grains, 60 mites, counterpoised in water, 3 grains, 32 mites. The weight of the like vessel, taken from a ram, was in air 3 pennyweights, 9 grains, 32 mites; and in water 5 grains, 3 mites.

§ 2. The weight of the Vena cava corresponding to the Aorta of the ewe, was in air equal to 1 pennyweight, 12 grains, 38 mites, and in water 2 grains, 98 mites; and the weight in air of that corresponding to the Aorta of the ram, was 2 pennyweights,

weights, 3 grains, 5 mites; and in water 4 grains, 69 mites.

§ 3. Hence it appears, that $\frac{6660}{6328}$ expresses the ratio which the Aorta of the ewe sheep bears to water, and $\frac{8122}{7029}$ denotes that of the other Aorta in the ram to the same fluid; consequently by dividing one ratio by the other, or what is more expeditious and sufficiently exact, by a subtraction of their respective Logarithms 0.0222077, 0.0277572, we shall obtain the Logarithm of the Quotient, equal to 0.0055495, which shews by the number corresponding thereto in the Tables, that the Aorta of the ram was superior in density to that of the ewe, in the proportion of 79 to 78 nearly.

§ 4. In like manner we shall find that the Logarithm 0.0047594, expresses the ratio, which the Vena of the ram bears to that of the ewe; and

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by comparing it with the number corresponding to it in the Tables, it appears, that the Vena cava in the ram, was with relation to density, superior to that of the Vena cava in the ewe, in nearly the proportion of 91 to 90.

EXPERIMENT XIX.

§ 1. Part of the great Artery, cut off at the branching of the Iliacs in the ewe sheep, mentioned in the preceding experiment, weighed in air 1 pennyweight, 19 grains, 9 mites, and in water 2 grains, 39 mites. Part of the great Artery of the ram, mentioned in the same experiment, and cut off at the branching of the Iliac Arteries, weighed in air 2 pennyweights, 7 grains, 4 mites, and the same counterpoised in water 3 grains, 79 mites.

§ 2,

§ 2. The Venæ cavæ corresponding to the preceeding Arteries of an ewe and a ram, weighed in air 1 pennyweight, 5 grains, 14 mites, and 1 pennyweight, 16 grains, 3 mites; and in water they counterpoised 2 grains, 14 mites, 3 grains, 17 mites respectively.

§ 3. Hence it appears, that the ratio which the Aorta at the Iliac branches of the ewe sheep bears to water, is expressed by $\frac{4209}{4076}$ and that $\frac{5504}{5125}$ denotes that proportion, which the Aorta of the ram, at the branching of the Iliac Arteries from it, bears also to water; hence by a computation in Logarithms, it appears, that the Logarithm of the Quotient, after the division of these two ratios, is equal to 0.0062024, which being compared with the number corresponding to it in the Tables, shews that the Artery of the ram, at the branching of the

Iliac Arteries, was to the Aorta of an ewe, near its division into the like vessels with respect to density, in a proportion somewhat greater than that of 71 to 70.

§ 4. Now $\frac{2914}{2700}$, $\frac{4003}{3686}$ respectively shew the ratio, which the Venæ cavæ in an ewe and a ram bear to the same fluid water, and the Quotient after division is equal to the Logarithm 0.0028084; consequently the number corresponding to this Logarithm, shews that the Vena cava of the ram near the Iliac branches, was superior in density to the Vena cava of the ewe near the origin of the like vessels from it, in the proportion of nearly 155 to 154.

§ 5. Comparing the Logarithms which express the ratio's $\frac{6660}{6328}$, $\frac{4309}{4070}$, $\frac{8132}{7629}$, $\frac{5504}{5125}$ in § 3. EXP. XVIII, and § 3. of the present experiment together, it appears, that the Aorta of the ewe sheep, was
superior

superior in density at the branching of the Iliac vessels from it, to that part of the same vessel near its exit from the heart, in the proportion of 170 to 169 nearly ; and the density of the Aorta of the ram near the same branches, was superior to that near the heart, in the proportion of 134 to 133 nearly.

§ 6. Comparing also the ratios respectively belonging the Veins mentioned in the two preceeding experiments, it appears that the Vena cava of the ewe, is superior in density to that Part of the same Vein continued to the Iliac branches, in the proportion of 108 to 107 nearly ; and the Vena cava of the ram, near its entrance into the heart, is to that part of the same Vein near the Iliac branches in the proportion of nearly 73 to 72,

§ 7. Hence it is evident, that altho' the corresponding Arteries and Veins in a ram are denser than those performing the same office in an ewe, yet the principal difference in this respect, subsists between the arterial vessels of the two animals, the Veins in the ewe being altogether as dense, or rather more so in respect of their corresponding Arteries, than the similar Veins in a ram to their respective arterial vessels.

EXPERIMENT XX.

§ 1. Part of the Aorta of a middle-sized ram, cut off near the origin of the Emulgent vessels, being fixed to the Condenser, the air was compressed in the top of the Gage with a force equal to 4.36 Atmospheres, before the coats of the Artery yielded to the pressure,

§ 2. The diameter of this part of the Artery was 0.3 of an inch, and consequently its area an inch in length will be expressed by the Logarithm $\bar{9}.9745117$. Now the pressure required to break this part of the Aorta, being equivalent to the weight of a column of Mercury, having the preceeding area for its base, and its altitude equal to 4.36 Atmospheres, it is evident, that the Logarithm 2.9446879 corresponding to 73 pounds, 4 ounces, 8 pennyweights, 5 grains troy, will give the force with which the Artery was compressed, and with which its Fibres burst asunder.

EXPERIMENT XXI.

§ 1. The Vena cava cut off from the same ram, and corresponding to the Artery mentioned in the preceeding experiment, bore the pressure of

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4.84

4.84 Atmospheres, before it was able to break the Vein, or produce any leakage through its coats.

§ 2. The diameter of this part of the Vein was 0.65 of an inch, and consequently the Logarithm 0.3102684 answering to 2.043 parts of a square inch, will express the area of an inch in length of this Vein. Hence it is evident, that the weight of 4.84 Atmospheres upon this area of the Vein will be an equivalent to so many ounces troy, as are expressed by the Logarithm 3.3258025; which corresponding to 176 pounds, 5 ounces, 8 pennyweights, shews that a weight equal to this was requisite to break the Vein an inch in length.

§ 3. Comparing the areas of this Vein and the preceeding Artery together, and likewise the weights required to break them, as they are severally

verally delivered above (a), it will be found that the Aorta at the branching of its Emulgent Arteries, upon an area equal to that of the Vein corresponding to it in the same place, would have required a force equivalent to 158 pounds, 11 ounces, 8 pennyweights, before it would have burst.

§ 4. Hence it is manifest, that the Vena cava of the ram near the Emulgents, was superior in strength to the corresponding Artery acting upon an equal quantity of blood, in the proportion of 1110 to 1000 nearly.

EXPERIMENT XXII.

§ 1. The Aorta of an ewe being cut off at the origin of the Emulgent Arteries, and fixed to the Condenser, I compressed the air in the sealed top of the Gage, with a force equal to

(a) See § 2. EXP. XX.

that

that of 3.52 Atmospheres, before I was able to break the coats of this part of the Aorta.

§ 2. The diameter of this Artery immediately above the Emulgent branches, was 0.27 of an inch, therefore an inch in length of its surface will be expressed by the Logarithm $\bar{9}.9294189$, and the weight incumbent on it from the pressure of 3.52 Atmospheres, will be equivalent to so many ounces troy, as correspond to the tabular Logarithm 2.8066513 , that is, to 53 pounds, 4 ounces, 14 pennyweights,

§ 3. Comparing the area of this Aorta of the ewe, with that of the Aorta of the ram, mentioned at § 2. EXP. XX. it will be found that the Aorta of the ewe, upon an equal area with that of the ram, would not have burst without the weight of 59 pounds,
2 ounces,

2 ounces, 15 pennyweights, 19 grains.

§ 4. Hence it is manifest, that the Aorta of the ram exceeded the strength of the Aorta of the ewe sheep, tho' equal in area to the former, in the proportion of 1238 to 1000 nearly.

EXPERIMENT XXIII.

§ 1. Part of the Vena cava, cut off immediately above the Emulgent Veins in the preceeding ewe, did not suffer any air to escape, till the pressure, given from the continuance of the condensation, was equal to 4.15 Atmospheres, at which time the Vein burst.

§ 2. The diameter of this part of the Vein was 0.56 of an inch; hence by comparing the area of this Vein an inch in length, with the area of an inch square, and the weight of a column of Mercury incumbent on that,
when

when the altitude is equal to 4.15 Atmospheres, it appears, that the weight sustained by an inch length of the Vein, will amount to 130 pounds, 4 ounces, 0 pennyweight, 4 grains.

§ 3. The weight incumbent on the Vena cava of this ewe, at the instant of its breaking, being expressed in Logarithms, is 3.1942505 ; hence comparing it with the Logarithm 2.8066513, corresponding to the weight incumbent on the area of an inch in length of the Aorta, answering to this Vein in the ewe ; and likewise comparing the respective areas of this Vein and Artery together, it appears, that the Aorta, upon an area equal to that of its corresponding Vein at the Emulgers, would not have yielded to any weight less than that of 110 pounds, 6 ounces, 12 pennyweights.

§ 4. Hence it appears that the Vein was superior to the corresponding Aorta at the Emulgents when compared together in equal areas, in the proportion of 1179 to 1000 nearly.

§ 5. The weight required to break the Vena cava of the ewe sheep, was 130 pounds, 4 ounces, 0 pennyweight, 4 grains, and that required to break the Vena cava of the ram was (a) 176 pounds, 5 ounces, 8 pennyweights; which weights being expressed by Logarithms, are equivalent to 3.1942505, 3.3258025. Now it follows from the comparison of these Logarithms with those of the areas 0.2455127, 0.3102684 respectively belonging these Veins in the ewe and the ram, that to break an equal area of the Vena cava of the ewe with that of the like Vein in the ram, the weight

(a) See § 2. EXP. XXI.

must

must have been 151 pounds, 4 ounces, 0 pennyweight.

§ 6. Hence it is manifest that the Vena cava of the ram was in strength superior to the Vena cava of the ewe, though of equal dimensions as to surface, in the proportion of nearly 1166 to 1000.

EXPERIMENT XXIV.

§ 1. The Aorta of the ram, we mentioned in EXP. XX. being cut off at the Iliac branches, and part of it fixed to the Condenser, the pressure required to break the Fibres of the Artery in this part of it, was equal to that of 4.11 Atmospheres.

§ 2. The diameter of the Aorta here at the Iliacs was 0.26 of an inch, consequently the Logarithm 9.9122752, corresponding to 0.8171 parts of a square inch, will give the
area

area of an inch length of this Artery. Now the pressure being equal to a column of Mercury having the preceeding area for its base, and its altitude equal to 11 9.19 inches, it follows that the weight of this column of Quicksilver will be equal to 59 pounds, 11 ounces, 2 pennyweights, 14 grains.

§ 3. Comparing the Logarithms $\bar{9}.9745117$, $\bar{9}.9122752$, 2.9446879 , 2.8568067 , which respectively shew the areas of an inch in length of the Aorta of the same ram at the Emulgents, and at the Iliac branches, and the weights incumbent on each of them ; it is manifest, that the Aorta at the Iliacs upon an area equal to an inch length of the same Vessel at the Emulgents, would not have broke without a pressure equal to 69 pounds, 1 ounce, 18 pennyweights, 14 grains.

§ 4. Hence also it is manifest, that the Aorta of this ram at the Emul-gents, was with respect to strength, superior to a portion of the same vessel at the Iliacs acting upon an equal quantity of blood, in the proportion of 436 to 411; that is, of 106 to 100 nearly.

EXPERIMENT XXV.

§ 1. The Iliac branch of the Artery, mentioned in the preceeding experiment, burst, when the pressure was equal to 4.04 Atmospheres.

§ 2. Now a column of Mercury, whose base is a square inch, and its height one Atmosphere, or 29 inches, being equal in value to so many ounces troy, as are found by the Tables of Logarithms to correspond to 2.3306897, it follows by analogy, that as the diameter of this Artery
was

was 0.195 of an inch, therefore the weight of a column of Mercury upon an area of an inch in length, and whose Altitude is 4.04 Atmospheres, will be expressed in the same manner by the Logarithm 2.7245316, which corresponding to 44 pounds, 2 ounces, 6 pennyweights, 9 grains, shews that this was the weight necessary to break an inch in length of this Iliac Artery.

§ 3. Comparing the weights, which the Iliac Artery and the Aorta of the same ram immediately above it, and at the Emulgents sustained upon their respective areas, as they are given in EXP. XXIV, XX, it is evident, that the Iliac Artery upon an area equal to the trunk it arose from, would have required the weight of 58 pounds, 10 ounces, 17 pennyweights, 14 grains, to break it; and 67 pounds, 11 ounces, 26 pennyweights, had its area been

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equal

equal to that part of the Aorta near the Emulgents.

§ 4. Hence it appears, that taking equal areas of the Aorta from which the Iliac Artery sprung, and of the Branch, that the former was superior in strength to the latter in the proportion of 1017 to 1000 nearly.

§ 5. Hence also it is evident, that the Aorta at the Emulgents, is stronger than the Iliac Artery of equal area with it, in the proportion of 1079 to 1000 nearly.

§ 6. It is manifest, that whether we consider the preceeding Vessels as so many Cones or Cylinders of equal Altitudes, their Capacities to each other will be in the same ratio as the squares of their diameters ; hence we find that the capacity of the Aorta of the ram mentioned at § 2. EXP. XX, is to its capacity in that part of it above the
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the Iliacs, mentioned at § 2. www.lit4001.com.cn EXP. XXIV. in the proportion of 900 to 676, that is, as 133 to 100 nearly. In like manner we shall find that the capacity of this last Artery, was to that of its Iliac branch, in the proportion of 67600 to 38025, that is as 18 to 10 nearly; and from hence we may observe, that the capacity of the Aorta, before the Emulgents spring from it, exceeded that of the Iliac Artery in a proportion greater than that of 23 to 10.

EXPERIMENT XXVI.

§ 1. The Aorta of the ram, whose strength and density we found in EXP. XVIII and XX, was in this place, *viz.* above the Emulgent Arteries, equal in thickness to 0.052 of an inch, that part of the same Artery at the origin of the Iliacs was 0.035
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of an inch thick, and the Iliac branch arising from it was 0.0254 of an inch in thickness.

§ 2. Comparing the thicknesſes of theſe veſſels with their reſpective diameters after the manner of § 2. *EXPER. XI.* as they are given in the preceding experiments, it appears from computation, that the fluid contained in the cavity of the Aorta at the origin of the Emulgent Arteries, is to the coat that contains it, in the proportion of 1229 to 1000 nearly, and the fluid contained in the cavity of the ſame veſſel at the origin of the Iliacs from it, will be to its coat in the proportion of 1636 to 1000 nearly; laſtly, the fluid within the cavity of the Iliac branch of the Artery, will bear to the coat that contains it, the proportion of 1698 to 1000 nearly.

§ 3. Hence 'tis evident, that the bulk of the solids acting upon the blood in that part of the Aorta of the ram above-mentioned, at the origin of the Emulgent Arteries, is, to the bulk of those acting upon it at the origin of the Iliac branches, and in the branch itself, with respect to the quantity of blood contained in equal lengths of these vessels, in a ratio compounded of the direct proportion of the bulk of their coats, and the reciprocal ratio of the quantity of fluid contained in their cavities, that is, as 49494016, 27849384, to 37170000, 20153376 respectively ; and consequently the bulk of the solids acting upon the blood in that part of the Aorta at the Emulgents, is superior to those acting upon it at the origin of the Iliac branches, in the proportion of 133 to 100 nearly, and of 138 to the same

quantity nearly, with respect to the Iliac branches.

§ 4. The thickness of the Aorta of this ram at the origin of the Emul-
gents, of the Iliacs, and of the Iliac
Artery, when expressed in Logarithms
will be 8.7160033, 8.5440680,
8.4048337 respectively : Hence com-
paring these Logarithms with those
expressing the weights sustained upon
equal areas of these vessels, as they are
given above (a), it is evident, that the
Aorta descendens of this ram at the
origin of the Iliac Arteries was com-
posed of Fibres so different in their
texture and cohesion to those, which
composed the superior part of the same
Artery at the origin of the Emulcents,
as to render a portion of this wider
part of the Aorta, inferior in strength
to one of equal bulk at the origin of

(a) § 3. EXP. XIV, XXV.

the

the Iliacs, in the proportion of 1000 to 1112.

§ 5. Thus also by a computation made after the same manner as the foregoing, it is evident that the texture of the Iliac Artery renders it not only stronger than a portion of the trunk it arose from, of equal dimensions in every respect with the branch, in the proportion of 1354 to 1000; but even to surpass the strength of a like equal portion of the Aorta itself at the origin of the Emulgents, in a still greater ratio, *viz.* that of 1897 to 1000.

§ 6. That the Aorta, the nearer it approaches the heart, should be less dense (*a*), of a weaker and more easily distensible texture than the branches, which immediately arise from it (*b*),

(*a*) EXP. XVIII, XIX.

(*b*) § 4. EXP. XV, XVII. and § 4, 5. EXP. XXVI.

and yet withal of so considerable a thickness, as that the fluids contained in this primary trunk bear a much less proportion to their coat, than those circulating in the branches to their respective coats (*a*), are circumstances not taken notice of by any Anatomist that I know of, and plainly shew, that the strength of the animal canals is not to be known by their density or thickness solely, but depends on some certain ratio compounded of both these together, suitable to their particular office and design. The different structure of the Aorta at the heart, from that part of it at the Iliacs or the Branches there arising, abundantly confirm this truth. For had not this vessel been endued with so considerable a degree of thickness, as to allow its density to be di-

(*a*) § 2, 3. Exp. XXVI.

minished

minished in that proportion, which several of the preceeding experiments shew it to be ; its strength must like that of the other vessels there mentioned, have been owing more to a closeness of its texture, than the thickness of its coat ; but this is a structure, which would by no means have answered the ends of animal life, as it is attended with the ill consequences already enumerated at § 5. Exp. V, XI. viz. its too soon growing so rigid and stiff, as not sufficiently to be distended by the force of the heart ; whence the animal, tho' young, would be subject to many inconveniences consequent on old age, and have its term of life much shortened ; inasmuch as this Artery, from the great impetus of the blood upon it, would in such circumstances become rigid, stiff, and inflexible much sooner than the rest,
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the consequence of which is an early old age. But though this would inevitably have been the case, was the Aorta so formed, yet this is not the sole inconvenience attending too tense and rigid a texture of this Artery. For upon every increase in the motion or quantity of the blood, or a sudden rarefaction of the humors, the animal would be in danger of immediate suffocation and death, from the great resistance which the blood would meet with, as well as the want of room to receive this increased quantity, in a vessel not capable of a proper and easy distention.

Now this does not equally hold good in the branches arising from it, on account of their increased dimensions in proportion to the trunk from which they arise, the capacities of all which, upon every division of the trunk,

trunk, when taken together, constantly exceeding that of the trunk from which they spring.

But as this laxity of the Aorta was necessary to the health of the animal, and the continuance of its life to its proper period, so was that increase of strength and density, which we have shewn at Exp. XIX, XIV and XV, the coats of the branches arising immediately out of this trunk are endowed with, no less necessary, for carrying on the circulation with sufficient vigour through the succeeding minute ramifications, which could scarcely have been performed, had not the vibrations been more smart and brisk than in the widest part of the trunk ; especially if we consider, not only the great resistance given to the blood at every ramification by the various angles and flexures of the vessels,

vessels, but together with this, the diminution of its velocity by the increase of cavity in the branches, which is necessarily much diminished on this account, as hydrostatical experiments undeniably assure us; and consequently had not these obstacles been removed by enduing the branches with a greater tensility, and thereby enabling them to exert a quicker and smarter vibration on the inclosed fluids than is produced by the coats of the great Aorta, the circulation could not have been performed with that vigour and advantage as now it is, had it been performed at all.

This is still more apparent, if we consider, that this increase of the cavity of the branches was indispensably necessary both to the life and structure of the animal. For had their united sum been less than in the trunk, or
only

only equal to it at every subdivision, the progress of the fluids must soon have been obstructed, since as the case now stands, where the ratio is increased, the capillary Arteries are only sufficient to transmit the blood in single Globules, as good Microscopes assure us, and consequently had the case been otherwise, the passage through them would have been wholly obstructed, long before the ramifications had been so numerous, as at present they are. Wherefore had the size of the animal been the same as now, the consequence must have been, either a total obstruction as above, or fewer ramifications, the former every one knows is inconsistent with life; and had the latter prevailed, the creature must have been extremely weak and languid, through the want of sufficient nourishment to warm and invigorate

gerate its parts, and enable it to perform the functions for which it was designed, even though we should suppose the secretions regularly performed, which in fewer ramifications can scarcely be supposed possible, at least in that perfection the present structure allows.

EXPERIMENT XXVII.

§ 1. The Vena cava cut off at the Iliacs of the ram, and corresponding to the Aorta mentioned in Exp. XXIV. required the force of 4.33 Atmospheres, which it endured without any visible leakage of air, till the rupture was effected by the foregoing pressure.

§ 2. The diameter of this part of the Vein was 0.36 of an inch, and consequently its area an inch in length will be expressed by the Logarithm 0.0534626, corresponding to 1.131 parts

parts of a square inch. The weight therefore incumbent on this area of the Vein, will be equal to that of a column of Mercury upon this base, and whose altitude is 4.33 Atmospheres, proceeding therefore with the respective Logarithms of these quantities, and of a cubic inch of Mercury(*a*), it appears, that 3.0206402 will be the Logarithm, which expresses the weight required, which corresponding to 87 pounds, 4 ounces, 14 pennyweights, shews us, that this was the force made use of to break the Vein in this experiment.

§ 3. Comparing the weights and areas which belong this Vein and its respective Artery as they are given above (*b*), it is evident, that the Artery upon an area equal to this here

(*a*) § 2. Exp. XIV.

(*b*) § 2. Exp. XXIV.

of

of its corresponding Vein, would have required the additional weight of 23 pounds, 0 ounces, 5 pennyweights, 5 grains to break it.

§ 4. Hence it appears, that the Vein corresponding to the Aorta at the Iliacs in the ram, was superior in strength to the Artery there of equal area, in nearly the proportion of 1053 to 1000.

§ 5. The weight required to break an inch in length of the Vena cava of this ram near the Emulgent branches, was 176 pounds, 5 ounces, 8 pennyweights; hence comparing the weight, which broke the same Vein an inch in length at the Iliacs, with this, and their respective areas together, it appears, that the Vein at the branching of the Iliac vessels, would, upon an area equal to an inch in length of the same Vein at the Emulgents, not have burst, unless

less the weight had been equivalent to 157 pounds, 10 ounces, 6 penny-weights.

§ 6. Hence it is evident, that the Vein corresponding to the Artery at the Iliac branches was inferior in point of strength to that part of it corresponding to the Artery at the Emulgents, though of equal area with this last, in the proportion of 1000 to 1117 nearly.

EXPERIMENT XXVIII.

§ 1. The Iliac Vein of the preceeding ram corresponding to the Artery in Exp. XXV, being tried in the same manner as the trunk in the preceeding experiment, bore without suffering any air to escape, till the rupture of its coats ensued, the pressure of 4.18 Atmospheres.

§ 2. The diameter of this Vein was 0.25 of an inch, and consequently the

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Logarithm of its area an inch in length will be equal to 5.8952567 , hence estimating the weight of a column of Mercury upon this area, whose altitude is equal to 4.18 Atmospheres; it appears, that the pressure incumbent on the Vein at the instant of its breaking was 58 pounds, 7 ounces, 5 pennyweights, 9 grains.

§ 3. The Logarithm of this weight, sufficient to break an inch in length of this Iliac Vein, being 2.8471227 , it is evident from the comparison of this Logarithm with the Logarithm 3.0206402 , which denotes the weight required to break an inch in length of the trunk, together with a comparison of the Logarithms of their respective areas, that the Iliac Vein, upon an area equal to an inch in length of its trunk, would have required the weight of 84 pounds, 4 ounces, 8 pennyweights to break it. § 4.

§ 4. Hence it appears, that the Iliac Vein of equal area to the trunk, was exceeded in strength by that, in the proportion of 1036 to 1000 nearly.

§ 5. The diameter of the Iliac Artery corresponding to the preceeding Vein was 0.195 of an inch (*a*), therefore the Logarithm of its area an inch in length will be $\bar{9}.7874605$, and the Logarithm of the weight required to break this area was 2.7245316 : Hence comparing these Logarithms with those respectively belonging the Vein as given in § 2, 3. of this experiment, it appears, that had the area of the Iliac Artery been equal to this of its corresponding Vein, the weight required to break it must have been equal to 56 pounds, 7 ounces, 14 pennyweights, 4 grains.

(*a*) § 2. EXP. XXV.

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§ 6.

§ 6. It appears therefore, that the Iliac Vein was superior with respect to strength to the corresponding Artery acting upon an equal quantity of blood as 1034 to 1000 nearly.

§ 7. In comparing the areas of the Veins corresponding to the preceeding Arteries in a ram at EXP. XX, XXIV and XXV, it is evident, that the capacity of the Vena cava at the Emul-gents, is to that of the Aorta above its Emulgent branches in the proportion of 4225 to 900, that is, in a proportion of 4694 to 1000 nearly; and the capacity of the Vein at the Iliac branches, is to that of the corresponding Artery, in the proportion of 1296 to 676, that is, of 191 to 100 nearly; and the capacity of the Iliac Vein exceeds the capacity of an equal length of the Iliac Artery, in the proportion of
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of 62500 to 38025, that is, as 164 to 100 nearly.

§ 8. In comparing the capacities of the Veins and corresponding Arteries together in equal lengths, it is evident, that the capacity of the Vena cava above the Emulgents, with respect to the capacity of the Vein at the Iliacs, is to the capacity of the Aorta at the origin of the Emulgents, with respect to the capacity of the Aorta at the origin of the Iliacs, in the proportion compounded of the direct ratio of the capacities of the Veins, and the reciprocal one of the Arteries, that is, in the proportion of 28561 to 11664, or nearly as 245 to 100 ; and consequently the Vena cava at the Emulgents, exceeds with respect to capacity that of an equal length of the Vein above the Iliacs, in the proportion of 326 to 100 nearly. In like

manner it is evident, that the capacity of the Vein above the Iliac branches, with respect to the capacity of an equal length of the branch discharging itself into it, is superior to the capacity of the corresponding Aorta, with respect to the capacity of an equal length of the branch arising thence in the ratio of 492804 to 422500, that is, in the proportion of 116 to 100 nearly; and from hence also it appears, that the capacity of the Vein above the Iliac branches, was to that of the branch of an equal length to it, in the proportion of 2073 to 1000 nearly.

§ 9. This extraordinary capacity of the Vena cava in this part above the origin of the Emulgents, in proportion to the corresponding Artery, is of singular service to the animal; as a reservoir to supply the heart immediately with a sufficient quantity of blood;

upon great and sudden evacuations, or even upon smaller, where the animal labours under any remarkable weakness of body; on defect of which it would frequently faint, and sometimes expire: the blood, though in sufficient quantity in the parts more remote, being incapable of supplying the heart with its due quantity on such sudden emergencies. But besides this advantage accruing to the animal, from the formation of this part of the Vena cava, according to the preceeding section; its enlarged capacity seems also necessary here, in order to receive that large quantity of blood, which must be discharged into it from the lower belly, upon strong straining of the body, in exerting its strength upon innumerable occasions; which as it cannot be performed, without a large discharge of the venal blood

into this Vessel, the Abdomen being straitned by the depression of the Diaphragm, the Heart in such circumstances, must have been frequently furcharged with so great a quantity of blood, as would have prevented its acting with that freedom it now does, had not this Vein been formed more large and capacious, with respect to its corresponding Artery, than they generally are. This we see happens upon great plenitude in Fevers even as the case now stands, and is relieved by bleeding, the vigour of the pulse being thereby increased in this case, as it is diminished in others. What then must have been the consequence, had the contrary structure prevailed, or even less room had been given, I have no occasion to explain?

EXPE-

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EXPERIMENT XXIX.

§ 1. The Aorta of the ewe sheep mentioned in EXP. XXII, being cut off immediately above the Iliac branches, and fixed to the Condenser, the pressure given it before any rupture could be made in its coats, was equal to 3.23 Atmospheres.

§ 2. The diameter of this part of the Aorta was 0.246 of an inch. Hence by comparing the area of this Vein an inch in length, with the area of an inch square, and the weight of a column of Mercury incumbent on it, when the altitude is equivalent to the pressure of 3.23 Atmospheres, it appears, that the area of an inch in length of this Artery, was pressed, at the instant of its breaking, with the weight of 44 pounds, 6 ounces, 14 pennyweights, 9 grains.

§ 3.

§ 3. The weight which pressed upon a similar part of the Aorta of the ram was 59 pounds, 11 ounces, 2 pennyweights, 14 grains (*a*). Now the Logarithm $\bar{9}.9122752$ expresses the area of an inch in length of the Aorta of the ram, and $\bar{9}.8882357$ expresses in like manner the area of the Aorta of the ewe ; hence comparing these weights and their respective areas together, it is evident, that the Aorta of the ewe above the Iliac branches would have required, had its area been equal to that of the Aorta of the ram in the same circumstances, the pressure of a weight equivalent to 47 pounds, 1 ounce, 3 pennyweights, 9 grains.

§ 4. Hence it appears, that the Aorta of the ram above the Iliac branches was superior to a portion of the Aorta of the ewe above the same branches

(*a*) § 2. EXP. XXIV.

acting

acting on an equal quantity of blood, with respect to strength, in the proportion of 1272 to 1000 nearly.

§ 5. Comparing in like manner the weights and areas, which pressed upon the Aorta of this ewe, at the origin of the Emulgent vessels and of the Iliacs, as they are given in this Experiment and EXP. XXII, it appears, that the Aorta of the ewe would upon an equal area of the Iliacs with that of the same vessel at the Emulgents, have required the weight of 48 pounds, 11 ounces, 18 pennyweights, 4 grains, to break it.

§ 6. Hence it is manifest, that the Aorta at the Emulgents was superior with respect to the strength of an equal area of the same Artery at the Iliacs in this ewe, in the proportion of 1089 to 1000 nearly.

EXPE-

www.lib~~ri~~EXPERIMENT XXX.

§ 1. The Iliac branch being cut off from the preceeding Aorta of the ewe, and fixed to the Condenser, the pressure required to break it was equal to 3.12 Atmospheres.

§ 2. The diameter of this branch was 0.19 of an inch, and consequently the area of an inch in length of this Artery, will be expressed by the Logarithm 9.7759743, corresponding to 0.5971 parts of a square inch; now a column of Mercury whose base is a square inch, and its height one Atmosphere, or 29 inches, being equal in value to so many ounces troy as correspond to the Logarithm 2.3306897, it is evident, that the weight upon the preceeding area from the pressure of 3.12 Atmospheres, will be expressed in like manner by the Logarithm 2.6008186;

2.6008186; which corresponds by the Tables to 33 pounds, 2 ounces, 17 pennyweights, and is equal to that incumbent on an inch length of the Iliac Artery when it broke.

§ 3. The area of an inch in length of the trunk of this Artery, being compared with the area of an inch in length of the branch, and likewise the weights which were requisite to break those areas respectively, as they are mentioned in this and the foregoing experiment, it is manifest, that the branch would, upon an equal area to its trunk, not have broke, unless the weight had been equal to 43 pounds, 0 ounces, 10 pennyweights, 9 grains.

§ 4. Hence it appears, that the trunk of the Aorta at the Iliacs in this ewe, was superior to the strength of the branch acting upon an equal quantity

quantity of blood, in the proportion of 1035 to 1000 nearly.

§ 5. The weight which pressed upon an area of an inch in length of the Iliac Artery of the ram was 44 pounds, 2 ounces, 6 pennyweights, 9 grains: Hence comparing this weight and area with those respectively belonging the Iliac Artery of the ewe in this experiment, it is evident, that the Iliac Artery of the ewe, had its area been equal to that of the same Artery in a ram, would have required the weight of 34 pounds, 1 ounce, 11 pennyweights to break it.

§ 6. Hence it appears, that an equal portion of the Iliac Artery as to surface, in the ram, was superior with respect to strength, to the like Artery in an ewe, in the proportion of 1295 to 1000 nearly.

§ 7. It appears from § 2. EXP. XX, § 3. EXP. XXV, § 2. EXP. XII, and XXX, that the weights required to break an equal portion of the Aorta at the Emulgent and of the Iliac Artery in the ram are 73 pounds, 4 ounces, 8 pennyweights, 5 grains, and 67 pounds, 11 ounces, 16 pennyweights respectively; and from the comparison of the weights and areas respectively belonging the analogous vessels in an ewe, it appears, that the weights required to break equal portions of these vessels are 53 pounds, 4 ounces, 14 pennyweights, and 47 pounds, 3 ounces, 17 pennyweights, 19 grains respectively; therefore the strength of the Iliac Artery of the ram with respect to an equal portion of the great Artery at the Emulgent, was superior to the strength of the Iliac Artery of the ewe, with respect to its Aorta

Aorta at the Emulgents, in equal areas to the former vessels in the ram, in a proportion compounded of the ratio of the weights, which belong the preceeding vessels in a ram, and of the ratio of the weights belonging the corresponding vessels in an ewe, which proportion appears from computation, to be that of 1046 to 1000 nearly.

§ 8. In comparing the areas of the preceeding Arteries together in equal lengths, it is manifest from § 2. EXP. XX, XII, XXIV, XV, XIX, and XXX, that the capacity of the trunk of the Aorta above the Iliac branches, and of the branch itself in an ewe, with respect to the capacity of the Aorta of the same animal above the Emulgents, is to the capacity of the corresponding vessels in a ram, with respect to that of their respective trunk at the Emulgents, in a proportion compounded of the

the ratio of the capacities of the Aortas at the Iliacs, and of the branches directly, and of the ratio of the capacities of the respective Aortas at the Emulgents inversely; that is, as 544644, 32490000, to 492804, 27720225 respectively; and consequently the capacity of the descending trunk of the Aorta at the Iliac branches, and of the branch itself, with respect to the capacity of an equal length of the same trunk above the Emulgent branches in an ewe, are superior to the capacities of equal lengths of the vessels performing the same office in a ram, with respect to their trunk above the Emulgent branches, in the proportion of 1105 to 1000, and of 117 to 100 nearly for the capacity of these different vessels in an ewe and a ram respectively.

§ 9. That the descending Aorta below the Emulgents, as well as the branches arising from it, should not only be larger in the female than the male, with respect to the quantity of blood thrown into each of them, at every systole of the heart in the two animals (*a*); but even larger also, in proportion to the superior part of the Aorta, in the first of these the ewe, than in the ram (*b*); will be sufficiently obvious to any, who considers the quantity of blood necessary for the nutrition of the fœtus. But the reason why the coats of these vessels, which as well as some others of that animal are found by the preceeding Experiments, to be in general weaker than the same in a ram, should still

(*a*) Compare § 2. EXP. XXVI. with § 8. EXP. XXX.

(*b*) See preceeding § 8.

be .

be comparatively weaker than those in a male, with relation to the respective Aorta of each animal, and the quantity of fluids they derive from thence, as we learn from § 7. of this Experiment they are, is not so easily assigned. Possibly the weak state of the Embryo in the beginning of pregnancy, may require that the blood be pushed with less force in these vessels than elsewhere, which yet were necessary to be so large, in order to supply it with a sufficient quantity of nourishment, as it increased in size, and approached nearer to maturity. Nor perhaps may this weakness in the vessels be less necessary upon its increase in bulk, lest upon any greater motion of the animal than ordinary, too great an energy in the vessels, joined with the increased motion of the fluids, should by increasing the

vibrations of the solids to an extraordinary pitch, occasion its exclusion before its proper period, as we find familiar to most animals upon great and vigorous motion of the body, a febrile disposition, and the like.

But it may possibly be objected with regard to human bodies, that none are so subject to accidents of this nature, as those women, which are troubled with weak nerves and hysteric disorders, whose Fibres and Vessels are known to be of a more lax and delicate texture than others. But this arises not from the natural structure and make of the Vessels, for all then would be subject to them, as they are to the menstrual flux, which arises from a cause not much unlike this in the vessels of the Uterus (*a*); but from too great Plenitude, high Diet, and the

(*a*) *Freind's Emmenologia*.

neglect

neglect of such Exercise, as is necessary to preserve the natural tone of the Fibres, and a due and equable secretion of the necessary fluids. On defect of which, the spirits are tumultuously determined into such parts, as are ever so little varied from their usual state of ease and quiet ; and consequently during pregnancy into the muscles of the Abdomen more copiously than the rest ; whence Contraction, Pain, and Abortion must frequently ensue. Nor will the acrimony of the juices prove of better consequence, by dissolving the Humors, and stimulating the Fibres to more frequent Vibrations, and thereby giving occasion to Pains and Hæmorrhages from the uterine vessels. But these symptoms are the effects, not of a natural, but a morbid disposition of the vessels and humors, and consequently

an objection of this kind has no place here, where the natural structure of the vessels, and a due disposition of the humors are presupposed.

EXPERIMENT XXXI.

§ 1. The Iliac Vein corresponding to the Artery of the ewe in the preceding Experiment, bore the pressure of 3.36 Atmospheres, before it was able to break the Vein, or produce any leakage thro' its coats.

§ 2. Now the pressure of 3.36 Atmospheres upon an inch in length of this Vein, will be equivalent to the weight of a column of Quicksilver upon this area, whose Altitude is equal to 97.44 inches in height, which being equal to the Logarithm 1.9887373, and its area to the corresponding Logarithm 9.8591383 the weight of 3.36 Atmospheres upon an inch in length

length of this Vein, will amount to 43 pounds, 4 ounces, 3 pennyweights, 19 grains.

§ 3. Comparing the Logarithms 5.7759743, 5.8591383, 2.6008186, 2.7161673, which denote the areas of an inch in length of the Artery and Vein corresponding thereto in the preceeding Experiments, and the weights incumbent on them respectively, it appears, that the Artery, had its area been equal to that of the Vein, would not have burst, unless the pressure had been equivalent to 40 pounds, 3 ounces, 0 pennyweight, 19 grains.

§ 4. Hence it appears, that the solids acting upon the blood contained in the cavity of the Iliac Vein of this ewe, were superior in strength to those of the corresponding Artery acting upon an equal quantity of the same

fluid, in the proportion of 1077 to 1000 nearly.

§ 5. Hence it is evident, that the Vena cava and Iliac Vein in this ewe, with relation to their corresponding Arteries in Exp. XXII and XXX, are superior with respect to strength to the same Veins in a ram, with reference to the strength of their corresponding Arteries in Exp. XX and XXV, in equal areas to the former vessels in an ewe, in a proportion compounded of the direct ratio of the pressures incumbent on the areas of the Veins in each animal at the moment of their bursting, and of the reciprocal ratio of the forces required to break the corresponding Arteries ; that is, in the proportion, as appears from computation, of 180940 to 170368, and of 135744 to 130416, which ratios are nearly as 1062, and 1040 to 1000 respectively.

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EXPERIMENT XXXII.

§ 1. The Aorta of the ewe was, in that part of it above the Emulgents, equal in thickness to 0.044 of an inch, and in that part above the Iliacs, and of the branch arising from it, the thickness was equal to 0.031, 0.023 of an inch respectively: The Vena cava of the ram and of the ewe above the Emulgents mentioned in Exp. XXI and XXIII, was 0.034, 0.028 of an inch thick respectively, and the Iliac Veins in the same mentioned in Exp. XXVIII, XXXI, were 0.014 and 0.011 of an inch respectively in thickness.

§ 2. Comparing the thicknesses of these Arteries in the ewe with their respective diameters, as they are given in the preceeding Experiments, and afterwards the proportions which the coats of these Arteries bear to the fluid con-

contained in their respective cavities with the proportions delivered at § 2. www.libtool.com.cn EXP. XXVI, it is manifest, that the coat of the Aorta of the ram above the Emulgents, with respect to the blood contained in its cavity, is superior in bulk to the coat of the corresponding Artery in an ewe, with respect to the fluid it contains in an equal length of these vessels, in the proportion of 1319 to 1229 nearly. In like manner it appears, that taking equal lengths of the Aorta above the Iliacs, and of the branch, in the ram and the ewe, the coats of those in the first of these, with respect to the fluid contained in their cavities, are superior in bulk to the coats of the corresponding vessels in the latter, *viz.* the ewe, with relation to the quantity of fluid they act upon, in the proportion of 1762, 1842 to 1636, 1698 respectively.

§ 3.

§ 3. Hence it appears, that the Vein above the Emulgents in the ram and in the ewe, which in the first was compressed with a force equivalent to 176 pounds, 5 ounces, 8 pennyweights, and in the second with 130 pounds, 4 ounces, 0 pennyweight, 4 grains, was nevertheless exceeded in thickness by the corresponding Aorta of each animal, which upon an equal area would not have burst, unless the weight upon that in the ram had been 158 pounds, 11 ounces, 8 pennyweights, and upon the Aorta in the ewe 110 pounds, 6 ounces, 12 pennyweights, in the proportion of 26,11 to 17 and 7 respectively. In like manner we shall find that the Iliac Artery in the ram, which upon an equal area with the corresponding Vein bore less than it by the weight of 1 pound, 11 ounces, 11 pennyweights, 5 grains, was yet superior

perior in thickness in the proportion of 127 to 70; lastly, tho' the strength of the Iliac Vein in the ewe was inferior to that of an equal area of the Aorta at the Emulgents of the same animal by scarcely $\frac{1}{21}$ part, yet the Artery was superior in thickness to this Vein in the proportion of 4 to 1.

§ 4. Hence we may observe, that the Anatomists are no less mistaken in their conclusions on the strength of the Veins, than they were, as has been already shewn, in their sentiments on that of the Arteries (*a*). Nor can they ever expect to avoid mistakes of this kind, whilst they suffer themselves to be led by appearance, and not by experiment, without which it is impossible to arrive at any tolerable degree of certainty in physical inquiries. For as a great modern Philosopher has al-

(*a*) § 5; 6. EXP. XVII. § 4, 5, 6. EXP. XXVI.
ready

ready observed, " All the real true
" Knowledge we have of Nature is
" intirely Experimental, inſomuch
" that how ſtrange ſoever the Affër-
" tion ſeems, we may lay this down
" as the firſt fundamental unerring
" Rule in Phyſics, That it is not
" within the Compaſs of human Un-
" derſtanding to aſſign a purely ſpe-
" culative Reaſon for any one Phæno-
" menon in Nature."

§ 5. Comparing the thickneſſes of
the preceeding Arteries in the ewe,
with their reſpective diameters, as
they are given in this and the preceed-
ing Experiments, it is evident, that the
bulk of the ſolids acting upon the blood
in that part of the Aorta of this ewe
above the Emulgents, are to thoſe
acting upon it at the origin of the Iliac
branches, and in the branch itſelf, with
reſpect to the fluid contained in equal
lengths

lengths of these vessels, in a ratio compounded of the proportion of the bulk of their coats directly, and the ratio of the quantity of fluid they contain inversely. Comparing therefore these proportions with those in § 3. EXP. XXVI, it is evident, that the bulk of the solids, in proportion to the blood contained in the cavity of the Aorta above the Iliacs, and in the Iliac branch, with respect to the bulk of an equal length of the Aorta in proportion to the quantity of fluid acted upon by the coat of this Artery above the Emulgents in the ram, is to the bulk of the corresponding vessels with respect to the bulk of the Aorta above the Emulgents in an ewe, and the quantity of fluid contained in each of these vessels, in a proportion compounded of the ratio of the bulk of the solids in the Aorta above the Iliacs, and

and in the branches of each animal directly, and of the reciprocal ratio of the bulk of the solids in the Aorta above the Emulgents in the same respectively. Hence it appears by the computation, that the bulk of these vessels in the ram are superior to that of the corresponding ones in an ewe, when compared together, with relation to the fluid they act upon, and their respective trunks above the Emulgent vessels in the proportion of 1243097208460800 to 1239314916483072, and of 401884597442304 to 397713360185856, that is, nearly as 1003 to 1000, and 10104 to 10000 respectively.

§ 6. Hence we may observe, that notwithstanding the coats of the vessels in an ewe, and particularly those mentioned in the preceeding section, bear a less proportion to the fluid they contain,

contain, than the corresponding ones in a ram, as has been already shewn at § 2, yet it is equally certain from the foregoing section, that even the bulk of the coats of these vessels in the ewe, with relation to the bulk of the principal trunk above the Emulgents, and the quantity of blood contained in each, bear nearly the same proportion as those performing the same office in a ram, when compared together in the same manner ; and consequently the comparative weakness of these vessels here in the descending part of the Aorta of the ewe, with respect to those in the ram, as has already been shewn at § 7. *Exp. XXX*, can scarcely be ascribed at least but in an inferior degree to the difference arising from the bulk of these coats in the ewe, and their bearing in this respect a less proportion to the original trunk

trunk they are derived from than that which the corresponding ones in a ram bear to their primary trunk, but must chiefly arise from the different texture of these vessels ; which contrivance of diminishing their strength without lessening their relative bulk, was necessary for preserving a sufficient thickness in the arterial coats at every division, which otherwise must either have been too weak or too narrow for the purpose designed, or subdivided into fewer ramifications than were necessary to the well-being of the animal.

§ 7. It is evident from § 4. EXP. XXII, XXIX. § 6. EXP. XXX. § 1, 2. EXP. XXVI, XXXII, that the fabrick of the ram, with regard to its solids, must be much stronger than that of the ewe, which probably is the case of all male animals with regard to fe-

K

males

males of the same species, whose Fibres and Vessels, *cæteris paribus*, are by common observation found to be more lax and yielding than those of the former. This is not only confirmed by the preceeding sections, where their different strength and thickneses are examined in various vessels, but likewise from their greater density shewn at § 3, 4. EXP. XVIII, XIX, which necessarily infers the texture of the Fibres themselves to be more firm and compact, as well as more closely wrought together in the coats of the vessels, otherwise the air would not be equally retained in these as the former, the reverse of which appears by experiment.

§ 8. It were easy hence to shew, that many diseases to which the female sex are more peculiarly subject than the male, are necessarily dependent
on

§ 9. It appears from the computation made after the manner of § 2. EXP. XI, that the fluid contained in the cavity of the Aorta of the ewe at the origin of the Emulgent vessels, of the Iliacs, and in the branch, bore to their

~~their containing~~ coats the proportion of nearly 1319, 1762, 1842 to 1000 respectively. Let now the diameter of this Aorta be from any cause increased only the $\frac{5}{100}$ of an inch, and as the areas of the vessels continually increase at every division of the trunk, let the preceeding proportion with respect to the diameter of this become smaller in the branches, and decrease even with relation to the diameters of these vessels ; as for instance, let the ratio of increase in the two last Arteries above-mentioned be 0.045, 0.034 respectively, then it is evident that if to the square of the diameters thus increased, *viz.* 0.1024, 0.084681, 0.050176, we add the space included between the outward and inward coat of each Artery, then 0.157664, 0.119029, 0.069772 inch, is the square of their respective diameters from

from outside to outside, and consequently the thicknesses of these Arteries will now be nearly as 0.0385, 0.027, 0.02 respectively of an inch, and the proportion which the fluid contained in the cavity of each will bear to their respective coats will be that of 1853, 2465, 2560 to 1000 nearly.

§ 10. It is evident from § 2. EXP. XXII, XXIX, and XXX, that the weights, incumbent on an inch in length of the Arteries above-mentioned in the preceeding section, at the instant of their breaking, were 53 pounds, 4 ounces, 14 pennyweights, 44 pounds, 6 ounces, 14 pennyweights, 9 grains, 33 pounds, 2 ounces, 17 pennyweights, 0 grains. If now we conceive these Arteries reduced to the thickness as given for each in the preceeding section, then it is evident,

by taking their value in Logarithms, and comparing these and the Logarithms of their former thicknesſes with the Logarithms of the weights above-mentioned, that the weight neceſſary to break them in this ſtate would be 46 pounds, 8 ounces, 12 pennyweights, 38 pounds, 9 ounces, 14 pennyweights, 14 grains, 28 pounds, 10 ounces, 16 pennyweights, 19 grains reſpectively.

§ 11. The ingenious *Dr. Hales*, in his concluſions from *Exp. 22d*, takes notice of the vaſt ſtrength of the animal veſſels in proportion to the action of the fluids upon them, which had it been leſs, would have rendered the animal ſubject to many inconveniences, particularly on great and continued action of the muſcles, the increaſed force of the circulation in ſuch diſeaſes as are capable of making any conſiderable diſtention of the veſſels, and

and the like. That this must frequently have been the case, appears very plain from the consideration of the two preceeding sections, where it is shewn that by a small increase of the diameter of the Aorta, the pressure of the fluids with respect to the solids is considerably increased, at the same time that their thickness and strength are both diminished ; and consequently had the vessels been endowed with no more strength than was necessary for the circulation in an healthful state, they must have wanted that elasticity, which in most cases is absolutely necessary for the discharge of such peccant matter, as either partially or totally obstructs these fine canals. This evidently appears from such diseases as are accompanied with too great a laxity of the Fibres, which as Physicians well

know, are of all others most difficultly relieved, thro' the quantity and tenacity of slimy and viscid humors which arise from this very cause, and so clog the Fibres in exerting their natural vibrations, as to render the best medicines wholly ineffectual. Not to mention the innumerable tumors, preternatural distentions, and ruptures of the vessels, many of which must have either proved presently mortal, or a lasting inconvenience to the animal. This we know is the necessary consequence of an universal weakness in the solids, and such at least must have been the consequence, had their strength been much less in proportion to the force of the fluids than nature has allotted, since where this is only little below its proper standard, tho' their force continues vastly superior to the impetus of the fluids upon them,

them, so great a weakness succeeds, as renders the party subject to many diseases, from which they whose Fibres are more tense and strong, are wholly exempt.

I might easily here also shew, how useless such an animal would be both to its self and others, inasmuch as it could scarcely bear the lightest touch of any other object, without being liable to all the effects consequent on contusions, and that too with little prospect of relief, the spring of the Fibres being the principal instrument Nature applies in the recovery of such cases. But besides all these inconveniences, the animal in all such cases as required a large and speedy depletion of the vessels, by which a sudden relaxation is immediately produced, must either have sunk under it, or at best never have recovered its former
vigour

vigour and activity, which even as the case now stands, where great evacuations have been preposterously made, is often very difficult to restore.

And hence it seems to be, that the weakest vessels I have hitherto examined, are capable of sustaining the weight of an Atmosphere without bursting, as appears by the trial of the Splenic and Emulgent Veins in *EXP. XXXV, XXXVII, XXXIX, XLVI*, which tho' prevented from breaking by the largeness of their pores, and laxity of their Fibres, would undoubtedly have sustained a somewhat greater weight, than is there expressed before a rupture had succeeded, had the air been sufficiently retained. To which instances, for the greater confirmation, I shall subjoin the following.

§ 12. I fixed part of the Pia Mater of a dog (the thinnest separable membrane

brane of an animal body) to the Condenser, and the pressure upon it was equal to 1.36 Atmosphere at the instant that it burst. Now the area of this membrane was 0.03143 parts of a square inch; hence it appears that the weight required to break it was 9 ounces, 3 pennyweights, $1\frac{1}{2}$ grains. The thickness of this membrane, being carefully taken, was no more than $\frac{1}{1698}$ of an inch.

§ 13. Part of the Pericardium of the same dog, bore upon being compressed with air the pressure of 6.18 Atmospheres without bursting; but a small stream of air at this time finding a passage thro' it, prevented the increase of so great a condensation, as was necessary to burst it. If therefore we estimate the pressure sustained by this membrane upon the foregoing area, we shall find the weight it bore
5 equal

equal to 3 pounds, 5 ounces, 12 pennyweights. The thickness of this membrane was $\frac{1}{413}$ of an inch, and consequently the Pericardium exceeded the thickness of the Pia Mater in the proportion of 33 to 8 nearly, and in strength in the proportion of 45 to 10 nearly.

§ 14. Common Experience sufficiently informs us, how much weak, lax, and delicate constitutions suffer upon great and sudden alterations in the weight of the Atmosphere; how great then the disorders must have been, had they not been framed with this extraordinary degree of strength, I have no occasion to explain, and the more especially, if we consider, how frequently hæmorrhages and other ruptures of the vessels are occasioned by this very cause, where their strength is diminished by any preternatural distention,

— tention, acrimony of the humors, or the like.

§ 15. Hence also we have a very obvious solution, why Fevers frequently occasion great changes, as well to the advantage as detriment of the constitution, exclusive of those more obvious ones relating to the forming or removing obstructions; since it is manifest from the very symptoms attending such disorders, that whatever the natural proportion between the solids and fluids might have been before the attack of the distemper, that ratio must frequently be destroyed, and a new one produced, sometimes to the advantage, but often to the damage of the constitution.

§ 16. Hence also it appears, why Intermittents and such other spring Fevers, as only moderately push open and distend the vessels without damaging

maging the Viscera, or straining the Constitution, are observed rather to invigorate than weaken those they attack ; as also why in young persons, they should be succeeded by a remarkable increase of their growth and stature.

EXPERIMENT XXXIII.

§ 1. The diameter of the Aorta descendens in a ram, exactly at the division of the great trunk, which proceeded immediately from the left ventricle of the heart, was 0.55 of an inch, and the Aorta ascendens was 0.41 of an inch in diameter. The thickness of the first was 0.102 of an inch, and that of the latter was 0.073. The diameter of the Vena cava ascendens, corresponding to the Aorta descendens was 0.72 of an inch, and the Vena cava descendens was 0.56 of an inch in diameter.

§ 2.

§ 2. The diameter of the Aorta descendens in an ewe, taken in the same manner as the like vessel in a ram in the preceeding section, was 0.46 of an inch, the diameter of the Aorta ascendens was 0.33 of an inch. The thickness of the first of these Arteries in the ewe was 0.078 of an inch, and that of the latter was 0.0571 of the same. The Vena cava ascendens was in diameter equal to 0.59 of an inch, and the Vein corresponding to the Aorta ascendens was in diameter equal to 0.435 of an inch.

§ 3. Hence it appears, that the capacity of the Vena cava ascendens in the ram, was superior to that of an equal length of the corresponding Artery, in the proportion of 5184 to 3025, that is, as 1713 to 1000 nearly. And the capacity of the Vena cava descendens, was superior to that of an equal length

length of the Aorta ascendens in the same animal, in the proportion of 3136 to 1681, that is, as 1865 to 1000 nearly.

§ 4. In like manner it appears, that the capacity of the Vena cava ascendens in the ewe, was superior to that of an equal length of the Aorta descendens, in the proportion of 3481 to 2116, that is, as 1645 to 1000 nearly; and the capacity of the Vena cava descendens in the same was to that of an equal length of the corresponding Artery, *viz.* the Aorta ascendens, in the proportion of 189225 to 108900, that is, in the proportion of 1737 to 1000 nearly.

§ 5. Hence it is evident, that the capacity of the Vena cava ascendens and descendens in the ram, with respect to the capacity of an equal length of their corresponding Arteries, is superior

perior to the capacity of the corresponding Veins in an ewe, with relation to the capacity of an equal length of their respective Arteries in the proportion of 10969344, 342410400, to 10530025, 318087225 respectively, that is, as 1041, and 1076 to 1000 nearly.

§ 6. Comparing the diameters which belong the descending and ascending Arteries in a ram and an ewe, it is evident, that the capacity of the Aorta descendens in a ram, with respect to the capacity of an equal length of the Aorta ascendens in the same, is to the capacity of the Aorta descendens, with respect to the capacity of an equal length of the Aorta ascendens in an ewe, in the proportion compounded of the direct ratio of the capacities of equal lengths of the descending Aortas in the ram and the ewe, and the reciprocal

ciprocal ratio of the capacities of equal lengths of the ascending Aortas in the same, that is, as it appears from computation, in the proportion of 3294225 to 3556996 ; and consequently the capacity of the descending Artery in the ewe, with respect to the capacity of an equal length of the ascending Aorta, was superior to the capacity of the descending Artery in a ram, with relation to the capacity of an equal length of the Aorta ascends in this animal, in the proportion of 1082 to 1000 nearly.

§ 7. In comparing the capacities of the Veins and corresponding Arteries of the ram and the ewe mentioned in EXP. XXI, XXIII, XXVIII, XXXI, it is evident, that the capacity of the Vein above the Emulgents and of the Iliac Vein, with respect to the capacity of an equal length of their respective

spective Artery in a ram, is superior to the capacity of the Veins performing the same office in an ewe, with respect to the capacity of an equal length of their respective Artery, in the proportion of 3080025, 22562500 to 2822400, 20115225 respectively; that is, the capacities of these Veins in the ram, are superior to the capacities of those in an ewe, with relation to the capacities of the Arteries they correspond to, in equal lengths to the Veins in both animals, in the proportion of 1091, 1121 to 1000 nearly.

§ 8. Comparing the thickneses of the preceeding Arteries in the ram and the ewe with their respective diameters, as they are given in this Experiment, and afterwards the proportions which the coats of these Arteries bear to the fluid contained in their respective cavities together, it is evident, that the

coat of the descending Aorta in the ram, with respect to the blood contained in its cavity, is superior in bulk to the coat of the corresponding Artery in an ewe, with respect to the fluid contained in an equal length of these vessels, in the proportion of 562889856 to 507764400, that is nearly in the proportion of 1108 to 1000. Thus also it will be found, that the bulk of the coat of the ascending Aorta in the ram, with respect to the fluid it acts upon, is superior to that of the coat of the ascending Aorta in the ewe, with relation to the fluid contained in an equal length of this vessel to that in the ram, in the proportion of 15358820400 to 14862332884, that is nearly in the proportion of 1033 to 1000.

§ 9. Comparing § 1. of this Experiment with § 7. EXP. XXVIII, it is evident,

dent, that the capacity of the Vein of the ram above the Emulgents in that Experiment, with respect to the capacity of an equal length of the corresponding Artery, is to the capacity of the Vena cava ascendens, with respect to the capacity of an equal length of the corresponding Aorta descendens in this Experiment, in the proportion of 12780625 to 4665600; and consequently the capacity of the Vena cava at the Emulgents, was superior to that of the Vena cava discharging its contents into the Sinus Venosus, when compared together with relation to the capacities of the Arteries they correspond to, in the manner above-mentioned, in the proportion of nearly 2739 to 1000. Now the thickness of the Vena cava ascendens in this Experiment was 0.0052 of an inch. Hence it is evident, that the bulk of

the coat of the preceeding Vein above the Emulgents, with respect to the fluid contained in its cavity, is to the bulk of the coat of the Vena cava ascendens near the right auricle of the heart, with respect to the fluid contained in its cavity equally long with that of the former, in the proportion of 482236416 to 63730576; and consequently, tho' the blood acted upon by the Vena cava ascendens near the right auricle of the heart, was superior in quantity to that contained in an equal length of the Vein above the Emulgents, in the proportion of 1227 to 1000 nearly; yet the coat of the Vein at the origin of the Emulgent vessels, was superior in bulk to that of the Vena cava ascendens, with relation to the blood acted upon by an equal length of each Vein, in the proportion of nearly 7566 to 1000.

§ 10. That the circulation is in general more flow and languid in females than males, is frequently observed by practical writers, but the cause little farther inquired, than by supposing the whole animal fabrick more weak, lax, and delicate; but from § 2, 8. EXP. XXXII, § 5, 6. EXP. XXX, § 8, 9. EXP. XXXIII, as well as from the less strength and density of the arterial vessels of females (a), we are furnished with a more substantial reason, why the circulation of the blood is naturally slower, and the pulse weaker in these than males. For the capacities of the Arteries being shewn in the preceeding sections to be greater, an equal portion of blood discharged by the heart would necessarily produce a less impulse on the coats of the vessels,

(a) EXP. XVIII, XIX.

and consequently these, a less renixus on the contained fluid, even tho' we should suppose the strength of the Fibres equal in both cases, which is far from being fact, the contrary appearing by several of the foregoing Experiments; whence of necessity the blood must both remain longer in the Arteries, and a weaker and slower circulation ensue; the quantity to be impelled being greater in proportion to the moving force.

§ 11. This appears also from the capacities of the Veins, which are diminished in proportion to the enlargement of the Arteries (*a*); there being no occasion for vessels of a large capacity in order to return a less quantity of blood, for so it may be esteemed on account of the slowness of its motion, less being derived into them

(*a*) § 5, 7. *Exp.* XXXIII.

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in a given time than in males. Nay had it been otherwise, the animal must have laboured under innumerable maladies. For the blood wanting here those vibrations, which kept it fluid whilst in the Arteries, must, had the Veins been as large as in the males, have moved extremely slow, and condensed into grumes, before it had arrived at the heart; the consequence of which would have been obstructions in the lungs, asthmas, consumptions, &c. So exactly nice is every part adjusted to its destined use, that it is altogether impossible for the most enlarged understanding either to comprehend the whole, or even see how the least parts could have been otherwise framed, so as to have answered the designed purposes in any tolerable manner. It were needless to apply this reasoning to shew how the direct
contrary

contrary must happen to males, as the effect must always be determined by its cause, and consequently where that structure is different, or contrary, the effect must be so too.

§ 12. But this greater capacity of the Arteries in proportion to that of the Veins of females, is not the only difference in this respect with regard to the female sex. For the coats of the Arteries in males tho' loaded with a smaller proportion of blood (*a*), are much stronger, thicker, and denser than those in females (*b*); whence not only a brisker circulation must ensue, but each part of the body being framed of vessels more strong, springy and elastic, the whole must be more robust, and capable of bearing more lasting and greater fatigues.

(*a*) § 8. EXP. XXX. § 12. EXP. XXXIII.

(*b*) § 5, 8. EXP. XXXII. § 8. XXXIII.

§ 13.

§ 13. There remains still another difference in the proportion of the sanguineous vessels of males to those of females, besides those above-mentioned, *viz.* the different proportion which the superior vessels bear to the inferior, which holds true in brutes as well as human bodies (*a*) ; but this being observed and explained by the very learned Physicians Dr. *Freind* and *Pitcairn*, I shall not trouble the reader with it.

§ 14. Besides the different proportions of the vessels with respect to the sex, male and female, there are two general circumstances relating to the Vena cava ascendens common to all or most animals, which are very little, if at all, taken notice of by Anatomists, *viz.* the larger capacity of this Vein in the Abdomen, in proportion

(*a*) § 6. EXP. XXXIII.

to

to the blood it receives from the corresponding Aorta ; being very little inferior in capacity to that of the same Vein in the Thorax (*a*), of which I have spoken already at § 8, 9. Exp. XXVIII. and 2dly, the superior thickness of its coat during its stay in the lower belly, occasioned by an additional coat it receives from the Peritonæum, by which means its cavity is preserved more free and open, and it approaches in some degree to an arterial nature, at least much more so than elsewhere (*b*). In consequence of this admirable contrivance, it becomes capable not only of receiving a large quantity of the returning blood with the greater facility, and there containing it as in a Reservoir to supply the equable discharges from the heart, but

(*a*) § 9. Exp. XXXIII.

(*b*) § 9. Exp. XXXIII.

also

also its coats being hereby rendered more elastic, do by the alternate action of the abdominal muscles propel it forward with the greater facility. Whereas had its texture been equally thin, and no more capable of resisting an external pressure than its superior part in the Thorax, or the Cava descends, its cavity would have been much more diminished by the superincumbent pressure, and its coats thro' the want of a sufficient degree of resistance must either have collapsed, or so nearly approached each other by the constant weight and pressure of the intestines, bladder, and other viscera, as instead of promoting, very much to have retarded, if not intirely prevented, the due and equable return of the blood from the lower parts.

EXPE-

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 EXPERIMENT XXXIV.

§ 1. The splenic Artery of the man, part of whose Aorta we found the strength of in EXP. XIV, being fixed to the Condenser, I compressed the air in the sealed top of the Gage, with a force equal to that of 6.2 Atmospheres, before I was able to break the coats of this small Artery.

§ 2. The diameter of this Artery was 0.12 of an inch, therefore an inch in length of its surface will be expressed by the Logarithm 9.5764565; and the weight incumbent on it from the pressure of 6.2 Atmospheres, will be equivalent to so many ounces troy, as correspond to the tabular Logarithm 2.6995379, that is, to 41 pounds, 8 ounces, 13 pennyweights.

§ 3. Comparing the area of this splenic Artery with that of the great
 I descend-

descending Aorta of the same person mentioned at § 2. EXP. XIV, it will be found, that the splenic Artery upon an equal area with that of the great trunk would not have burst without the weight of 173 pounds, 10 ounces, 6 pennyweights.

§ 4. Hence it is manifest, that the texture and cohesion of the Fibres, which compose the splenic Artery, is such, as even to render it stronger than a portion of equal area of the great Aorta descendens where its diameter was $\frac{1}{2}$ inch, in the proportion of 1319 to 1000 nearly.

EXPERIMENT XXXV.

§ 1. The splenic Vein corresponding to the Artery in the preceeding Experiment, permitted the air so freely to escape thro' its pores, after the pressure given it from the condensation, amounted

amounted to something more than the weight of one Atmosphere, that the greatest force with which I could compress the air in the top of the Gage was, I found, equal to 1.43 Atmospheres.

§ 2. The diameter of this Vein was 0.43 of an inch ; hence by comparing the area of this Vein an inch in length with the area of an inch square, and the weight of a column of Quicksilver incumbent on that, when the altitude is equal to 1.43 Atmospheres, it appears, that the weight sustained by an inch length of this Vein will amount to 34 pounds, 5 ounces, 14 pennyweights.

§ 3. The surface of this Vein an inch in length, and the foregoing weight incumbent on it, being expressed in Logarithms, are 0.1306553, 2.6166810 respectively ; hence comparing

paring these with the Logarithms, which express the area, and weight incumbent on it, with relation to the splenic Artery, as they are given in the preceeding experiment, it appears, that the splenic Artery upon an area equal to that of its corresponding Vein, would not have yielded to any weight less than that of 149 pounds, 5 ounces, 12 pennyweights.

§ 4. Hence it appears, that a portion of the splenic Artery of equal area with that of its corresponding Vein was superior in strength to it, in the proportion of 4336 to 1000 nearly.

EXPERIMENT XXXVI.

§ 1. The splenic Artery of the ewe mentioned in Exp. XXII, gave no admittance to the air, till the pressure amounted to that of 4.62 Atmospheres,

spheres, at which instant its Fibres burst asunder.

§ 2. The diameter of this Artery being 0.08 of an inch, its area an inch in length will correspond to the Logarithm 9.4003653, and the weight incumbent on this area from the preceeding pressure, will be found equivalent to the Logarithm 2.3956970, that is, to 20 pounds, 8 ounces, 14 pennyweights, 4 grains.

§ 3. The area of an inch in length of the Aorta of this ewe was equivalent to the Logarithm 9.9294189, and the weight required to break it was equal, when expressed in Logarithms, to 2.8066513. Hence it is evident from the comparison of these with the Logarithms answering thereto in the preceeding section, that the weight required to break the splenic Artery, supposing its area equal to that

that of the Aorta, must have been 70 pounds, 0 ounce, 18 penny-weights, 9 grains.

§ 4. Hence it appears, that a portion of the Splenic Artery of equal area with the Aorta at the origin of the Emulgent vessels, was superior in strength to it in this ewe, in the proportion of 1312 to 1000 nearly.

§ 5. Comparing after the same manner the strength of equal portions of the Splenic and Iliac Artery of the same ewe, as we find it given in *Exp. XXX.* it appears, that the Splenic Artery was superior in this respect to the Iliac Artery, when compared in equal areas together, in the proportion of 148 to 100 nearly.

EXPERIMENT XXXVII.

§ 1. The Splenic Vein being fixed to the Condenser, no rupture could be

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made from the ready escape, which the air made through its pores, inso-much, that the pressure could never be increased beyond that of 0.96 Atmospheres.

§ 2. The weight incumbent on an inch length of this Vein, whose diameter was 0.28 of an inch, from the preceeding pressure, will be found by computation to be equal to 15 pounds, 0 ounce, 18 pennyweights; and consequently the Splenic Artery exceeded the strength of an equal portion of this Vein with respect to surface, in the proportion of 4812 to 1000 nearly.

§ 3. Comparing the preceeding section with § 2. EXP. XXXI, it is evident, that had the Iliac Vein in the same ewe been equal in area to this here of the Splenic, the force required to break it, must have been equivalent

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to

to the weight of 52 pounds, 9 ounces,
3 pennyweights, 4 grains.

§ 4. Hence it is manifest, that the
Hiac Vein was superior in strength to
an equal area of the Splenic in the
same animal, in the proportion of
nearly 35 to 10.

EXPERIMENT XXXVIII.

§ 1. The Emulgent Artery of the
ram mentioned in Exp. XX. being
fixed to the Condenser, it sustained
the pressure of 5.56 Atmospheres,
without any previous leakage of air,
till by this means a perfect rupture of
its coats was made.

§ 2. The diameter of this branch
of the Artery was 0.1 of an inch, and
consequently its area an inch in length
will be expressed in parts of a square
inch by the Logarithm 9.4973444,
and the weight of the column of Mer-
M 3 cury,

cury, taken in ounce troy, by the value of the Logarithm 2.5731539, equal as appears by computation to 31 pounds, 2 ounces, 4 pennyweights, 19 grains.

§ 3. The Logarithm 2.9446879 expresses the weight incumbent on an inch in length of the trunk of this Emulgent Artery, and the Logarithm 5.9745117 expresses the area (*a*). Hence comparing these Logarithms with the corresponding ones in the preceeding section, it appears, that had the area of the Emulgent Artery been equal to that of the trunk it was derived from, it would not have burst till the pressure had been equal to the weight of 93 pounds, 7 ounces.

§ 4. Hence it is manifest, that a portion of the Emulgent Artery, was stronger than a like one with respect

(*a*) § 2. EXP. XX.

to

to the surface of the trunk itself in this ram, in the proportion of 51 to 40.

§ 5. The weight incumbent on an inch in length of the Iliac Artery of the same ram was 44 pounds, 2 ounces, 6 pennyweights, 9 grains; comparing therefore this area and weight with those belonging the Emulgent Artery in § 2. it appears, that the Emulgent Artery would have required the additional weight of 29 pounds, 7 ounces, 13 pennyweights, 14 grains to break it, had its area been equal to that of the Iliac Artery.

§ 6. Hence it is manifest, that the Emulgent Artery surpassed the strength of the Iliac in the same animal, when compared in equal areas together, in the proportion of 1376 to 1000 nearly.

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 EXPERIMENT XXXIX.

§ 1. The Emulgent Vein corresponding to the Artery in the preceding Experiment, tho' it did not burst with the pressure of 1.36 Atmospheres, yet during the compression, air so plentifully escaped thro' its coats, that it could never be condensed with any greater force than that above-mentioned.

§ 2. This Vein was in diameter 0.34 of an inch ; hence it appears, by computing the pressure of 1.36 Atmospheres upon an area of it an inch in length, that the weight incumbent on it was equal to 25 pounds, 11 ounces, 0 pennyweight, 10 grains.

§ 3. The Logarithm of this weight is 2.4927998 ; hence comparing this weight and area with those belonging the corresponding Artery, it appears
 that

that the Emulgent Artery, had its area been equal to that of the Vein corresponding to it, would have required the weight of 105 pounds, 11 ounces, 14 pennyweights to break it.

§ 4. Hence it is manifest, that the Emulgent Artery was superior with respect to strength, to the Emulgent Vein when compared in equal areas together, in the proportion of 4088 to 1000 nearly.

§ 5. Comparing this Experiment with EXP. XX, XXI, XXV, XXVIII, in which we found the strengths of the Aorta at the Emulgents and of the Iliac Artery in the same animal, and likewise the strengths of the Veins corresponding thereto, it is evident, that the Vena cava and Iliac Vein, with relation to their corresponding Arteries, are superior with respect to strength, to the Emulgent Vein in the same ram,
with

with reference to the strength of its corresponding Artery, in equal areas to the former vessels, in a proportion compounded of the direct ratio of the pressures incumbent on the areas of the Veins at the moment of their bursting, and of the reciprocal ratio of the forces required to break the corresponding Arteries in equal portions to the Veins ; that is as appears by computation, in the proportion of 269104, 232408 to 59296, 54944 respectively ; and consequently the strength of the Vena cava at the Emulgents, and of the Iliac Vein with respect to that of an equal area of their corresponding Arteries, is superior to the strength of a like portion of the Emulgent Vein, with relation to its corresponding Artery, in the proportion of nearly 4538 to 1000 and 423 to 100 respectively.

§ 6. In comparing the areas of the Veins and Arteries in the preceeding Experiments together in equal lengths, it is manifest, that the Splenic Vein is superior in capacity to that of an equal length of the Splenic Artery in the man, in the proportion of 1284 to 100 nearly, and that in the ewe, the capacity of the Splenic Vein with respect to that of an equal length of the corresponding Artery, is superior to the capacity of the Iliac Vein in the same animal, with respect to that of an equal length of its corresponding Artery, in the proportion of 283024 to 33856, that is, as 836 to 100 nearly.

§ 7. Thus also it appears, that the capacity of the Emulgent Vein is superior to that of an equal length of the corresponding Artery in the proportion of 1156 to 100; and consequently

quently the capacity of this Vein with respect to that of an equal length of the Emulgent Artery, is superior to the capacity of the Vena cava at the Emulgents, or of the Iliac Vein, with relation to the capacities of an equal length of their respective Arteries, in the proportion of 10404, 439569, to 4225, 62500 respectively, that is in the first instance as 2462 to 1000, and in the second with relation to the Iliac Vein, as 703 to 100 nearly.

EXPERIMENT XL.

§ 1. The Emulgent Artery was in thickness equal to 0.037 of an inch, and the Splenic Artery was 0.028 of an inch thick in Exp. XXXVI. The Emulgent Vein corresponding to the preceeding Artery was 0.0036 of an inch thick, and the Splenic Vein was in thickness equal to 0.0025 of an inch.

§ 2.

§ 2. Comparing the thicknesses of these vessels with their respective diameters, as given above in § 2. EXP. XXXVIII, XXXIX, XXXVI and XXXVII, it is evident, that the fluid contained in the cavity of the Emulgent Artery, is to the coat that contains it, in the proportion of 1000 to 2027 nearly, and consequently the bulk of the solids in the Emulgent Artery, with respect to the fluid they act on, is superior to the bulk of the solids acting on the fluid contained in an equal length of the trunk it was derived from, and to those of the Iliac Artery in the same animal, with respect to the fluid they act on in equal lengths to the former, in the proportion of 182484, 7709949 to 73216, 2239264 respectively, that is, as 2629 to 1000, and as 344 to 100 nearly.

§ 3. Thus also it appears, that the fluid in the cavity of the Splenic Artery, is, to the coat that contains it, in the proportion of 6400 to 12096; and consequently the bulk of the Splenic arterial Coat in the ewe, with respect to the fluid it acts upon, is superior to the bulk of the coat of the Iliac Artery in the same animal, with respect to the fluid contained in an equal length of this vessel, in the proportion of 4366656 to 1254144, that is nearly as 348 to 100.

§ 4. On the contrary it appears from computation, that the bulk of the solids in the Vena cava at the Emulgents and those of the Iliac Vein in the ram, with respect to the fluids they act on, is superior to the bulk of the solids acting on the fluid contained in an equal length of the Emulgent Vein, in the proportion of 107535744,
17090304,

17090304, to 20904624, 3092400 respectively, that is, nearly as 514, 552 to 100. In like manner it appears that the bulk of the solids in the Iliac Vein with respect to the fluid they act upon, is superior to the bulk of the solids acting on the fluid contained in an equal length of the Splenic Vein in the same animal, the ewe, in the proportion of 8313536 to 1494425, that is, as 556 to 100 nearly.

§ 5. Hence we may observe, upon how narrow a bottom the ingenious Dr. *Keil* has founded his estimation of the quantity of blood in an animal body. For tho' by comparing the area of the Aorta and Vena cava in a calf with the thickness of these vessels, he obtained the proportion of the fluid to the solid in each, yet these data were extremely insufficient for determining that difficult Question, with regard

regard only to the quantity circulating in the larger branches of the arterial system ; inasmuch as the rule and proportion laid down by him as a basis to proceed on in that Inquiry, is, by several of the foregoing sections, not only varied in every branch (*a*), but directly contradicted in some of the next branches issuing from it (*b*). The few instances we have here enumerated, are however sufficient to shew us, what care and circumspection we ought to employ in all our inquiries, into that complicated machine, an animal body. For however uniform the workmanship of nature may appear in the formation of the corresponding organs in different animals; yet the texture of the several vessels which compose the same individual,

(*a*) § 2, 3. EXP. XXVI, § 9. EXP. XXXIII.

(*b*) § 6, 7. EXP. XXXIX, § 2, 3, 4 EXP. XL.

is,

is, we see, infinitely various, and consequently where the particulars for our observation are so numerous, we shall be in perpetual danger either of advancing opinions absolutely uncertain for certain truths, or things absolutely false for matters of fact and reality, unless we will be at the labour and expence of examining the structure she has framed, as it were, inch by inch ; and learn by a particular Encheirefis, what is the disposition, what the order, what the relation of the several component parts, by which its movements are best acquired, and its being preserved to that period of time for which it was naturally intended.

§ 6. Hence also it appears, on how weak a basis every general Hypothesis relating to the secretions in an animal body must be founded ; since 'tis demonstrable, that not only the different

rent angles at which the branches arise from their trunks, as well in the larger as in their minuter ramifications, are extremely various, but even the Arteries themselves are almost infinitely diversified in their strength and capacity with regard to the moving fluid. The consequence of this must be, that in some parts their action will be more strong and brisk, in others more weak and sluggish, and that in such peculiar proportion, as is necessary to prepare and secrete each particular fluid, which can never be explained with any tolerable degree of exactness and certainty, till these are better determined, and their different proportions to each other adjusted.

EXPERIMENT XII.

§ 1. The Vena porta of the *ewe* sheep mentioned in several of the foregoing

going Experiments did not suffer any air to escape through, till the pressure given from the continuance of the condensation was equal to 4.98 Atmospheres, at which time a small stream of air passing thro' its coats, prevented a perfect rupture.

§ 2. The diameter of this Venn was 0.49 of an inch, its area an inch in length, will correspond to the Logarithm 0.1875207, and the weight it bore upon this area, will, if taken in ounce troy, correspond to the Logarithm 3.2154397, and shews that the pressure amounted to 136 pounds, 10 ounces, 4 pennyweights, 14 grains.

§ 3. The Logarithms 0.2455127, 3.1942505 respectively denote the area of an inch in length of the Vena cava of the same ewe, and the weight required to break it (a). Hence com-

(a) § 2, 3. Exp. XXIII.

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paring these with the foregoing Logarithms in § 2, it is manifest, that had the area of the Vena porta been equal to this of the Vena cava, the weight to break it must have been 156 pounds, 4 ounces, 17 pennyweights, 19 grains.

§ 4. Hence it is evident, that the Vena porta was superior in strength to a portion of the Vena cava of equal area with it in the same cwe in the proportion of 6 to 5.

§ 5. Comparing the area and weight sustained on it by the Vena porta in this Experiment, with those corresponding to the Aorta of the same animal in EXP. XXII. it is evident, that had the area of the Aorta been equal to this here of the Vena porta, yet it would only have sustained the weight of 96 pounds, 8 ounces, 16 pennyweights.

§ 6.

§ 6. Hence it is manifest, that the Vena porta was superior in strength to the great descending trunk of the Aorta at the Emulgents, when taken in equal areas, in the proportion of 1414 to 1000 nearly.

§ 7. The area of an inch in length of the Splenic Vein being compared with the area of the Vena porta, and likewise the weights required to break these areas respectively, as they are given in this and Exp. XXXVII, it is evident, that had the area of the Splenic Vein been equal to that of the Vena porta in the same ewe, yet the weight incumbent on it, and to which it would have yielded, would have been no more than that of 26 pounds, 4 ounces, 12 pennyweights, 4 grains.

§ 8. Hence we learn, that the Vena porta was stronger than a portion of the Splenic Vein of equal area with

it in the proportion of 51.87 to 1000 nearly. It appears from § 2. Exp. XXIII, that the Aorta of the ewe sheep required the weight of 53 pounds, 4 ounces, 14 pennyweights, to break an inch in length of its substance. Now from Exp. XXXII, and XL, it is farther evident, that the thickness of this Aorta and of the Splenic Artery was 0.044, 0.028 of an inch respectively; and the Vena porta in this was 0.0093 of an inch thick. If now we conceive the Aorta remaining in its texture and surface still the same, but its thickness varied so as to be diminished to that of the Splenic Artery or Vena porta in the same animal, it is evident, that by reducing the preceding thicknesses of these vessels to their value in Logarithms, and comparing them with the Logarithms of the weights

weights above mentioned, that the Aorta would, in the first of these suppositions, have required to break the same area, no more than the weight of 33 pounds, 11 ounces, 14 pennyweights, 4 grains; and in the second instance, no more than the weight of 6 pounds, 5 ounces, 3 pennyweights, 10 grains. Whereas it appears from § 3. Exp. XXXVI, and from § 5. of this Experiment, that the Splenic Artery and Vena porta were of so different a texture from the Aorta in the same animal, that a portion of these vessels, tho' of no greater area or thickness than that just above assigned to this great descending trunk, would not have broke unless the weight upon them had been equal to 70 pounds, 0 ounce, 18 pennyweights, 9 grains, 75 pounds, 6 ounces, 8 pennyweights, 10 grains respectively.

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§ 10.

§ 10. Hence we may see, how many conclusions in the animal œconomy, as well as many arguments of the Anatomists would have been much better grounded, had they studied invention less, and nature more. For they finding the Arteries in general upon every subdivision to decrease in the thickness of their coats, have erroneously concluded their strength to decrease in the same proportion; which is so far from being true, that whoever will examine the strength of the thinnest vessels, will find that these are endowed with a much greater degree of strength in proportion to their thickness than the other. Nay and not only so, but that several vessels whose coats are extremely thin, exceed the strength of the Aorta itself, whose coats are more than ten times as thick.

EXPE-

www EXPERIMENT XLII.

§ 1. The Aorta of an old dog a terrier being cut off at the origin of the Emulgent Arteries, and fixed to the Condenser, the air was compressed with a force equal to that of 4.07 Atmospheres before a rupture or leakage could be made in its coats.

§ 2. The diameter of this part of the Artery was 0.11 of an inch, and consequently its area an inch in length will be expressed in parts of a square inch by the Logarithm 9.5386994. Now the weight of one Atmosphere upon an inch square being equal to 214.136 ounces troy, it is manifest, that the weight of 4.07 Atmospheres upon this area will be equivalent to 25 pounds, 1 ounce, 5 pennyweights, 19 grains.

EXPE-

EXPERIMENT XLIII.

§ 1. The Vena cava corresponding to the Aorta in the preceding Experiment, and tried in the same manner as that, did not suffer any air to escape, till the pressure was equal to 3.71 Atmospheres, with which it burst.

§ 2. The diameter of this Vein at the Emulgents was 0.23 of an inch, and consequently the Logarithm 9.8591383, corresponding to 0.723 parts of a square inch, will give the area of an inch in length of this Vein. Hence it is evident, that the Logarithm 2.7592019 will correspond to so many ounces troy, as pressed upon this area of the Vein at the time of its bursting, which by computation amounts to the weight of 47 pounds, 10 ounces, 7 pennyweights, 19 grains.

§ 3. Comparing the weight necessary to break the preceeding area of this Vein with those belonging the corresponding Artery, as they are given in the preceeding Experiment, it appears, that had the Aorta of this dog been equal in area to its corresponding Vein at the Emulgents, it would not have burst unless the weight had been equivalent to 52 pounds, 6 ounces, 2 pennyweights, 9 grains.

§ 4. Hence it appears, that the Aorta of this old terrier was superior in strength to the corresponding Vein at the origin of the Emulgent Vessels, when compared in equal areas together, in the proportion of 1097 to 1060 nearly. And consequently, as we have already shewn, that age continually adds to the density of the Artery in several of the foregoing Experiments;

means (a); so from hence it is no less manifest, that they are constantly acquiring more strength, inasmuch that those Veins, which in young animals were in equal areas stronger than their corresponding Arteries, lose their superiority over them in this respect in old ones.

§ 5. 'Tis a common observation, and verified by innumerable instances, that such as early in youth habituate themselves to excessive drinking, and other debaucheries of that kind, have their constitutions broken and shattered in much shorter time, than those who later in life enter upon the like pernicious courses; which from the increasing strength of the arterial vessels is easily explained. For as the body is by such a method of living

(a) See Exp. VI. to Exp. XII.

kept constantly in a febrile state, it cannot otherwise happen, but that the arterial vessels of young persons, on which the rarefying humors exert their principal force, must suffer greater alterations in their tone and dimensions, than of those that are older, whose superior strength renders them more capable of resisting the preternatural impetus of the circulating humors. Not to mention the effect of youth itself exclusive of these debaucheries, in which the natural force of the fluids themselves is in some degree an over-balance to the solid parts, as appears by the increasing stature of all animals, as is before sufficiently explained.

EXPERIMENT XLIV.

§ I. The Vena porta of the same dog endured without any visible leakage of air the pressure of 5.73 Atmospheres,

spheres, before a rupture succeeded from the continuance of the condensation.

§ 2. The diameter of this Vein was 0.2 of an inch, and therefore its area; an inch in length will correspond to the Logarithm 9.7983053, and the weight incumbent on it will be found equal to the value of the Logarithm 2.8871496 taken in ounces troy; that is, as appears by computation, to 64 pounds, 3 ounces, 2 pennyweights, 9 grains.

§ 3. Comparing the area of an inch in length, and the weight sustained upon it by the Aorta of this dog in EXP. XLII, with those given in the preceeding section for the Vena porta in the same animal, it is evident, that had the area of the Aorta been equal to that of the Vena porta, yet the weight required to break it, would not have

have been more than that of 45 pounds, 7 ounces, 15 pennyweights.

§ 4. Hence it is evident, that the strength of the Vena porta surpassed that of a portion of the Aorta of equal area with it, notwithstanding the increase of strength in this latter, and the loss of it in the former by age and a longer circulation, in the proportion of 1407 to 1000 nearly.

§ 5. Comparing likewise the area of an inch in length of the Vena cava, and the weight incumbent on it at the time of its bursting, with those belonging the Vena porta in the same dog, it appears by computation, that the Vena porta would not have broke, had its area been equal to that of the Vena cava, unless the weight upon it was equivalent to 73 pounds, 11 ounces, 2 pennyweights, 9 grains.

§ 6. Hence we learn, that the Vena porta was superior in strength to a portion of the Vena cava at the origin of the Emulgent Vessels in the same dog, tho' compared in equal areas together, in the proportion of 1544 to 1000 nearly.

§ 7. An inch in length of the Aorta in EXP. XLII, required the weight of 25 pounds, 1 ounce, 5 pennyweights, 19 grains, to break it. Now this Artery and the Vena porta in this dog were in thickness equal to 0.024, 0.0029 of an inch respectively, and from EXP. XXXII. § 14. we learn, that the Pericardium and the Pia Mater of the same dog were $\frac{1}{413}$, $\frac{1}{1698}$ of an inch thick respectively. Hence if we take the Logarithms of these thicknesses, and compare them with the Logarithm of the weight above-mentioned, it is evident, that was the Aorta
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of an equal thickness with the Vena porta, the weight of 3 pounds, 0 ounce, 8 pennyweights, 2 grains, would be sufficient to break an inch length of it. Now it is evident, that the Vena porta in the same circumstances would have required the weight of 35 pounds, 4 ounces, 4 pennyweights, to break it. Lastly, if we imagine the Aorta reduced to the thickness of the two preceeding membranes, we shall find its strength in the first of these instances yielding to the weight of 2 pounds, 6 ounces, 7 pennyweights, 20 grains; and in the second to the weight of 7 ounces, 7 pennyweights, 20 grains $\frac{1}{2}$; whereas the first of these membranes, *viz.* the Pericardium, would upon the same terms have required the weight of 38 pounds, 1 ounce, 10 pennyweights, and the latter of them, *viz.* the Pia Mater,

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Mater, in the same Circumstances, would not have broke, unless the weight had been equal to 8 pounds, 4 ounces, 12 pennyweights ; that is in this last instance, more pounds than the Aorta of the same dog would sustain ounces, when upon an equality with it, as well with respect to surface as thickness ; and this from no other cause, but the difference of texture ; there being nothing besides that excepted in the comparison between them.

§ 8. Hence appears the reason of those acute and exquisite pains, which affect the membranous parts in inflammations and other acute diseases, in proportion to those which affect such as are more lax and flabby, and especially when they are so connected to the contiguous parts, as to leave very little room for their extension, as is the
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the case of the Periofteum, Pleura, and many others.

§ 9. Hence alfo it appears, why in the fame difeafes, and where the fame parts in different perfons are affected, the fenfation of pain fhall be in one moft exquisite, whilft in the other it is very tolerable, merely on account of the greater laxity in the one, and rigidity and density of the membranes in the other. And laftly, hence like-wife it appears, why difeafes attended with relaxation of the Fibres, are more eafily relieved in fuch whole Fibres are naturally tenfe and ftrong, than in fuch where their texture is lax and yielding, and *vice verfa* : The conftitution of the fick in the one promoting, in the other abating the efficacy of the medicines.

www.libtlibt **EXPERIMENT XLV.**

§ 1. The Emulgent Artery being cut off from the Aorta in EXP. XLII, I compressed the air in the sealed top of the Gage with a force equal to that of 5.28 Atmospheres, before I was able to produce any leakage or rupture in the coats of this Artery.

§ 2. The diameter of this Artery was 0.035 of an inch ; therefore the Logarithm 5.0413927 will express an inch in length of its surface, and the weight incumbent on it from the preceeding pressure will be equivalent to so many ounces troy as correspond to the Logarithm 2.0947163, equal, as appears by computation, to the weight of 10 pounds, 4 ounces, 8 penny-weights.

§ 3. The weight incumbent on the trunk of this Artery, having its area
equal

equal to 0.3457 parts of a square inch, was 25 pounds, 1 ounce, 5 pennyweights, 19 grains. Comparing therefore these quantities with those belonging the Emulgent Artery of the same animal in § 2. of this Experiment, it appears, that had the area of this Artery been equal to that of an inch in length of the trunk it was derived from, it would not have broke, unless the weight upon it was equal to 32 pounds, 6 ounces, 18 pennyweights.

§ 4. Hence it is evident, that the Emulgent Artery in this old dog of equal area with the Aorta it sprung from, was superior in strength to it, in the proportion of 13 to 10 nearly.

EXPERIMENT XLVI.

§ 1. The Emulgent Vein, corresponding to the Artery in the preceding Experiment, burst when the

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pressure was equivalent to 1.206 Atmospheres, but had in the mean time suffered a small portion of air to escape through its pores.

§ 2. The diameter of this Vein was 0.12 of an inch, and consequently the Logarithm of its area an inch long, will be 5.5764565, and that of the weight required to burst it, will be 1.9884935, corresponding to 8 pounds, 1 ounce, 7 pennyweights, 18 grains.

§ 3. The weight required to break the area of an inch long of the trunk of this Vein was by Exp. XLIII, 47 pounds, 10 ounces, 7 pennyweights, 19 grains; hence comparing their respective areas and weights together, it is evident, that had the Emulgent Vein been equal in area to the Vena cava, where it receives what the other discharges, the weight of 15 pounds, 6 ounces, 15 pennyweights, 14 grains,

grains, would have been sufficient to break it.

§ 4. Hence it is evident, that the Emulgent Vein was exceeded by the Vena cava in strength when compared together in equal areas, in the same animal, in the proportion of 3076 to 1000 nearly.

§ 5. The weight required to break an inch in length of the Emulgent Artery, was by the preceeding Experiment equal to 10 pounds, 4 ounces, 8 pennyweights ; hence comparing the weight in § 2. which broke an inch in length of the Emulgent Vein, with this, and their respective areas together, it appears, that the Artery would not have burst, had its area been equal to that of the corresponding Emulgent Vein, unless the weight upon it was equivalent to 35 pounds, 6 ounces, 6 pennyweights, 19 grains.

§ 6. Hence it appears, that the Emulgent Artery was stronger than a portion of the corresponding Vein of equal area, in the proportion of 4378 to 1000 nearly.

§ 7. Comparing the areas of the Vena porta and Emulgent Vein together, and likewise the weights required to break them, as they are severally delivered above (a), it appears, that the Emulgent Vein upon an area equal to that of the Vena porta of the same animal, would break with the weight of 13 pounds, 6 ounces, 6 pennyweights, 19 grains.

§ 8. Hence it is evident, that a portion of the Vena porta of equal area with the Emulgent Vein, was superior in strength to it, in the proportion of 4751 to 1000 nearly.

(a) § 2. EXP. XLIV.

§ 9. In comparing the areas of the Arteries and Veins in this old dog, it is evident from the foregoing Experiments, that the capacity of the Vena cava at the Emulgents, is superior to that of an equal length of the corresponding Aorta, in the proportion of 437 to 100 nearly. And the capacity of the Emulgent Vein exceeds the capacity of an equal length of its corresponding Artery, in the proportion of 14400 to 1225, that is, as 1176 to 100 nearly.

EXPERIMENT XLVII.

§ 1. The thickness of the Emulgent Artery of this dog was 0.013 of an inch, and that of the Vein corresponding to it was 0.0011 of an inch. The Vena cava at the Emulgents was 0.012 of an inch in thickness.

§ 2.

§ 2. Comparing the thickness of this Emulgent Artery with that of the Aorta it arose from, given in § 7. Exp. XLIV, and their respective diameters together, it is evident, that the fluid contained in the cavity of this Aorta, is, to the coat that contains it, in the proportion of 121 to 128 nearly; and the fluid in the cavity of the Emulgent Artery, is, to its respective coat, in the proportion of 1000 to 2037 nearly.

§ 3. In like manner it appears, that the fluid contained in the cavity of the Vena cava of this dog at the Emulgents is to the coat of this Vein, in the proportion of 4594 to 1000 nearly; and that contained in the cavity of the Emulgent Vein will be, to its coat, in the proportion of 2702 to 100 nearly. Hence it is evident, that the bulk of the solids of that part of the Vena

Vena cava into which this Emulgent Vein empties its contents, is with respect to the fluid they act on, superior to the bulk of the solids acting on the fluid contained in an equal length of the Emulgent Vein, in the proportion of 167270400 to 28187236, that is, nearly as 593 to 100.

§ 4. The diameter of the Vena porta of the sheep was 0.49 of an inch, and its thickness 0.0053 of an inch (a). Hence it is evident, that the fluid contained in the cavity of this Vein is to the coat that contains it, in the proportion of 2286 to 100 nearly. In like manner the fluid contained in the cavity of the Vena porta of the dog, is superior in bulk to the solid that acts upon it, in the proportion of 17 to 1 nearly.

(a) § 9. EXP. XLI.

§ 5. Hence it is evident, that notwithstanding the bulk of the solid in the Vena porta in each of the preceding animals, with respect to the fluid it propels, differs but little from that acting on an equal quantity of blood in the Emulgent and Splenic Veins, yet the strength of the Vena porta, as well in the dog as in the sheep, not only far exceeds that, which those above-mentioned are endowed with, but is likewise greatly superior to that of the Vena cava, Aorta and Emulgent Artery respectively, notwithstanding the coats of these vessels are so much thicker, and so far surpass in bulk that of the Vena porta acting on an equal quantity of fluid (*a*).

§ 6. I have already shewn at § 4. EXP. XV, XVII, § 3, 4. EXP. XXIV,

(*a*) § 3. to § 10. EXP. XLI. § 3. to § 8. EXP. XLIV. § 7, 8. EXP. XLVI.

XXV,

XXV, XXXIV, XXXV, and in many others, too numerous to be quoted here, the great difference of strength in several branches of the Arteries, with respect to the trunks from which they spring, and consequently their action, with regard to each other, on the contained fluids, so far as depends on this cause ; but how far this proportion is carried, is a Problem I shall not undertake to solve. Tho' it is not improbable, that more light might be gained, even in this dark part of the animal structure, than has hitherto been discovered, was it attempted by proper experiments.

That indeed such an increased degree of strength, as is found in some of the larger ramifications, is propagated thro' the minutest divisions of the Arteries, is by no means probable ; but that the smallest branches have a greater

greater degree of strength in proportion to their size, than their respective trunks is highly credible ; inasmuch as the protrusive force of the heart in these vessels must be extremely small, for the reasons above alledged, *viz.* the increased capacity or aggregate of the branches in proportion to their trunks, as also from their angles and curvatures, and consequently the circulation carried on much by the lateral impulse, and the vibrations, they receive from the pulsation of the larger vessels, which is smartly returned upon the fluids contained in these minute canals by their own natural springiness and elasticity. Nor will this seem strange and unaccountable to any one, who considers, how agreeable it is to the operation of nature in many other instances, where not only the circulation is principally carried on, but secretions

cretions performed more by the impulse of the contiguous parts *ab extra*, than from the protrusive force of the heart; as appears most evidently in the liver, and its appendage the spleen, wherein the alternate Contractions and Relaxations of the Diaphragm, and Muscles of the Thorax and Abdomen, have the principal share in promoting the operation of these two complicated Organs.

That various degrees of Strength are requisite in the branches, in order to the due performance of each particular secretion, seems plainly deducible from the various Cohesion, Density, and Strength of the secreting Organs, as well as from the different nature and tenacity of the Liquors themselves. That the branches also are endowed with degrees of Strength, differing very much in proportion from those

those of their Trunks, is sufficiently
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apparent from the foregoing Experi-
ments ; but what these are, or how
far from the Aorta this increased de-
gree of Strength is carried, cannot
easily, if at all be determined, be-
cause of the extreme minuteness of a
Capillary Vessel ; tho' it is not impro-
bable, it may be continued in diffe-
rent parts in very different propor-
tions, according to the various uses for
which they are designed, possibly till
the secretion is absolutely perfected in
the Gland itself ; which is usually
formed of various Convolutions and
Contorsions of it, as appears by those
of the Conglobate kind. Whether
this be so or not, I shall not presume
to determine, but the more firm con-
texture of these, than the other parts
of the Secretory Organs, render it not
wholly improbable. Nor is the case
otherwise

otherwise in the Conglomerate kind, which tho' not capable of an equal scrutiny thro' their extreme smallness, appear to be a Congeries of such like Organs wrapt up in one common Tegument, and generally discharging themselves into one common Duct, but always appear more firm and compact in that part, where the Secretion is performed, than any other part of the Viscus to which they belong.

Nor is this weaker and more easily distensible texture the sole particularity in the structure of the Aorta with regard to others, the whole intermediate substance betwixt the outward and innermost Coat, tho' of an Elastic nature, which way soever it be drawn or compressed, having a very different degree of Cohæsion, and being much more brittle and friable than in the Branches, especially such as are at

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some

some distance from it, which are much tougher, and have a greater degree of elasticity in proportion to their size than the Aorta itself (*a*). But tho' this seems to be the case in all the larger Branches with regard to their Trunks, yet it is extremely various according to the different purposes, for which such Arteries are designed, particularly where any remarkable Secretion is to be made, or the Humors prepared for a subsequent preparation, in which cases they are much stronger than elsewhere. Instances of which are the Emulgent and Splenic Arteries, which though much smaller are vastly stronger than the Aorta itself, when compared in portions of equal Areas (*b*). Which is still further evi-

(*a*) § 4. EXP. XV, XVII. § 4, 5. EXP. XXVI.

(*b*) § 3, 4 EXP. XXXIV, XXXVI, XXXVIII, XLV.

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dent from § 5. *Exp.* XXXVI: § 5, 6.

Exp. XXXVIII: § 2, 3. *Exp.* XL.

where these Arteries are compared with the Iliacs of the same Animal, by which no Secretion is made. And indeed, this seems necessary, of whatever kind the secreted Fluid shall be supposed to be. For in case a thin Fluid is to be separated from the gross substance of the Blood, the remainder, when deprived of its thinnest parts, must require a greater Force and Energy in the Vessels to propel it into the corresponding Veins. In like manner if we suppose the Secretion of a Viscous and Tenacious Humor designed, the thin and more fluxile parts must first necessarily be drawn off, before such a separation, and consequently a strong force will be necessary, as well in the Secretory Organ, to strain off, and convey this Hu-

mor, as in the Artery itself, which is obliged to convey the Blood thus deprived of its most fluid parts, not only to the corresponding Veins, but into the Gland itself, which without a considerable force it could not enter, but must regurgitate and distend the coats of the Artery, as is evident to the senses in most Chronic Diseases from Dissections, even to such a degree, that the vessels themselves are found frequently burst near such obstructions.

But what adds still more strength and light in this matter, is, the size and texture of such Veins, as carry the remaining Blood from the Secretory Organs, which are so different from those, that serve in general only for conveying the Blood back to the Heart, that these are as remarkable for their largeness, weakness, thinness
and

and laxity (*a*), as their corresponding Arteries are for the contrary qualities; as appears by the Veins corresponding to the Arteries above-mentioned, *viz.* the Splenic and Emulgent Veins. By which admirable contrivance the resistance to the Artery in performing the Secretion is not only rendered as small as possible, but the obstructions in it, as also any impediments to the Secretion from a turgescentcy in the Vena cava, prevented. For if we suppose, (as must often happen either from a long and vigorous exercise of the Muscles, a violent passion of anger, or any other like cause, by which the motion of the Blood is accelerated) a greater quantity than usual suddenly derived into the Veins, the return of the blood from these

(*a*) § 3, 4. EXP. XXXVII. § 5, 6, 7. EXP. XXXIX. § 4. EXP. XL. § 3, 4, 9. EXP. XLVI. § 3. EXP. XLVII.

Secretory Organs, would from the increased resistance in the larger Veins, arising from their Plenitude and Strength of their Coats, be in some measure prevented, or at least delayed; whence the resistance to the Blood in the Artery, would be considerably augmented, its progress interrupted, and obstructions formed in the Capillary Branches, and consequently the necessary Secretions stopped or disturbed.

This seems in most places to be the design of Nature in making the reductory Trunks of these Veins so weak, large and thin, by which means they are admirably suited to the above-mentioned purpose; becoming as it were a kind of Reservoir to the returning Blood, till such time as it can be received by the Vena cava without any disorder in the Animal, or impediment

diment to particular Secretions. But this still appears more plain from the comparison of these Veins, with such, as convey the Blood not immediately from any Secretory Organ, but serve only for reconveying it to the Heart in order to a fresh Circulation, as with the Iliac Veins, and Vena cava itself, which bear a proportion to their Arteries very different from those corresponding to the Veins above-mentioned, as well with regard to Strength and Thickness, as their Size and Capacity (*a*).

Whether this degree of Laxity and Weakness be continued to its union with the Branches of the Artery, still remains a secret. 'Tis indeed probable it does not, but that it is extremely variable both in its Size and

(*a*) § 5, 6, 7. EXP. XXXIX. § 4. EXP. XL.
§ 3, 4, 9. EXP. XLVI.

Tensity, according to the different resistance necessary to the separation of each particular Fluid, inasmuch as the more vigorously it is propelled by the Artery, and the greater resistance it meets with in the Capillary Vein, the more strongly it will be compressed and agitated in the Gland, and *vice versa*; and consequently suited, by these infinite degrees of action, to innumerable Secretions.

Hence we may see how by the accidental hurt or contusion, or other fault of a particular Gland, the most mischievous effects may be produced, even tho' the Juices derived to it, may not deviate from their natural state, as in the case of Schirrous and Cancerous Glands, made so by casual hurts or bruises; which, if timely eradicated, before the malignancy of the Humor has infected the adjacent Vessels, are
often

often speedily and safely cured without any farther inconvenience, than arises from the loss of the part itself, which afterwards is vainly attempted by ignorant Quacks, to the irreparable damage of the Sick.

But though the mechanism of the Gland itself, as explained above, seems so necessary to its structure, that the Secretions could otherwise scarce have been performed in any tolerable manner, yet this alone would hardly have been sufficient for answering the design, and producing them in a proper quantity, and with their due qualities, without a farther contrivance ; by which the several kinds of Particles, necessary for forming that vast variety of thin, subtile, and tenacious Juices, might likewise be determined in greater or less proportion to the Secretory Organ.

Now

Now this great design is brought about, partly by the different Figures, Densities, and Velocities of the particles constituting the Blood, whereby each kind (tho' kept blended together by the superior force of the Circulation) have a perpetual tendency to fly off at some Angles in greater proportion than others, and partly, by that infinite diversity in the Angles, Flexures, and Degrees of strength in different parts of the adductory Vessels. By the former of these, their Nisus to cohere or fly off by the Branches is increased or diminished; whilst their tendency towards each particular Gland is promoted or restrained by the latter, in such degree and proportion, as the all-wise Author of Nature saw best adapted to the use and preservation of each Individual Animal.

From

From this Inquiry on the foregoing Experiments, and the nature of Animal Secretions, it is not difficult to account for many of their Disorders, and shew how necessarily they must be altered from their natural State, either by an increased or more tardy Circulation of the Blood, than is consistent with the Health of the Animal. For supposing the force of the Circulation increased, it is evident, that many Particles of a grosser nature, than those usually separated by any particular Glands, must now have their natural direction so altered, and their Velocities augmented, as to be detached from the Mass sooner than they naturally would be, and by their increased Impetus enter Vessels, which otherwise they would not ; and consequently be carried in too great proportion to such Glands, as are designed for

for more fluid Secretions ; as is apparent from the high-coloured and turbid urine in Fevers. On the contrary, where the Motion is too much diminished, the Particles forming the more Gross, Viscous and Terrestrial Juices, being neither sufficiently agitated and attenuated to preserve a due mixture with the Aqueous, nor propelled with a proper force to pass the smaller Vessels, will remain in too great quantity in the larger, whilst the Aqueous, which should serve as a Vehicle to the rest, pass in too great proportion by the smallest Collaterals, and there stagnate and putrefy, thro' the want of a sufficient Energy in the coats of the Vessels; altering thereby both the nature and quantity of all the Secretions, till at length the Disorder concludes in putting a fatal Period to the whole Animal System, as is apparently the case of such

Valve cannot be placed here on this account. The use then of the Valves here placed must be, not to sustain this constant pressure, but to prevent the repulsion of the Blood back into the Secretory Organ, when urged by some other concurrent force applied *ab extra*; and such is the force of the Muscles of the Thorax, Abdomen, and Diaphragm, whose Contractions and Relaxations alternately compress and widen all the Veins of the lower Belly, and would necessarily produce this effect, if not prevented by the Valves. Nor is this less evident from the Valves in Brutes, which are equally numerous with regard to their Structure, as in Men, and even in these Veins, whose natural position is Horizontal, as is the Vena cava of Quadrupeds. Now the principal design here cannot be to take off the constant

stant equal pressure of the superincumbent Fluid, in its return towards the Heart, which in this case amounts to very little, since the same Apparatus is allotted by the wise Architect without any variation for the erect position of Men, where the pressure is very considerable.

This then must be the use of the Valves, in the reductory Veins of these great Secretary Organs; to which that of those in the ascending ones, seems nearly similar, and equally worthy of the wise Author of Nature. Inasmuch as upon strong and violent motions of the body, in running, leaping, or the like, the Venal Blood must have acted in the containing Vessels, not only with the weight of its whole incumbent Column, as it naturally and necessarily does; but with this great weight increased at every leap or step in such motions;

motions ; as appears from the nature of gravity, Hydraulics, and the action of bodies on each other ; and consequently have rendered the lowest Veins subject to Varicose Tumors, as they sometimes are from such violent motions, tho' assisted by the Valves.

For the action of the incumbent weight being here not only the greatest, but the resistance of the Vessels less than above ; however small the Vein may be supposed, its Coat must be acted upon, with the force of the incumbent Column. But this effect is in a great measure prevented by the Valves ; as every such impulse of the Venal Blood, can only act in proportion to the distance of the Valves from each other, instead of that which would otherwise be produced by the height of the whole Column.

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As I have before shewn the reason why the ~~reduitory~~ Veins from the Secretory Organs, should be more large and lax than others; so hence appears the reason, why these should be endued with contrary qualities; there being an absolute necessity, that the Circulation should be performed in due time, and with due vigour; otherwise neither the Secretions themselves could be perfected, nor even the life of the Animal preserved, had the common Veins been as large and weak, as those designed for the former purposes.

The wisdom of this contrivance is still more evident from the numerous Valves placed in the Lymphatics, which are here apparently necessary on account of the exceeding tenuity of their Coats; which would be in perpetual danger of breaking, especially in

in the Abdomen, by the strong and frequent action of those Muscles; was not the pressure thence arising, distributed in a due proportion, on every part of these tender Coats, by means of numerous Valves. For the contained Fluid, being by means of the Muscles, pressed *quaquaversum*, would recoil towards its source, with a force too great to be sustained by the Vessels without a rupture of their Coats; and thence an Ascites, and Death of the Animal. But as the case now stands, they much facilitate its progress. For the liquor not being able to recede by reason of the Valves, must on compression of the Vessels flow forward, being there least resisted. But this is only consequential of their precluding its recess on compression, and not properly any action of the Valves. And indeed, in this sense, they may

be allowed in these and several other parts to promote the Circulation ; but not in the manner supposed by the Vulgar Anatomists, as is above sufficiently explained.

There are indeed other uses besides these flowing from this Mechanism. For the impulse on the Fluid from the Heart being here extremely diminished, it was necessary, that in every part of its progress, its recess should be prevented by a Valve ; otherwise upon any Languor or Abatement in the Velocity of the circulating Humors, it would be apt to be re-forbed by the Blood-vessels, and thereby increase the resistance in the Capillaries ; and this at a time when the propelling force was already too deficient to the prejudice of most, if not, all, the Animal Secretions.

These

These seem to me to be the most probable reasons of the different Texture of these weak and thin Veins from others, but if any one shall assign others more probable and substantial, I shall readily give my assent to them. For I seek Truth only, and shall be glad to meet with it from whatever Quarter it may come.

Nor is this less remarkable in the Secretion of the Bile, tho' performed by a Vein: Nature in this case having not only endued the Vena porta with an extraordinary Coat upon its entrance into the Liver, where the great Business of Secretion was to be performed, as Anatomists very well know; but has also given it a greater degree of Strength than any other Vein in the Body (*a*), which is a mat-

(*a*) § 3, 4, 7. EXP. XLI. § 5, 6. EXP. XLIV.
§ 7, 8. EXP. XLVI.

ter not so much as suspected by the most accurate. Thus we find by Experiment, that the Vena porta is not only much stronger than the Vena cava, but even superior to the Aorta, tho' the Coat of this Vessel vastly surpasses in bulk, that of the Vena porta acting on an equal quantity of Fluid (*a*) ; which remarkable Strength in this particular Vein, in different Animals of different Species, above the rest, cannot be supposed casual and accidental, but must be designed by the wise Author of Nature for some very remarkable End and Purpose ; but as nothing is here performed, except the Secretion of the Bile, a Liquor indeed absolutely necessary to the Life of the Animal, it is evident, that this superior degree of strength must be allotted for that

(*a*) § 5. EXP. XLVII. purpose.

purpose. And indeed if we consider the great quantity and variety of Humors, which were here to be collected, in order to form the Biliary Juice, and all these necessarily to be mixed and perfectly blended together by the joint force of the Muscles of the Thorax, Diaphragm, and Abdomen, and after that propelled with a sufficient degree of force for separating so viscous a Liquor as the Bile, it will at first sight appear evident, that a greater strength was necessary in this Vein, than in such, whose sole office consists in returning the Blood back to the Heart, where the pressure of the contained Fluid without any force *ab extra* was to be regarded.

Besides if we consider this Vein as destitute of Valves, which it could not be supplied with in regard to its use, which was perfectly to blend and

mix together the Juices derived into it, ~~whether~~ brought from above, or below, we must own a superior degree of Strength was necessary on this, as well as the forementioned account. For Valves by dividing the Vein, as it were, into so many Cells, do not only strengthen the Coats of the Vessels in such Parts, as they are placed, but by diminishing the agitation of the contained Fluid, render its Impulses against the sides of the Vessels less capable of distending them beyond their proper Dimensions, by the repeated strokes of the Muscles serving to this purpose. And consequently as on the first of these accounts they would have been improperly placed in this Vein, by preventing the equable mixture of the Juices discharged into it, so on the latter, a superior degree of Strength was necessary, in order to enable

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enable it to perform its destined office, without that assistance which is frequently allowed to other Veins. So exactly nice is the Balance of the all-wise Creator, that every part of this so complicated Machine is provided with the most apt degree of Strength imaginable, for performing the office allotted to it.

Now, if after the separation of the Biliary Juice, we examine the structure of the Vessel designed for reconveying the Blood back to the Heart, we shall find it not a small Vein, but a vast Sinus extended near the whole length of the upper-side of the Liver, its Diameter being considerably larger here, than either before it enter, or after it has left this Bowel. Now it is evident from Hydraulics, that the resistance in Fluids is, *cæteris paribus*, as the altitude of the incumbent Column,

lumen, by which it is conveyed to its Reservoir, but never increases according to the wideness of the latter, how broad soever it be supposed; and consequently this large Sinus, was not only the most proper imaginable, to receive so great a quantity of Blood, as must be returned from this Viscus, but must also give the least resistance and impediment to the Secretory Vessels. For the quantity to be returned being in this case very great, and requiring a constant agitation of its parts, to preserve its Fluidity, and prevent its growing Grumous, both these intentions could in no wise have been answered, had it returned by so weak and lax a Vessel as either the Emulgent or Splenic Vein, which must soon have yielded to this superior weight, but are here sufficiently provided for by the strength of its Coats, whilst the resistance to the

the Secretory Organs is in a great measure taken off not only by the small weight of the superincumbent Fluid, but by the capaciousness of the returning Vessel, which can scarce be ever so distended by the remaining Blood, as to give any considerable resistance to it, especially if it be considered, how large a quantity of Blood is derived from this Vein into the Heart at every Diastole.

§ 7. Hence by the bye appears the reason, why in many diseases of the Abdomen, where the Obstructions in the Glands are recent, and the Vessels tolerably strong, the frequent concussions, and alternate contraction and relaxation of the Abdominal Muscles necessarily attendant on exercise, especially on horseback, should be of such singular service in the cure of diseases of these Vessels; while in the contrary

contrary state, where they are much weakened by distention, the Glands Schirrous, and the Obstructions inveterate, their same degree and kind of motion shall occasion their rupture, bring on an incurable Ascites, and apparently hasten the Death of the Sick: As also why strong and frequent Vomits, violent Cathartics, and the like too forcible medicines should in such cases produce the same effect.

EXPERIMENT XLVIII.

§ 1. The different nature of the CrySTALLINE, Vitreous, and Aqueous Humors, together with a strict inquiry into the Anatomical Structure of the Eye, more especially of the Ciliary Processes and Capsula inclosing the CrySTALLINE, and the Experiments made by Sir *Isaac Newton* on the Properties of Light, induced me to draw up some
Conclu-

Conclusions with regard to the Theory of Vision, which appearing to me, more satisfactory, than what I had met with in the writers on that subject, I designed to have added in this place. But finding myself preceeded herein by an eminent Pen of a very late Date, I shall refer my Reader thither (a), where he will meet with the Nature of Vision deduced from Principles concurring with those I intended to have subjoined, and confine myself to such Remarks and Experiments, as are left untouched by that learned Gentleman, and may be of some use in further illustrating this difficult point.

§ 2. The weight of both the Crystalline Humors taken fresh from the

(a) Dr. Jurin's Essay on distinct and indistinct Vision, published at the End of Dr. Smith's System of Optics.

Eyes

Eyes of an Ox, and carefully freed from the Capsula: they were included in, was in Air equal to 2 pennyweights, 20 grains, 40 mites. The same counterpoised in Water 6 grains, 56 mites.

§ 3. But as this substance is very far from possessing the same degree of Firmness throughout, but manifestly much stiffer and more resisting in its middle parts, than elsewhere; I pared off from two other Crystallines, taken fresh from an Animal of the same Species, their external glutinous substance, till this greater degree of Firmness appeared, the remainder weighed in Air 1 pennyweight, 2 grains, 2 mites, and in Water 3 grains, 36 mites.

§ 4. I found the weight of the Capsula including these Humors to be in Air equal to 0 grain, 90 mites, and in Water they counterpoised 4 mites.

§ 5. Hence it is evident, that the Specific Gravity of the Crystalline Humors in § 2. was to Water, in the proportion of 6840 to 6184, that is, as 1106 to 1000 nearly.

§ 6. Hence also it is evident, that the Specific Gravity of the Crystallines in § 3. was to Water, in the proportion of 2602 to 2266, that is, nearly in the proportion of 1148 to 1000; and consequently the Density of these Crystallines, whose outside was pared off, exceeded that of those which were entire in § 2. in the proportion of 271 to 26 nearly.

§ 7. It appears from § 4. that the Capsulae of the Crystalline Humors were to Water with relation to their Specific Gravities, in the ratio of 1046 to 1000 nearly. Hence by comparing the Specific Gravity of these Capsulae with that of the Crystallines in § 5, and

and 6, it is evident, that they are exceeded in Density by the latter, in nearly the proportion of 1057, 1097 to 1000 respectively.

§ 8. That Objects placed before the Eye at different Distances might be seen sufficiently distinct, there were two things absolutely necessary ; *First*, that the Lens thro' which the Rays were to pass, should change its Figure in proportion to that Distance. *Secondly*, that the Rays should undergo a considerable degree of Refraction. How well the Architect of this noble Organ has provided in the first of these respects, I have no occasion to mention, after what Dr. *Jurin* has observed upon this Head. And how far Vision is rendered more perfect as to the second particular, we may gather from the preceeding Experiment, in which the superior Density of the Crystalline

Cryſtalline above that of its Capſula or the Aqueous Humor is clearly ſhewn. For, ſince from the nature of Light, the Refractive Powers of different Mediums, are, *cæteris paribus*, proportional to their Denſities, and the direction of this Refractive Force in any Medium acting upon them, is every-where perpendicular to the Refracting Surface, it is evident, that the Particles of Light will be accelerated or retarded, in the ſame perpendicular direction, according as the power of the Medium conſpires with, or againſt the courſe of their motion, and conſequently had the Rays of Light been tranſmitted thro' Mediums of no greater a Denſity, than that of either the above-mentioned, *viz.* the Capſula or Aqueous Humor, the Incurvation of the Rays flowing from every point of an object in their paſſage

R ſage

face thro' such Mediums, would have been equally insufficient for procuring their union, or distinct representation within a proper compass of the Retina, as if they had fallen upon it with a great degree of Divergency; whence instead of obtaining, as by the present Mechanism, the most perfect view, the situation of the object will allow, the Animal could be sensible of nothing besides a glimmering Light attended with the utmost Irregularity and Confusion.

§ 9. The Density of Glass has generally been assumed by the writers in Optics for that of the Crystalline Humour. Now the Specific Gravity of Glass is to that of Water, as 2.58 to 1, and from § 4. of the present Experiment, it appears, that the Density of the Crystalline, when compared with the same Fluid, was nearly as 1.106 to 1. Hence
Glass

Glas was not only an improper substitute on account of too great a disproportion between the Densities of these Mediums, but still more unfit to supply the place of this Humor, when we consider it with regard to the nature of Light, and the laws observed by it in its passage thro' various refracting Mediums. For the Specific Gravity of the Crystalline, being nearly a mean between that of Glas and Water, renders it much more adapted to these Laws, and the representing the Images of exterior Radiants upon the Retina, brighter and more distinct than Glas itself can; inasmuch as this has been demonstrated by Sir *Isaac Newton*, too dense to make the Angle of Refraction a *maximum*, and Water by its levity refracts as much too little to effect it.

§ 10. Hence also appears the reason, why the Crystalline Humor is not of an uniform Density and Consistence thro' all its parts, but grows sensibly less and less compact, as you recede from the Centre towards the Circumference, insomuch that as the accurate Anatomist *Morgagni* has assured us, and indeed any one from his own observation on the Crystallines of Men and other Animals may be convinced, the substance immediately under its Tunic is of so liquid a nature, as to flow out upon making the least incision into it. For had its Texture been otherwise, or of an equal Density and Firmness with that, we find in § 6. it has acquired at the Centre, it is evident, that every Contraction and Dilatation of the *Ligamenta Ciliaria* must produce the like effect in the Capsula of the Crystalline
line

line Humor; had therefore the action of these muscular Fibres been able to alter its figure at all, they must have caused an irregular and uneven Superficies in a substance so firm and resisting, as that at the Nucleus of this Lens appears to be, and consequently been destructive of that Vision, for which this part was originally designed. But this is intirely prevented by their acting upon a substance of so fluid a nature, and whose Particles are so loosely connected together, as readily to conform to the proper Curvature, when pressed with the least force one way more than another.

EXPERIMENT XLIX.

§ 1. Having first poised a Vial with a narrow neck very exactly in the Scales, I filled it with Water, and found the weight of the Fluid to be

R 3 1 ounce,

1 ounce, 0 pennyweight, 15 grains, 90 mites. Then having perfectly cleared the Vial from the Water, I found the weight of an equal quantity of the Vitreous Humor of an Ox's Eye to counterpoise 1 ounce, 0 pennyweight, 16 grains, 8 mites.

§ 2. Hence it appears, that the Specific Gravity of the Vitreous Humor was to Water, in the proportion of 49608 to 49490, that is, nearly as 10024 to 10000.

§ 3. Hence comparing the Specific Gravity of the Vitreous Humor with that of the Crystalline in § 5. *EXPERIMENT XLVIII*, it is evident, that the Density of the latter Medium is superior to that of the other, in the proportion of 338511600 to 306775872, that is, in the ratio of nearly 10 to 9.

§ 4. Having by this and the foregoing Experiment found the Specific Gravities

Gravities of the several Humors of the Eye with respect to Water, we may hence be enabled to discover, what are the real Refractive Powers of these Mediums, and consequently what is the proportion, which the respective Sines of the Angles of Incidence and Refraction out of each into the other, must bear amongst themselves, whatever be the Inclination of the incident Ray. For, since by comparing the Densities of several Mediums of similar component Parts with the respective Sines of the Angles of Incidence and Refraction, Sir *Isaac Newton* found, that not only the Powers of those Mediums in refracting the Rays of Light were nearly proportional to their Densities, but that the same held true without any sensible Difference, in substances distinguished from each other with

R 4

respect

respect to their Specific Gravities, in the proportion of 4400 to 1; it is evident, that the Sine of the Angle of Incidence out of Air into the Aqueous Humor or Water being to the Sine of Refraction as 4 to 3, and the Specific Gravity of the CrySTALLINE Humor to the same Medium being by § 5. Exp. XLVIII, as 6840 to 6184, consequently the Sine of Incidence will be to that of Refraction, out of Air into the CrySTALLINE, as 14 to 10, or 7 to 5 very nearly. Now the proportion of the Sine of Incidence to the Sine of Refraction in Rays of the same denomination, passing from one Medium to another, is compounded of the proportion of the Sine of Incidence to the Sine of Refraction out of the first Medium into any third, and of the proportion of the Sine of Incidence to the Sine of Refraction, out of
of

of that Medium into the second, consequently by a reciprocal Multiplication of the foregoing Sines, it will be found, that the Sine of Incidence is to the Sine of Refraction out of the Aqueous Humor into the Crystalline, in the proportion of 21 to 20 very nearly.

§ 5. No one, that is versed in Anatomy, will I imagine deny, that the Crystalline Humor, together with its Capsula, may be considered as a variable Lens, being so lodged between the Aqueous and Vitreous, as by means of the Ciliary Processes, to have its Spheroidical Figure considerably changed. Tho' this Alteration of the Crystalline from a Lenticular to a more Globous Form and the contrary, serves to many excellent Uses, yet as all Refractions to a Focus absolutely require the Mediums from
and

and into which the Rays are to be refracted by the Lens, to be of a different Density from itself, so the preceding Experiments both demonstrate this Truth, and the great Advantages which must accrue to Vision from a Situation of the refracting Mediums, so remarkable in the Formation of the Eye. The Density of the Vitreous as it appears to be far inferior to the CrySTALLINE, so is it very little superior to the Aqueous, yet both of them far exceeding the Density of common Air. Hence Homogeneous Rays are not only made to converge much sooner and more accurately to a Focus, but as Sir *Isaac Newton* has demonstrated, the Refraction of Heterogeneous Rays, proceeding in the same Line of Direction to a denser Medium, is greatly augmented or diminished by the Rarity of that, from whence

whence they are transmitted, therefore as the Specific Gravity of the external Air to either the Aqueous or the Vitreous Humor is nearly in the reciprocal proportion of 850 to 1, this great disproportion must not only cause a much stronger Refraction of the Rays upon the Retina, but joined with some other properties of those Humors very much contribute to the Certainty and Equality of Vision. For these Mediums not being at any time subject to vary in their Densities, or Refractive Powers, and almost, if not altogether incompressible, the Rays thus transmitted will undergo the most equable Refraction, whereas had the Retina been situated in a Medium liable to great Alterations, or the same Changes with common Air, the Refractions so made, must have been generally irregular and unequal, and

con-

consequently Vision rendered very uncertain and precarious.

EXPERIMENT L.

§ 1. By Experiment XLVIII, the Specific Gravity of the Capsula of the Crystalline Humor in an Ox's Eye, with respect to Water, was found to be in the proportion of 1046 to 1000. Now by the Specific Gravity of the Cornea to the same Fluid, taken at a Medium from several Trials, the difference between the Cornea and the Capsula in point of Density could not exceed the $\frac{1}{1221}$ Part. I therefore fixed each of them to the Condenser, and found that the pressure required to burst the Capsula was equal to 1.08 Atmospheres, and the Cornea bore the pressure of 7.7 Atmospheres, without breaking, but not without suffering

ing such a Stream of Air to pass thro' its Pores, as prevented its Rupture.

§ 2. Now the Arch of the Cornea from one Canthus of the Eye to the other, was equal in length to 5.28 upon the small diagonal Scale divided into $\frac{1}{4}$ Inches, and the length of the other Arch intersecting it across the Vertex, was equal to 4.16 in Parts of the same denomination. Hence reducing these Quantities into Inches, and the Decimal Parts of an Inch, and calling them respectively by the literal Characters c and t ; this Surface of the Cornea may be considered as an Elliptical Area equal to that of a Circle, having its Diameter $=\sqrt{ct}$, whence putting its Periphery equal to p , the Area of the Cornea will be equal to $\frac{p\sqrt{ct}}{4}$, equal as appears from Computation to so many Parts of a square Inch, as correspond to the

the Tabular Logarithm 0.0326981.

Hence the weight incumbent on this Area from the pressure of 7.7 Atmospheres, will be found equivalent to so many ounces troy, as correspond to the Logarithm 3.2498785, that is, to 148 pounds, 1 ounce, 15 pennyweights, 14 grains.

§ 3. The Capsula of the Crystalline Humor broke with the pressure of 1.08 Atmospheres, hence it is evident, that had its Area been equal to the Cornea, the weight incumbent on it, at the time of its breaking, would have been equal to 20 pounds, 9 ounces, 7 pennyweights, 2 grains; and consequently the strength of the Cornea was superior to a portion of the same Area of the Capsula, in the proportion of 7129 to 1000 nearly.

§ 4. Hence we may observe, that altho' the Cornea so far surpasses the
Capsula

Capula of the Crystalline in point of strength, yet the Densities and Refractive Powers of those Membranes are very nearly equal, as are also those of the Humors immediately surrounding the Crystalline, consequently the Rays of Light in their passage thro' these Membranes will at the most receive no other variation in their first direction, than what they would have acquired by being transmitted thro' a Medium of the same Curvature as at present, and of equal Density with the Vitreous, which exhibits to our View a wise Contrivance for the Security of the whole Organ by this great strength of the Cornea, and that by a Substance highly conducing to distinct Vision the principal Design of the Eye itself.

EXPER-

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EXPERIMENT LI.

§ 1. The Cornea of an Ox's Eye, whose strength we found in the preceeding Experiment, was equal in thickness to $\frac{1}{25}$ of an Inch. The Capsula of the CrySTALLINE Humor was $\frac{1}{488}$, and the Retina of the same Eye was $\frac{1}{1171}$ of an Inch in thickness.

§ 2. Hence it is evident that as the Cornea by § 3. of the preceeding Experiment was superior in strength to the Capsula of the CrySTALLINE Humor in the proportion of 7129 to 1000, so was it likewise in respect of thickness, in the proportion of 188 to 10 nearly.

§ 3. Hence also it appears, that the Retina was so exceedingly thin, as to be exceeded in thickness by the Capsula, and the Cornea, in the proportion of nearly 24 and 508 to 10 respectively.

§ 4-

§ 4. That a Membrane of greater Substance, or less Tenderness than the Retina, could not have answered the End so well, we may easily infer from hence, *viz.* that the Particles of Light being extremely minute, and thence acting with a very small Impulse, it was absolutely necessary, that the Membrane, on which they impinge, should by its Fineness and the Delicacy of its Structure, be susceptible of different Vibrations according to the various Degrees of their Action, and consequently be extremely thin and tender; otherwise no Sensation could have been produced, much less could any Comparison between the Sensations been distinguished, all our Ideas acquired by Sight depending upon the Comparison, which the Mind forms from the different Impulses of the Rays

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upon

upon the Retina, and not from any Reflection drawn from the Picture painted upon it. For that all the Knowledge of external Objects, and their mutual Relations cannot be conveyed to the Mind by the Assistance of this Organ, any other way, but by that above-mentioned, is evident from this Consideration, *viz.* that there is no Connexion between our Idea of the Magnitude of the Object, and its Picture upon the Retina. Since was there any such Agreement, how comes it to pass, that in looking at an Object from the distance of 14 Feet down to that of 5 Inches, we still judge it of the same size, tho' it is demonstrable, that the Angle formed in the Eye at several Positions of the Body viewed within this Compass, must be double, treble, quadruple, &c. of what it was at the first distance

distance of 14 Feet? So far is the Mind from forming a true Judgment of Body, and all the various Modes and Accidents it appears under, by what it receives from Vision, that, without any Injury to Truth, I may safely venture to affirm, had Man enjoyed only this single Sense of Sight, and been left destitute of all the rest, it would have been absolutely impossible for him to have gained the Knowledge of the real Length, Breadth, Thickness, Solidity, Magnitude and Distance of such Objects, as should present themselves to his View. For to form a right Judgment of most of the foregoing Particulars, actual Feeling must concur with the Sight, and Experience join with it in them all.

§ 5. Since the Impulse of an exceeding fine Pencil of Rays, whose varicoloured Particles strike the Retina

in a particular manner and direction, is, as we have shewn in the foregoing Section, the true efficient Cause of Vision; we may hence perceive how far Optical writers have been mistaken in this Point, when they ascribe all our Knowledge of the Distance, Place, Magnitude, and Situation of Objects to a Reflection drawn by the Mind from the Geometry of the Lines and Angles formed by the refracted Rays upon this Membrane. For that it cannot possibly depend upon these, is demonstrable from the Structure of the Eye itself with respect to the manner of its discerning Objects, when brought from an obscure into a bright and dazzling Light. In this case, the Pupil of the Eye is almost instantaneously contracted, and till this is done in a sufficient manner, neither the Distance,
Situation.

Situation or Magnitude of the Object can be at all discovered, as is abundantly confirmed by Experience. Now nothing is hereby altered with respect to the Lines and Angles drawn upon the Retina ; but the Quantity of Rays, which would otherwise illuminate each Physical point of it, are very much so, being diminished by the Contraction of the Uvea, in such a Proportion, as is necessary to give that Vibration to its Fibres, which is proper for a distinct Representation of the Object without either Confusion or Sense of Uneasiness to the Animal, either of which would have rendered the Design of the whole Structure ineffectual.

§ 6. Having in the foregoing Sections examined into the Structure of the Retina with respect to its Substance, and shewn, how necessary its extraordinary

Thinness was to Vision, and the forming thence a true Judgment of external Objects; I cannot finish these Remarks without taking notice of another Particular relating to it, *viz.* the Concave Spheroidical Figure of this Membrane. This is a Circumstance little regarded indeed by those who have wrote on this Organ, out of an Opinion, that this Figure was merely accidental, in conformity to the Sphericity of the Eye itself, and not the Effect of Skill and Design. But that the Figure best suited to answer the Purpose of the wise Architect, by allowing the most distinct and perfect Representation possible of any Object, should be the Effect only of Chance and Accident, seems too hasty a Conclusion, with regard to the exquisite Art and Contrivance, used in the Formation of this wonderful

derful Machine. For allowing the Globular Form of the Eye to be undoubtedly the best, and given it for its ready Motion in all Directions, this is no Reason, why the Expansion of the Optic Nerve might not have been formed into a Membrane extended within this Orb, after the same manner as the Tympanum is in the Ear, had the Rays of Light naturally fallen with equal or greater Advantage on a flat Superficies. But so opposite would such a Structure of the Retina have been to the due Reception of the Rays of Light, that had it been formed into any other Figure, besides the present, that alone would have rendered the Action of all the other Parts of this Organ very often confused, and always imperfect.

For let the circular Arch *AVD*
 FIG. I. represent the posterior Surface of the
 Capsula of the Crystalline Humor, *C*
 its Centre, *F* that Point in the Axis
CV prolonged, to which all such
 Rays of an external Radiant are re-
 fracted as fell infinitely near the Per-
 pendicular one at the Vertex of the
 Cornea after their Passage thro' this
 Membrane, the Aqueous Humor and
 the anterior Surface of the Crystalline,
 and from which they may be again
 considered as proceeding towards the
 posterior Surface of the same Medium
 in innumerable Directions. Suppose
 one of these Rays to impinge on the
 Curve Surface *AVD* in the Direction
FI near the Vertex *V*, then from the
 Point *I* let fall the Perpendicular *OI*
 upon the Axis *VC*, intersecting it in
O, and joining the Points *I* and *C*,
 the Line *IC* will, from the Contraction
 of

of the Evoluta of the Circular Arch AVD into one Point C , be a Ray of the Evoluta. Hence calling the known Quantities $VC=a$, $FV=g$, the unknown, OI the Semiordinate $=y$, the Absciss $Vo=x$, and the Focal distance from the Vertex $V=f$, we shall by the Method of Fluxions obtain the Fluxion of the Incident Ray equal to $\frac{yy+gx+xx}{\sqrt{yy+gg+2gx+xx}}$, and the Fluxion of the Refracted Ray equal to $\frac{yy-fx+xx}{\sqrt{yy+ff-2fx+xx}}$. But it is demonstrable from the Doctrine of Caustics, that the Fluxion of the Incident Ray is to the Fluxion of the Refracted Ray, as the Sine of the Angle of Incidence is to the Sine of the Angle of Refraction, and by § 4. EXP. XLIX, when the Rays of Light pass from the Crystalline Humor into the Vitreous,

treous, it appears, that the Sine of the Angle of Incidence was to the Sine of the Angle of Refraction as 20 to 21, or as s to r , therefore

$$\frac{yy+gx+xx}{\sqrt{yy+gg+2gx+x^2}} : \frac{fx-yy-xx}{\sqrt{yy+ff-2fx+xx}} :: s : r.$$

Now the Equation of the Curve being $yy=2ax-xx$, yy will be equal to $ax-xx$, and consequently by equal Substitution, we shall have

$$\frac{gx+ax}{\sqrt{2ax+2gx+gg}} : \frac{fx-ax}{\sqrt{2ax+ff-2fx}} :: s : r;$$

whence multiplying the Terms of this Analogy for an Equation and dividing by the Fluxionary Quantity x , it will be reduced to

$$\frac{sf-sa}{\sqrt{2ax-2fx+ff}} = \frac{rg+ra}{\sqrt{2ax+2gx+gg}}. \quad \text{But}$$

since by the Supposition, the Focus here sought is that, which is made by the Coincidence of such Rays as fall near the Vertex V , let the Quantity

tity x be supposed to vanish, and then the Equation will in that case become

$$\frac{sf - sa}{\sqrt{ff}} = \frac{rg + ra}{\sqrt{gg}}; \text{ and consequently after}$$

due Reduction the Value of the sought Quantity f will be found equal to $\frac{asg}{sg - rg - ra}$. Draw now thro' the

Points V and C (the Vertex and Centre of the refracting Curve) the indefinite right Lines VE , CG , parallel to each other, and perpendicular to the Axis VC ; and from the Focus F draw the right Line FB , intersecting the Tangent VE in B , and the Radius produced in G . In CG produced take $C\gamma$ to CG , as the Sine of the refracted Angle is to the Sine of the Angle of Incidence, that is, as r to s , then from γ thro' the Point B draw the right Line γf , meeting with the Axis CV produced in the Point f , join the Points G and f , and thro'

thro' the Point B draw Bd parallel to Gf . Now from the foregoing Construction it appears, that $CG:Ve$
 $\left(\frac{sg-ar-srg}{ar+rg}\right):Ve\left(\frac{sg}{ar+rg}\right)::fC-$
 $fV(a):fV=\frac{asg}{sg-rg-ra}$, which being equal to the Value of fV found above, it is manifest, that the Rays of Light diverging from the luminous Point F , and impinging near the Vertex V of the Curve Surface AVD , are after their Refraction by the Vitreous Humor collected in the Focus f . Let now HT be a Tangent to the Curve in the Point H , FH an Incident Ray, and Hf the Refracted one as found above. Suppose Fb another of the Incident Rays diverging from F , and impinging on the Refracting Curve AVD in the Point b , in the Direction Fb infinitely near to the former Ray FH . Draw HL and HP

HP perpendicular, and LT and TP parallel to FH and fH respectively, intersecting the Axis FC , and the Tangent HT , in the Points L and T , and from the Centre C thro' the Point of Concurrence P draw the Line PC , and produce it till it meets with the Refracted Ray fH in the Point ϕ . Lastly, produce Fb till it meets with HL in the Point R , and from the Point b of the Curve to the Point ϕ , draw $b\phi$, and from the Centre C , let fall upon FH and Hf the Perpendiculars CQ , CS , intersecting Fb and $b\phi$ in the Points q and s . Now because the Points H and b are supposed infinitely near each other, it is evident, that the infinitely small Arch Hb may be esteemed as a strait Line, coinciding with the Tangent HT , and the Triangles HRb HLT , and Htb HPT as similar; whence

we

we have $CQ : CS :: qC : rC$. But by the Property of Refraction CQ is to CS as s is to r , therefore qC must also bear the same Proportion to rC , as the Sine of the Angle of Incidence does to the Sine of the Angle of Refraction. Now the Difference of the Lines Cq and Cs from real Perpendiculars let fall from the Centre C upon the Lines Fb and $h\phi$, is infinitely small, therefore they may with sufficient Accuracy be substituted for the true; and consequently the Course of all such Rays as Fb , which lay in the Plane of the Triangle FHf , will meet in the Point ϕ . But it was shewn above, that all those Rays which are situated in the Conical Surfaces generated by the Revolution of the Triangle FHf about the Side Ff , are collected in the Point f , therefore it is manifest, that the greatest

greatest Quantity of Rays will naturally after their Refraction thro' the Vitreous Humor fall upon that Part of the Diacaustic Curve, which lies between the Points f and ϕ , for instance near the middle at the Point c . Now it is evident, that what we have here demonstrated of Rays issuing from the luminous Point F given in any Image formed by the Union of the Refracted Rays, which are transmitted from every Point of an external Radiant thro' the Aqueous and anterior Surface of the Crystalline Humors, is equally true of any other Point in the same Image under the like Restrictions; therefore by comparing the Figure of the Refracting Surface AVD with the Proportion, which the Sines of the Angles of Incidence and Refraction must always bear to each other, as given above,
it

it necessarily follows, that the whole radiant Surface will after the complete Refraction of its Rays thro' all the Humors of the Eye be then represented in the most lively and effectual manner, when its Image is delineated on a Curvilinear Surface Concave towards the exterior Portion of the Capsula of the CrySTALLINE Humor, and passing thro' the extreme Point of the Axis of the Vitreous.

§ 7. Hence we may plainly perceive, how far the natural Eye exceeds the artificial one, as some Authors have named the *Camera obscura*, even in the manner, in which the Images of their respective Radiants are received. For since in the latter Machine, the common Basis of the Rays after their Refraction is a Plain Surface, it is manifest, that the Representation of the Object upon it, must

must suffer in these three respects.

First, The Image must be imperfect, inasmuch as it is demonstrated in the foregoing Section, that only one Cone of Rays out of all that vast Number, which continually flow from the Object, can be exactly terminated in that Plane, all the rest either falling short, or naturally exceeding the Bounds fixed for their Reception. *Secondly*, The natural Divergency of the Rays being greater, than if they were received on a proper Curve, the Picture formed by them will be more indistinct; and *Thirdly*, from both the former Causes, its Light or Brightness will be much diminished. Now these Defects are only such, as attend the Representation of an Object on a Plane, where the Distance, Situation, and Magnitude of the one are adapted to the Position of the other, in

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the best manner possible. But how small and faint a Resemblance does such a limited Instance, as the foregoing, bear to that immense Variety, which daily present themselves before the Organ of Vision ! For here, tho' the Rays which impinge on the Retina, flow almost every Moment from Objects infinitely distinguished from each other in all the foregoing particulars, as well as many other respects, yet are they received upon it with such Order and Exactness, by falling on the proper Curve, that the Images thence formed appear not only accurately true, (as far as the nature of Refracted Light will admit) when brought under the strictest Examination of Reason and Geometry (*a*) ; but give in Fact, the strongest Proofs of a surprising Regularity and Distinct-

(*a*) See § 6. foregoing.

nels,

ness, by affording the Animal that clear and ready Perception of all those singular Differences and innumerable Relations, either naturally essential to, or accidentally belonging that Multiplicity of Objects, they here respectively represent. Whereas on the contrary, had the Expansion of the Optic Nerve been formed into a Membrane of a flat Superficies, and this substituted instead of its present Concave Spheroidical Figure, so far would the Rays flowing from a like numberless Series of external Radiants be from forming upon this supposed Plane, a Representation of equal Beauty and Uniformity with the preceeding, or that delineated on the Curvilinear Surface of the Retina, that it is evident from the foregoing Section, the principal Foci could not so much as once have been collected in their true and proper Place,

and consequently the Impulse of the Rays being thus rendered irregular and uncertain, most of the Ideas, which the Animal could have acquired by the Use of this Organ, must have been so indistinct, confused, and imperfect, as instead of conducing both to its Safety and Convenience, very frequently be the means of leading it into Error, and sometimes perhaps to its Destruction.

EXPERIMENT LII.

§ I. The Resistance, which arises solely from the Cohesion and Tenuity of the Particles of any Fluid, being as the time, the Body takes up in passing thro' ; it is evident, that if a given Ball be supposed to fall from Rest in two Fluids of equal Densities, but unequal Viscidities, the Times of its descent thro' those Fluids compared together,

together, will give the Degree of Resistance, which is occasion'd by the adhering Particles of one Fluid above those in the other. Now it is evident from EXP. XLIX. that the Vitreous Humor with respect to its Specific Gravity differs very little from common Water, but is apparently more glutinous and viscid. Hence tho' the greater Loss of Motion, which a heavy Body would undergo in surmounting the Resistance of this Humor from the mere Tenacity of its Particles, above what it would in Water, might be found by its Descent in each, was its Fall continued to a considerable length, yet as that is impracticable, I shall endeavour to ascertain it in the following manner.

§ 2. A piece of Lead, which weighed in Air 3 pennyweights, 0 grain, 27 mites, counterpoised in Water 2

T 3 penny-

pennyweights, 17 grains, 90 mites ; then taking the pure Vitreous Humor from an Ox's Eye with as little Agitation as possible, I immersed it into this, and found the Weight which kept it in *Æquilibrium* to be 2 pennyweights, 17 grains, 21 mites.

§ 3. Hence we may observe that the Cohesion of the Vitreous Humor of an Ox's Eye is such, that the Weight lost by a heavy Body as Lead upon its Immersion into it, above what it would lose in Water, surpasses the Weight of what it ought to lose in this Fluid, above what it does in Water, on account merely of the superior Specific Gravity of this Humor, in a Proportion greater than that of 45 to 1; and consequently the Specific Gravities of Bodies equal in Bulk being to one another in the same Ratio with their absolute Weights, it is manifest

manifest from the Comparifon of this and the preceeding Section with § 2. EXP. XLIX, that the Cohesion of this Humor will diminish the Weight of any heavy Body immerfed in it, or promote its Suspension therein, juft as much as if its Specific Gravity with refpect to Water, had been increased almoft $\frac{1}{3}$ of what it at prefent is, in its natural ftate.

§ 4. That fo great a Degree of Cohesion as the Vitreous Humor is poffeffed of, above what is allotted to the Particles of Water, cannot be given it with any Defign to retard the Motion of Light in its Paffage thro' this Medium, feems obvious from the Nature and Intent of Vifion; and that the Rays do not meet with any Obstruction on this Account, is demonftrable from the Path which they defcribe by the Refraction of this Humor, as has been already fhewn at

§ 6. EXP. LI. But why a more perfect Fluid, of equal Density and Refractive Power with the Vitreous Humor, might not have been substituted in its Place, is a Question not easily resolved. To me the most probable Reasons for this Mechanism seem to be these. *First*, That had the Vitreous been less Viscous, the Crystalline could not have remained in the same Position, and with the same Steadiness as at present. For either the Specific Gravity of this Fluid must have been considerably augmented, which we have already shewn at § 5. EXP. XLIX. inconsistent with Vision; or the *Ligamentum Ciliare* must have been formed with a much greater Degree of Strength. But this Increase of Strength in these Fibres would have been attended with an Inconvenience equally destructive to Vision with the former. For upon every

every Contraction of the Longitudinal Fibres of this Muscle, the Capsula of the CrySTALLINE would indeed have been drawn outwards, but then the Cornea must have been drawn inwards, the consequence of which Action would have been this, that whilst one was fitting the Organ for the View of near Objects, the other was putting it in a State for seeing such as lay at a remote Distance. Whereas by thus increasing the Tenuity of the Vitreous Humor without augmenting its Density, the Refraction of the Rays of Light is preserved equable and undisturbed, and the *Ligamenta Ciliaria* have strength sufficient to extend so thin and tender a Membrane as the Capsula of the CrySTALLINE, without being capable of exerting any Force that can possibly at the same time contract so strong and thick a Tunic as the Cornea, into which these Fibres are likewise inserted.

This

This Viscosity of the Vitreous Humor seems also necessary for preventing that intestine Motion of its Particles, which upon the Motion and Changes thereby made in the Eye, must have been consequent to so thin a Fluid as Water, or the Aqueous Humor, and consequently whatever Direction the Rays of Light have acquired by their Refractions in the Crystalline, that must be preserved without the least Alteration of their Course by any Agitation this Fluid can be exposed to from the ordinary Motions of the Animal, till they impinge on the Retina with that Order, which is necessary to distinct Vision.

EXPERIMENT LIII.

§ I. In order to take the Dimensions of the Eye of an Ox, I placed it on a Horizontal Board, and applied
three

three moveable Silk Threads, which were kept extended by small Plum-mets, so as to be exact Tangents to the Arch of the Cornea, as well at each Canthus, as at the Vertex, then applying a very exactly divided Scale, I found that the Chord of the Cornea was equal to 1.05 of an Inch, the versed Sine of this Chord to be 0.29, and consequently the Radius of the Cornea was equal to 0.620215 of an Inch.

§ 2. I then carefully took off the Cornea, and replaced the Eye as before, and found by applying one of the Threads as a Tangent to the Vertex of the Cryftalline, that the Distance between this and the Vertex of the Cornea was 0.355 of an Inch. Afterwards I took the Cryftalline out without injuring its Figure, or displacing the Capfula, and then applying the Threads

Threads to each Surface of this Humor, as was done before to the Arch of the Cornea, I found that the Chord of the CrySTALLINE was 0.74 of an Inch, and its versed Sine with respect to the anterior Surface to be 0.189 of an Inch, and consequently the Radius of this Surface was 0.45665 of the same. In like manner the versed Sine to the same Chord with respect to the posterior Surface of the CrySTALLINE I found to be equal to 0.266 of an Inch, and therefore the Radius to this Arch will be equal to 0.38845 of an Inch. Lastly, I found the Axis of the CrySTALLINE, and that of the whole Eye from the Cornea to the Retina to be 0.575. 2.21 of an Inch respectively.

§ 3. Hence it appears from the Construction that an Ox's Eye may fitly enough be represented by Figure II. in which *ACB* represents the Arch of the
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the Cornea, *ASB* the Sclerotica, joining the Cornea in *A* and *B*, *Aa Ba* the Uvea, *aa* the Aperture of the Pupil, *scs* the anterior Surface of the Capsula of the CrySTALLINE Humor, *ses* the posterior Surface of the same Lens, *eV* the Axis of the Vitreous Humor, *nd, nd* the *Ligamenta Ciliaria*, and *Rr* the Expansion of the Optic Nerve *ON*.

§ 4. As the Distance and Position of Objects before the Eye admit of all possible Variation, it is plain, that the Focal Distances of the Eye from the Cornea to the Retina, must vary with the Multitude of Objects presented to it, and consequently the Proportions laid down in the preceeding Sections are not such, as are always permanent and immutable, but are rendered so far relative by transmitting the Images of exterior Radiants, that the Eye can
scarce

scarce one Moment remain the same in Situ as before.

§ 5. Hence in all probability arose that Error so commonly met with in Optical and Anatomical writers, relating to the CrySTALLINE and Vitreous Humors, *viz.* in ascribing a frequent Change of Place to the one, and of Density to the other. For they perceiving a mutable Focus to be thus indispensably necessary, too easily concluded, it must be effected by one or both of these means. But this Solution will by no means hold good for the following Reasons : *First*, Whoever duly examines the Compact Figure and Texture of the Eye, will find himself under a Necessity of concluding, that no such Motion, as is above ascribed to the CrySTALLINE, can be performed by a Body of that Bulk, within Cavities so exactly filled, as those
those

those of the Eye are. *Secondly*, To procure, or suppose any Change in the Vitreous or Aqueous Humors from a Compression how great soever, amounts almost to an Impossibility, since the Capsula's in which they are included, are capable of an easy Contraction and Dilatation. *Thirdly*, Because by the Hypothesis these Mediums must be subject to frequent Change both of Figure and Position; and consequently their Particles would be in a perpetual undulating State. To convey therefore any distinct Image by Rays transmitted thro' Mediums of equal Density with these Humors, and liable to these Accidents, is not only demonstrable from the Nature of Light and known Laws of Refraction impossible to succeed, but is in Fact confirmed by the Experiment of the Diving Bell, in which its great Improver,

prover, the learned Dr. *Halley*, assures us, that notwithstanding he with some others enjoyed a sufficient Quantity of Light when under Water, by the help of a strong Convex Lens, fixed for the Reception of the Rays at the Head of the Machine, whilst it remained calm and serene, yet whenever by any Accident the superincumbent Fluid was disturbed, or put in Agitation, the Rays suffered so much in their Passage by such Irregular Refractions, as to throw them into Confusion and Darkness. How vague then, and indeterminate must the Focus of those Rays have been, whose Refractions were to be effected by Mediums subject to ten thousand Accidents, and I make no doubt, that, had the Eye been so constituted, upon taking a Review of the same Persons and Things, the
Scene

Scene would appear quite altered, and too often force the Spectator to complain in the Language of the Poet (a),

Mille hominum Species, & Rerum discolor Usus.

But as the Compression of the Vitreous Humor is so generally insisted on by the Writers on this Subject, tho' I was fully satisfied from the Dilatability of the containing Parts, and the small Force of the Muscles applied, that it was altogether impossible, it could be compressed into a less Space by their means, yet to put the matter beyond all Doubt, I made the following Experiment.

I put the Vitreous Humor of an Ox's Eye into a Syphon Hermetically sealed at one End, then fixing the Condenser to the other, I compressed it with all the Force I was able to give,

(a) PERS. Sat. V.

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and this without any more Effect, than if I had applied the Force to Water, which as every one knows, has not yet been found to give way to the greatest Pressure. Whether this Humor may be equally incompressible with the above-mentioned, I cannot affirm, but this I am sure of, that a hundred times the Strength of the Muscles supposed to produce this Change in it, would have no such Effect.

§ 6. Another very considerable Variation in the foregoing Dimensions, without which, Vision in many cases could not possibly be obtained, arises from the muscular Structure of the Uvea *Ba, Aa*; in consequence of which, the Aperture of the Pupil *aa* is increased or diminished, according as the Contraction is made by the strait or circular Fibres which compose
this

this Membrane. Simple and obvious as this Contrivance of changing the Orifice, through which the Rays of Light were to be transmitted to the Retina, may appear, yet has its principal Use and Design been overlooked, and a fictitious one ascribed in its stead, *viz.* the Power of altering the Projection of an Object upon the Retina, so as to change its apparent Magnitude. But this Effect is absolutely inconsistent with the Mechanism employed in the Formation of the Pupil. For the Magnitude of the Picture upon the Retina is longer, or shorter in Proportion to the Angle made by the two Rays, which proceed from the Extremities of the Object to the Eye. In every Contraction therefore of the Circular Fibres of the Uvea, the Pupil will still remain the Basis of each Cone of Rays, that can

fall upon it from every Point of the Object; consequently the narrowness of the Aperture may obstruct the Passage of part of the Sides of those Cones, and thereby render the Object more or less bright, but can never change the apparent Magnitude of a given Object, since that will still be in the reciprocal Ratio of its Distance from the Eye, as well after, as before the Contraction of the Pupil.

§ 7. Having thus proved that the apparent Dimensions of any Object are transmitted to the Sensorium with the same Accuracy and Exactness, however its Light or Brightness be increased or diminished by the different State of the Pupil; we cannot but observe under how miserable a Condition every Animal, and particularly the Human, must have laboured, had the contrary Supposition prevailed; or the

the apparent Magnitude of the Object been as the Latitude of the Pupil. For by the many unavoidable and necessary Changes in this Aperture of the Eye, all our Ideas of Things and their Relations to each other, must have become so vague and indetermined, that we ought not to wonder, if what at one time appeared to a Spectator, with all the Magnificence of a Palace, should afterwards to the same Person from no other Change, but a more contracted Pupil seem shrunk into the scanty Limits of a beggarly Cottage: The natural consequence of which would be, that finding himself thus exposed to perpetual Delusion and Uncertainty, he would often be at a loss how to proceed, and being fully satisfied, that he could place no Trust or Security in the Use of this particular Sense, would

very probably at last doubt of all the
~~rest, and thence~~ constitute some hu-
 morous Opinion, like that of the
 Poets, the ruling Principle of all his
 Actions, *viz.* that,

Πάντα γέλωι, καὶ πάντα κήνῃ, καὶ πάντα τὸ μὲν
 Πάντα γὰρ ἐξ ἀλόγων ἐστὶ τὰ γινόμενα.

§ 8. From the Structure of the Eye
 itself, the manner in which it does,
 and must act, if it answer the Ends of
 its Formation, as at large delineated
 and explained above (*a*) we are fur-
 nished with an undeniable Argument
 in Opposition to the Sentiments of
 some Philosophers who have asserted
 the Rays of Light to be equally dif-
 fused thro' the whole System of Na-
 ture, not necessarily emitted from the
 Sun, but always present in a constant
 and invariable Quantity. A Doctrine

(*a*) Compare § 5, 6, 7. EXP. LI. with § 5, 6.
 preceding.

so repugnant to the Nature of Light, the known Laws of Refraction, and the manner in which it is transmitted to the Retina, that I should not have taken any Notice of it here, had it not of late Years been strenuously espoused and defended by several excellent Writers, and in particular, by the Learned *Boerhaave*, in his Treatise of Chymistry; in which the Reader finding many noble Truths, might the more easily swallow down Error, when disguised *Specie Veri*. For if this Supposition was true, all that curious and delicate Mechanism, which we so justly admire in the Formation of the Eye, would for the two following Reasons answer no End or Purpose.

First, Since by the Hypothesis, the Rays of Light are little Corpuscles every-where floating in the vast Regions of Space; whenever we suppose

ally Parcel of them to be put in Motion, from the Cause that impels it, and its Direction be what it will, that Impulse will by the 42d Prop. Book 2d of *Newton's Princip.* be instantaneously propagated on all Sides and in all manner of Directions, and consequently the Rays of Light determined after this manner, could neither enter the Aperture of the Pupil, nor the Hole of a dark Chamber in straight Lines, as we are assured from the manner in which Vision is performed, they certainly must, and from the Use of the Prism they really do. But this Direction or spreading of the Rays of Light *quaquaversum* upon the least Impulse or Pressure, tho' it be an insuperable Difficulty, yet it is not the only Inconsistency, which attends this Hypothesis in relation to Vision. For

Secondly,

Secondly, What would be still equally destructive of it, and prevent the Projection of any Object upon the Retina, (which is placed in a much darker Situation for the due Reception of such Images, than the darkest Room contrived by human Art) is this, that the smallest Hole as well as the greatest would equally serve for the Illumination of a whole Chamber, inasmuch as a single Pencil of Rays, would, from the Nature of Pressure communicated to such Bodies, alter the Position, and put in Motion all the rest, that were in a Room tho' of the largest Size, of which we have a clear and undeniable Instance in the Propagation of Sound, corresponding very exactly to the Motion of Light, as laid down by the foregoing Hypothesis. I might shew several other Absurdities deducible

cible from this Scheme, but as they all flow from Experiments, in which Vision is not the Point in Question, but presupposed, the Relation of them would be foreign to my present Purpose.

EXPERIMENT LIV.

§ 1. Having placed the Eye of an Ox as in EXP. LIII. beneath a fine Silk-Thread $\frac{1}{10}$ of an Inch distant from the Vertex of the Cornea, I fixed others on the lower Edge of the same Tunic, so as to embrace it as a Sphincter. Hence I found by hanging on Plum-mets, that to raise the Vertex of the Cornea, till it became a Tangent to the forementioned Thread, the Weight required must be equal to 3 ounces, 2 pennyweights, 9 grains.

§ 2. This Force in the Eye of an Ox must therefore be exerted by the muscular

muscular Ring of the Uvea, in case it answered the End proposed by Dr. *Jurin* (a); but whether it be capable of exerting such a Force with the greatest Facility, as it must do, if it be supposed the Cause of this Alteration in the Figure of the Eye, on account of its frequent and reiterated Action, is a Point too difficult, I fear, to be determined to an exact Truth, the extreme Tenderness of the Uvea, and the Smallness of the muscular Substance being too great Obstacles to be surmounted in the Way to it. However the following Experiment will, I hope, put this Matter on so good a Basis, as to render this Opinion, if not absolutely certain, at least highly probable.

(a) See Art. 141, 142. in the Dissertation on Vision at the End of Dr. *Smith's* Optics.

EXPE-

EXPERIMENT LV.

§ 1. Having cleared the Eye of an Ox from all its Humors, I introduced between the Edge of the Uvea and its Junction with the Cornea a long small Needle, upon which fixing a very light Scale, I found by the Addition of Weights to it, that $\frac{1}{4}$ of an Inch and 23 Hundredths in Length of this muscular Ring separated from the Cornea, and broke, when the Weight including that of the Scale was equal to 19 pennyweights, tho' in some other Trials, I have known it to sustain above an ounce Troy.

§ 2. Now the Circumference of the whole muscular Ring, I found to be upon the Diagonal Scale divided into $\frac{1}{4}$ Inches, equal in length to 12.3 of those Divisions, and therefore to separate and break the whole Ring from
its

its Connection with the Cornea, the Weight must have been equal to 9 ounces, 10 pennyweights, at the least.

§ 3. Since then the greatest Contraction necessary for raising the Cornea, as we learn from the preceding Experiment, was effected by the Pressure or Weight of 3 ounces, 2 pennyweights, 9 grains, it is evident, that the muscular Ring of the Uvea is furnished with a sufficient Degree of Strength to procure this Change of Conformation in the Sphericity of the Cornea.

§ 4. By this Contraction of the Cornea, the Rays of Light which would remain after their Refraction thro' the Aqueous Humor in a strong Degree of Divergency, viz. such as proceed from very small Objects at small Distances, are made to converge in a speedy and effectual manner,

ner, so as to paint a distinct Image upon the Retina, and sufficient for the Ends of Vision. Hence we are enabled to rectify a Mistake even of the best Anatomists, in supposing one of the principal Uses of the Muscles allotted this Organ to consist, in giving such a Change to the whole Globe of the Eye, and the Sphericity of its Humors, as thereby to produce the preceeding Effect. For supposing them capable of any such Action, the Consequence of it would be directly opposite and contradictory to that produced by the *Processus Ciliares* at the same Moment of Time. A Fault too great to be committed by the meanest Mechanic, and cannot therefore be admitted here.

§ 5. Hence if an Object placed before a Human Eye be so exceedingly small and subtile, as that in order to
make

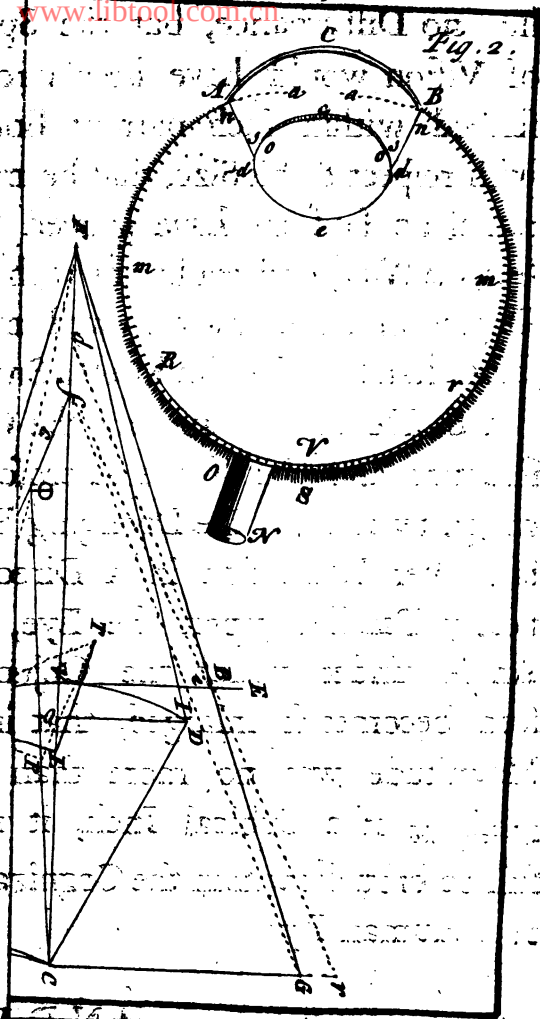
make it subtend an Angle of one Minute, the least Distance, viz. 5 Inches at which we see an Object with any Distinctness, must be contracted to 3 or less, the Consequence of this would be that the Divergency of the Rays would then be so great, that as such minute Objects would not be discerned at all, so even large ones in the same Situation would be seen with great Pain and Inaccuracy. This Limitation of Vision in Man, is so far from concluding any Imperfection or Deficiency in the Formation of his Eye, that it proves the direct contrary. For had it been formed only for the discerning of Objects posited at so small a Distance; not only many that would have been useless, but even disagreeable and offensive to him, would have perpetually presented themselves to his View, which

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PAGE 2. Line 11. *for even, read in.* p. 8. l. 8. and elsewhere, *for cava, r. Cava.* p. 53. l. 15. *for ad, r. to.* p. 65. l. penult. *for Vena of, r. Vena Cava of.* p. 91. l. 9. *r. thus, shewa* (at Exp. XIV. XV. and XIX.) p. 178. l. penult. and elsewhere, *for Porta, r. Portæ.* p. 210. l. 12. *for Preparation, r. Separation.* p. 224. l. 13. *for in, r. on.* p. 234. l. 17. *for had it returned, r. had it been returned.* p. 236. l. 4. *for their, r. the.*

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