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MICROGRAPHIA NOVA:
 OR, A NEW
TREATISE
 ON THE
MICROSCOPE,
 AND
MICROSCOPIC OBJECTS.

CONTAINING

I. The DESCRIPTION and Use of two different REFLECTING MICROSCOPES, of a new Form and Structure, and furnish'd with a MICROMETER; viz. one design'd for the POCKET, the other mounted on a BALL and SOCKET, which renders it of *Universal Use*.

II. A large and particular Account of all Kinds of MICROSCOPIC OBJECTS, to be found in the HUMAN BODY, in QUADRUPEDS, in FOWLS, FISHES, INSECTS, REPTILES, &c. in PLANTS and VEGETABLES of every kind; in EARTHS, MINERALS, and FOSSIL SUBSTANCES; and various other *Miscellaneous Subjects*.

With Directions how to procure and prepare them for Use; and divers occasional Remarks interspersed thro' the whole.

To which is added, An ACCOUNT of the
 CAMERA OBSCURA, and the SOLAR MICROSCOPE,
 OR
 METHOD of *Magnifying Objects* in a *Darken'd Chamber*, 5.
 In every Way by REFLECTION and REFRACTION.

By *BENJAMIN MARTIN*.

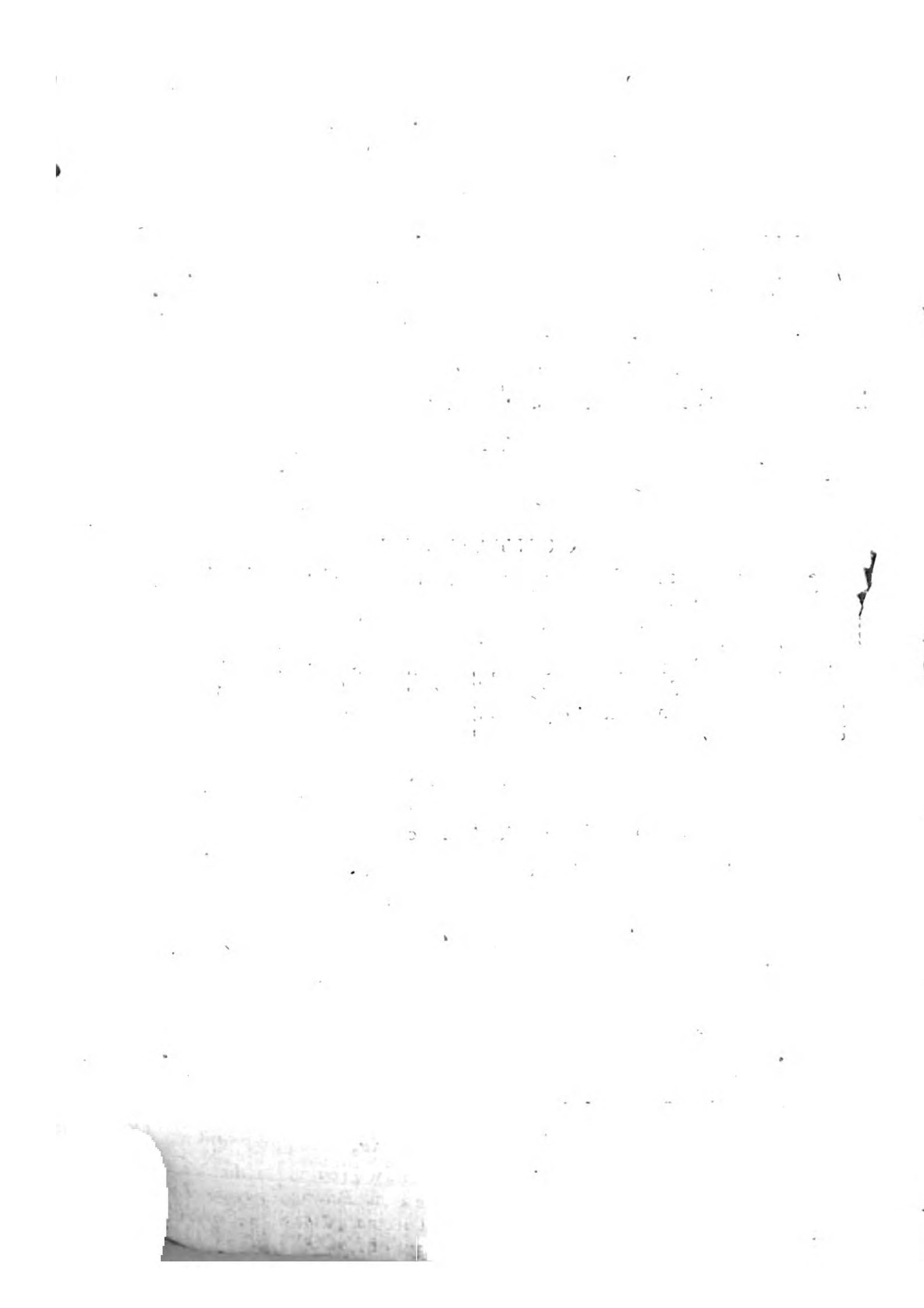
PSAL. CXI. 2.

גדלים מעשי יהוה לרושים לכל-חפציהם

READING,

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To His G R A C E the
Duke of RICHMOND.

My LORD,

THE Usefulness and Dignity of the Subject of the following Sheets are superlative, and claim, on that Account, your Grace's Patronage. The Works of Creation, and the Means to display them, are exactly in your Grace's Taste; and cannot but be acceptable to the most refined

Philosophical Genius. Providence has not only distinguished you with a high Station in Life, but has made you capable to ennoble it by all the Qualifications of a PATRIOT and a MECÆNAS. Nor is your Grace's Character, as a VIRTUOSO, less conspicuous; as every Gentleman can witness who has had the Honour of your Grace's Acquaintance, or a Seat in that Illustrious Society, of which your Grace is so distinguish'd a Member.

EVERY one who has been at *Goodwood*, is a Witness that your Grace has epitomized the larger and more surprizing Scenes of the Animal and Vegetable World, and erected, as it were in Miniature, a MUSEUM of *universal Nature*. All Nations, from *Lapland* to the remotest *Indies*, have paid Tribute of their choicest Product of *Beasts*, *Birds*, and *Plants*, of every Tribe and Class, to the DUKE OF RICHMOND.

I CAN scarce forbear saying more — but dwelling too long on Merit itself, is often irksome, and I should be afraid of offending no
Man

Man so soon as your Grace in this Respect. I am sure, MY LORD, if I know either myself or You, no Flattery has stain'd the Page; the mean Artifice of little Minds, who never fail to bewray their Stupidity to make their Patrons ridiculous. If I have spoke the Truth too far, 'tis owing to the fertile Theme. Vouchsafe to Accept and Patronize an Attempt to improve the most delicate and exquisite of all our Senses; and to disclose some of those invisible Scenes of infinite Beauty, Perfection and Art, which lye unheeded, and recluse from vulgar Eyes, in every Part of the Creation; I shall then promise myself auspicious Success. This Address to Your GRACE can admit of no Apology; being but the Discharge of a Duty which Justice and Gratitude enjoin. The Meanness of the Author, or Manner of the Performance, can be no Objection, since every one knows, that, in Physical Matters, finite Quantities vanish when found connected with those which are infinite.

I WISH Health (the Basis of all sublunary Bliss) to Your GRACE and Noble FAMILY; and

(vi)

and am, with the sincerest and most profound
Respect and Duty,

Your GRACE's

Most obedient

humble Servant,

B. MARTIN.

T H E
P R E F A C E.

AS the first Part of this Book is wholly employ'd in the Description of the Parts and Structure of each new Microscope here propos'd to Sale, 'tis needless to say any thing more in that Respect; I shall only add, that the Form is not only the most beautiful, elegant and convenient, but the Glasses in each Sort are the largest and best that can be made, and therefore the Perfection of these Microscopes the greatest that possibly can be. And that no Gentleman may be at a Loss for an adequate Idea thereof, I have caused the Prints of them to be engraved as large as the Instruments themselves are made. So that whether we regard the Novelty of the Form, the Improvement by the Micrometer, the Perfection of the Mechanism, or the Moderateness of the Price, I appeal to any competent and disinterested Judge, whether they do not exceed any thing of this kind ever yet propos'd to the Publick.

I have oftentimes been requested by Gentlemen to give a Catalogue of Microscopic Objects, which I have here done, and I presume so compleat, that scarce any extraordinary Phænomenon, which requires the Use of this Instrument, and within the Reach of a Person in private Life, will be found wanting in it. I could make a
considerable

considerable Apology for its being done in no better Manner; but 'tis sufficient to let the Virtuoso know that it was wrote at a Time,

Cum Sol non solito Lumine riferit,
Et Fortuna volubilis
Fati difficilem jecerit Aleam.

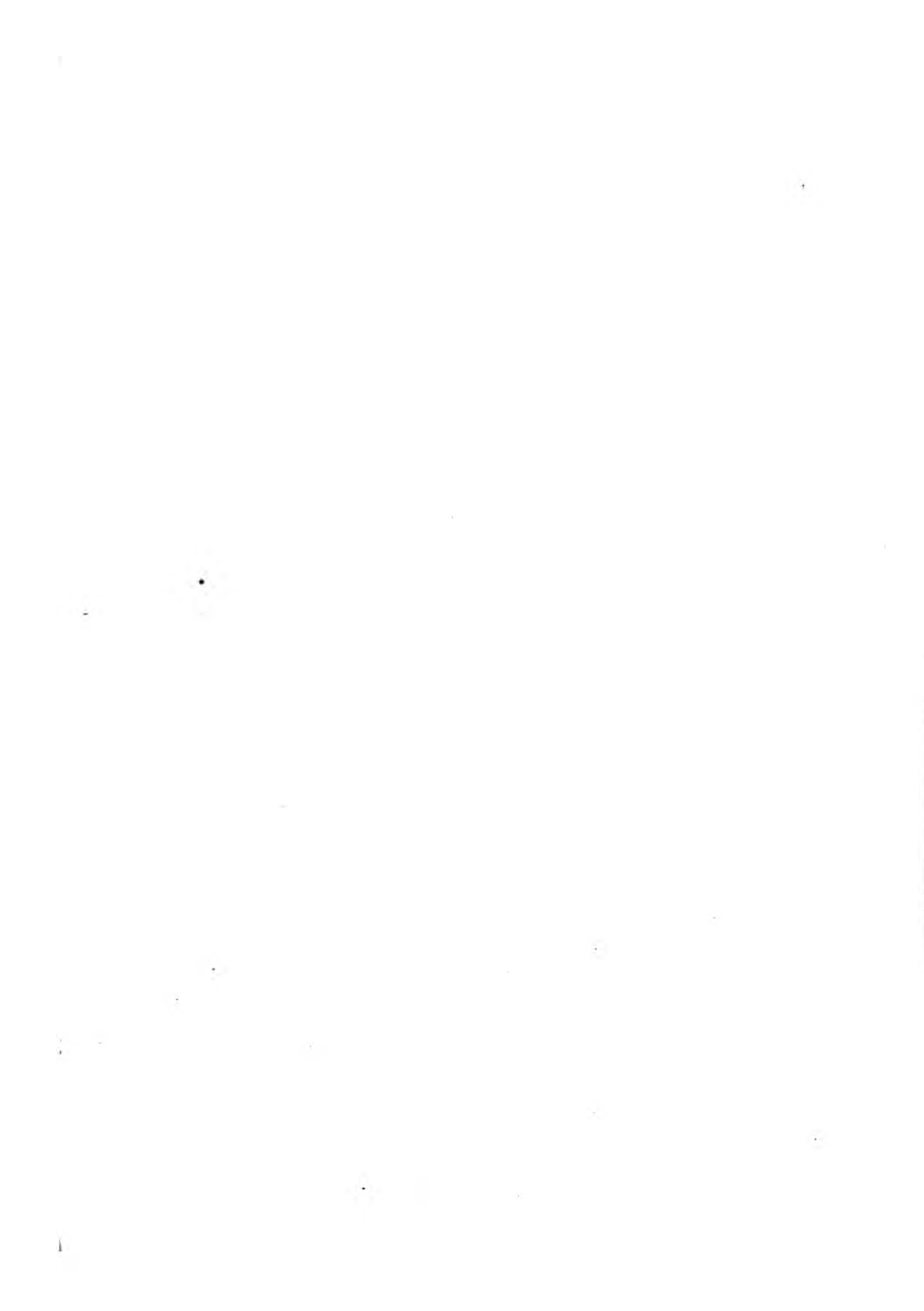
CASIM. *Lib. I. Od. II.*

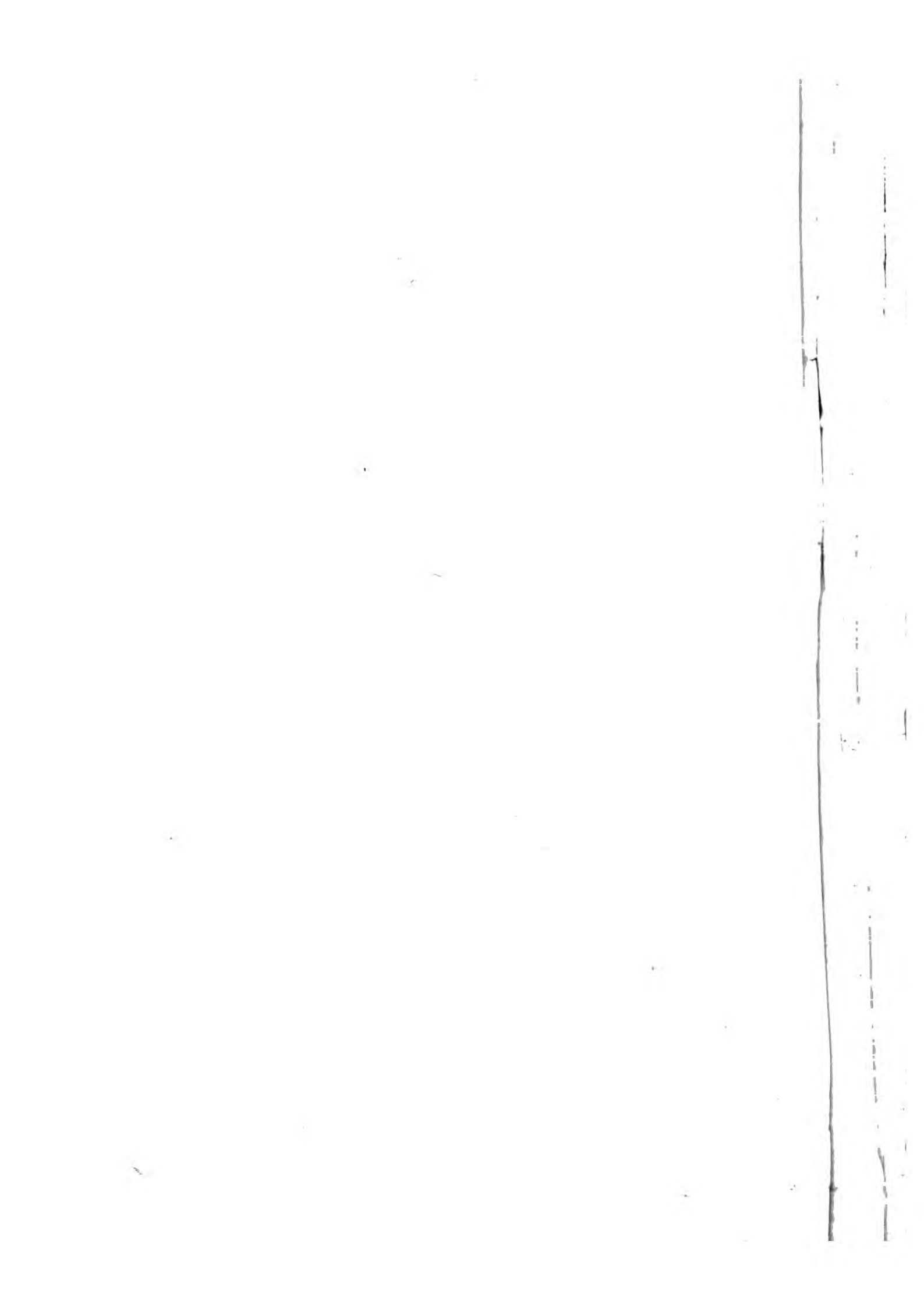
THE Method of Magnifying Objects in the Camera Obscura is so curious a Subject, and so analogous to the Microscope, that I believe the Reader will not think it foreign, to find a large and particular Account thereof added at the End of this Tract.

I shall take my Leave of the Reader in the Words of that excellent Naturalist Ælian,

“ Notwithstanding I well know there are extant the Lucubrations of other Men on this Subject, yet I fully persuade myself, that the Subjects I have here collected together, and deliver'd in a familiar Style, will prove no vulgar Theme, a Treasure not to be despised; and if it appears thus excellent to another, let him enjoy it; if not, let him leave it to be foster'd and caref'd by its Parent Author.

PRÆF. *ad Lib. I. DE NAT. ANIM.*





C H A P. I.

*A Description of the Pocket Reflecting
Microscope.*

THIS Microscope finish'd and fit for Use is represented in *Fig. 1*: It consists of the following Parts, or Materials, *viz.* (1.) *Wood-Work*, containing the Glasses; (2.) Glasses, for magnifying Objects; (3.) A *Micrometer* for measuring small Objects; (4.) *Tubes*, or *Cases*, which makes the Body of the Instrument; (5.) A *Brass Bottom*, containing a reflecting Mirrour; and is a proper *Basis* for the Instrument to stand firmly upon. Of these I shall give a particular Account: And

First, THE *Cases* or *Tubes* which make the Body of the *Microscope*, are two; (1.) The external Case DEFG, is made very substantial and strong, lined with black Shagreen, or cover'd with Nurfa Skin, which is also very beautiful; (2.) The internal or inner Case, contains the *Wood-Work*, and moves within the other Case; Part thereof H is seen thro' the Aperture LMN cut in the outer Tube. Its farther Use will be hinted by and by.

THE *Wood-Work* consists of several Parts or Pieces. As (1.) the Upper or Eye-Piece AB, which at B screws into (2.) the Middle or Micrometer-Piece BC, which contains the upper Glafs, the Micrometer, and the Image of the Object. This again at C
B screws

ferews into (3.) the Piece CD, which contains the lower Eye-Glass, and is fast glued into the upper Part of the internal Tube H. (4.) At the lower End of this moveable Tube, is glued in a round thin Piece, in the Center whereof is made to screw (5.) the small Pipe or Tube I; on the lower End of which screws on (6.) the Button or little Cell K, which contains the Object Glass, and has a small Perforation to admit a proper Degree of Light. Of these Buttons there are three to the larger Sort of *Microscopes*, and two to the lesser.

THE *Glasses* in the *Microscope*, which serve to Vision, are all Lenses of the Convex Sort; and these of three different Magnitudes and focal Distances. As (1.) The upper Eye-Glass, whose Place is at B; and whose Size is represented (in *Fig. 2.*) at GH. Its focal Distance is about $1\frac{1}{2}$ Inch. (2.) The lower Eye-Glass, which is placed at C, and represented at DE in *Fig. 2.* in its proper Size: It is sometimes a double Convex; sometimes a Plano-Convex, as there. (3.) The third Sort of Lens, is the Object-Lens contain'd in the Button K, and is represented at *de*, in *Fig. 2.* Of these there are three Sizes, as there is of focal Lengths, which are $\frac{1}{2}$, $\frac{2}{3}$, and 1 Inch.

THE other Glasses are two Mirrours; (1.) A plain transparent one, placed within the Bottom of the Case at LN, on which the Objects to be view'd are laid, in the Middle thereof, as at *o*. This Glass may be taken out and in at Pleasure. (2.) The other is a quick-silver'd Mirrour contain'd in the lower Part of the Brass Bottom R, its Use is to reflect Light on transparent Objects while we view them.

THE *Micrometer* consists of two Parts, the Plate and Screw. (1.) The Plate is represented at X in its proper Size; and is graduated into ten large Parts, each of which is divided by a Dot into two; so that in the whole there are 20 Parts or Divisions in the Circumference. (2.) The Screw *oq*, and small Index *qr* are represented in *Fig. 2.* on this Screw there are 50 Threads to an Inch;

so that one Turn or Revolution of the Index moves the Screw $\frac{1}{10}$ of an Inch backward or forward. But of this more hereafter.

THE brass Top at A is common to all *Microscopes* of the better Sort: But the brass Bottom EFR is peculiar to this; it consists of two Parts, *viz.* (1.) EF, which is strongly fasten'd into the *Microscope* on the upper Part; and on the lower Part is a Rim or Border on which (2.) the other Part or Box, containing the Mirror, shuts very fast, and on the hinder Part is connected to the other by a very strong brass Joint, by which Means it is at any Time easily let down for the Reflection of Light, or shut up again when in disuse.

IN the Case or Body of this *Microscope* are two Apertures; a large one before, as LMN, to place the Object, and admit the Light; and a small one behind, as PQ, in which we place a long Piece of plain Glass S, for moving the Object this way and that; or a small hollow Tube thro' the round Hole, which Tube is represented by T.

THE Use of the Tube is to contain living Subjects for viewing the Circulation of the Blood, &c. as an Eft, a Frog, a Fish, &c. As *Animalculæ* in *Water*, &c. are placed under the *Microscope* in the small Concave V. Which Tube and Concave Glass are fold with the *Microscope*.

CHAP. II.

*Of the Manner of Magnifying Objects ; and
of procuring distinct Vision by the Mi-
croscope.*

IN order to form a proper Notion of the Magnifying Power of the *Microscope*, or the Method of computing it, without the Mathematical Theory, we must well attend to the following Observations or Rules.

First, IF Parallel Rays, as those of the Sun, fall on any Convex Lens, they will be all collected into one Point on the other Side : Which Point is call'd the *Focus* of the Glas ; and its Distance from the Glas, its *focal Distance*.

Secondly, IF therefore an Object be placed in the Focus of such a Lens, the Rays after having pass'd thro' it, will proceed parallel, and form an Image at an infinite Distance.

Thirdly, IF an Object be placed farther from the Lense, than the Focus, all the Rays coming from any one Point of the Object, having pass'd thro' the Lens, will be united in a certain Point on the other Side ; and the Distance of this *secondary Focus* (for so I here call it) is found by the following Rule ; *viz. Multiply the focal Distance by the Distance of the Object ; divide that Product by the Difference of those two Distances, the Quotient is the Distance of the secondary Focus or Image.*

Fourthly, IF the Object be placed nearer to the Lens than is its Focus, the Rays going from any Point thereof having pass'd the Lens, will proceed less diverging, as if they came from a Point farther from the Lens than the Object ; which Point is the secondary

dary Focus, and is now negative, or on the same Side with the Object.

Fifthly, THE Object and Image are seen under equal Angles from the Vertex of the Lens; and are therefore to each other as their Distances directly.

Sixthly, THE Eye can only have distinct Vision when the Rays fall on it parallel, or very nearly so; because the *Retina*, which is the Organ of Sight is placed just in the Focus of the Crystalline Humour, which performs the Office of a Lens in collecting Rays, and forming the Image in the Bottom of the Eye.

THESE Theorems, and all others relating to these Matters, are fully demonstrated in my *New and Compendious System of Optics*.

SINCE no distinct Vision can be produced but by parallel Rays, and no parallel Rays can proceed from a Lens, but when the Object is placed in the Focus thereof; it evidently follows, that whatever we view in the *Microscope* by means of the upper Eye-Glass, must necessarily be situated in the Focus of that Glass. Thus suppose the Glass be *GH*, and let its focal Distance *LB* be 1 $\frac{1}{2}$ Inch; then will *B* the Focus, be the Place of every Thing that appears clearly and distinctly thro' the *Microscope*.

I NEED not say, that whatever appears or is seen in that Focus, is not the Object we propose to view, but its Image there form'd by means of the other Glasses. How this is done by the Object Glass *de* alone is easy to conceive. For suppose the focal Distance *fb* be half an Inch, then if an Object *ae* be placed at a small Distance beyond, or below the Focus *b*, the Rays which proceed from every Point thereof falling on the Lens *de*, will be converg'd at some considerable Distance in so many Points on the other Side, and there form an Image of the Object; and this Image will be as much larger than the Object, as its Distance from the Lens *de* is greater than the Distance of the Object.

Now 'tis easy to understand that as this Lens *de* is contain'd in the Button *K*, by sliding the Tube *H* a little up and down, its

Distance from the Object O may be so adjusted that the Distance of the Image shall throw it just in the Focus of the upper Eye-Glass at B , where it will be very clearly seen by an Eye at I .

BUT if besides the Object Lens de , and the Eye-Glass GH , there be interposed another Lens DE ; this Lens will intercept the Rays before they are converged to the Focus of the Eye Glass GH , and will cause 'em to converge or meet sooner, and so form an Image below the Focus of the said Lens GH , which therefore cannot be seen distinctly thro' it.

HENCE, in this Case, 'tis necessary to move the Lens de a small Matter nearer to the Object than before, in order that its Image might be thrown somewhat above B (if the Glass DE were away) as to MN , that by means of the Glass DE the Rays might be converg'd and the Image form'd lower, *viz.* in the Point B , the Focus of GH ; where it will be again visible as before.

So that in either Case, of one or two Eye-Glasses, 'tis easy by sliding the Tube H up and down judiciously, to get the Image form'd precisely in the Focus B , where only it can be perfectly and distinctly discern'd.

THE principal Use of the lower Eye-Glass DE is to enlarge the View, or what is call'd the *Field of Vision*, or that circular Area which is visible in the *Microscope*; for 'tis evident by interposing the Glass DE , the Angle DfE will be considerably increased; and consequently so will the Angle afc : But the greater the Angle afc is, the greater Length of the Object ac will be taken into the View; for all the Object between the Rays af and fc , will be seen in the *Microscope*. And the more of the Object can be seen, the pleasanter will be the View.

BUT tho' by the Glass DE , a greater Part of the Object is brought into View, yet the visible Part of the Image depends on the largeness of the Lens HG ; for since the Image is in the Focus B , no Rays will be convened at the Pupil of the Eye at I , but what proceed parallel from it to the Lens, as CH , BL , AG ,
confe-

consequently the visible Part of the Image is equal to the Area of the Lens G H; and is therefore greater or lesser as that is so.

C H A P. III.

The Method of computing the Magnifying Power of the Microscope.

SINCE we find by common Experience that no Object can be distinctly seen by the naked Eye at less than *seven Inches Distance*; and, in the Generality of Eyes, perhaps, not at less than *eight*: And also since any Object is visible distinctly thro' a Lens, when placed in the Focus thereof; it must follow, that the Object will appear as much bigger thro' the Lens, than to the naked Eye, as it is nearer; that is, as the focal Distance of the Lens is less than 8 Inches.

FOR Example: Suppose I view an Object thro' a Lens of 1 Inch focal Distance, then will its Diameter or Length be magnified 8 times, its Surface 64 times, and its Solidity 512 times. In like Manner, if the focal Distance of the Lens were half an Inch, then would its Diameter be magnified 16 times, its Surface 256 times, and its solid Content 4096 times. Once more; if the focal Distance be a quarter of an Inch, the Diameter will be magnified 32 times, the Surface 1024 times, and the solid Content 32768 than by the naked Eye at the Distance of 8 Inches.

HENCE it appears how very considerable a Microscope is a single Lens. And indeed those famous ones of Mr. *Lewenboeck*, and the costly one of *Wilson's* Make, were nothing but single Lenses, whose focal Distances were exceeding short; as the $\frac{1}{10}$, $\frac{1}{20}$, $\frac{1}{30}$, $\frac{1}{40}$, $\frac{1}{50}$, &c. Part

Part of an Inch ; these magnify extremely, 'tis true ; but that is far from ballancing the Disadvantages arising from so great a magnifying ; the Difficulty of making such Glasses, of viewing the Object, the small Part of it seen, the Expence of the Instrument, &c. has made it necessary to have recourse to Compound Microscopes for the Conveniency and Pleasure of using them.

IN these, if but two Glasses are used, (*viz.* an Object-Glass *de*, and one Eye-Glass *HG*;) a Computation of the Power of Magnifying would be very easy, in this Manner *B* is the Focus of the Glass *GH*, where the Image *AC* must be form'd ; therefore the Length of the Image is to the Length of the Object, as the Distance *fB* (suppose 6 Inches) to the Distance *fb* (suppose half an Inch,) that is, as 12 to 1. And so much is the Object magnified by the small Lens *de*.

Again, suppose the focal Distance of the Lens *GH* be $1\frac{1}{2}$ Inch ; then as 8 Inches is to $1\frac{1}{2}$ (or as 6 to 1) so is the Magnitude of the Image seen thro' the Glass *GH* to what it would be seen by the naked Eye at the Distance of 8 Inches. So that the Image is magnified in Diameter 6 times by the Glass *GH*.

THEREFORE the whole Diameter of the Object *ac* is magnified by both the Lenses 12 times 6, or 72 times ; or its Length is 72 times greater in such a Microscope than it would appear to the bare Eye at the Distance of 8 Inches.

BUT this Construction with two Glasses is not so good as one with three ; tho' the Computation of the Magnifying Power be in this Case somewhat more intricate, yet it may easily be apprehended in this Manner : Suppose the focal Length of the Lens *de* = $\frac{1}{2}$ Inch, of *DE* 3 Inches, and of *GH* $1\frac{1}{2}$ Inch, and the Distance of the two Eye-Glasses *LF* = $2\frac{1}{2}$ Inches ; then will *FB* = 1 Inch ; and suppose *Ff* = 5 Inches, then will *fB* = 6 Inches.

THESE Things premised ; it must be remember'd that I said the Lens *de* must be placed so near the Object *ac* as to throw the Image above the Point *B* (supposing the Glass *DE* away) to some
Point

Point P, that upon admitting the Glafs DE, the said Image may be brought to the focal Point B as required. In order to this, the Distance F P must be determined, which is done (by having given the Distance F B = 1 Inch, and the focal Distance of the Glafs DE 3 Inches) in the following Analogy.

As the Difference between BF and the focal Distance of DE, is to the said Distance BF ;

So is the focal Distance of DE to the Distance F P.

That is in the present Case, as $2 : 1 :: 3 : 1,5 = F P$.

Therefore $f P$ added to $F f$ gives $f P = 6\frac{1}{2}$ Inches.

Now that $f P$ may be $6\frac{1}{2}$, the Distance of the Object must be $\frac{24}{100}$ of an Inch; which is just 12 times less than the Distance $f P$; and therefore the Length of the Image MN would be 12 times greater than that of the Object ac .

By the Interposition of the Glafs, the Image is brought down from P to B; draw MF, and NF, and also st parallel to MN, then shall mn be the Length of the Image form'd a second Time. Now 'tis evident, as $f P$ is to FB, so is MN to mn ; that is, in Numbers, $1\frac{1}{2} : 1 :: 12 : 8 = mn$; the Length of the Image, therefore, by the two Glasses, is 8 times that of the Object.

THIS being the Case; the Glafs GH magnifies 6 times: Therefore the Object ac is magnified by this Microscope 6 times 8, or 48 times in *Length*, 2304 times in *Surface*, and 110592 times in *Solidity*; by an Object Lens of half an Inch focal Distance. And in the same Manner it may be computed for any other Object Lens, whose focal Length is known.

FROM what has been said, it appears, that as the Glafs DE amplifies the *Area* or *Field of View*, so it contracts or diminishes the Image of Objects, one third of the Diameter or Length, in the Case before us; and yet this without any Disadvantage; for a Microscope may as well magnify too much as too little; a *Flea* may be magnified to the Bulk of an *Elephant*, but to little or no purpose. For the more an Object is magnified the more obscure

it appears ; there is therefore a just Degree of magnifying, more or less than which would be a Fault : So true is the Observation of *Horace*,

*Est Modus in Rebus ; sunt certi denique Fines,
Quos ultra citraque nequit consistere Rectum.*

THERE are other Methods by which the magnifying Power may be computed ; but this, here deliver'd, I take to be the easiest of any mathematical one, and may be applied for any focal Length of the Object Lens. But if this be not understood, the Reader will find a most plain and practical Method of finding how much the *Microscope* magnifies with any Object Lens whatsoever, by the *Micrometer* only, at the End of the next Chapter, which he cannot fail to understand or practise.

CHAP. IV.

Of the Micrometer, and its Use in measuring very small Objects.

THE Parts of this Instrument have been already described, from whence its Use will be understood in a very few Words.

THE *Micrometer oq* is fix'd in the Focus of the Eye-Glass GH, and therefore its Point *o* will be clearly seen to move over the Parts of the Image, and to be, as it were, coincident with it. When any Object or Part thereof is to be measured, the Point is to be set very nicely to one Side thereof, while the Index *qr* points to the Beginning of the Divisions on the upper Part of the Plate, or Number

(II)

ber 10. Then holding the Microscope fast with one Hand, with the other turn the Index till the Point of the *Micrometer* appears to be moved just over the Part, which will easily be discover'd by the Eye. Then observe how many Revolutions and Parts have been made, and you will easily know the Dimensions of the Object, thus :

SINCE there are 50 Threads to an Inch, every Revolution will measure the 50th Part of an Inch in the Image ; and since there are 20 small Divisions on the Plate, each of these will give the Measure of 1000th Part of an Inch in the Image, these 50th Parts and 1000th Parts added together, will give the whole Measurement made by the *Micrometer* on the Image ; and since the Proportion between the Image and Object is supposed to be known, the Measure of the Object will be known also. But this Matter will be best apprehended by Example.

SUPPOSE one of the *Annuli*, or Rings on the Body of the Insect A C, were to be measured : Set the Point *o* to one Side thereof, as represented in the Figure ; then suppose the Index makes just one Revolution while the Point *o* moves just over the *Annulus* ; you will immediately know the Thickness of the *Annulus* in the Image is just one 50th Part of an Inch : And then suppose the Image 8 times as large as the Object, it must follow that the *Annulus* of the Object is but one 8th of that 50th Part ; that is, but one 400^{dth} Part of an Inch. This is a plain Case.

BUT suppose in measuring another Part, you make 3 Revolutions, and 15 Parts of another, then the 3 Revolutions will be $\frac{3}{50}$ of an Inch, and the 15 small Divisions will be $\frac{15}{1000}$ of an Inch ; these two added together, make $\frac{75}{1000}$ of an Inch in the Image, and therefore but $\frac{1}{8}$ so much in the Object, *viz.* $\frac{75}{8000}$, which is almost $\frac{1}{100}$ Part of an Inch.

NOTE, That $\frac{3}{50}$ added to $\frac{15}{1000}$ make $\frac{75}{1000}$, is easy to conceive by considering that every $\frac{1}{50}$ is equal to $\frac{20}{1000}$; and consequently that $\frac{3}{50}$ must be equal to $\frac{60}{1000}$, which added to $\frac{15}{1000}$, make $\frac{75}{1000}$, as before.

OR thus in short; make the Number of small Divisions, pass'd over during the whole Motion, *the Numerator of a Fraction*, and the Number expressing the Power of Magnifying with three Cyphers annex'd, the Denominator of that Fraction; then will that Fraction express what Part of an Inch the Part measured is equal to in the Object. Thus in the last Example, there were 75 Divisions in all pass'd over, which therefore is the Numerator; and since the Object was magnified 8 times, the Number 8 with three Cyphers, is the Denominator; and so the Fraction is $\frac{75}{8000}$, as above.

'TIS well known by Experience, that the 100^{dth} Part of an Inch is visible to the naked Eye: In a Microscope, therefore, that magnifies 4, 6, 8, or 10 times, the 400^{dth}, 600^{dth}, 800^{dth}, or 1000^{dth} Part of an Inch will be visible, and therefore may be easily measured by the Micrometer. And since the thousandth Part of an Inch may be so easily seen and measured, we may judge very nearly of others much less, at least 10 times less; thus we may be certain of the surprizing Minuteness of Objects almost to the 10000^{dth} Part of an Inch in Diameter, the 100000000^{dth} Part of a square Inch in Surface; and the 1000000000000^{dth} Part of a Cubic Inch, in Bulk, or Solidity. To what a prodigious Degree, then, does the Microscope, thus constructed, extend our *Geometry*, as well as our *Philosophy*!

IN the last Chapter I promised an easy Method of finding the *Magnifying Power* of the Microscope, for any Object Glass, by the Micrometer; which is done in this Manner: Take any Ruler, &c. which has Inches divided into *Tenths*, and place it under the Microscope so that you may have one of those Tenths in full View in the Image, then measure it carefully with the Micrometer, and count how many Turns were made in so doing; divide that Number by 5, and the Quotient will shew how many times the Image is bigger than the Object. Thus suppose in Measuring one of those Tenths I make 40 Turns, that divided by 5 quotes 8; and so many times does the Microscope magnify with the Glass.

B
DE The Tubes, or body of the microscope.

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NOTE,

NOTE, the Reason why you divide by 5, is because there being 50 Threads to an Inch, 5 must be equal to one Tenth in the Object ; and therefore as many times 5 as there are in the Image, so many times must the Object be magnified.

CHAP. V.

A Description of the UNIVERSAL MICROSCOPE, mounted on a BALL and SOCKET.

THE usual Construction of the large double Microscope confines its Use to those Objects only which are placed *below it*, on a circular Plate of Brass, included between, and supported by the three brass Legs of the Microscope. Hence only one Position of the Microscope, and only those Objects which can be put between the said Legs, can be of use in this Structure.

To remedy this Inconvenience, by applying the said large double Microscope to view all Kinds of Objects in every possible Position or Situation, I have contrived a new Form or Structure thereof, by means of a *Ball and Socket*, mounted on a cylindric Shaft of Brass, on which a *Quadrantal Plate* of Brass moves horizontally, all which are represented in *Plate II*, as large as the Instrument itself. A particular Account of which here follows :

A, is the Brass Top of the Microscope.

AB, the Part containing the upper Eye-Glass.

BC, the Part containing the lower Eye-Glass, and Micrometer X.

DE, the Tubes, or Body of the Microscope.

I, K, the Snout, and Button, with the Object-Glass.

F, F, a strong hollow Ring or Socket of Brass, in which the Body of the Microscope is fixed.

F G, a Brass Arm, in the Cavity of which, G, is fasten'd

L, the Neck of the Brass Ball, by

H, a small Screw.

M, the Brass Ball.

N O, the Socket which contains it; the Part N screwing on the other Part O.

P, the Brass Stem or Shaft, on which the Socket O is screw'd.

Q R S, a Quadrantal Piece of Brass moving horizontally on

T, a small Brass Socket moveable on the Stem P, and fix'd at Pleasure by a Screw.

V U, a Circular Piece of Glass, on which the Object is laid.

W Y, the Box or *Basin* of the Microscope, with a Drawer, Z, containing the other Buttons, Glasses, &c. which belong to the Microscope.

a, b, c, d, the Brass Case, containing the Mirrour for Reflecting Light thro' transparent Objects.

FROM this Description and Representation of the Parts, 'tis easy to observe how much this Form of the Microscope excels that in common Use; for (1.) By means of the *Ball and Socket*, the Microscope may be applied to view Objects in any Situation obliquely, as well as perpendicularly below it, which the other cannot. (2.) Objects of any Shape or Form, or placed in any convenient Vessel, may be here placed under or before the Microscope, which very often cannot be done in the usual Form, by reason of the Nearness of the Legs to each other. (3.) Objects placed on the Quadrantal Plate R Q may be moved horizontally under the Instrument, 'till all its Parts successively pass under the Object Glass, or are seen in the *Field of View*; which Plate in the other is fix'd and immoveable. (4.) Transparent Bodies are view'd to a much greater

greater Advantage by means of the long circular Piece of Glas V U, which passes thro' the whole Length of it under the Object Glas, than in the common Sort where the Hole is circular and immovable; because (5.) here the Object, once well posited, is not moved, but the Plate whereon it lyes; but *there*, 'tis most times necessary to move the Object itself this way and that, which is very inconvenient. (6.) The Beauty, Simplicity, and Freedom so conspicuous in the Structure of this Instrument must recommend it to every Gentleman of good Taste, who chuse to have a Microscope of any other than the *Pocket Form*.

THEY who are conversant in the Microscope will easily judge with how much Ease and Pleasure the grand *Phænomena* of the *Animalculæ* in Water, in *Semine Masculino*, the Circulation of the Blood, and various other Philosophical Experiments, will succeed in this more than in any other Form yet invented for the larger Microscope.

IN the first Edition of this Piece I gave a Print of this *Universal Microscope* somewhat different from this, and which was very well approved and accepted; but as very few Things are perfect with the first Thought, so this Instrument, upon mature Deliberation, I found was capable of considerable Alteration and Improvement in its Structure, both in regard of Elegance and Usefulness; and with which they are now made accordingly. I likewise gave the Print of the former in Miniature, but here the whole, and every Part, has the same Size and Proportion as the Microscope itself; which I judged was necessary to exhibit a just and adequate Idea of the same.

C H A P. VI.

A Computation of the extreme Minuteness of visible Animalculæ; and the prodigious Subtilty of their Blood-Vessels, and Sanguineous Particles.

IN order to make a Calculation of the Magnitude of an *Animalcule* that is but just visible to the Eye, we must know that 'tis found by Experience, *that an Object is then just visible when it subtends an Angle of but one Minute to the Eye.*

Now suppose the lower Glass DE taken away, and that the Distance of the Image BF is ten Times the Distance of the Object *bf* from the Lens *de*, then will every Particle in the Image be ten times greater than the same Particle in the Object.

AGAIN, suppose the focal Distance of the Eye Glass IL or LB be just one Inch; then a Particle in the Image, which is but just visible to the Eye by such a Glass, will be seen under an Angle of one Minute. Let such a Particle be represented by AB (in *Fig. III.*) and the focal Distance of the Eye-Glass by CB = 1 Inch: Then in the Right-angled Triangle ABC there is given the Side BC = 1 Inch, and the Angle C = 1 Minute, to find the Length of the Particle AB.

IN this Case BC is *Radius*, and AB the *Tangent* of the Angle C; but when the said Angle C is *one Minute*, the *Radius* is to the *Tangent* as 10.000.000 to 2909; that is, in round Numbers, as 10000 to 3; so that the Particle AB is in Length $\frac{3}{10000}$ of an Inch. All this is evident from the Tables of Sines and Tangents.

Now

Now since AB is equal to $\frac{3}{10000}$ in the Image, and the Image is 10 times larger than the Object, the said Particle in the Object will be but $\frac{1}{10}$ of $\frac{3}{10000}$, or $\frac{3}{100000}$ Parts of an Inch. Now 'tis well known that there are some Animalcules in Water, so small that when they are magnified 10 times they appear but as Points in the Microscope; and as they are of a spherical Figure, the Diameter of one of these Animalcules may be represented by $AB = \frac{3}{100000}$; and therefore the Magnitude of the Animalcule must be express'd by the Cube of that Number, *viz.* $\frac{27}{100000.00000.000000}$ multiplied by 0.5236, which makes $\frac{14}{100.000000.0000000}$, that is, if a *Cubic Inch* were divided into a *Thousand Millions of Millions of equal Parts*, the Magnitude of one of these Animalcules would be equal to but 14 of them.

HENCE (says Dr. Keill) what some Philosophers have dreamed concerning Angels, is true of these small Creatures, *viz.* *That many Thousands of them may dance on the Point of a small Needle.*

FROM the above Calculation it appears, that the Concavity of a Globe $2\frac{1}{2}$ Inches Diameter, will contain more than a *Thousand Million of Millions* of those *Animalculæ*.

SINCE the Vessels of organized Bodies are in Proportion to the Magnitude of the Bodies, as we may reasonably suppose; and since the human Body contains, at a Mean, about 3 Cubic Feet, or 5184 Inches; therefore as 5184 is to $\frac{14}{100.000000.0000000}$, so are the smallest Vessels discoverable in a human Body to the like Capillary Vessels in an Animalcule.

BUT Capillary Vessels have been observed in the human Body so small that the Diameter of one of them is but about $\frac{1}{80000}$ Part of an Inch; now the Diameter of a like Capillary in the Animalcule will be in proportion to the above Diameter $\frac{1}{80000}$, as the Cube Root of the Magnitude of the Animalcule $\frac{14}{100.000000.0000000}$ to the Cube Root of the Magnitude of the human Body 5184. But the Cube Root of 5184 is nearly 17, and that of $\frac{14}{100.000000.0000000}$ is nearly $\frac{2.4}{100000}$; therefore as 17 is to $\frac{2.4}{100000}$ so is $\frac{1}{80000}$ to $\frac{2.4}{1360000.000000}$ or $\frac{1}{57.000.000.000}$; which therefore expresses the Diameter of the Capillary in the Animalcule; that

is in Words, if an Animalcule be divided into *Fifty-seven Thousand Millions of equal Parts*, then will the said Diameter be equal to *one of them*.

Now the Diameter of a Blood-Globule which flows thro' one of these Vessels, must be less than $\frac{1}{57.000.000.000}$ Part of an Inch; therefore if we suppose those Globules round, the Solidity or Magnitude of one must be less than the Cube of $\frac{1}{57.000.000.000}$ multiplied by 0.5236; that is less than $\frac{1}{96948.00000000.00000000.00000000}$, or in round Numbers $\frac{1}{100000.000.000.000.000.000.000.000.000.000}$ Parts, which Number being so exceeding small, cannot be express'd in Words that will give a clear Idea of such an extreme Subtilty of the Particles of the Fluid which circulates thro' the Capillaries of those *Animalculæ*.

I SHALL therefore take another Method to assist the Conception in this Matter, which is by finding a Mean Proportional between the Magnitude of the aforesaid Particle, and that of the the Globe of the whole Earth. To this Purpose I shall consider the Earth as a Sphere whose Diameter is 8000 Miles. Therefore the Solidity of the Earth is equal to 512000.000.000 multiplied by 0.5236, that is to 2680832000.00 Cubic Miles; and in one Cubic Mile there is 254358061056000 Cubic Inches: Therefore the Magnitude of the whole Earth is 681.890.000.000.000.000.000.000.000.00 Cubic Inches (true enough for the Proportion.) A mean Proportional therefore between the Numbers expressing the Magnitude of the Earth and the Particle, must be the Square Root of this Fraction $\frac{681.890.000.000.000.000.000.000.00}{1000.000.000.000.000.000.000.000.000.000}$, viz. the Fraction $\frac{8257645000.000}{10.000.000.000.000.000}$; this being divided by 0.5236, and the Cube Root of the Quotient extracted, will be the Diameter of a mean Proportional sought, viz. $\frac{20212}{173640}$, or $\frac{20}{173}$; which is little more than one Tenth of an Inch. *Therefore a Globe or Ball of one Tenth of an Inch Diameter, is a mean Proportional between the Globe of the Earth and one of those sanguineous Particles: Or such a Particle is as much less than a Globe of one Tenth of an Inch Diameter, as that Globe is less than the Globe of the whole Earth.*

IN this *Calculus* we have supposed nothing absurd, yea nothing that is not agreeable to the Analogy which Nature observes in all her Operations. If Magnitudes increase or decrease in such extreme and remote Gradations as surpass our Comprehension or Conception, it makes nothing against the Possibility or Probability of the Thing; the Proportion is all the Difference, which is indifferent to Nature, and only affects us. We think the infinite Divisibility of Matter a strange and incredible Thing, yet nothing admits of a more strict Mathematical Demonstration. The Globules we have been considering, and think so wondrous small, we should think, perhaps, as monstrously large, could we compare 'em with other Bodies in the *Scale of Miniature* below them; as the Particles of the Fluid in which they float; or those of the animal Spirits in those *Animalculæ*; or lastly, to the Particles of Light, which probably are as much less than those Blood-Globules we have been computing, as we have found them less than the Globe of the Earth.

HENCE then we conclude, there is *either nothing, or every thing*, to be wonder'd at in Nature: And that of the infinite Scale of Magnitude we view but a very few Steps or Degrees, even when assisted by the best of Microscopes and Telescopes (the only Helps in this Case which Art can afford us :) How very narrow, then, and contracted must be the Extent of their Speculation and Ideas, who are Strangers to these excellent Instruments, and are confined solely to the Notions derived from their *natural Sight and Senses?*

C H A P. VII.

*General Directions for the right Use of the
Microscope.*

THE Glassess ought to be look'd at when you view an Object, to see that they are perfectly clean and clear; if they are not, they must be taken out and wiped with a Piece of soft Leather, fine Linen, or Silk, doubled over the Glassess; and replaced without touching 'em with the Fingers unless by the Edges only.

IN replacing the Glassess, Care must be taken to lay them level or even in their Places; for if they should be placed obliquely, the Object will be distorted and discolour'd.

IN viewing an Object, always be sure to hold the Microscope perpendicular or down-right, and not a slant; for then the Object, if unconfined, will roll out of Sight.

TAKE Care to hold the large Aperture towards the Light, that the Object may be as much illuminated as possible, and to the best Advantage.

IN setting the Microscope for View, hold the outer Case firmly and steadily with the Left-hand, and with the Right-hand very gently move the inner Tube up and down till you find the Object, and have got a clear and distinct Sight of it; and there let it stand.

FOR the better apprehending the Object, be careful to lay it just on the Middle of the Glass, under the Object Lens in the Button. For those Rays which come from the Middle, afford the most perfect Vision; the Collateral Rays being very unfit for that Purpose.

HOLDING your Eye over the Aperture of the Brass Top, move it

it gently up and down till you find the Place where you have the clearest and largest View of the Object, for such a particular Point there is.

IF there be several in company, each Person ought to set the Microscope to his own Eye ; and not view it as set by another ; for every particular Eye has a Focus peculiar to itself.

IF the Object does not appear exceeding clear and perfect, you may conclude the Instrument is not well adjusted.

LET the Part to be viewed be so placed as to receive the strongest Light, if the Object be a dark, black, or opaque Substance.

IF the Object be transparent, let down the Reflector in the brass Bottom, that the Light may be reflected strongly thro' it. Nor is this Mirrour of any Use but when the Object is pellucid ; and should therefore in all other Cases be shut up.

FOR larger Objects the larger Object-Lens is to be used, and for smaller, the smaller Lenses ; also the Object should be as much magnified as it will bear that you intend to measure with the Micrometer.

EXTREMELY small Objects should have the strongest Light of the Sun, and the greatest Magnifier. If it be the Circulation of the Blood, the Seminal Animalcules, or those small ones which tinge the Water ; they should be moreover illuminated by the Sun's Rays collected by a Convex Lens held in the Hand.

IN a dark Day, or darksome Room, no one should attempt to view Objects, unless white, or of some strong bright Colour ; for if the Object be not well enlighten'd it will appear but dimly, and give no Satisfaction ; whence a very ill Opinion is conceived of the Instrument without any other Reason but their own Unskillfulness in the Use.

IN looking into the Microscope, take Care not to let your Breath fall on the Eye-Glass ; and that you hold not your warm Hand long on those Parts of the Microscope where the Glasses lye, for they contract a Moisture from the Hand, which in the Appearance

ance of a fine Dew, absolutely obstructs all Sight of the Object.

THESE Directions and Cautions are all I can think necessary for an Instrument whose plain and simple Structure so naturally indicate its easy and obvious Manner of Use.

CHAP. VIII.

Of Microscopic Objects; and first of Animal Substances, in the Human Body, and those of Quadrupedes.

HUMAN HAIR; its bulbous Root; its long small Cylindric Form; the Substance, if black, opaque; otherwise, transparent.

HORSE-HAIR; the same things, but more apparently.

HOGS BRISTLES; besides what is common to Hair in general, these appear tubular or hollow; for the thin transverse Sections will appear perforated in the middle, if nicely cut with a sharp Pen-knife or Razor.

MOUSE'S HAIR; I mention these because Dr. *Derham* relates some Things very curious and peculiar to them, in regard of their Structure; which, tho' I have often sought for, I could never yet observe.

THE SMELLERS of Cats, Tygers, Leopards, &c. they are round, opaque, and solid throughout.

THE CUTICLE, or SCARF-SKIN of the human Body; this appears to be made up of several Lays or Rows of exceeding small Scales, lying partly on each other. Under these Scales are said to
open

open the Orifices of the excretory Ducts of the Glands serving to Perspiration : These are innumerable, and incredibly small.

THE SKIN ; in which are the *Papillæ Pyramidales* ; infinite in Number ; between these open the Orifices of the Ducts of the *Miliary Glands* ; which Glands lye under the nervous Texture of the Skin.

MEMBRANA ADIPOSA ; in this Membrane, which lyes next under the Skin, you see the Fat of Animals, and will find it to be an oily Substance, contain'd in an infinite Number of small Vesicles, or little Bladders, which appear very plainly in the Fat of Beef, Mutton, &c. cut into very thin pellucid Slices when cold.

MUSCULAR FIBRES ; these when separated artfully in the muscular Flesh of Beef, Mutton, Bacon, &c. appear to be nothing but *Fasciculi*, or Bundles of fine capillary Threads or Fibrils, perfectly transparent, and nearly round ; having in all Respects the Appearance of very fine pellucid Hairs. They are of different Sizes in different Animals ; but larger in Fish than Quadrupedes, and largest of all in the Flesh of Shell-Fish, as *Crabs*, &c.

THE NERVES ; these appear to be a Bundle of long small Pipes or hollow Fibres, as some Authors say, but I could never discover their Hollowness, or separate 'em like the Fibres of Muscles.

ARTERIES and VEINS ; the Coats which compose them, when separated in a proper Manner afford a fine Subject for the Microscope.

THE INTESTINES or GUTS ; their Texture consisting in the various and wonderful Dispositions, Order, and Direction of the nervous Fibres, make a curious Speculation.

THE LACTEALS ; those fine Ducts imbibe the Chyle from the Intestines, and are only to be seen in living Subjects.

THE LYMPHADUCTS, are of a curious Structure and Form, and well worth a Microscopic Observation.

THE LUNGS, LIVER, KIDNEYS, PANCREAS, SPLEEN, &c. when divested of their parenchymous Substance by Maceration, discover a surprizing Contexture of vesicular, and vascular Ramifications.

of Arteries, Veins, Nerves, &c. inosculating with each other, and make a wonderful Subject.

THE SEMINAL VESSELS; their wondrous Contortions and Convulsions in the *Epididymis*.

THE TESTICLES; the fine and beautiful Ramifications of Blood Vessels on the Membranes inclosed; their glandulous Substance artfully dried, and cut into thin Slices, are a delicate Subject. Those of Bulls or Horses are best for this Purpose.

THE PENIS; its cavernous or cellular Substance, when prepared and dried; also the Substance of the *Glans* makes a curious Sight.

THE BRAIN; wherein the cineritious and medullary Substance, the Union of the Nerves, the *Plexus Choroides*, the *Rete Mirabile*, &c. are Subjects for the Microscope: As also the *Meninges*, or *Pia* and *Dura Mater*, the Membranes which contain the Brain and *Cerebellum*.

THE EYE; here the several Coats, the Aqueous, Vitreous, and especially the Crystalline Humour, deserve a particular Inspection; the Colour of the *Iris*; the Fibres of the *Ligamentum Ciliare*, and *Choroides*; and above all the *Retina* or fine Expansion of the Optic Nerve, with the Branchery of Blood Vessels thereon, afford the finest Entertainment to the Microscopic Observer.

THE NOSE; in this Organ we have the *Ossa Spongiosa*, and the Expansion of the Olfactory Nerve over all its *Laminae*; the glandulous Membrane, and the *Vibrissi* or Hairs, are worth our Notice.

THE EAR; the Hair, the Wax, the *Tympanum* or Drum, the little Bones, the Auditory Nerve spread over the several Cavities, may be examin'd by the Microscope.

THE TONGUE; the curious Disposition of the Fibres (which compose its Substance) in several Planes, and various Directions, afford a pleasing View; and more especially so, the nervous *Papillae* (which are the immediate Organs of *Taste*) in the internal Membrane or Coat of the Tongue, and their Cases in the external Membrane,

Membrane, which make the Tongue so rough, and are so visible and large in a Neat's Tongue, and other large Animals.

THE BLOOD; this vital Fluid yields the sublimest Speculations by the Microscope in regard of the following Particulars, *viz.* the small red Globules or Particles, which constitute the red Part, or *Crassamentum*; and these are easily visible if diluted with Water, and laid thin on a Glass: Some say each of these Globules consists of *Six lesser Ones*, but that I could never yet be apprized of. These red Particles by a constant Dilution with Water will lose their Colour, and become white Blood. By this Dilution of the Blood its Salts are extracted, and when the Humidity is evaporated, they appear very plain on a Glass laid under the Microscope. The *Serum* of the Blood consists of an infinite Number of fine invisible Filaments, Membranes, and vascular Parts, some of which are obvious to the Eye by the Microscope, and this is the Reason why the least Heat will cause it to coagulate. But the most noble Phenomenon is the *Motion or Circulation of the Blood*. The principal Subjects for this Purpose are the transparent Tails of Tadpoles, and the yellow Sort of Water-Eft or Neut; it is visible also in the Fins and Tails of most Sorts of Fish and Eels, and likewise in the Feet of Frogs, &c. To see this with the greatest Pleasure, use the largest Magnifier, and let the Object be confined in the long Glass Tube, and the Part for View well enlighten'd by a Refracter above, and the Reflecting Concave below. If the Animal be near expiring, you'll plainly see the Motion of the Blood decrease, and the Globules glide slower and slower along, till at length they are perfectly quiescent, and the Animal quite dead.

THE SEMEN; the infinitely small and numerous *Animalculæ* in all Male Sperm are the most astonishing Spectacle, and as yet the highest Attainment of the Microscope; you cannot fail of seeing Millions of these in the smallest Quantity of the human Semen, if laid under the Microscope while warm, and view'd with the greatest Magnifier, and most strongly illuminated, by

the Sun's Light refracted and reflected upon it.

THE URINE; in this the various Sediments; the *Arenæ*, or Sand; the *Nebulæ*, or Motes; and the Salts obtain'd by evaporating the humid Part, are proper Subjects for the Microscope.

THE BONES; these in the Fœtal State are soft and spongy, consisting of an Assemblage of bony Fibres, which are very wonderful to behold; these curious Objects are to be seen among the Preparations of Anatomists and Surgeons.

THE NAILS and HOOPS of Beasts; the latter in Cows, and especially in Horses, are very porous, as may be easily seen by cutting their Slices, and laying them under the Glass with the Light reflected thro' them. Whence it appears, that the Nails and Hoofs of Animals are made up of innumerable small cylindric *Tubulæ*, or Pipes, which are, as it were, cemented or conglutinated together, by a viscous, hard, or horny Substance. Some Things of this Kind are also to be observed in the Horns of Animals.

C H A P. IX.

Of Microscopic Objects peculiar to Birds.

AMONG this Tribe of Animals, the first Thing which presents itself for a Microscopic View, is

THE FEATHERS; in these the wonderful Variety of beauteous Colours delights the Eye, assisted to view them with a Glass. The Feathers of the Jay, the Pheasant, the Peacock, the Mallard, &c. are surprizingly fine thus view'd. As to the several Parts of a Feather, the Plumage is that which deserves our first Notice; these appear extremely pleasant, if view'd either together, or separately; each *Plumula* having then the Appearance of a large Feather.

Feather. Those in the delicate white soft Feathers of the Ostrich, or of a Peacock's Tail, afford these *Plumulæ* of the finest Sort. The *Quill-Part* and *Rib* of the Feather have nothing which strikes the Eye; but the white Pith, if cut transversely into extremely thin Slices, and laid on a Piece of Glass, will shew an admirable Contexture of Net-work; which shews that the Substance thereof is composed of an infinite Number of *Vesiculæ*, or small Bladders.

THE HAIRY FEATHERS of the *Casaware* are worth observing.

THE FINE LONG HAIRS which appear on the Bodies of most Fowl when pick'd, with their brushy Tops and bulbous Roots, may be view'd with the Microscope.

THE RED COMBS and GILLS of Cocks,

THE SCALY SKIN of the Legs,

THE WEB or *Membrane* in the Feet of Water Fowl, are all proper Subjects.

THE FLESHY FIBRES in general, and particularly those of the *Gizzard*, shew a wondrous Mechanism; and are view'd with great Satisfaction, if the Gizzard be partly dried, and cut into thin Pieces.

IN large Birds the Substance of the BILL, or *Beaker*; and in small ones, the *Lamellæ*, or thin Plates of the Skull, the Interstice, with the bony *Fibrillæ* which connect these Plates, are very curious Subjects.

THE EGG is the most copious Source of Microscopic Themes belonging to this Tribe; for in many there is a beautiful Variety of Colours, Tincts, and Dyes, which make a fine Appearance. The hard crustaceous Part or Shell, if seeth'd in Vinegar 'till it becomes soft, will appear to consist of small, white, hard Globules, or stony Particles, as it were cemented together on a strong white Membrane; and with the Point of a Needle, or Penknife, may be easily separated from each other. The Membrane which contains the *Yolk*, appears to be an opaque Substance when dry. The *White* of an Egg seems to be a vascular Substance (somewhat like the

the vitreous Humour of the Eye,) on which Account it immediately coagulates by Heat; but affords nothing extraordinary to the View. The *Yolk*, or yellow Part, being boil'd hard, and when almost dry, gently rubb'd on the Glass, will shew that it consists of very small roundish Globules of a faint red Colour; which, 'tis supposed, are small Bladders containing an oleaginous Substance proper for the Nutriment of the young Chick, while confined in the Egg.

THE COLOUR'D IRIS in the Eyes of some Birds, makes a very fine Object in the Microscope.

THE BREAST BONE, SCAPULÆ, &c. in small Birds, are almost transparent, and afford a curious View of the Course which the Vessels take thro' their Substance. The *Meditullium*, or internal spongy Substance of Bones is better observ'd in those of Birds than any other Animals.

THE BAT, or *Flutter-Mouse*, is rather a *flying Quadrupede*, than any thing of the Bird-kind; and is a wondrous Connection of those two Species of Animals. The peculiar Sort of membranaceous Wings are a fit Object for the Microscope, and, I think, is all that intitles them to a Consideration here.

CHAP. X.

Of Microscopic Objects peculiar to Fishes.

NO Person unacquainted with the Microscope can imagine what a glorious and beautiful Creature a *Fish* is. Were it possible to view the whole Body of a *Carp*, for Instance, as magnified by the Microscope, I dare say a Person would pronounce it the finest Animal he had ever beheld with his Eyes. For

THE SCALES of that Fish, when view'd in the Microscope, appear all bespangled with Stars of a golden Hue, with a great Number of Specks and Spots delightfully interspersed. In this Scale appears a beautiful Form and Texture, the Root largely denticulated, by which 'tis inserted into the Body; from whence it appears ribb'd to the middle Part, where they radiate or spread like the Sticks in a Fan towards the curv'd Extremity, which is variously figured in the Scales of different Fishes. The Scales of those we call Flat-Fish, are exceeding small and beautiful, as in the Plaice, Flounder, Turbet, &c. The Scales of an Eel are a great Curiosity; they were never known but by the Microscope; they appear perfectly transparent, of an oblong Form, and of a Reticular or Net-like Texture. In order to see these to the best Advantage, take a Piece of the Skin of the Eel on the Side, and while moist spread it on a Piece of Glass to dry very smooth; when thus dry'd the Surface will appear all over dimpled or pitted by the Scales, which lye under a Sort of Cuticle or thin Skin; this Skin must be raised with the sharp Point of a Pen-knife, together with the Scale, which will then easily slip out, and thus you may get as many of them as you please. Or they may be tolerably well seen thro' the dried Skin, if it be thin and clear and strongly illuminated by the Reflector.

THE Skin of all Fish and Eels appears more or less variegated with a great Number of Specks, Spots, Tincts, and Colours of various Dyes; as any one will soon be convinced, by viewing the Skin of an *Herring*, but more especially of a *Mackerel*, by the Microscope.

INSTEAD of *Scales* some Fish are arm'd with small but very sharp-pointed Spines or Prickles which grow very thick all over the Surface of their Bodies; these are most remarkable in that which we vulgarly call a *Seal's Skin* (which on this Account is of great Use among Joyners;) they appear, when view'd by the Microscope, to consist of several single *Spiculæ* proceeding from a large
Base

Base, and terminating in a sharp Point at Top, which is somewhat curv'd, that so they might lay the fatter hold on any thing they are struck into.

SOME Fish have neither Scales, nor *Spiculæ*, but have their Armour purely defenfative; as is evident in that curious Instance of what Tradesmen call the *Nurfa-Skin*; this Skin is beautifully studded all over with hemispherular Bodies, some large, some small, with white Heads; speckled on the outside, within white as Ivory, and harder than a Bone. So that this Fish-Skin makes a Coat of Mail impenetrable even to Steel. It is of great Use in covering the Cases of Microscopes, Telescopes, and those for Chirurgical Instruments.

THE SKIN which covers the *Saw* of the *Saw-Fish*, is a most curious Subject for the Microscope; but whether the Skin which covers the Body of that Fish be in the same Manner decorated, I cannot say, having never seen more of that Fish than the Saw.

THE FINS of *Fishes* are a wondrous fine Subject; for they are beautifully colour'd, and stellated beyond any other Part; they consist of hard, round, spinous, jointed Ribs, connected together by a transparent Membrane; on which Account the Blood-Vessels are very visible in the Fins and Tails of Fishes, and consequently the Circulation of the Blood thro' them; which here may be seen as evidently as in almost any Subject whatsoever.

THE FLESHY FIBRES of *Fish* appear to be larger than those of any other Animals, as I have already observ'd, particularly those of Crabs, Lobsters, &c. But what is most remarkable is the Disposition and Direction of those Fibres (in the Flesh of some large Fishes) which lye next the Skin; for in the Flesh which is left on the *Nurfa-Skin* we find an infinite Number of *Strata* or Layers of Fibres lying on each other, the Fibres of one *Stratum* being precisely at Right Angles with those of the other. Hence if two of these *Laminæ* or Layers of Fibres be carefully separated from the rest (as may be easily done by Maceration in cold Water) they will

will then so nicely represent a Piece of fine Linen, that I have more than once shewn it for such, without any Discovery of the Deceit ; for tho' in Linen the Threads are interwoven, and in the Flesh of Fish they lye upon each other, yet the Appearance is much the same in both ; so nearly does Nature and Art, in this Case, coincide.

THE SPERM, or *hard Roe of Fishes*, appears by the Microscope to be nothing but an *Ovarium* of Eggs, which are larger or smaller in different Subjects, are perfectly round, and are in the Crab or Lobster a very pretty Object, when magnified.

THE TEETH in several Fishes, and particularly in Eels, are so small, so sharp pointed, so regularly disposed, as to make a delightful View in the Microscope.

THE BRAIN, with the fine Ramification of Blood Vessels, the several Nerves, &c.

THE EYE, its beautiful colour'd *Iris*, and perfectly round crystalline Humour, with the Expansion of the Optic Nerve,

THE peculiar Structure of the Lungs, and other *Viscera*,

THE GILLS, and their particular Make ; are all Subjects which give particular Satisfaction and Pleasure, when duly examined by the Microscope.

THE EYES of a Crab or Lobster, (and all of that kind) are of a particular Structure ; the Body of the Eye is here of a long or oblong Form, not round as in other Animals ; the Fore-part, or *Cornea*, is prominent and full of Lattice-Work, or small Squares, each whereof is, we may suppose, an Aperture (if not an Object-Lens) to a small long round Tube, which lyes immediately below it, and goes to the Bottom of the Eye ; these *Tubulæ*, or fine Pipes, may therefore be esteem'd so many very small Telescopes, or somewhat analogous thereto ; and so one of those Eyes may be look'd on as a compound Organ, consisting of so many simple Instruments of Vision, as there are small Tubes in its Composition. For as Nature does sometimes produce an Infinity of Effects by one
and

and the same Cause; so, on the contrary, she very often furnishes a very large Apparatus of Means or simple Causes, which all jointly conspire to produce one single Effect.

THE SHELLS of most sorts of Shell-Fish have something extraordinary in their Colours, Forms, or Contexture, discoverable by the Microscope, which will be more than evident in viewing proper Parts of the Shells of Crabs, Lobsters, Oysters, &c. The single thin Plates or *Laminæ*, which compose the latter, appear of a Retiform or Net-like Texture; *i. e.* full of Pores, or small Holes, but round.

THE FIMBRIÆ, or fringed Extremities of the Parts of the Shells of Crabs or Lobsters, and particularly the latter, are a beautiful subject; for they appear to consist either of hard bristly Hairs alone, or else of these and other Parts, like *Feathers*, alternately set together. These small *Plumulæ*, or Feathers, are form'd most plentifully on the under Parts of the *Annuli*, or Rings of a Lobster's Tail.

ANY one who will give himself the Trouble of dissecting a Shell-Fish of the Oyster, Muscle, or Scollop Kind, will find himself well rewarded with an unexpected Variety of curious Microscopic Objects, which will at once delight and instruct his Mind in the Knowledge of that Part of animal Nature, hitherto so very little known. I should not have mention'd the Ordure or Excrement of those Fishes (best view'd in a Scollop) but that it makes a most delicate Appearance, both in regard of the Matter, which seems to be an exceeding fine Earth, and the exquisite fine and beautiful Impression of the Intestine, which excludes it; a just Idea of which can only be had from the Microscope, and not from any Description in Words.

CHAP. XI.

Of Microscopic Objects arising from the various Kinds of Insects.

THE most evident and perfect Transition from one Species of Animals to another, is that from the Quadrupede to the Insect in the *Gryllotalpa* or *Mole-Cricket*; a Creature of singular Beauty, and a surprizing Conformation of Parts; as indeed are all of the Insect Tribe.

THIS Genus of Animals is very extensive, and contains several subordinate Species; the principal of which are those which follow; *viz.* (1.) The *Papilionaceous*, or the Butter-fly and Moth-kind; (2.) the *Apian*, or Bee-kind; (3.) the *Ichneumon*, or Fly-kind; (4.) the Gnat-kind; (5.) the Cricket-kind; (6.) the *Scarabæous*, or Beetle-kind; (7.) the Louse-kind; (8.) the Spider-kind; (9.) *Aquatic* Insects, of which the Species are almost innumerable.

IN the *Butterfly* every thing is wonderful, and the Subject of the Microscope; as the curious *Head*, with the two *prominent hemispherical Eyes*, which are finely chequer'd, and of various Colours; and in some I have observed a sort of Hair grow all over their Surface; which is a Particularity not to be found in any other Creature. The *Antennæ*, or Feelers, are the Objects which next present themselves; and these in Butterflies consist of a long round Shaft or Stem, with an oblong hollow Head at the Top, which contains a clear Lymph. In the *Phalæna* or Moth-kind these *Antennæ* are of a most curious Form, being in some of the large ones of a plumiform Shape, or like a fine large Feather, as are also those which are bred of the Silk-worm. The *Proboscis*, or long pointed

pointed Spears which these Insects thrust to the Bottom of Flowers, to gather from thence their Nourishment, is of an admirable Form, and curiously coil'd up when not in use. This Part is best view'd in the largest Sort of Moth. The several Parts in and about the Mouths of these Insects are an odd and wonderful Appearance. But in this Species the most delightful Spectacle is that gay and rich Variety of Colour in their Wings, and that farinaceous or mealy Matter with which their Wings and Bodies are cover'd; the divers, distinct, and regular Forms and Appearance of which Phænomena never fail to give the greatest Delight and Satisfaction, even to the most indifferent Beholder.

OF the *Apian*, or Bee-kind, the most considerable are the Hornet, the Bee, the Wasp, and the *Bombylius*, or Humble-Bee. In these we view a very fine Head, with two oblong prominent chequer'd Eyes; a curious Apparatus of Parts about the Mouth; with a large *Proboscis*, with which the Bee collects the Mellific Particles of Flowers, &c. the Hair which grows on the Bodies, especially of the Humble-Bee; the curious Legs, and fine Claws or Hooks on the Feet; the transparent membranaceous Wings, with the curious Divarications of strong fibrous Ribs; and above all, and what is peculiar to this Species, the fine Spear in the Tail, which we call the *Sting*, with its barbed Top, and the Duplicatures of the *Vagina*, or Sheath which contains it; the *Annuli*, or Rings, which make the abdominal or hinder Part of the Body, which appear beautifully speck'd and dimpled all over the Superficies.

I can't here pass by the most curious and delightful Appearance of the muscular Fibres, as they lye in small Bundles of Fleth in the middle Part of these Insects, and are seen immediately upon dissecting and raising that Part; this may be most successfully attempted in the Humble-bee, after it has been dead two or three Weeks; for then the Fleth is pretty dry and hard, and the *Fasciculi* or Bundles of Fibres may be taken out together, and are easily separated

rated or dissected so as to observe them singly with the same Distinctness as the fleshy Fibres of Quadrupedes, or larger Animals. The *Membranes* and *Viscera* of Insects, are also a most delicate Subject, especially as they appear upon dissecting the Abdomen of the largest Sort of Moth, the Hornet, the Buck-Fly, or *Grillotalpa*.

AMONG the *Fly-kind*, that which we call the *Dragon-Fly*, is the largest, and deserves our first Notice; its very large transparent chequer'd Eyes, with their fine Colours; the beautiful Parts of the Head and Mouth; the exquisite Colours, &c. of the Body; the Legs; and the large transparent membranous Wings of a peculiar Make and Texture, are all Objects for a Microscopic View. In the *Flesh-Fly* we find, perhaps, the most beautiful Head and Eyes that any Creature wears; nor are the Colours of its bristly Body less noble, strong, and glaring; particularly the green, the blue, and red of some that fly wild among the Trees of the Garden and Fields. The Eggs of the *Flesh-Fly*, which we call *Fly-Bloats*, are a very pretty Spectacle in the Microscope. Among the infinite Species of the *Fly-kind*, we find something ever new and surprizing either in the Colour, Make, Size, or various Structure of the Parts, which would be endless to recount.

IN the *Gnat-kind* we find several remarkable Particulars; as their fine small Head; round globous chequer'd Eyes; their curious small, long, knotted, and hairy *Antennæ*, in some; in others they are brushy or plumiform; their very long and small Legs, and hooked Claws; the Length and Tenuity of their Bodies; and lastly, the long small pointed Spear that goes from the Tail of some of those Species. The *Eggs* of *Gnats* are of various Forms, and disposed in a very beautiful and wondrous Manner in the Water, for the most part, some among the fine Moss on the Sides of Walls, and others in other Places. Those in the Water exclude a small Animal, of an odd and ridiculous Form: From this we have a second Metamorphosis into an Animal of an hideous Shape, and makes the merriest Figure in the

Microscope. Both these rise in great Number to the Surface of stagnant Water, and the former ever hangs in an inverted Posture, with its Head downwards; from the latter, at mature Age, proceeds the infant Gnat, by slow Degrees, in a perpendicular Manner, with its Head upwards; in a short Time after its Exclusion it finds its Legs, and then its Wings; flutters on the Surface of the Water a while, and then attempts its Flight in the new but natural Element, the Air. The Gnat which is bred from the *Chrysalis* in the Wall, is a most delicate, but seemingly a very foolish or shiftless Creature; for as soon as they are hatch'd they fly to some near adjacent Place, and there they stay as long as you can have Patience to observe 'em, without ever moving from the first Place for many Days together.

THE *Ephemeron Fly* is of the Gnat-kind; and is, perhaps, as great a Curiosity as any in Nature. It takes its Name from the short Duration of its Life, which is but the Space of *one Day* at most, and ordinarily not above 6, 10, or 15 Hours, as I have found by sufficient Experience. They are bred from Eggs laid on the Surface of Water; from these Eggs are first produced a small long red Worm, which flings itself along in the Water in the Form of the Letter S, and by that means has a Motion peculiar to itself. The Make of this Worm is very curious; when it has arrived to its mature State, it makes itself a *Theca*, or Case, in the Mud at the Bottom of the Water, the Top of which is open, where they put out their Heads, and thus they continue 'till the Time of Metamorphosis, when they are changed into an incomparable fine Animal like a Fish, which at its full Growth is about half an Inch long; this Animalcule is too curious and singular in all its Parts to be here described, nor will any Method be sufficient to represent it but the Microscope. From this Creature at last is produced the *Ephemeron Fly* or *Gnat*, which is the most delicate and beautiful of all this Class; it is bred or hatch'd about Six in the Evening; they frisk about a few Hours on the Surface of the Water, engender,

der; lay their Eggs, grow old, and dye, generally before Six the next Morning. I have often tried, but could never above once keep one of them alive Forty-eight Hours.

THE *Cricket-kind* has many Subjects worth our Observation. The *Gryllotalpa* or Mole-Cricket is the first of this Tribe, and is matchless in regard both of its amphigeneous Nature and Form, and the Beauty of its Parts, as they appear thro' the Microscope. The *Grasshopper* is another Insect of this kind; every Part of which makes a fit Subject for the Microscope, especially in the large green Sort, where the Legs beautifully colour'd, and set with sharp Spines, are a very pretty Spectacle. This Creature in its Nympha-State within the white Froth, which it emits all around, is also a very curious Object to view. Of this Sort also are those cantillating Domesticks we call *Crickets*, which harbour in our Chimneys. The *Locusts* are the Head of this Species; but as they are not to be come at in our Country, 'tis to no Purpose to take further Notice of 'em here.

THE *Scarabæi*, or Beetle-kind, subdivides into various Species, of which the Principal is the great Stag-Fly; the Eyes of this Creature, its Horns, the Surface of its Head and Body, its Wings, and Legs, and Claws, are all proper Subjects to employ the curious Eye. And also the internal Parts, which appear upon Dissection. In the common *Black-Beetle* nothing can equal the noble Mazarine Dye of the Thighs, and the delicate Form of their Feet; the *Antennæ* in some of these are of a curious Structure, I need only instance in those of the common *Chafer*, which I would recommend to the View of the inquisitive Reader. The *Lady-Bird*, or *Lady-Cow*, is also of this Class; whose Spots and other Accidents, make it the Subject of the Microscope. The *Ear-Wig* is remarkable for the *Forceps* or Pinchers in its Tail, which must appear very formidable to the Eyes of those Creatures which see 'em much larger than we can do by the Microscope.

OF the *Louse-kind*, the most notable are those we call *Ticks*,
which

which however loathsome or disagreeable they are to the naked Eye, they make a very pleasant and admirable Appearance in the Microscope. The *Lice* which infest the Bodies of most Animals are worthy our Inspection ; particularly that *Opprobrium* of our own Species, that contemptible little Animal, which crawls so intrepidly over our Bodies, and riots in our Blood, when view'd by the Microscope gives more Pleasure than ever it did Pain before ; and when we view well every Part of its Body we must necessarily have a different Opinion both of it and ourselves than what we conceiv'd before. The *Knits* which stick on the Hair, are the Eggs of these Creatures ; and make a pretty Microscopic Object. The *Flea* is not indeed of the *Louse-kind*, properly speaking ; but being near Neighbours, and Mefs-mates, they may be rank'd together : The Flea makes as odd and surprizing a *Phænomenon* in the Microscope, as it is singular in its Nature and Form. The *Death-Watch* (I mean the most common Sort) is of this Tribe ; in common Appearance they very much resemble Lice, and are always found amongst Dust behind Picture Frames, and in old Books : they are a very pretty Object when view'd in the Microscope. The other Sort of *Death-Watch*, is a little brown Insect, which make and harbour in those little Holes we observe in the Wood of our Window Boards, Frames, &c. The *Mites* belong to this Class ; and are a Subject of which we can form no Idea but by the Microscope, for by reason of their smallness they elude the common Sight ; but this way they appear to be a most beautiful, brisk, and nimble Animal, arm'd with sharp Spines all over their Bodies ; and, when those which are found in Meal or Cheese are view'd, they make a very diverting Object, as they appear in living Heaps crawling and tumbling over one another. As for the Lice on Plants they are properly of the Fly-kind in their mature or last State ; but both these small Flies, and their Lice-like *Nymphæ* are in their several Kinds curious Objects for the Microscope.

THE *Spider-Genus* affords a rich Variety of Subjects, both in
regard

regard of the *numerous Species*, as well as the *peculiar Structure of Parts*, in each Individual. The large *Garden-Spider* is finely beautified with Colours, which make that Sort of Hair wherewith they are cover'd, have a very grand and noble Look. The smaller Sort of *Garden* or rather *Wall-Spider* is also richly variegated with Colours: And the very small *Red Spider* is a most delightful Object, when view'd by the Microscope. The large *Green* and *Yellow Spider* (found in the Fields) are worth observing. The *Eyes of Spiders* are a peculiar *Phænomenon*; in some you view *two*, in others *four*, in others *eight* Eyes, as in most of the very large *House-Spiders*; when well magnified, they look as large as Sloes, and are perfectly round, and of a shining jetty black; situated very prominently, in two Ranks, in the upper Part of the Head. The Eyes in Spiders being small and immoveable, is the Reason why they are furnish'd with so many, for by this Means they have a keen Sight, and command the whole Hemisphere about 'em. The *Mouths of Spiders* are furnish'd with an horrible *Apparatus* of Instruments, by which they readily seize on, and devour their Prey. To view one of these Creatures, sucking the Blood of a poor Victim-Fly, with a Microscope, is at once both a diverting and shocking Sight. The hairy Legs and sharp Talons or Claws in Spiders, are a pretty Sight, especially those very long ones of the *Shepherd*, or *Carter*, which indeed is a wondrous Creature all over, as any one must confess who has view'd it. The little Tubercles about the Tail of the Spider, from whence they spin their Web, are evident by the Microscope; and to see them exert their *Textrine Art* with this Instrument, will give you the highest Satisfaction. Nor is that Web itself in some Species of Spiders, a trivial Object; but will present you with the Appearance of a fine Thread or String of Beads. The *Exuvia*, or Skins which the Spiders cast, are a Curiosity worth our preserving. And a Nest of *Spiders Eggs*, and especially the young ones, when just hatch'd, are a most entertaining Sight in the Microscope.

THE *Emmet* or *Pismire* is a Creature of the Insect-kind; and when it is seen by a Microscope that will take in the whole, it makes such an awkward comical Figure, that a Person who beholds it, and can forbear laughing, must be a Man of great Equanimity indeed.

AMONG the *Aquatic* or *Water-Insects*; there are many Sorts of Water Gnats which play on the Surface, and a great Variety of large and curious Insects which live wholly in that Element, that are exceedingly well worthy our Observation and Inspection with the Microscope. The best Way to catch 'em is to turn a Piece of Wire in the Form of a Ring about three or four Inches Diameter, and to stick one End into the End of a Cane or Staff, then putting a Piece of fine Linen over it to hang down with a Bag like a Net, you may with this Instrument take any Animal you can see in the Water, and by this Means acquire as great a Variety, as you can find on the Land; and some Objects whose Parts are more different, and more surprizingly disposed, than can well be imagined by any one who has not survey'd the watry Tribe.

C H A P. XII.

Of Microscopic Objects arising from the Reptile and Serpent Kinds.

BY REPTILES I mean all those Animals which move by *creeping, crawling, or hopping along on many small Feet.* A *Reptile* being so call'd from *Repo*, (*reptum*,) to creep or crawl along.

AND by SERPENTS I understand all that insinuate themselves along or move forward without Feet. As Adders, Snakes, Slow-Worms, &c.*

OF the *Reptile Genus* there are many Species, both on Land and Water, and most of them without a Name. I shall take Notice of some of the Principal which are more immediately the Subject of the Microscope.

THE *Millepede-kind* make here the first Class; among which the large *Centipede* brought from *India*, is an extraordinary Subject, if we regard the Eyes, the large *Forceps* or Pincers on its Head, its long pointed Body, and its numerous Feet and Claws. Somewhat like this in Form, is that long slender nimble Worm found at the Roots of Trees and Flowers in digging of Gardens; as also one of the *Noctiluca-kind*, or those Animals that shine by Night. If either of these Animals be taken alive, and placed under the Concave Glass, so that they may have Room to move, and then view'd with the Microscope, 'twill be very surprizing to see that orderly yet confused Motion of all the little Legs on each Side the Body.

THE common *Noctiluca*, or *Glow-worm*, is a proper Subject for the Microscope, for if it be view'd with the least Magnifier in the Luminous Part while shining, you will perceive a faint, still Glare, inclining to a bluish Colour, which this Creature can make to appear or disappear at Pleasure: The Head, Eyes, Legs, and other Parts of this Reptile are likewise worth observing.

THE *Chefs-Bug*, or *Wood-Louse*, is a Creature of a curious Make or Structure, as will appear if you take a View of its variegated Coat of plated Armour, in some of the larger and more beautiful Sort.

The *Grub-kind* is very extensive; I mean the various Sorts of

* Thus *Serpent* is derived of *Serpo*, (*Serpens*.) to creep, to slide along on the Belly. And indeed both *Serpo* and *Repo* (by a *Metathesis*) are form'd of the Greek *ῥῆμα*, to creep, or crawl along.

Maggots hatch'd from the Eggs of Insects deposited in the Earth, rotten Trees, &c. among which the inquisitive Virtuoso will find many entertaining Subjects, when view'd with the Microscope, though generally esteem'd so very disagreeable a Spectacle to the naked Eye.

THE *Caterpillar-kind* are undoubtedly the most *singular, delicate, and gaudy* Part of the animal Creation. Nor does any Species of living Creatures regale the Eye with a more delightful Variety of Peculiarities; some are exceeding glabrous and smooth; others richly ornamented with delicate Tufts of Hair of various Dyes and Colours; others surprizingly bracteated with brilliant Protuberancies or Spangles all over their Bodies. To view their numerous Claws in each short broad Foot; their painted, polish'd, spangled, hairy Bodies; their Eyes and Mouth, and the Manner of their feeding on Leaves; the Web or Silk which they spin, and the curious Manner in which they dispose it with their Mouths; and lastly, the various Forms and beautiful Colour and Tints of the *Aureliæ* into which they are transform'd for their last Change, are all of them such Arguments of infinite Wisdom, Design, and Providence, that I would recommend them not so much to the *Curioso* for his Delight, as to the *Atheist* for his Conviction and full Satisfaction of the Existence of a Deity.

THE *Cados-Worm, Cod-Baits, Straw-Worms,* and all the *Phryganean* Tribe, which make themselves *Thecæ* of Straw, Pebbles, Sticks, small Snag-Shells, &c. are, both themselves and their *Thecæ* or Cases, very proper Subjects for the Microscope. And more especially a small Land-Animal of this Sort, which are found in great Plenty crawling on Fruit-Trees or Walls, with their *Thecæ* almost perpendicular, about the Size of a Barley Corn. To view the Form of this Creature, the most curious Composition of its *Theca*, while it is crawling under the Concave-Glass, is a *Phænomenon* to the last Degree entertaining and delightful.

THERE are various other Animals of the *Reptile-kind*, which
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the curious Enquirer will find on every Spot; but as they have no particular Names, nor are reducible to any general Class or Species, I am obliged to pass them by, and shall next proceed to the Principal Objects among

THE *Serpent-kind*, or those which crawl on their Bellies without Legs or Feet. Of these the most remarkable is the *Viper* or *Adder*; in which we view the *various colour'd Scales* which cover its Body, in the *Exuviae* or old cast Skin; its Eyes, its forked Tongue and Teeth, among which we observe that peculiar Tooth or Fang, thro' which in the Bite distills that deadly Drop, for which those Creatures are so terrible, and often fatal, to Mankind. The Use of the Microscope in dissecting this Animal is every Way very great, as may be seen in Dr. *Mead's* Essay on Poyson, and others who are refer'd to in that Book.

IN the same Manner we may examine and take a View of the several Parts of the *Snake* and the *Slow-Worm*, both external and internal; and not without the greatest Pleasure and Improvement of the Mind, to those who are delighted with the Knowledge of the different Methods, and infinite Variety of Nature in the Structure of Animal Bodies.

THE *Earth-Worms* are another Class of the *Serpentine-kind*; of these there are divers Sorts. They also cast their Skins, which being so exceeding fine and transparent, are seldom to be found, but when they are, make an extraordinary Subject for the Microscope; as do also the very fine Scales which make them feel so rough to the Hand drawn from the Tail towards the Head. The *Mouths* of these Animals are only discoverable by the Microscope. The *Viscera* and Intestines of Worms are worthy our Inspection, and their *Dung* or Excrement, both *moist* and *dry*, for Reasons which will then be apparent.

THE *Snails* are a notable Species of this creeping Kind. Their *Shells* are many of them beautifully embellish'd and variegated with Colours, and curiously wrought. The Eyes of *Snails* are a re-

markable Oddity, they are seated on the tops of their large Horns, by which means they can be drawn into the Head or thrust out at Pleasure. Their *Teeth* are another Microscopic Object, and it is very pretty to see 'em feed on Leaves, &c. with this Instrument. This Animal is *Hermaphrodite*, and the *Parts of Generation* are in the Neck, which *in Coitu* are easily examined by the Microscope. The *Eggs* of Snails are round and white, and, when hatch'd, the young tender Brood make a very pretty Scene in the Microscopic Theatre.

C H A P. XIII.

Of Microscopic Objects arising from Plants and Vegetables.

TH O' a great deal has been said, and Volumes wrote on the Subject of PLANTS and VEGETABLES, little worth our Notice has been discover'd in their Nature, Parts and Texture, 'till the Use of the Microscope was applied to that Purpose. Since that Time Philosophy, in this Part, has received the greatest Improvement; and 'tis surprizing to consider in how short a Time, by this Means the Oeconomy of Nature in the various Processes and Gradations of Vegetation has been most accurately detected, and expos'd to the View of Mankind.

FOR upon a Microscopic View and *Examen* of the *Cortex*, or *Bark* of Trees, we find it to consist of *Lignous Fibres* implicated in a retiform Manner, the Interstices of which are fill'd with *Utriculi* or little Bags or Bladders turgid with Juice; which, when they pour out, become flaccid, and make a fine dry Skin or Membrane,

brane, which is easy to be observ'd in the Rinds of the *Plumb-Tree*, *Cherry-Tree*, *Beach*, &c.

THE *Lignous Fibres* lye in several *Strata* one upon another, and their Intervals diminish as they approach the Trunk; they consist of numerous hollow *Fibrillæ*, or Threads, which contain a Liquor that passes thro' them in a Sort of Circulation. The Orifices of these Sap Vessels are plainly to be seen in a transverse Section of some Cortices; and the *Utriculi* or small Globular Bladders in thin Slices of Cork, make as pretty an Appearance as as any thing, perhaps, that is view'd in the Microscope.

THE *Stem* or *Trunk* of Trees, when view'd in a transverse Section, appear also to consist of vascular Parts, or hollow Fibres; and a *Parenchyma* of Utricles, which fill up their Intervals. Thus if a Vine Branch be so cut into thin Slices, you will see a most beautiful Appearance of Orifices of Vessels, and Fibres, and Utricles all tending to, or rather radiating from, the Center or Pith, which you will easily perceive consists of an infinite Number of fine transparent Bladders, particularly if it be that of Elder, or such like Wood.

THE *Lignous Fibres* and Vessels lye in various Directions, some perpendicular, others horizontal, and others run obliquely. These perpendicular and horizontal Fibres lying *Stratum super Stratum*, make the Appearance of a most curious Texture, or *Web of Warp and Woof*; as is most visible in a Piece of *Fir* or *Deal*; or in a Piece of *Touch-Wood* rightly split, especially that taken from a rotten *Elm-Tree*.

AMONG these hollow Fibres some grow in a *spiral Form*, like the Worm of a common *Bottle-Screw*; these are larger, and less numerous than the rest; they are supposed to be the *Tracheæ* or Air-Vessels in Plants. These spiral Fibres are most easily view'd in the Foot of a Vine-Leaf, carefully broken while succulent or full of Juice; for then if a Microscope be applied to the Fracture, there will be seen those spiral Fibres going from one Part to the other,

other, more or less drawn out or uncoil'd; and not only one but several of them, which make a most delightful View.

THE Structure of the Roots of Plants and Trees is nearly the same with that of their Stems or Trunks; consisting of *Sap* and *Air* Vessels, with a *Parenchyma* of Utricles; but in this Part we see no Pith; and tho' the Root be that Part which sucks in the nutritious Juices for Vegetation, yet are the Orifices of the Vessels too small to be seen by the best of Microscopes: But the Vessels themselves in the Body of the Root are more discernible than in the Trunk, if we cut it transversely into thin Slices; and for this Purpose, the Elm-Root is the most eligible among Trees, and the Root of Fern among Plants is the most beautiful Sight that can be seen of this kind if cut in the thickest Part, and view'd when dry.

THE *Gems* or *Buds* of Trees are a noble Subject for the Microscope; for they afford a particular Pleasure if analysed with this Instrument, by viewing the various Forms and Colours of the *Involucra* or external Coverings, which in some are smooth, in others downy, and like Scales lye one upon another, within which is contain'd the tender Branch, whose several Twigs and Leaves, if carefully unfolded, may be easily seen in Miniature. The *Gems* of Flowers in Fruit-Trees, when open'd, discover a curious Prospect in the squamous Leaves of the *Involucrum*, border'd with pearly Globules, or nicely ferrated with regular Denticles; and under these appear the delicate Flower folded up, yet all its Parts distinct and visible: And lastly the Embryo-Fruit, which if cut asunder shews all its Parts duly form'd, only in small, and in a juicy or *fœtal* State, which is afterward matured by Age.

THE *Leaves* of Trees are the Subject of the Microscope throughout; for in regard of their Surfaces, we observe in many of them a curious *Phænomenon* of Adjuncts or Increscences, in various Shapes and Colours; as of pellucid aqueous Globules in *Mints*, *Hyssop*, *Pennyroyal*, &c. of opake, white, waxen Balls, or *Pilulæ*, in those
of

of *Sage*; of pearly Drops in *Spinage*, especially wild *Spinage*; thus the Leaves of Hops are nobly imbossed with golden Studs: And, finally, the Surfaces of *Sow-thistle Leaves* are curiously decorated with innumerable Strings of Bead-like Bodies; not to mention various others which the *Virtuoso* will find in several other Plants.

IF *Leaves* are steep'd in Water for Maceration, the Pellicle or thin Skin of both Sides will easily peel off, which laid on a Glass and view'd with the Light reflected thro' them, will discover a most delicate Texture in fine diaphanous Membranes of Net-work; as may be seen in those of *Oak, Maple, Holly, Walnut, Orange,* and all the Evergreens. But as for the Pores which some have pretended to have discover'd, I never could by any Means attain to the Sight of them in any Subject I have examined.

BETWEEN these two Skins is contain'd the Parenchymous Substance of the Leaf, which appears to consist of an infinite Number of Utricles, or little pellucid Bags of a green Liquor or Juice, which are all implicated or contain'd in an internal fine Membrane, which is extended thro' the whole Leaf between the *Areolæ* of the Lignous Fibres. This may be examined in all the grosser Leaves; as of the Fig-Tree, &c.

THE lignous or fibrous Part of the Leaf, when divested of all the *Parenchyma* by Maceration in Water, makes a most beautiful Spectacle, consisting of a large Body or Stem in the Middle, with a great Number of Collateral Branches issuing from either Side, which again are most minutely ramified into numberless *Fibrillæ* intervening and inosculating with each other towards the Extremities, so as to form a Texture exceeding the richest and most exquisite Piece of Lace-Work ever yet seen. And what is most remarkable, is, that this Skeleton of lignous Fibres is composed of two Layers or Courses of Fibres, superposited one upon the other, and are easily divided or separated from each other throughout, by Maceration, by a dextrous and experienc'd Hand, especially in
the

the *Holly-Leaf*, or, which is much finer, the *Apple-Leaf*. These are supposed to be analogous to the System of Arteries and Veins in the human Body, which constantly accompany each other thro' all their Infinity of Ramifications, tho' not so unitedly as in this Case of Plants.

THE broad long Leaves or Blades of Grass, Corn, and annual Plants, as Onions, Leeks, &c. if inspected in the aforesaid Manner by the Microscope, will afford Entertainment enough to the ingenious Naturalist. To observe the *Aculeoli*, or spinous Stings of Nettle; the uncated Tenters, or Hooks of Clivers; the scarlet or crimson *Aciculæ* or Pin-like *Stamina* on the Foot-Stalks of the Leaves of the Filbert-Tree, &c. with the various colour'd *Lanugo*, Down, Hairs, &c. observable on many kind of Plants, are Topics of the finest philosophical Amusement.

THE *Flower in Plants* is the next Part which offers itself to the Microscopic Eye; here Nature exuberates in Gaiety and Variety, and seems ostentatious of Contrivance and Design. How noble, how rich, how delicate, is the whole Composure of every Flower! How various, deep, and bold, are the Colours of the Leaves! How delicate the Attire of tender *Stamina*, with Heads of a *Semiform* Matter or Dust, which appear perfect Globules in all the Degrees of Miniature! These are largest and very beautiful in the *Marshmallow Flower*, the *Tulip*, *Lilly*, &c. The *Stylus* is often of a curious Shape on the Top, it is supposed to be hollow in all Flowers, serving as a *Vagina* to receive the Semen or Dust of the Apices of the *Stamina*, and to convey it to the *Matrix*, or Fruit, which, as *in Utero*, contain the true Seed or Kernel from whence the Plants proceed. This is the Theory of the Generation of Plants and Trees; which, as in that of Animals, is of such a Sort, that having proved one Part, we are obliged to suppose the other.

THE *Fruit of Plants* is contrived with infinite Variety for the Use abovemention'd; 'tis impossible to take Notice of every Part here

here that well deserves our Regard and Inspection by the Microscope. I shall only just remark, that the succulent pulpy Part in Apples, Gooseberries, Cherries, &c. if cut into very thin Slices, and laid under the Microscope, will discover a fine Contexture or Branchery of fibrous or vascular Parts, whose Interstices are fill'd with Utricles of Juice, in many, so delightful to the Taste: And also that the Kernel does consist of an infinite Number of round or spheroidical Corpuscles, which also compose the Substance of all Kinds of Pulse, as Beans, Pease, &c. These are evidently seen if a Bean, for instance, when boil'd, be gently rubb'd on a Glass, and then laid under the Microscope. In the last Place, a great Curiosity it is to view the future Plant in the present Fruit, compleat in every Respect, even while it is yet in the Pod, or Shell. This may be very easily observ'd in the larger Sort of Garden and Kidney Beans, and in the Fruit of divers Plants and Trees.

THE small *Seeds* of Plants and Vegetables of the lesser Species, are a copious Subject for the Microscope; particularly that of *Fern*, which grows in small *Heads* on the underside of the Leaves round the Edges; these are of the same kind with those which grow on the Leaves of Hart's-Tongue, which when ripe, and rubb'd on a Glass, will disclose and shed abundance of small Seed like Dust, but when view'd with the Microscope appear perfectly round, and so small that Millions grow on a Leaf. These pulverulent Seeds grow in a somewhat different Form on the Leaves of *Hart's-Tongue*, and the Maiden-Hairs; in which latter Plant they are of such a curious and peculiar Form, that you would be apt to mistake 'em for a beautiful small Sort of Caterpillar, were you not told beforehand what they were and whence.

THE several Sorts of Mosses will employ the leisure Hours of the Microscopic Virtuoso to very good Purpose; as also the various Species of *Mushrooms*, *Puff-Balls*, *Truffles*, &c. The Excrecences of Trees, particularly that *Fungus* we call *Jew's Ear*, is a

very pretty Phænomenon in the Microscope.

THE *Flower* of Grass and Corn; the *Beard* of *Wheat*, *Rye*, and especially *Barley*; the *Iuli*, or Catkins of *Haste*, *Willow*, &c. with a thousand other Adjuncts, will offer themselves to the View and Admiration of any one who shall undertake to reconnoitre the numberless Curiosities of Vegetables.

CHAP. XIV.

Of various Microscopic Objects not reducible to the foregoing Classes.

I SHALL begin this miscellaneous Account of Microscopic Objects with those *Animalculæ* which are to be found in Water, wherein Pepper, Flesh, Leaves, or any other Substance has been steep'd for some Days in the Summer-Sun.

THE first and most remarkable of these is the *Monoculus*, or one-eyed Animalcule, which will be found in great Numbers in every Puddle towards the latter End of the Summer. They are of an odd but curious Form, with one black Eye in the Middle of the Head, and are transparent, insomuch that six or seven young ones are often to be seen in the Body of the old ones. A good Cut of this Creature Mr. *Bradley* has given in his *Survey of the Works of Nature*.

ANOTHER very remarkable Species have Shells of the Bivalve Kind, somewhat like a Muscle; 'tis very pleasant to see how nimbly they move, and with what Agility they work their fine Legs and Limbs, when the Shell is open. Of these there seems to be several Sorts; some are as large as great Pins Heads, and others so small

small as scarce to be discern'd with the Microscope ; some round, others oblong ; some green, others brown, and others almost white.

THERE is another most beautiful Sort of Animalcule, which can't be well described, but in this Particular that it bears its Sperm in two Clusters on its Tail, like two Bunches of Grapes ; one Sort has but one of those spermatic Clusters of Eggs. The Reader will be best satisfied in viewing it ; or he may see the Figure of it among several which Mr. *Lewenboeck* has given in the *Philosophical Transactions*.

THERE is another Sort of *Animalculæ* which have neither Shells nor Legs, but seem to be of the Maggot-kind, they are of an oblong Form, which they greatly vary in their Motion ; they are in prodigious Numbers in prepar'd Water, and move with great Celerity confusedly among each other ; they grow from a small to a larger Size ; *viz.* about the 10th of an Inch long. They have a surprizing Tenacity of Life ; for I have put 'em in a Glass Tube in a freezing Mixture, where they have remain'd frozen in the Ice for an Hour and more ; yet upon thawing the same, those which were not torn afunder by the Extension of the Ice, soon recover'd Life and Motion, and were as well, to Appearance, as before.

AMONG these small Creatures I have sometimes observed a Sort of Spider, at least, a small Creature like one, with a little Body and several Legs proceeding from each Side ; but these are not very numerous, nor often to be observ'd.

ANOTHER kind of *Animalculæ* appear like so many *Vesiculæ* or little Bladders, tumbling and wavering about in a very odd Manner ; they are not perfectly round ; have neither Head, Tail, nor Legs which one can distinguish, nor are they transparent, nor quite opake. These Characters I believe will convince the Reader when he sees the Animal I mean.

THE last Species of these Animalcules I shall mention, are the most wonderful and surprizing of all, in regard of their Number

and Minutenefs; for they appear but as Points thro' the largest Magnifier: They make that Scum or thin Spume we often observe on the Surface of stagnant Waters of a greenish Colour, sometimes of a yellowish, and sometimes of a bluish Hue. If a Piece of Glass be carefully put under it to take up a Part, and then laid under the Microscope and strongly illuminated, you will perceive an infinite Number of living moving Points, as it were; they are of a roundish Figure, and nearly as small as those in *Semine Masculino*. They appear all at once on the Surface of the Water, and almost as suddenly disappear; and what becomes of 'em, I believe he only knows who at first gave them being. However they are conjectured to be the Nympha State of some small Insects which fly invisible in the Air, which lay their Eggs on the Water, as the the Gnat-kind are known to do.

IN *Vinegar* there is another Sort of *Animalculæ*, which is of the *Anguicular* or *Eel-kind*; for they differ in nothing but Fins from the Form of Eels that I could ever observe: They are not to be found in all *Vinegar*, but chiefly that which is stale, and the last Run of the Cask. They are often so large as to be seen with the naked Eye. The best way to get a great many in a little Compass is to take a Quantity of that *Vinegar* in which they are found, and filter it thro' a Piece of Paper to as small a Quantity as you desire, and then putting it under the Microscope, you will have a most entertaining Sight of those curious little Creatures, which will now look large, and resemble those in our larger Ponds.

I have found these *Anguiculæ* likewise in the Water which stands in the Cavities of *Cow-Dung* after a Shower of Rain; and I find others have seen them in mouldy Paste; but I confess I never could, tho' I have often sought after them in that Substance. I have likewise very carefully, and often examined Blood, Milk, Urine, and other animal Fluids, but could never see the least Appearance of an Animal in any of them, but the *Semen*; tho' I know

know some have asserted they have. The same I can say of all fermented Liquors, as Wine, Beer, Cyder, &c.

IF while you are viewing these *Animalculæ* you let fall a small Drop of any Spirit, as Brandy, into the Water, you will perceive they will be greatly disturbed, and soon become motionless and die, which plainly proves that Water is their only Element to live in.

C H A P. XV.

Of Miscellaneous Subjects for the Microscope.

I SHALL here treat of those Subjects which could not well be reduced to any of the foregoing Classes; and as they are heterogeneous and independent of each other, I shall pen them down just as they occur, without any regard to Order; and first, among these, is

SPONGE; this is a submarine Plant or Moss, which upon being view'd in the Microscope, will discover such a Composition and Texture of Parts, as are equally full of Wonder and Entertainment. There are many other Productions of this Sort to be found in the *Museums* of the Curious, well worth our Inspection by the Microscopē.

SEA-WATER evaporated on a Piece of Glass over a gentle Fire, and laid under the Microscope, will present you a clear View of the Particles which compose our common Salt, in their simple natural State, whence you'll be able to form a true Notion of their Figure, Size, &c.

ALSO the ASHES of any Wood or Plant being some Time steep'd in Water, will communicate its Salt to the Lye; a little of which evaporated, as before, will shew the peculiar Figure of the Salts of that Plant; and by this Means you will obtain a great Variety of Vegetable Salts. The several Figures and Forms in which they are disposed in the Fibres of Plants, you may see in Dr. *Grew's Anatomy of Plants*.

A PIECE of any Sort of fine *Linnen, Silk, Ribbon, &c.* looks so coarse and comically, that it never fails of making a very agreeable and merry Subject for the Microscope.

SAND when thus view'd, appears like an Heap of Stones or Crystal; for they are, for the most Part, transparent; but some are opake: They consist of polish'd Surfaces, and many sharp or pointed Angles in general, on which Account they make a very pretty Spectacle, when the Light is reflected among them especially.

To view the *Edges of Pen-knives and Razors*, and see how jagged and serrated they are; or the Points of the sharpest and finest *Pins or Needles*, and observe how coarse and rugged they are; or lastly, to view the most polish'd Surfaces, as those of Reflecting Mirroures, and see the innumerable Pores, the Scratches and Strokes of the Putty, &c. never fail to excite Admiration and Surprize. In natural Objects, the Politure is heighten'd the more, the more they are magnified; and in all Cases, the more intimately we can approach Nature, the more perfectly her Works appear; quite contrary to what happens in all the Effects of Art, as is very evident by the Microscope.

IF in *striking Fire* with a *Flint and Steel*, the Sparkles are caught in a Piece of Paper folded up, and then placed under the Microscope, they will appear as so many *Iron Bullets*, being perfectly round; which Form they receive from the Particles of Steel being melted by Ignition, and cooling so suddenly

suddenly in the Air, must necessarily conform to a spherical Figure.

THE *Teeth* of a *Rasp* or *File*, of the finer Sort, are worth our View; we shall no longer wonder at their Effects in working on Brass or Iron, when once we behold 'em in a Microscope.

IF a Piece of *Steel* be broke, and view'd on the fractured End, the Particles of the *Steel* will look exceeding bright and beautiful, yea they shine with such a Lustre and *Eclat*, as make them resemble precious Stones.

SNOW is a Meteor wherein Nature seems to observe the strictest Rules of Geometry; every simple original Particle of Snow consists of a central Part with six *Radii* proceeding from the same at equal Angles, which Angles are therefore each 60 Degrees; the central Part is in most a regular *Hexagon*. Each of the *Radii* is richly embellish'd with a Sort of Foliage or *Pinnulae*; and each *Pinnula* variously lacinated, like a Branch of Fern. So that each Particle of *Snow* makes a most rich and beautiful Figure in the Microscope, far beyond what can be supposed by any who have not seen them.

THE *Frost* on Glass Windows is a wonderful Piece of Natural Tapestry in the vegetable Way. The finer and more delicate Parts thereof appear thro' a Microscope so noble and exquisitely fine, that nothing can compare with it in all the Works of Art. The Frost also on the Leaves of Plants makes a glorious Figure; and some Sorts seem to have a kind of Vegetation, which shoot into Leaves, and Stems, on the Tops whereof grow hollow Cups, of six Sides and Angles, all equal and regular. With several other *Phænomena* peculiar to or resembling the vegetable Kind.

VARIOUS Sorts of *Stones*, *Fossils*, *Marcasites*, &c. when broken, exhibit very curious Appearances in the Microscope: Also several Sorts of *Drugs*, and Chemical Preparations; as *Phosphorus*, &c. deserve a Microscopical Examination.

ANY sort of *Spirits*; as *Brandy*, &c. when placed in the
Concave

Concave under the Microscope, will appear to have a confused intestine Motion, the Motes being driven and impell'd this way and that, in all Directions, with unequal Motion ; sometimes very rapid, then stopping at once, then flying backwards, and in this turbulent State it will continue till all the spirituous Part is escaped or gone off, after which the aqueous Part will remain perfectly quiet and still.

IF in any *Acid*, as *Vinegar*, any alkaline Substance be mixed, while under your View, you will perceive a great Colluctation and Effervescence ensue, which will prove a very diverting Spectacle to the curious Beholder.

THE finest *Paper* looks exceeding coarse in the Microscope, and 'tis no unpleasing Sight to view the Impression of Letters in the smallest Print or Writing. If the *Paper* be burnt, and then viewed in the Ashes while yet entire, you will see most distinctly how all the Threads lay in its Composition by the *Stamina* which yet remain, and make a very pleasant Spectacle.

IF that which we call the *Vinew* or Mould of any Subject be view'd, it will discover a most beautiful Scene of Vegetation of a peculiar kind ; there you will discover Fields of standing Corn, *i. e.* *Stamina*, with globular *Apices* ; and various other Plants *sui Generis* ; and you will not rarely find those Fields and Meadows stocked with a Sort of nimble small Cattle and Herds, which skip sportively over the Lawns. You will also see their various Pursuits, Contests, and horrid Attacks and Engagements ; with divers other diverting Incidents among the Inhabitants of this *Terra invisæ*, or invisible Land.

A N
A C C O U N T
O F T H E
Camera Obscura, and the Solar Microscope,
O R
M E T H O D of *Magnifying Objects* in a *Darken'd Chamber,*
In every Way by REFLECTION and REFRACTION.

IT may be proper in a Work of this Nature, to give a short Account of the Methods of magnifying small Objects in a *Camera Obscura*, or *Darken'd Chamber*; especially as it was omitted in my *System of Optics*, and is in itself a Matter of very great Curiosity.

THE Methods of doing this are two; the *first* by *Lenses*, where the Magnified Image is form'd by refracted Rays; the *second* is by *Mirrors*, where the said Image is form'd by Reflection. In both Cases the Image may be magnified to what Degree you please; and the Object though exceeding small itself, will be beheld in that Image with equal Pleasure and Surprize.

THE *Apparatus* for the first Method is as follows: (1.) The Chamber or Room is to be made as dark as possible; (2.) A Scioptic Ball and Socket is to be fix'd in the Hole of the Window-

Shutter, as usual, but without its Glasses; (3.) A Tube is to be provided of about $2\frac{1}{4}$ Inches Diameter, and 5 Inches long; (4.) One End of this Tube is to be fitted in a Piece of Wood-Work, on the outer Part of which it is to be screw'd into the Hole of the Ball in the Socket; (5.) And on the inner Part is placed or fix'd by a Screw, a Lens of about 2 Inches Diameter, and 3 Inches focal Distance; (6.) Within the other End of the Tube slides a second Tube about 4 Inches long; (7.) At the inmost End of which a Piece of plain Glass is made to take out and in, by means of a Wood-Screw; (8.) And on the outermost End is fitted a Piece of Wood-work, in which is made to screw a long wooden Tube of $\frac{1}{2}$ an Inch Diameter, containing (9.) a small Lens of about $1\frac{1}{2}$ Inch focal Distance. These are the several Parts of the Instrument; their Uses severally are as follow:

THE Object is to be extended and laid on the Piece of plain Glass (*Art. 7.*) with a little Size or Gum-Water to make it stick fast, then screw'd into its Place. The external Tube with its Lens being into the Ball in the Window-Shutter, the inner Tube with the Object is to be placed within it, at such a Distance, that the Sun-Beams collected by the Lens (*Art. 5.*) may illumine the Object to what Degree you find necessary. This done, the small Lens (*Art. 9.*) is to be mov'd forwards and backwards till it be well adjusted for giving a perfect Image at the Distance you require it.

AND now there will be exhibited a glorious Spectacle indeed, and worthy the Attention of every *Curioso*; provided the Object be pellucid or transparent; as the Wings of Flies, the Skin or Pellicles of Animals or Plants, the *Animalculæ* in Fluids; and in this Manner, that grand Curiosity, the *Circulation of the Blood*, if skillfully and dexterously managed, may be shewn to the greatest Advantage in the transparent Tails of Tadpoles, or Efts, &c. as also the *Animalculæ in Semine Masculino*, may, with proper Care, in this Way, have their Forms, Motions, &c. made evident to a most wonderful and amazing Degree.

THE hollow Glass Tube belonging to the Microscope, will be most convenient for the *Animalculæ* in Water, which may be moved thro' two Holes made in the external Tube about half an Inch nearer the large Lens than its Focus; for then the Objects will be thoroughly enlighten'd.

IN this manner also very small and long Objects, if not transparent may be magnified with a great deal of Pleasure, as Hairs and Fibres of Flesh; the *Antennæ*, Legs, Claws, Bristles, &c. of Insects; the Skeletons of Leaves; Sponge, and porous Bodies, as Cork, &c. the Beards of Corn; fine Linnen, &c. these all afford the most entertaining *Phænomena*.

IF the Object be large and opaque, the Image of it will be distinctly exhibited, and well defined; so that it may be drawn with Ease; but the Images of such Objects are properly Shadows only, and so none of the Colours can be in this Manner shewn.

BUT this Inconvenience may be thus remedied; instead of the Convex Lens (*Art. 5.*) you are to place a Concave Mirrour of about $1\frac{1}{2}$ Inch focal Distance on the other Side the Object, with a small Hole in the Middle. The Sun Beams falling on this Mirrour will be reflected to the interior Side of the Object, which, being thus strongly illuminated, will be shewn very distinct in all its Colours in the Image, which will be form'd by the same Object Lens placed near the Central Hole of the Mirrour.

In making this Experiment, Care must be taken, that the Solar Rays fall perpendicularly on the large Lens or Mirrour, so that they may receive the greatest Quantity, and the Light on the Object be the strongest possible. Hence it follows that the Image of Objects will be thrown on the Floor of the darken'd Room at all Times, except when the Sun is very near the Horizon, when the Rays will go nearly parallel to the Floor across the Room to the opposite Wall where the Image will then be projected; and this can be only in the Morning or Evening.

BUT that this may be done at any Time of the Day, you need only so place a Piece of plain Looking-Glass on the outside of the Socket or Window-Shutter, moveable on a Hinge, that by means of a Thread or wire Screw it may be raised or lower'd to such a Position, that the Rays falling on it shall be reflected thro' the Hole of the Ball, and pass parallel to the Floor, on the opposite Wall, where in this Manner the Image may be always represented more commodiously than on the Floor. A little Practice and Experience will make the whole Process very easy.

THE other Method of magnifying Objects in a *Dark Chamber* is very simple, easy, and most perfect; thus, let the Rays of the Sun come into the Room thro' a Hole in the Window-Shutter (without the Ball and Socket) about 1 $\frac{1}{2}$ Inch Diameter: Then hold a well polish'd Mirrour (better of Metal than Glass) of 2, 3, or 4 Inches focal Distance, any where in the Cylinder of Rays, and an Object held in the other Hand, at a little more than the focal Distance of the Mirrour, will have its Image thrown on the opposite Part of the Room very fair and perfect; and by varying the Position of the Mirrour you may form the Image on any Part of the Room you please.

INSTEAD of holding the Mirrour in your Hand, you may fix it on a small Stand, and moveable in a Semicircle of Brass which may be raised higher or lower as occasion requires: And the Object may also be fix'd in its proper Place by a like Contrivance, so that the Experiment may be made in this Manner, without any Fatigue or Trouble, and will succeed very well if the Object be transparent; but if it be opaque, it must be enlighten'd by another Mirrour and Cylinder of Rays, let in by another Hole near the first.

WHEN the Room is darken'd, besides this Method of magnifying Objects, it may be used for other Purposes very curious and important. Thus if a Lens of about 6, 8, or 10 Feet focal Distance, be fix'd in the Scioptric Ball, then if the Sun shine strongly on the Objects without, opposite to the Window, the Images of all will
be

be distinctly form'd on a Wall or large Sheet or Screen of white Paper placed in the Focus of the Glafs; the Result of which will be a beautiful and most perfect *Piece of Perspective*, if the Objects are Buildings, &c. but Gardens, Fields, Meadows, Hills, Groves, &c. present you with a most exquisite and inimitable *Landscape*.

IN both the *Perspective* and *Landscape*, the Lights and Shadows are most beautifully and strongly express'd with all the charming Variety of Colours more vivid and intense than in the Objects themselves by far; and what is peculiar to this sort of Painting, the Motions of Objects are also represented, the Trees wave, the Leaves quiver, People walk, Birds fly, Ships sail, Chimneys smoke, and every thing is Life itself in Miniature, and greatly heighten'd.

ANOTHER noble Experiment in the *Dark Chamber*, is exhibiting the Sun's Face, with the Spots that frequently appear thereon. Thus if the same Glafs be made use of as before, and turn'd to the Sun, its Image will be form'd in the Focus; and if the Distance of the Focus be 10 or 12 Feet, the Image of the Sun will begin to shew the Spots, without more ado: But a much better Way is, with a Reflecting Mirrour to throw the said Image very large on the Cieling, or Side of the Room, where it may be view'd without Offence to the Eyes, and the Spots will be greatly magnified and afford a most delightful Spectacle.

IF a common Prism be held in the Beam of Rays let into the *Dark Chamber*, they will be all so refracted in passing thro' it, as to be separated into their distinct and proper Species, each of which Species will produce a distinct and vivid Colour. These Species of original or homogeneous Rays are seven; and therefore seven strong and lively Colours will be produced from a single Beam of Light, which will make a glorious and surprizing *Phænomenon* on the Cieling or opposite Wall of the Room.

THE last Use of the *Dark Chamber* I shall mention, is for the Sake of the Designer; for if any Object be placed at double the focal Distance of the Lens in the Ball without Doors in the Sun, its Image will be form'd at the same Distance from the Lens in the *Darken'd Room*, and of an equal Size with the Object. If the Object be placed near or farther from the Lens, the Image will be proportionally greater or lesser, and by this Means any Object may be drawn in any Proportion of Magnitude, which will be found extremely useful on many Occasions to the practical and ingenious Artift.

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Earth ; III. Astronomical Circles ; IV. Chronological Tables ;
and V. Astronomical Tables.