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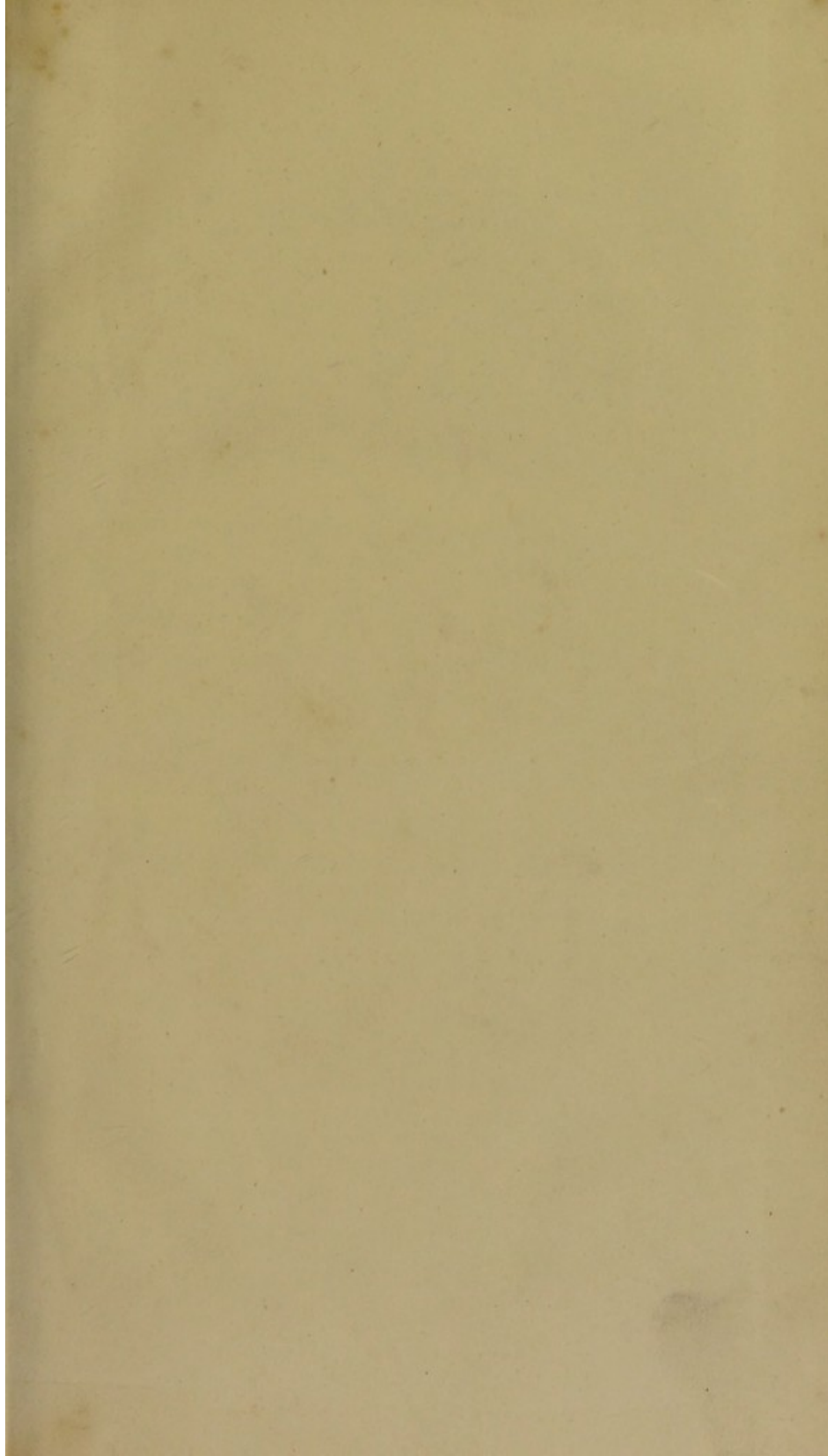
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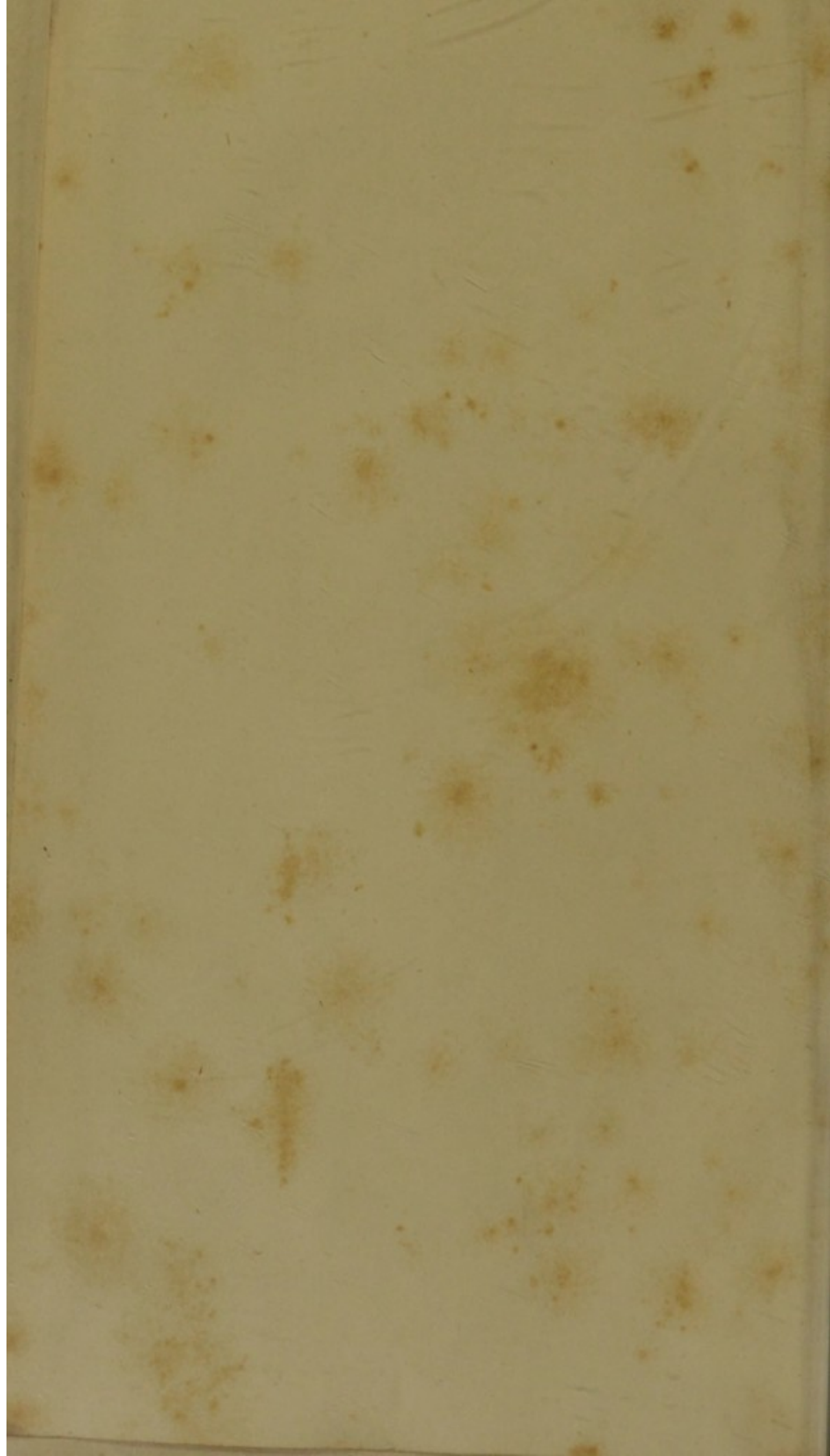


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R Baker

OF

MICROSCOPES,

AND THE

DISCOVERIES

MADE THEREBY.

ILLUSTRATED WITH MANY COPPER-PLATES.

By HENRY BAKER,
Fellow of the *Royal Society*, and Member of the *Society of*
Antiquaries, in *London*.

IN TWO VOLUMES.

VOL. I. THE MICROSCOPE MADE EASY.

VOL. II. EMPLOYMENT FOR THE MICROSCOPE.

V O L. I.

A N E W E D I T I O N.

Rerum Natura nusquam magis quàm in Minimis tota est.

PLIN. Nat. Hist. Lib. xi. c. 2.

L O N D O N:
PRINTED FOR J DODSLEY, IN PALL-MALL.

M.DCC.LXXXV.



V O L. I.

THE
M I C R O S C O P E
M A D E E A S Y:

O R,

I. *The Nature, Uses, and Magnifying Powers*
of the best Kinds of MICROSCOPES
Described, Calculated, and Explained:

For the Instruction of such, particularly, as desire to
search into the WONDERS of the *Minute Creation*,
tho' they are not acquainted with *Optics*.

T O G E T H E R W I T H

Full Directions how to *prepare, apply, examine, and preserve*,
all Sorts of OBJECTS;
And proper Cautions to be observed in viewing them.

II. An Account of what surprising *Discoveries*
have been already made by the MICROSCOPE:
With useful Reflections on them.

A N D A L S O

A great Variety of new *Experiments and Observations*
pointing out many uncommon Subjects for the
Examination of the CURIOUS.

With an additional *Plate* of the SOLAR MICROSCOPE,
and some farther Accounts of the POLYPS.

At a Meeting of the *Royal Society*,
October 28, 1742.

IMPRIMATUR.

M. FOLKES, *P. R. S.*

TO
Martin Folkes, *Esq;*
P R E S I D E N T,
And to the
COUNCIL and FELLOWS
OF THE
ROYAL SOCIETY OF LONDON.

GENTLEMEN,

AN Attempt to excite in Mankind a general Desire of searching into the Wonders of NATURE, will, I persuade myself, be accepted favourably by you, whose Endeavours for the Advancement of Natural Knowledge, according to the Purpose of your Institution, are esteemed by all the World.

It is something more than an hundred and twenty Years since the MICROSCOPE was happily invented; and to the valuable Discoveries made thereby, we stand indebted, as the following Sheets will shew, for a great Part of our present Philosophy. In such a Length of Time, it is however probable, many more Advantages might have been reaped from it, had not some Difficulties and Discouragements prevented its general Use.

At the Beginning it was confined to very few; who, making a Secret of it, endeavoured all they could to keep it to themselves; and, when it became a little more publick, the Price was fixed so high, that the most Curious and Industrious, who have not always the greatest Share of Money, could not conveniently get at it.

Of

Of late Years, indeed, the Expence has been much less; but then new Discouragements have started up from Mistake and Prejudice.

For Many have been frightened from the Use of it, by imagining it required great Skill in Optics, and Abundance of other Learning, to comprehend it to any Purpose: whereas nothing is really needful but good Glassees, good Eyes, a little Practice, and a common Understanding, to distinguish what is seen; and a Love of Truth, to give a faithful Account thereof. Others have considered it as a mere Play-thing, a Matter of Amusement and Fancy only, that raises our Wonder for a Moment, but is of no farther Service: which Mistake they have fallen into, from being unacquainted

with any Principles whereby to form a right Judgment of what they see. Many, again, have laid the Microscope aside, after a little Use, for want of knowing what Objects to examine, where to find, how to prepare, and in what Manner to apply them. The Trouble of managing it has also frightened some.

But we are now so fortunate as to have this Instrument greatly improved amongst ourselves, the Apparatus made much easier as well as more useful, and the Price considerably reduced. The Solar or *Camera Obscura* Microscope, and the Microscope for viewing Objects that have no Transparency, by throwing a strong reflected Light upon them, are also new Inventions, from whence great Things may be expected.

Nothing

DEDICATION. ix

Nothing therefore is now wanting, but a general Inclination to employ these Instruments, for a farther Discovery of the Minute Wonders of the Creation ; which may not, perhaps, improve our Knowledge less than the grander Parts thereof. Bears, Tigers, Lions, Crocodiles and Whales, Oaks and Cedars, Seas and Mountains, Comets, Stars, Worlds and Suns, are the CAPITALS in Nature's mighty Volume, and of them we should not be ignorant : but whoever would read there with Understanding, must make himself Master of the *little Letters* likewise, which occur a thousand Times more frequently, and, if he does not know them, will stop him short at every Syllable.

The likeliest Method of discovering
II
ing

ing Truth, is, by the Experiments of Many upon the same Subject; and the most probable Way of engaging People in such Experiments, is, by rendering them easy, intelligible, and pleasant. To effect this, is my Endeavour in the following Treatise, which may serve as the Representation of an Object for the Instrument I am recommending; small, indeed, and seemingly of no Consequence; but what, upon Examination, will be found, perhaps, to contain as many useful Parts as those that are much bulkier: for, to drop the Allusion here, I am certain, that with half the Pains I could have made it twice as large.

Think me not so presumptuous, to dream of instructing you, in Matters you are much better acquainted with
than

DEDICATION. xi

than I can pretend to be ; but give me Leave to request the Favour of your Concurrence, in my Desire of explaining, to those that are ignorant, a Science that may prove of the most eminent Service towards the Advancement of True Knowledge, and in which every body that has Inclination and Opportunity may be able to do something.

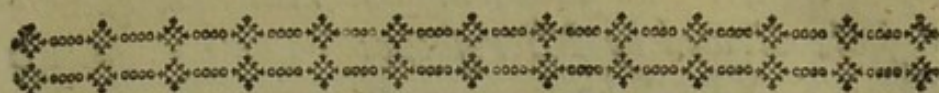
Excuse my Mistakes, forgive my detaining you thus long, and permit me the Honour to be, with all possible Respect and Veneration,

GENTLEMEN,

Your most Obedient

and devoted Humble Servant,

Henry Baker.



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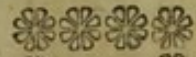
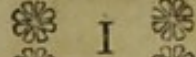
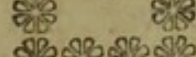
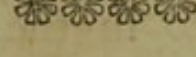
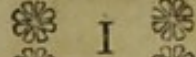

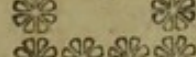
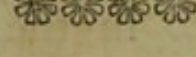
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T H E

INTRODUCTION.





 N this inquisitive Age, when the

 I  Desire of Knowledge has spread


 itself far and wide, and we sit not
 down contented, as heretofore,
 with the Opinions of ancient Times, but
 resolve to examine for Ourselves, and judge
 from our own Experience ; it may not, per-
 haps, prove unacceptable to point out some
 proper Subjects of Enquiry.

The Works of Nature are the only Source
 of true Knowledge, and the Study of them
 the most noble Employment of the Mind of
 Man. Every Part of the Creation demands
 his Attention, and proclaims the Power and

Wisdom of its Almighty Author. The smallest Seed, the minutest Insect, shews the Skill of Providence in the Aptness of its Contrivance for the Purposes it is to serve, and displays an Elegance of Beauty beyond the utmost Stretch of Art.

The Wise in all Ages have been sensible of this Truth ; and, as far as they were able, have studied and enquired into the Recesses of Nature ; but for Want of proper Helps have frequently been mistaken. As certain Principles must first be learned ere we can become Masters of any Science, so in the School of Nature, we must begin with the *Minutiæ*, the smallest and most uncompounded Parts, ere we can understand the larger and more considerable.

The Ancients, having only their naked Eyes to trust to, were incapable of any great Discoveries of this Sort : but we are so happy, that, by the Help of Glasses, we can distinguish and examine Objects many Thousands of Times less than what the sharpest Eye, unassisted, can discern. In short, MI-

CROSCOPES

CROSCOPES furnish us as it were with a new Sense, unfold the amazing Operations of Nature, and present us with Wonders unthought of by former Ages.

Who, a thousand Years ago, would have imagined it possible to distinguish Myriads of living Creatures in a single Drop of Water? Or, that the Purple Tide of Life, and even the Globules of the Blood should be seen distinctly, rolling thro' Veins and Arteries smaller than the finest Hair? That Millions of Millions of Animalcules should be discovered in the *Semen Masculinum* of all Creatures? That not only the exterior Form, but even the internal Structure of the Bowels, and the Motion of the Fluids in a *Gnat* or *Louse*, should be rendered Objects of Sight? Or, that numberless Species of Creatures should be made visible, tho' so minute, that a Million of them are less than a Grain of Sand?

These are noble *Discoveries*, whereon a new Philosophy has been raised, that enlarges the Capacity of the human Soul, and

a 2 furnishes

furnishes a more just and sublime Idea than Mankind had before, of the Grandeur and Magnificence of Nature, and the infinite Power, Wisdom, and Goodness of Nature's Almighty Parent.

That Man is certainly the happiest, who is able to find out the greatest Number of reasonable and useful Amusements, easily attainable and within his Power: and, if so, he that is delighted with the Works of Nature, and makes them his Study, must undoubtedly be happy; since every Animal, Flower, Fruit, or Insect, nay, almost every Particle of Matter, affords him an Entertainment. Such a Man never can feel his Time hang heavy on his Hands, or be weary of himself, for want of knowing how to employ his Thoughts: each Garden or Field is to him a Cabinet of Curiosities, every one of which he longs to examine fully; and he considers the whole Universe as a Magazine of Wonders, which infinite Ages are scarce sufficient to contemplate and admire enough.

The Invention of GLASSES has brought under our Examination the two Extremes of the Creation, if I may be allowed to call them so, which were out of the Reach of former Ages : I mean, those vast and distant Bodies of our System, the SUN and PLANETS ; whose Dimensions, Distances, Motions, Regularity and Order, we are become acquainted with by the Help of TELESCOPES : and those exceedingly minute, and to them invisible, and unknown (though every where at Hand) Species of Animals, Plants, &c. which the MICROSCOPE has discovered to us. I leave the TELESCOPE to others, who are better able to do it Justice : my Intent in this Discourse is to treat of the MICROSCOPE, and encourage its more general Use, by shewing the Pleasure and Instruction it can afford us.

Mr. BOYLE says, in his Discourse of the *Usefulness of Experimental Philosophy*, that his Wonder dwells not so much on Nature's *Clocks* as on her *Watches* ; and, indeed, upon comparing the Structure of a *Mite* with
that

that of an *Elephant*, I believe we shall concur in the same Opinion. The Largeness and Strength of the one may strike us with Wonder and Terror, but we shall find ourselves quite lost in Amazement, if we attentively examine the several minute Parts of the other. For the Mite has more Limbs than the Elephant, each of which is furnished with Veins and Arteries, Nerves, Muscles, Tendons, and Bones : it has Eyes, a Mouth, and a Proboscis too (as well as the Elephant) to take in its Food ; it has a Stomach to digest it, and Intestines to carry off what is not retained for Nourishment : it has an Heart to propel the Circulation of its Blood, a Brain to supply Nerves every where, and Parts of Generation as perfect as the largest Animal. Let us now stop, look back, and consider, as far as our Abilities can reach, the excessive Minuteness of all these Parts ; and if we find them so surprizing and beyond our Ideas, what shall we say of those many Species of *Animalcules*, to whom a Mite itself, in Size, is as it were an Elephant ?

All

All these, and numberless Wonders more, the MICROSCOPE can exhibit to us. I shall therefore proceed to describe this noble Invention, shew how far it is improved at present, give a brief Account of what Discoveries have been made, and point out some Objects for the Curious to examine by it. In doing this, I shall avoid as much as possible all Affectation of Learning, or Expressions that are not in common Speech, being desirous that every body may understand me.

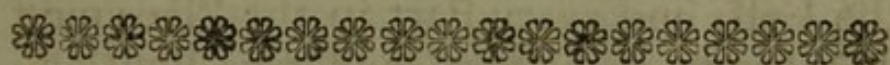
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THE
MICROSCOPE

MADE EASY, &c.



CHAP. I.

Of MICROSCOPES in General.

BY MICROSCOPES we are understood to mean, *Instruments of whatever Structure or Contrivance, that can make small Objects appear larger than they do to the naked Eye.*

This is effected by Glasses formed convex.

VOL. I.

B

When

2 Of MICROSCOPES in General.

When only one such convex Glass or *Lens* * is used for this Intent, the Instrument it is fixt in, however fashioned, is called a *Single Microscope* : but if two or more Glasses are employed, conjointly, to magnify Objects more, it is then called a *Double* or *Compound Microscope*.

One remarkable Difference in the Effect of these two Instruments is, that an Object viewed through a single convex Glass appears magnified, in the same Position exactly as when seen by the naked Eye ; but when viewed through a Double Microscope, composed of three convex Glasses, all Parts of it become inverted ; that is, the Top of the Object appears at Bottom, the Right Side on the Left, and every Part in the Place most opposite to its natural and true Position : The Lights and Shades being also inverted, the sinking Parts appear to rise, and the rising Parts to sink in.

To what Accident, to what Country, or to whom, we are obliged for the Invention

* The Word *Lens* properly signifies a small Glass in Figure of a Lentil ; but is extended to any Optic Glass not very thick, which either collects the Rays of Light into a Point in their Passage through it, or disperses them apart, according to the Laws of Refraction. If convex on both Sides, it is called a *Convex Lens* ; but if one Side be flat, a *Plano-Convex* ; If concave on both Sides, it is termed a *Concave Lens* ; if flat on one Side, a *Plano-Concave* ; if convex on one Side, and concave on the other, a *Convexo-Concave*, or *Concavo-Convex*.

of Microscopes, is not in me to determine: the Honour has been given by some to DREBBEL, a *Dutchman*; by others to FONTANA, a *Neapolitan*; and by others still to different People. The first Appearance of them however was about the Year 1621; since when they have been improving down to the present Time.

As my Desire is, to make People sensible of the Pleasure and Information the Microscope can afford, and instruct them how to manage and understand it, rather than how to make it, I shall take up none of their Time with the Manner of melting, grinding, polishing, or setting of Glasses; a Work very few of my Readers will ever trouble themselves about. But, instead thereof, I shall endeavour, with all the Brevity and Clearness I am able, to explain the Effects of Glasses on the Sight, and lead them gradually into the Nature, Uses, and magnifying Powers of Microscopes.

When Objects are seen through a perfectly flat Glass, the Rays of Light pass through it, from them to the Eye, in a strait Direction, and parallel to each other; and consequently the Objects appear very little either diminished or enlarged, or nearer or farther off, than to the naked Eye. But if the Glass they are seen through has any Degree of Convexity, the Rays of Light are directed from the Circumference towards the

4 Of MICROSCOPES in General.

Center, in an Angle proportionable to the Convexity of the Glafs, and meet in a Point, at a greater or lefs Distance from the Glafs, as it is lefs or more convex. This Point, where the Rays meet, is called the *Focus*; and this Focus is nearer or farther off, according to the Convexity of the Glafs: for as a little Convexity throws it to a considerable Distance, when the Convexity is much, the Focus is very near. Its *magnifying Power* is also in the same Proportion to the Convexity: for as a flat Glafs magnifies scarce at all, the lefs a Glafs departs from Flatness, the lefs of course it magnifies; and the more it approaches towards a globular Figure, the nearer its Focus is, and the more its magnifying Power.

People's different Length of Sight depends on the same Principle, and arises from a more or lefs Convexity of the *Cornea* and *Crystalline Humour* of the Eye: the rounder these are, the nearer will the *Focus* or *Point of meeting Rays* be, and the nearer an Object must be brought to see it well. The Case of short-sighted People is only an Over-roundness of the Eye, which makes a very near Focus; and that of old People is a Sinking or Flattening of the Eye, whereby the Focus is thrown to a great Distance: so that the former may properly be called Eyes of too short, and the latter, Eyes of too long a Focus. Hence too the Remedy for
the

the last is a convex Glass, to supply the Want of Convexity in the Eye itself, and bring the Rays to a shorter Focus; whereas a concave Glass is needful for the first, to scatter the Rays, and prevent their coming to a Point too soon.

Nothing is more common than to observe old People holding Objects they would examine at a great Distance from them, for the Reason above-mentioned; and every body knows, short-sighted People cannot distinguish any thing without bringing it very near their Eyes. Both Extremes are inconvenient; but those whose Eyes are flat by Age should remember with Satisfaction, that they have enjoyed the Pleasure of them for many Years; and the Short-sighted may comfort themselves, that they can distinguish much smaller Objects than long-sighted People: for the Object is magnified in Proportion to the Roundness of the Eye and the Nearness of the Focus, and consequently appears four times as big to an Eye whose Focus is but four Inches off, as it does to one whose focal Distance is at eight Inches. They have also this farther Advantage, that Age improves their Eyes, by the same Means it impairs other People's, that is, by making them more flat.

The nearer any Object can be brought to the Eye, the larger will be the Angle under which it appears, and the more it will be

6 *Of MICROSCOPES in General.*

magnified. Now, that Distance from the naked Eye, where the Generality of People are supposed to see small Objects best, is at about eight Inches; consequently, when such Objects are brought nearer than eight Inches (suppose to six) they'll become less distinct; and if nearer still, on to four or three, they will scarce be seen at all. But by the Help of convex Glasses we are enabled to view things, clearly, at much shorter Distances than these: for the Nature of a convex Lens is, to render an Object distinctly visible to the Eye at the Distance of its Focus; wherefore the smaller a Lens is, and the more its Convexity, the nearer is its Focus, and the more its magnifying Power.

As it is an easy matter to melt a Glass Drop or Globule of a much smaller Diameter than any Lens can possibly be ground, and as the Focus of a Globule is no farther off than one quarter of its own Diameter, and consequently it must magnify to a prodigious Degree, some Years ago People were extremely fond of such Globules, and imagined no good Microscope could be without them: but Experience has since taught, that they admit so little Light, can shew such an exceeding minute Part only of any Object, are so difficult to make use of, and strain the Eyes so much, that their Power of magnifying, for Want of due Distinctness, is rather apt to produce Error than discover Truth:

Truth: and therefore now they are very rarely employed.

C H A P. II.

Of the Kinds of MICROSCOPES.

MICROSCOPES are either Single or Double: the Single have but one Lens; the Double are a Combination of two or more. Each of these two Kinds has its particular Advantage: for a single Glafs shews the Object nearer at hand, and rather more distinct; and a Combination of Glasses presents a larger Field, or, in other Words, exhibits more of an Object, equally magnified, at one View. It is difficult to determine which of these to recommend, since each affords a different Kind of Pleasure. Each of them too can produce considerable Authorities in its Favour; for Mr. LEEUWENHOEK † never used any but single

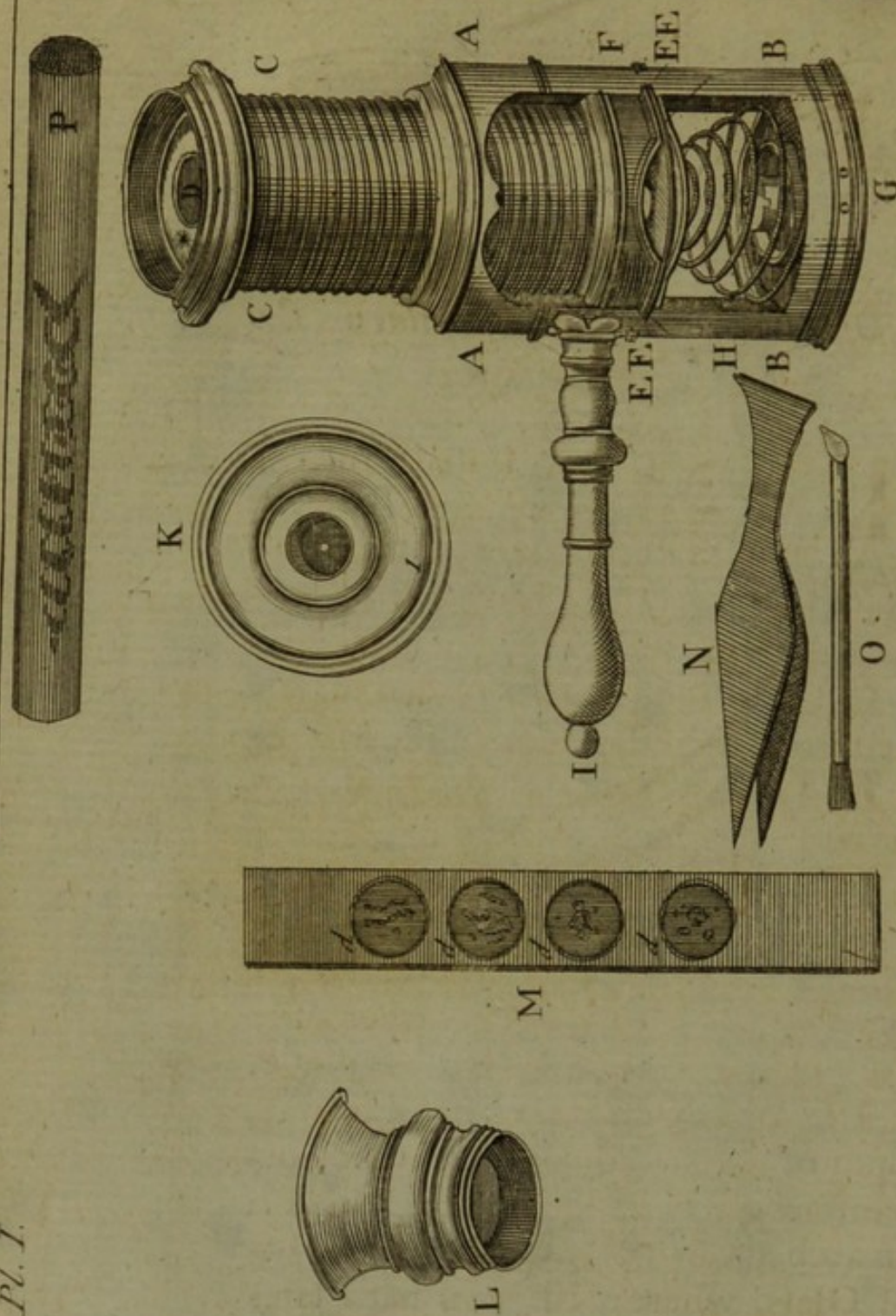
† Several Writers represent the Glasses Mr. LEEUWENHOEK made use of in his Microscopes, to be little Globules or Spheres of Glafs; which Mistake most probably arises from their undertaking to describe what they had never seen: for at the Time I am writing this, the Cabinet of Microscopes left by that famous Man, at his Death, to the *Royal Society* as a Legacy, is standing upon my Table; and I can assure the World, that every one of the twenty-six Microscopes contained therein is a double convex Lens, and not a Sphere or Globule.

8 *Of the Kinds of* MICROSCOPES.

Microscopes ; and, on the contrary, Mr. HOOKE made all his Observations with double ones.

The famous Microscopes of Mr. LEEUWENHOEK are the most simple possible, being only a single Lens, set between two Plates of Silver perforated with a small Hole, with a moveable Pin before it, to place the Object on, and adjust it to the Eye of the Beholder. By these he made those wonderful Discoveries which surprized the World so much, and introduced a new System of Philosophy and Reasoning, as in the Course of this Treatise I shall find Occasion more at large to mention.

There are many pretty little Contrivances sold at the Shops for the viewing of small Objects, which are entertaining as far as can reasonably be expected from them : but to enumerate all these would be a tedious Task. It should also be a Matter more of Curiosity than Profit, to describe the Forms and Apparatus of the several Kinds of Microscopes that have been contrived since the first Invention of them. I shall therefore confine myself to give an Account of such only in use among ourselves at present, as, by having a proper Set of Glasses, gradually magnifying one above another, are fit to make Discoveries of Consequence.



C H A P. III.

*Of Mr. WILSON'S Single Pocket
Microscope.*

THE first that I shall mention, is Mr. WILSON'S *Single Pocket Microscope*; the Body whereof, made either of Brass, Ivory, or Silver, is represented (*Plate I.*) by AA. BB.

CC. is a long fine-threaded male Screw, that turns into the Body of the Microscope.

D. a convex Glass at the End of the said Screw.

* Two concave round Pieces of thin Brass, with Holes of different Diameters in the Middle of them, to cover the said Glass, and thereby diminish the Aperture, when the greatest Magnifiers are employed.

EE. three thin Plates of Brass within the Body of the Microscope, one whereof is bent semicircularly in the Middle, so as to form an arched Cavity for the Reception of a Tube of Glass, whereas the two flat Plates are to receive and hold the Sliders between them.

F. a Piece of Wood or Ivory, arched in the Manner of the semicircular Plate, and cemented thereto.

G. the other End of the Body of the Microscope, where a hollow female Screw is adapted to receive the different Magnifiers.

H. a

10 WILSON'S *Single Pocket Microscope.*

H. a spiral Spring of Steel, between the said End G and the Plates of Brass; intended to keep the Plates in a right Position, and counteract against the long Screw CC.

I. a small turned Handle, for the better holding of the Instrument, to screw on or off at Pleasure.

To this Microscope belong seven different magnifying Glasses: six of them are set in Silver, Brass, or Ivory, as in the Figure K, and marked 1. 2. 3. 4. 5. 6.; the lowest Numbers being the greatest Magnifiers.

L. is the seventh Magnifier, set in the Manner of a little Barrel, to be held in the Hand for the viewing any larger Object.

M. is a flat Slip of Ivory, called a Slider, with four round Holes through it, wherein to place Objects between two Glasses, or Pieces of *Muscovy* Talc, as they appear *d d d d.*

Eight such Ivory Sliders, and one of Brass, are usually sold with this Microscope; some with Objects placed in them, and others empty, for viewing any thing that may offer: but whoever pleases to make a large Collection of Objects, may have as many as he desires.

The Brass Slider is to confine any small Object, that it may be viewed without crushing or destroying it.

N. is a Forceps or Pair of Pliers, for the taking up of Insects, or other Objects, and adjusting them to the Glasses.

O. is

WILSON'S *Single Pocket Microscope.* 11

O. is a little Hair Brush or Pencil, wherewith to wipe any Dust from off the Glasses, or to take up any small Drop of Liquid one would examine, and put it upon the Talcs or Isinglass.

P. is a Tube of Glas, contrived to confine living Objects, such as Frogs, Fishes, &c. in order to discover the Blood, as it streams along the Veins and Arteries.

All these Particulars are contained in a little neat Box, very convenient for carrying in the Pocket.

When an Object is to be viewed, thrust the Ivory Slider, in which the said Object is placed, between the two flat Brass Plates EE: observing always to put that Side of the Slider where the Brass Rings are, farthest from your Eye. Then screw on the magnifying Glas you intend to use, at the End of the Instrument G; and looking through it against the Light, turn the long Screw CC, till your Object be brought to fit your Eye; which you will know by its appearing then perfectly distinct and clear.—'Tis best to look at it first, through a Magnifier that can shew the Whole thereof at once, and afterwards to inspect the several Parts more particularly with one of the greatest Magnifiers: for thus you will gain a true Idea of the Whole, and of all its Parts. And tho' the greatest Magnifiers can shew but a minute Portion of any Object at once, such as

the Claw of a Flea, the Horn of a Louse, or the like ; yet by gently moving the Slider that contains your Object, the Eye will gradually overlook it all : and if any Part should be out of Distance, the Screw CC will easily bring it to the true Focus.

As Objects must be brought very near the Glasses when the greatest Magnifiers are used, be particularly careful not to scratch them by rubbing the Slider against them as you move it in or out. A few Turns of the Screw CC will easily prevent this Mischief, by giving them Room enough.

You may change the Objects in your Sliders, for what others you think proper, by taking out the Brass Rings with the Point of a Pen-knife; the Isinglass will then fall out, if you but turn the Sliders ; and after putting what you please between them, by replacing the Brass Rings, you will fasten them as they were before. 'Tis proper to have some Sliders furnished with Talcs, but without any Objects between them, to be always in Readiness for the Examination of Fluids, Salts, Sands, Powders, the *Farina* of Flowers, or any other casual Objects of such sort as need only be applied to the Outside of the Talc.

The Circulation of the Blood may easiest be seen in the Tails or Fins of Fishes, in the fine Membranes between a Frog's Toes, or, best of all, in the Tail of a Water-Newt.

If

If your Object be a small Fish, place it within the Tube, and spread its Tail or Fin against the Side thereof: if a Frog, chuse such an one as can but just be got into your Tube, and with a Pen or Stick expand the transparent Membrane between the Toes of the Frog's hind Foot as wide as you are able. When your Object is so adjusted that no Part thereof can intercept the Light from the Place you intend to view, unscrew the long screw CC, and thrust your Tube into the arched Cavity, quite through the Body of the Microscope; then screw it to the true focal Distance, and you will see the Blood passing along its Vessels with a rapid Motion, and in a most surprising Manner.

Make use of the third or fourth Magnifier for Frogs or Fishes; but for the Tails of Water-Newts, the fifth or sixth will do; because the Globules of their Blood are twice as large as those of Frogs or Fish. The first or second Magnifier cannot well be employed to this Purpose; for the Thickness of the Tube wherein the Object lies, will scarce admit its being brought so near as the focal Distance of the Magnifier.

The *Single Microscope* above described may be formed into a *Double One*, by screwing it to a Tube with an Eye-Glass at the End thereof: it is also made to answer nearly the Purposes of the large *Double Reflecting Microscope*, by the Contrivance following.

C H A P.

C H A P. IV.

A new Invention for fixing the POCKET MICROSCOPE, and giving Light to it by a Speculum. Plate II.

IN this Plate, A is a Scroll of Brass, fixed upright on a round Pedestal of Wood B, so as to stand perfectly firm and steady.

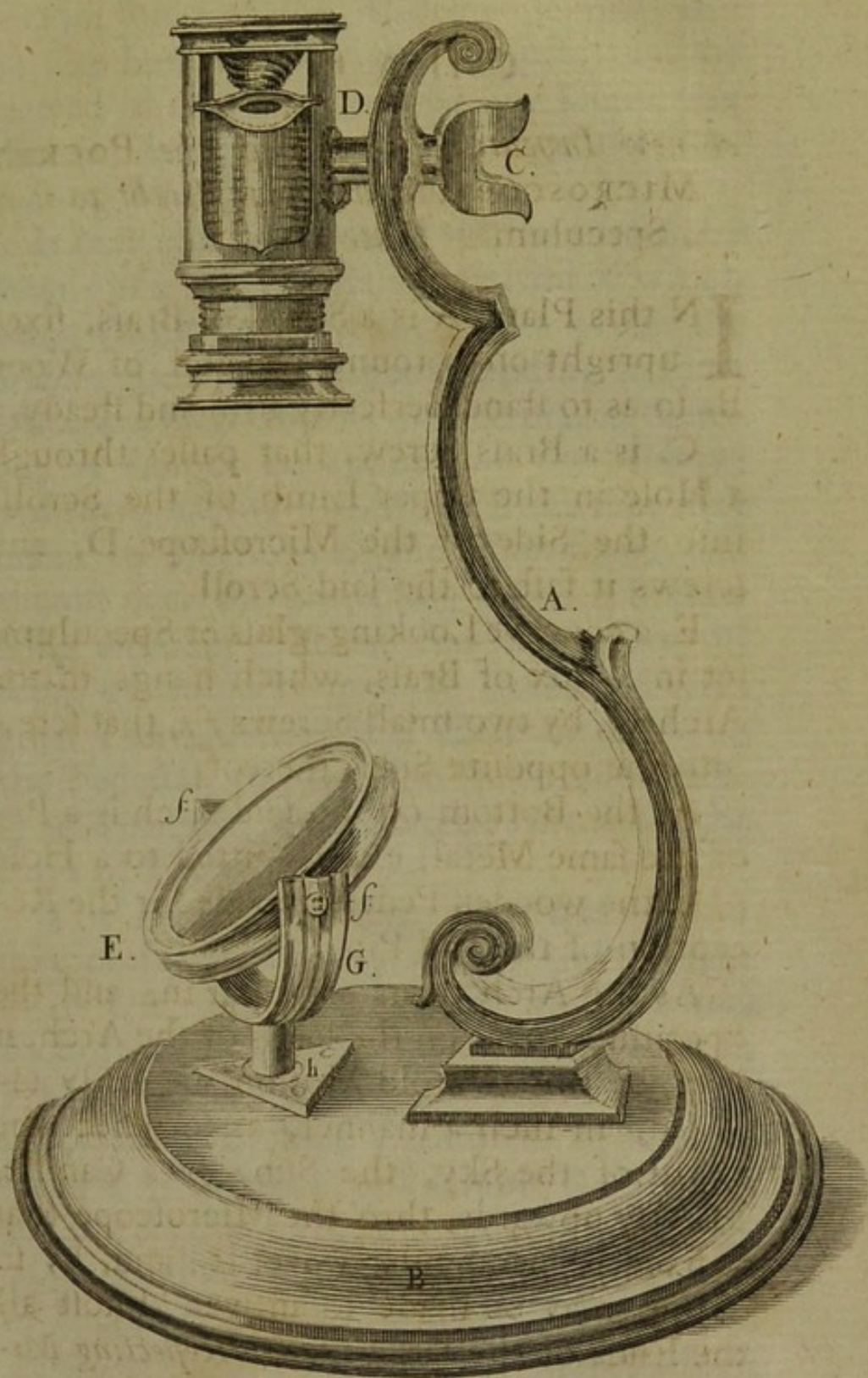
C. is a Brass Screw, that passes through a Hole in the upper Limb of the Scroll, into the Side of the Microscope D, and screws it fast to the said Scroll.

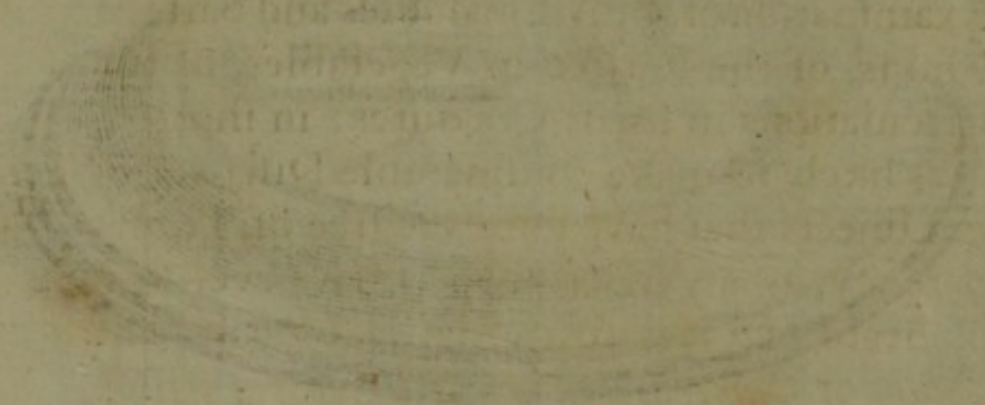
E. a concave Looking-glass or Speculum, set in a Box of Brass, which hangs in the Arch G, by two small Screws *ff*, that screw into the opposite Sides thereof.

At the Bottom of the said Arch is a Pin of the same Metal, exactly fitted to a Hole *h*, in the wooden Pedestal made for the Reception of the said Pin.

As the Arch turns on this Pin, and the Speculum turns on the Ends of the Arch, it may, by this twofold Motion, be easily adjusted, in such a manner, as to reflect the Light of the Sky, the Sun, or a Candle, directly upwards, thro' the Microscope that is fixed perpendicularly over it; and, by so doing, may be made to answer almost all the Ends of the large *Double Reflecting Microscope*, which I shall presently describe.

The





The Body of the Microscope may also be fixt horizontally, and Objects may be viewed in that Position, by any Light you choose; which is an Advantage the Reflecting Microscope has not.

It may also be rendered farther useful, by means of a Slip of Glafs, one End of which being thrust between the Plates where the Sliders go, and the other extending to some Distance, such Objects may be placed thereon, as cannot be applied on the Sliders: and then, having a Limb of Brass that may fasten to the Body of the Microscope, and extend over the projecting Glafs a hollow Ring wherein to screw the Magnifiers, all Sorts of Subjects may be examined with great Conveniency, if a Hole be made in the Pedestal, to place the Speculum exactly underneath, and thereby throw up the Rays of Light.

The *Pocket Microscope* thus fixt is, if I may presume to judge, as easy and pleasant in its Use, and as fit for the most curious Examination of the Animalcules and Salts in Fluids, of the Farinæ in Vegetables, of the Circulations in small Creatures: in short, it is as likely to make considerable Discoveries in Objects that have some Degree of Transparency, as any Microscope I have ever seen or heard of. It is also a material Part of the *Solar*, or *Camera Obscura Microscope*, which I shall by and by describe.

C H A P.

C H A P. V.

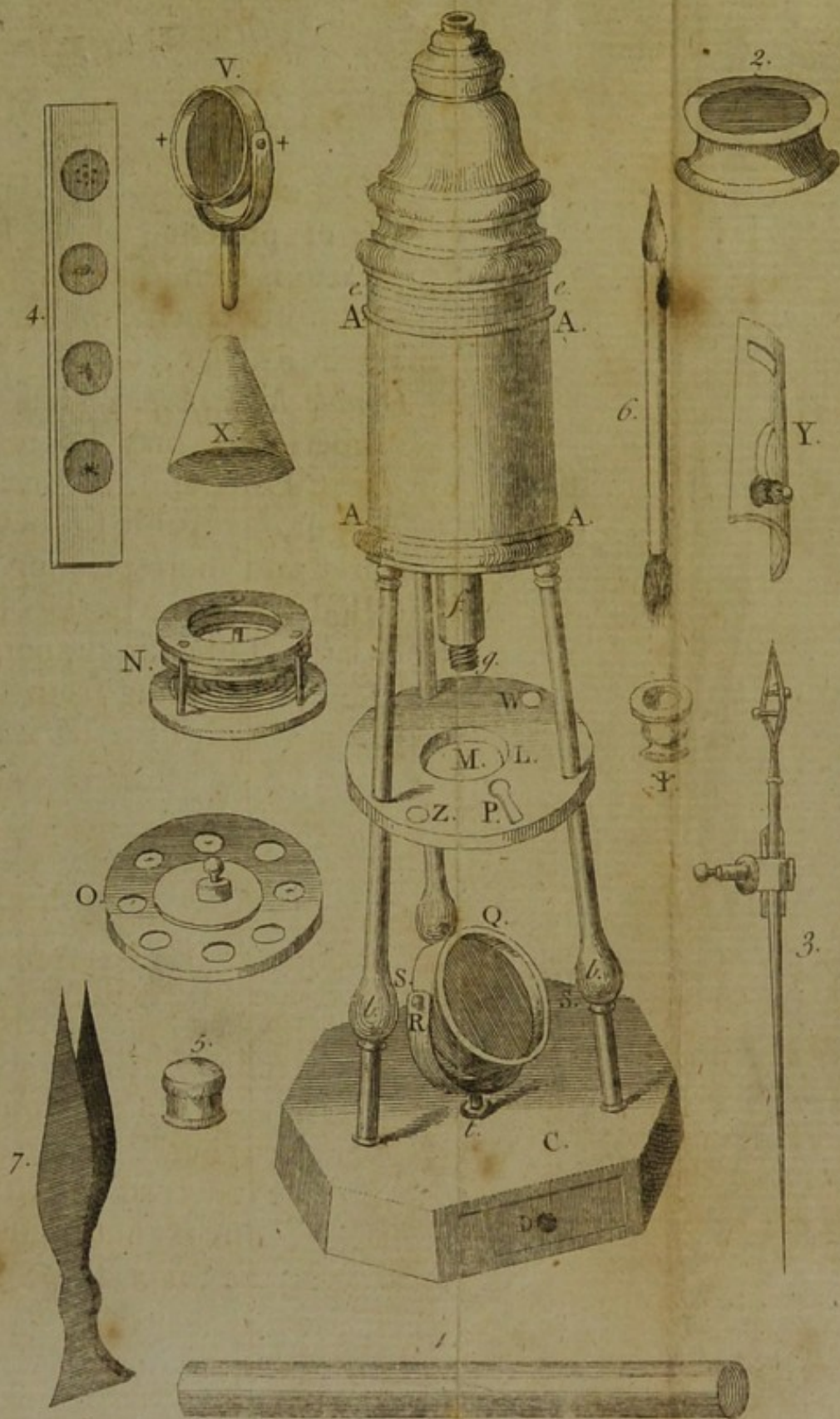
Of the Double REFLECTING MICROSCOPE.

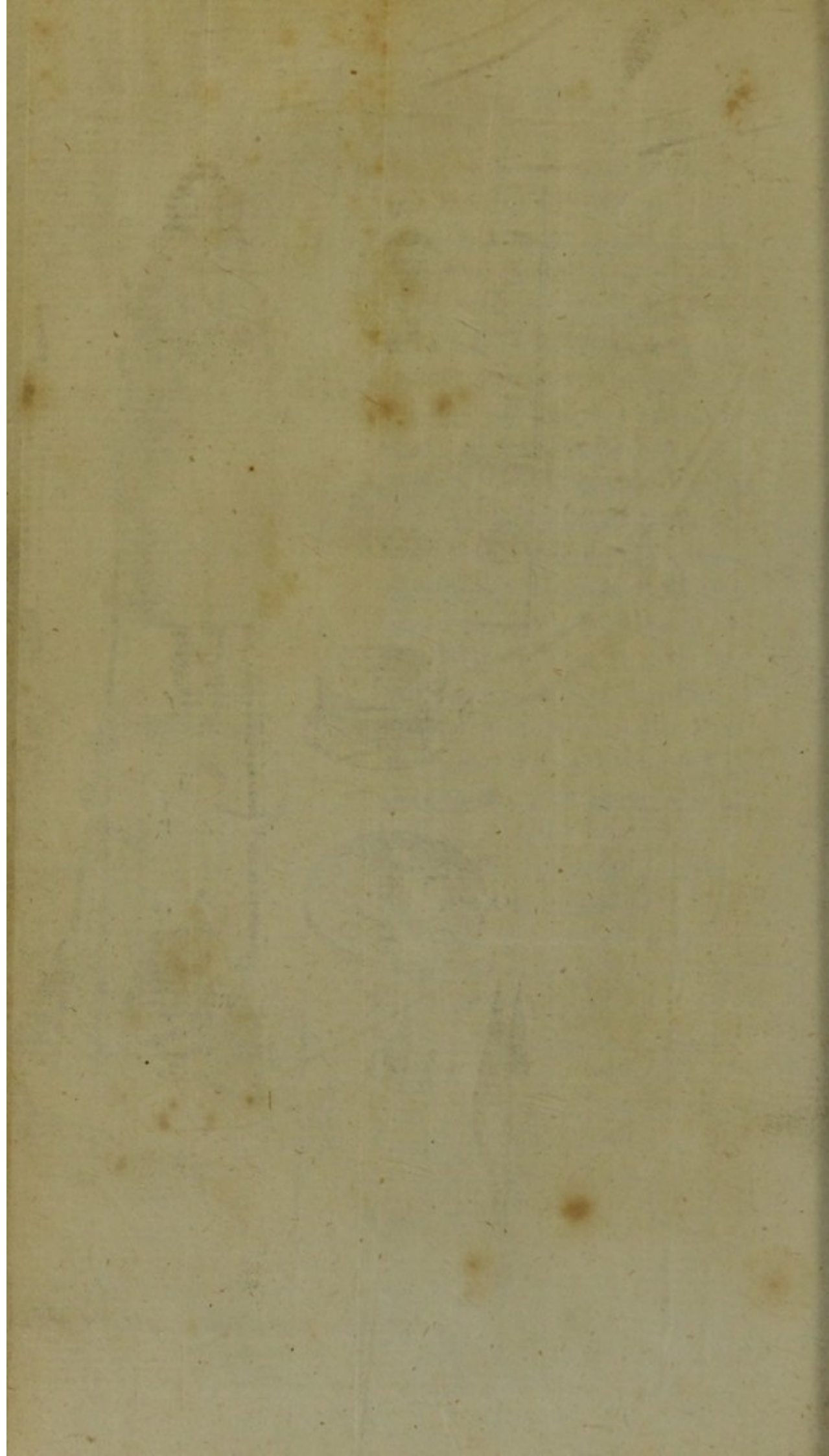
THE *Double Reflecting Microscope* in Use at present (whose Picture with its Apparatus is seen Plate III.) is an Alteration and Improvement, by Mr. CULPEPER and Mr. SCARLET, of Mr. MARSHAL'S *large Double Microscope*; than which it is less cumbersome, may be managed with much more Ease, and, by means of a reflected Light, is capable of shewing Objects in a clearer and more pleasing Manner.

The Body of this Microscope A A A A, being a large Tube, is supported by three Brass Pillars *b b b*, rising from a wooden Pedestal C; in which Pedestal is a Drawer D, to hold the Object-Glasses and other Parts of the Apparatus.

A lesser Tube, *e e*, slides into the greater, and sends from its Bottom another Tube much smaller than itself, *f*, with a male Screw *g*, at the End thereof, whereon to screw the Object-Glass or Magnifier.

There are five of these Magnifiers, numbered 1. 2. 3. 4. 5. which Numbers are also marked on the inner Tube, to direct whereabouts to place it according to the Magnifier made use of: but if then it fits not the Eye exactly, slide the inner Tube gently higher
or





Or lower, turn the Screw of the Magnifier, gradually, till the Object appears distinct.—Take Notice, that the greatest Magnifiers have the smallest Apertures and the lowest Numbers.

L. is a circular Plate of Brass, fixt horizontally between the three Brass Pillars; and in the Center thereof a round Hole M. is adapted to receive a proper Contrivance N. for holding Ivory Sliders, wherein Objects are placed: which Contrivance consists of a spiral Steel Wire confined between three Brass Circles, one whereof is moveable for the Admission of a Slider.

O. is a round Brass Plate, with several Holes for placing Objects in, some of which are usually furnished with them at the Shops: but two Holes are commonly reserved for small concave Glasses, whereon to place a Drop of any Liquid, in order to view the Animalcules, &c. There is also a Piece of white Ivory, and a Piece of black Ebony, of the same Size and Shape as the Holes for Objects: the Ivory is to put opake Objects on that are black, and the Ebony is to receive such as are white; by which Contrariety of Colours they will be seen more clearly.—At the Bottom of this Object-Plate is a Button, to slip into a Slit P. that fits it, on the circular Plate of Brass: and by turning it round on this Pin, all the Objects

may be examined successively with very little Trouble.

Q. is a concave Looking-glass, set in a Box of Brass, and turning in an Arch R. upon two small Screws *s s.* From the Bottom of the Arch comes a Pin, which, being let down into a Hole *t*, in the Center of the Pedestal, enables the Looking-glass to turn vertically, or horizontally, and reflect the Light, either of a Candle, or the Sky, directly upwards on the Object to be viewed.

V. is a plano-convex Lens, which by turning on two Screws**, when the Pin at the Bottom of it is placed, the Hole W. for its Reception in the circular Plate L. will transmit the Light of a Candle, to illuminate any opaque Object that is put on the round Piece of Ivory, or on the Ebony, for Examination: and it may be moved higher or lower as the Light requires. This Glass is of good Service to point the Sunshine, or the Light of a Candle, upon any opaque Object; but in plain Day-light it is of no great Use.

X. a Cone of black Ivory, to fasten on a Shank underneath the Brass circular Plate L. principally, when the first or second Magnifier is made use of, and the Object very transparent: for Experience teaches, that such Objects are rendered much more distinctly visible, by intercepting some Part of the oblique Rays reflected from the concave Looking-glass.

The

The Brass Fish-pan Y. is to fasten a Smelt, Gudgeon, or any such small Fish upon, to see the Blood circulate in its Tail. For which Purpose, the Tail of the Fish must be spread across the oblong Hole at the smallest End of the Pan: then, by slipping the Button on the Backside of the Pan into the Slit P. through the circular Plate L. the Spring that comes from the Button will make it steady, and present it well to View.

But if it be a Frog, a Newt, or Eel, in which the Circulation is desired to be shewn, a Glass Tube 1. is fittest for the Purpose. The Tail of a Newt, or Eel, or, in a Frog, the Web between the Toes of the Hind-Foot, are the Parts where it may be seen best. When the Object is well expanded on the Inside of the Tube, slide the Tube along under the circular Brass Plate L. (where there are two Springs and a Cavity made in the Shank to hold it) and bring your Object directly under the Magnifier.

There are three of these Glass Tubes, smaller one than another, and the Size of the Object must direct which to use; but in general, the less Room the Creature has to move about in, the easier it may be managed, and the quieter it will lie to be managed.

The Cell 2. with a concave and a plain Glass in it, is intended to confine Fleas, Lice, Mites, or any small living Objects,
C 2 during

during Pleasure ; and by placing it over the Hole M. in the Middle of the circular Brass Plate, they may be viewed with much Conveniency.—Three loose Glasses, *viz.* one plain, and two concave, belong also to this Microscope, and are designed to confine Objects, or place them upon occasionally.

The long Steel Wire 3. with a Pair of Pliers at one End, and a Point at the other, to hold fast, or stick Objects on, slip backwards or forwards in a Brass short Tube, whereto a Button is fastened, which fits into the little Hole *z*, near the Edge of the Brass Plate L: and, then, the Object may be readily brought to a right Position, and a Light be cast upon it, either by the Looking-glass underneath, or, if it be opaque, by the plano-convex Lens V.

4. is a flat Piece of Ivory called a Slider, with four round Holes through it, and Objects placed in them between *Muscovy* Talcs or Isinglass, kept in by Brass Wires.

It is proper to have a Number of these Sliders filled with curious Objects, always ready, as well as some empty ones, for any new Thing that offers. When made use of, thrust them between the Brass Rings of the Contrivance on purpose for them, N. which shoots into the round Hole M. in the Center of the Brass Plate L. This keeps them steady, and at the same time permits them to be moved to and fro for a thorough Examination.

A little

A little Ivory round Box 5. to hold Pieces of Ifinglaſs for the Sliders.

6. a ſmall Hair Bruſh, to wipe any Duſt off the Glaſs, or to apply a Drop of any Liquid.

7. A Pair of Nippers, to take up any Object to be examined.

The two Microscopes I ſhall deſcribe next, *viz.* the *Solar*, or *Camera Obscura Microscope*, and the *Microscope for Opake Objects*, are of a foreign Invention, and but lately known to us. We are, indeed, obliged for them both to a Gentleman of *Prussia*, the ingenious Dr. LIBERKHUN, who, when he was in *England*, in the Year 1740, ſhewed an Apparatus for each of theſe Purpoſes to ſeveral Gentlemen of the *Royal Society*, and alſo to ſome Opticians; amongſt whom, Mr. CUFF, againſt *Serjeant's Inn Gate*, in *Fleet-Street*, has taken great Pains to improve and bring them to Perfection: and therefore I ſhall give a Deſcription of them, as made and ſold by him.

C H A P. VI.

*The SOLAR, or CAMERA OBSCURA
Microscope.*

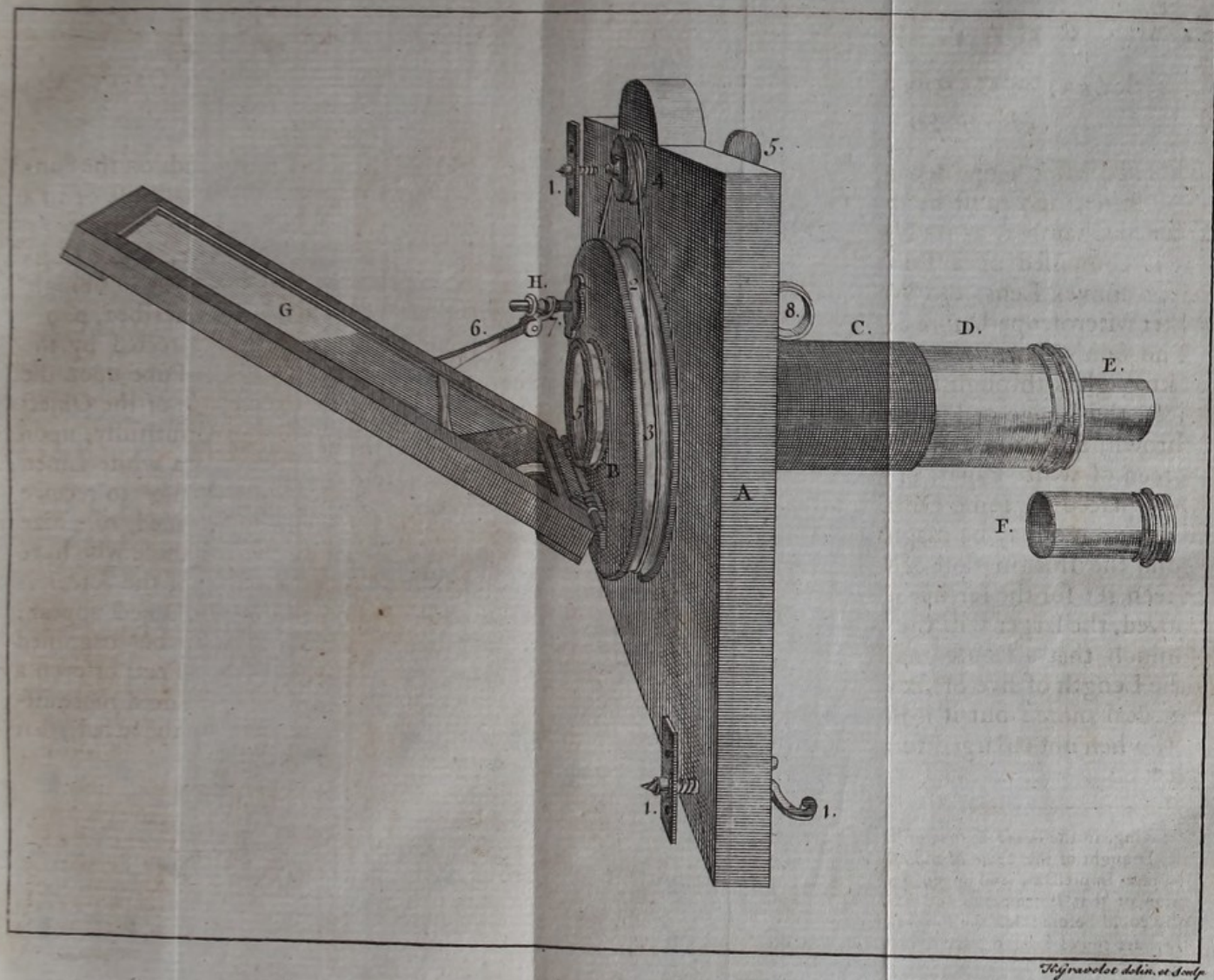
THIS Microscope depends on the Sun-
shine, and must be made use of in a
darkened Chamber, as its Name implies.

It is composed of a Tube, a Looking-
glass, a convex Lens, and WILSON'S Single
Pocket Microscope before described, p. 9.

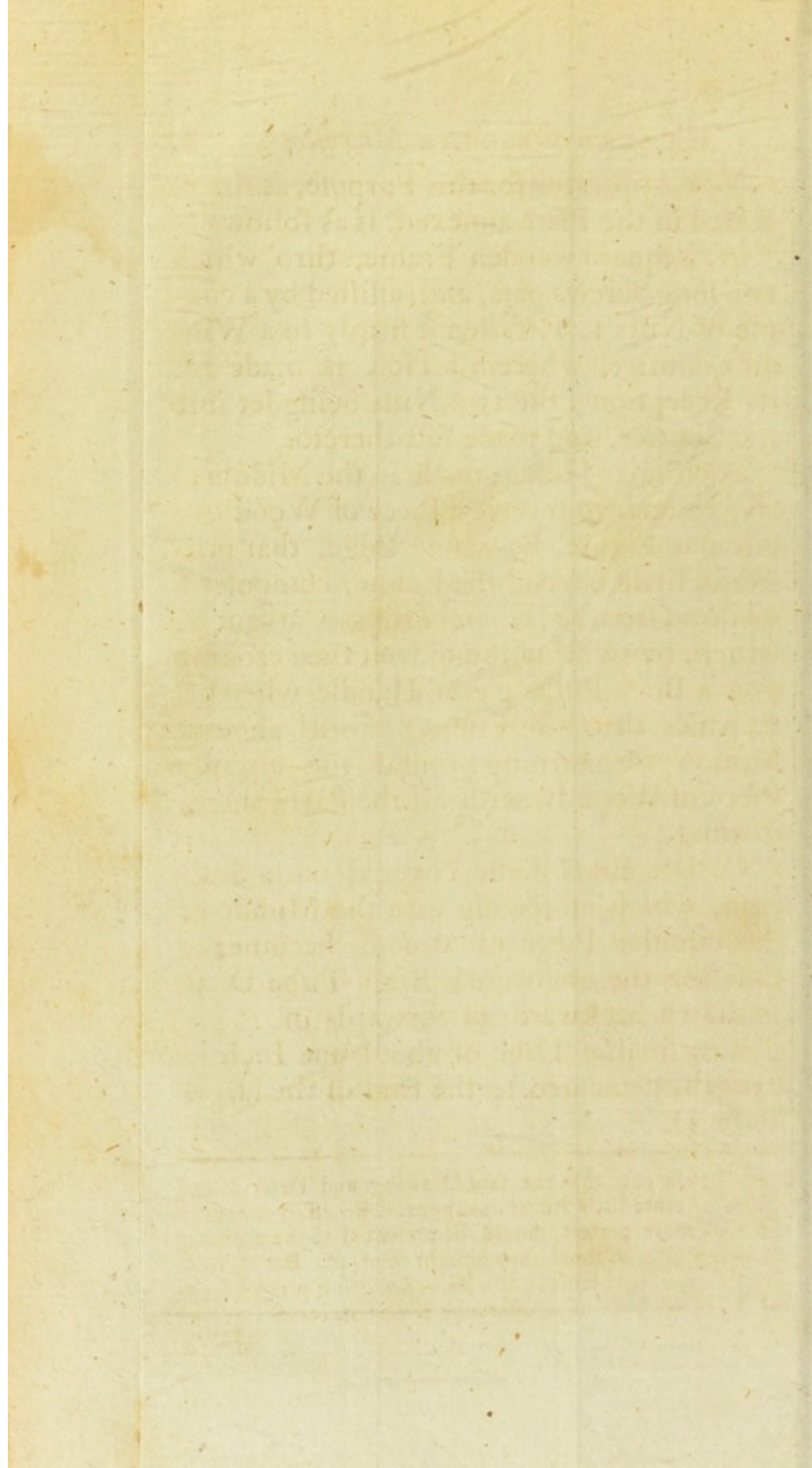
The Sun's Rays being directed by the
Looking-glass through the Tube upon the
Object, the Image or Picture of the Object
is thrown, distinctly and beautifully, upon
a Screen of white Paper, or a white Linen
Sheet, placed at some Distance to receive
the same; and may be magnified, to a Size
beyond the Imagination of those who have
not seen it: for the farther off the Screen is
removed, the larger will the Object appear;
insomuch that a Louse may be magnified
to the Length of five or six Feet, or even a
great deal more: but it is indeed more dis-
tinct, when not enlarged to above half that
Size *.

The

* Having, in the *second Edition* of this Work, inserted a
curious Draught of the *Solar Microscope*, which was not in
the former Impression, and given a more particular De-
scription of that Instrument, and its Apparatus, than I
possibly could before: lest the *Purchasers* of the *first Edition*
should have found Reason to complain of being unkindly
used,



Hydraulot delin. et sculp.



The Apparatus for this Purpose, as represented in the Plate annexed, is as follows.

A. a square wooden Frame, thro' which two long Screws pass, and, assisted by a couple of Nuts 1. 1. fasten it firmly to a Window-shutter, wherein a Hole is made for its Reception; the two Nuts being let into the Shutter, and made fast thereto.

A circular Hole is made in the Middle of this Frame, to receive a Piece of Wood of a circular Figure, B, whose Edge, that projects a little beyond the Frame, composes a shallow Groove 2, wherein runs a Cat-gut 3; which, by twisting round, and then crossing over a Brass Pully 4 (the Handle whereof, 5, passes thro' the Frame) affords an easy Motion for turning round the circular Piece of Wood B, with all the Parts thereto affixt.

C. is a Brass Tube covered with Seal-Skin, which, screwing into the Middle of the circular Piece of Wood, becomes a Case for the uncovered Brass Tube D. to be drawn backwards or forwards in.

E. a smaller Tube of about one Inch in Length, cemented to the End of the larger Tube D.

used, I took care that the said Drawing and Description, with what other little Additions appeared necessary to render the book more perfect, should be presented to them *gratis*, upon applying to those they bought them of. But no such Care is requisite at present, this *Impression* being printed from the *second*, without any Difference of Consequence.

F. is another short Brass Tube, made to slide over the above-described Tube E. To the End hereof the Microscope must be screwed when we come to use it.

5. a convex Lens, whose Focus is about twelve Inches, designed to collect the Sun's Rays, and throw them more strongly upon the Object.

G. a Looking-glass of an oblong Figure, set in a wooden Frame, fastened by Hinges to the circular Piece of Wood B, and turning about therewith, by Means of the above-mentioned Cat-gut.

H. a jointed Wire, partly Brass and partly Iron: the Brass Part whereof, which is flat, 6, being fastened to the Looking-glass, and the Iron Part, which is round, 7, passing through the wooden Frame, enable the Observer (by putting it backwards or forwards) to elevate or decline the Glass according to the Sun's Altitude.

I. a Brass Ring at the End of the jointed Wire, whereby to manage it with the greater Ease.

N. B. The Extremities of the Cat-gut are fastened to a Brass Pin, by turning of which it may be braced up, if at any time it becomes too slack. This Pin lying behind, could not be shewn in the Picture.

When this Microscope is employed, the Room must be rendered as dark as possible: for on the Darkeness of the Room, and

the Brightness of the Sun-shine, depend the Sharpness and Perfection of your Image. Then putting the Looking-glass G. through the Hole in your Window-shutter, fasten the square Frame A. to the said Shutter by its two Screws and Nuts 1. 1.

This done, adjust your Looking-glass to the Elevation and Situation of the Sun, by Means of the jointed Wire H. together with the Cat-gut and Pully, 3. 4. For the first of these raising or lowering the Glass, and the other inclining it to either Side, there results a twofold Motion, which may easily be so managed as to bring the Glass to a right Position, that is, to make it reflect the Sun's Rays directly through the Lens 5. upon the Paper Screen, and form thereon a Spot of Light exactly round *.

As soon as this appears, screw the Tube C. into the Brass Collar provided for it in the Middle of your Wood-work, taking Care not to alter your Looking-glass: then screwing the Magnifier you chuse to employ to the End of your Microscope, in the

* Though obtaining a perfect circular Spot of Light upon the Screen, before you apply the Microscope, is a certain Proof that your Looking-glass is adjusted right, that Proof must not always be expected: for the Sun is so low in Winter, that if it shines in a direct Line against the Window, it cannot then afford a Spot of Light exactly round. But if it be on either Side of you, a round Spot may be obtained even in *December*.

usual Manner, take away the Lens at the other End thereof, and place a Slider, containing the Object to be examined, between the thin Brass Plates, as in the other Ways of using the Microscope.

Things being thus prepared, screw the Body of your Microscope to the short Brass Tube F. which slip over the smallest End E. of the Tube D. and pull out the said Tube D. less or more, as your Object is capable of enduring the Sun's Heat. Dead Objects may be brought within about an Inch of the Focus of the convex Lens, 5; but the Distance must be shortened for living Creatures, or they will soon be killed.

If the Light falls not exactly right, you may easily, by a gentle Motion of the jointed Wire and Pully, direct it through the Axis of the microscopie Lens.

The short Tube F. which your Microscope is screwed to, enables you, by sliding it backwards or forwards on the other Tube E. to bring your Objects to their true focal Distance; which will be known by the Sharpness and Clearness of their Appearance: they may also be turned round by the same Means, without being in the least disordered.

The Magnifiers most useful in the Solar Microscope are, in general, the fourth, fifth, or sixth.

Mention having been often made of a Screen to throw the Images of Objects on,
it

it is proper to inform the Reader, that such a Screen is usually composed of a Sheet of the largest Elephant Paper, strained on a Frame, which slides up or down, or turns about at Pleasure on a round wooden Pillar, in the Manner of some Fire-screens. Larger Screens are likewise made sometimes with several Sheets of the same Paper pasted together on Cloth, and let down from the Ceiling with a Roller, like a large Map.

This Microscope is the most entertaining of any; and, perhaps, the most capable of making Discoveries, in Objects that are not too opake: as it shews them much larger than can be done any other Way. There are also several Conveniences attending it, which no other Microscope can have: for the weakest Eyes may use it without the least Straining or Fatigue: Numbers of People may view any Object together at the same Time, and, by pointing to the particular Parts thereof, and discoursing on what lies before them, may be able better to understand one another, and more likely to find out the Truth, than when, in other Microscopes, they must peep one after another, and perhaps see the Object neither in the same Light, nor the same Position. Such too as have no Skill in Drawing, may, by this Contrivance, easily sketch out the exact Figure of an Object they have a Mind to preserve a Picture of; since they need only
fasten

fasten a Paper upon the Screen, and trace it out thereon, either with a Pen or Pencil, as it appears before them.

It is worth their while, who are desirous to take many Draughts this Way, to get a Frame, wherein a Sheet of Paper may be put or taken out at Pleasure; for if the Paper be single, the Image of an Object will be seen as plainly almost on the back as on the fore Side, and, by standing behind the Screen, the Shade of the Hand will not obstruct the Light in Drawing, as it must in some Degree when one stands before it.

I must observe, that Dr. LIBERKHUN's Solar Microscope had no Looking-glass belonging to it, and therefore was of Use a few Hours only in a Day, when the Tube could be placed directly against the Body of the Sun, and even then not without a good deal of Trouble: but, by this lucky Contrivance of a Looking-glass, the Sun's Rays may be reflected through the Tube, whatever its Height or Situation be, provided it shines at all upon the Window, and that too with much Ease and Advantage.

C H A P. VII.

Of the Microscope for Opake Objects.

THIS Microscope remedies the Inconvenience of having the dark Side of an Object next the Eye, which has hitherto been an unfurmountable Obstruction to the making Observations on opake Objects with any considerable Degree of Exactness or Satisfaction; for in all other Contrivances commonly known, the Nearness of the Instrument to the Object (when Glasses that magnify much are used) unavoidably overshadows it so much, as to render its Appearance obscure and undistinct. And, notwithstanding Ways have been tried to point Light upon an Object, from the Sun or a Candle, by a convex Glass placed on the Side thereof, the Rays from either can be thrown upon it in such an acute Angle only, that they serve to give a confused Glare, but are insufficient to afford a clear and perfect View of the Object.

But in this new Microscope, by means of a concave *Speculum* of Silver, highly polished, in whose Center a magnifying Lens is placed, so direct and strong a Light is reflected upon the Object, that it may be examined with all imaginable Ease and Pleasure.

The

The Apparatus for this Purpose (as in the Plate, Numb. IV.) has afforded me more Delight and Satisfaction than I am able to describe; and whoever tries it, will, I believe, join in my Opinion, that he never before saw an opake Object with so much Clearness, and in so perfect and true a Manner.

The several Parts of this Instrument, made either of Brass or Silver, are as follows.

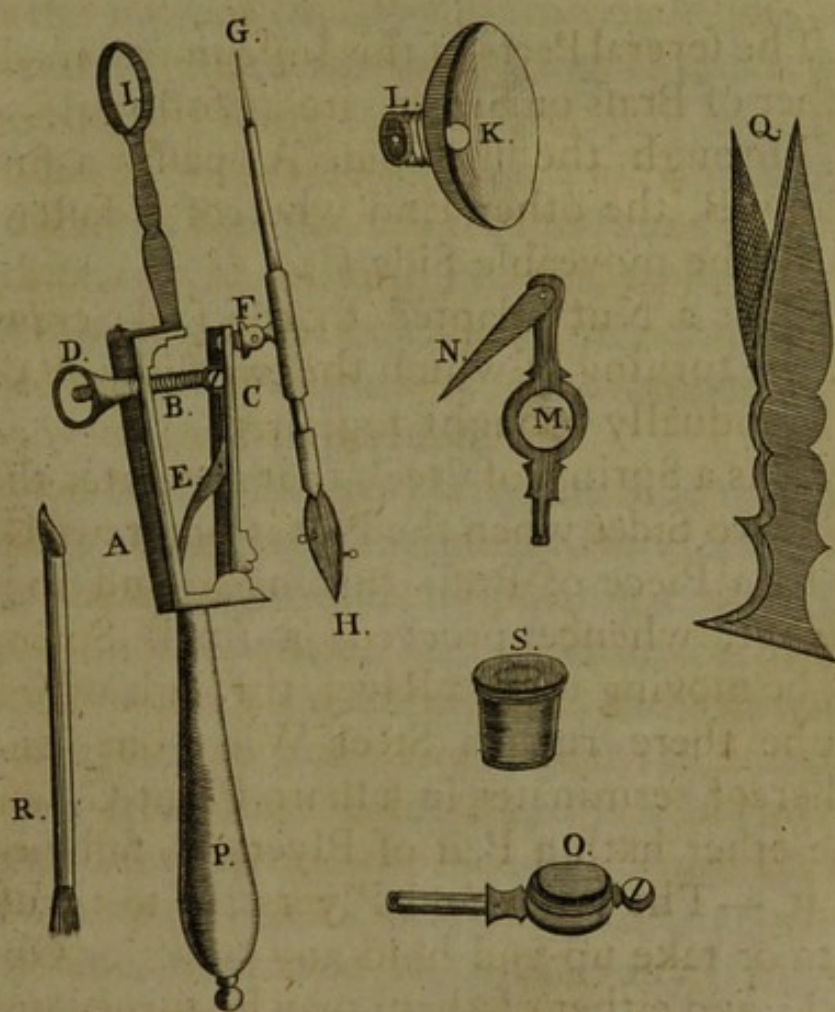
Through the first Side A. passes a fine Screw B. the other End whereof is fastened to the moveable Side C.

D. is a Nut adapted to the said Screw, by the turning of which the two Sides A.C. are gradually brought together.

E. is a Spring of Steel, that separates the said two Sides when the Nut is unscrewed.

F. a Piece of Brass turning round in a Socket, whence proceeds a small Spring Tube moving upon a Rivet, through which Tube there runs a Steel Wire, one End whereof terminates in a sharp Point G. and the other hath a Pair of Pliers H. fastened to it.—The Point and Pliers are to thrust into or take up and hold any Insect or Object: and either of them may be turned upwards, as suits your Purpose best.

I. a Ring of Brass, with a female Screw within it, mounted on an upright Piece of the same Metal, which turns round on a Rivet, that it may be set at a due Distance
when



when the least Magnifiers are employed.—
This Ring receives the Screws of all the
Magnifiers.

K. a concave Speculum of Silver, polished as bright as possible, in the Center of which a double convex Lens is placed, with a proper Aperture to look through it. On the Back of this Speculum a male Screw L. is made fit to the Brass Ring I. to screw into the said Ring at Pleasure.

There are four of these concave Specula, of different Depths, adapted to four Glasses of different magnifying Powers, to be used as Objects to be examined may require. The greatest Magnifiers are known by having the least Apertures.

M. a round Object-Plate, one Side white and the other black, intended to render Objects the more visible, by placing them, if black on the white, and if white on the black Side. A Steel Spring N. turns down on each Side to make any Object fast: and issuing from the Object-Plate is a hollow Pipe, to screw it on the Needle's Point G.

O. a small Box of Brass, with a Glass on each Side, contrived to confine any living Object, in order to examine it: this also has a Pipe to screw upon the End of the Needle G.

P. a turned Handle of Wood, to screw into the Instrument when it is made use of.

Q. a Pair of Brass Pliers, to take up any Object, or manage it with Conveniency.

R. a soft Hair Brush, to clean the Glasses or Specula, or apply a Drop of any Liquid to the Ifinglass of the Box O. in order to view the Animalcules.

S. a small Ivory Box for Ifinglasses, to be placed, when wanted, in the small Brass Box O.

When you would view any Object, screw the Speculum, with the Magnifier you think best to use, into the Brass Ring I. Place your Object either on the Needle G. in the Pliers H. on the Object-Plate M. or in the Brass hollow Box O. as may be most convenient, according to the Nature and Condition of it: then holding up your Instrument by the Handle P. look against the Light, through the magnifying Lens, and by means of the Nut D. together with the Motion of the Needle, by managing its lower End, the Object may be turned about, raised, or depressed, brought nearer the Glass, or put farther from it, till you hit the true focal Distance, and the Light be seen reflected from the Speculum strongly upon the Object: by which means it will be shewn in a Manner surprisingly distinct and clear. And, for this Purpose, the Light of the Sky, or of a Candle, will answer to your Satisfaction.

This Microscope is principally intended for opaque Objects, but transparent ones may also be viewed by it: observing only, that
when

when such come under Examination, it will not always be proper to throw on them the Light reflected from the Speculum : for the Light transmitted through them meeting the reflected Light, may, together, produce too great a Glare. A little Practice will teach how to regulate both these Lights to good Advantage.

There is Reason to expect great Discoveries may be made by the *Apparatus* above described, as opake Objects are a large Field, but little hitherto examined; by reason of the great Difficulty in doing it.

Having given a Description of the several Sorts of Microscopes in Use amongst us at present, and shewn what particular Advantages may be expected from each, I shall proceed to instruct the Ignorant in these Things, with all the Clearness I can, to find out the magnifying Powers of the Glasses they make use of, and calculate how many Times they enlarge the Diameter, the Superficies, and the Cube * or solid Square of any Object under Examination. And this, I persuade myself, will be highly satisfactory,

* Some, perhaps, may dislike my supposing the Cube of an Object to be magnified, since, in reality, the Superficies only can be seen : but the Necessity of such a Supposition will appear plainly in the Progress of this Work, when we come to consider the true Size of Microscopical Objects, by comparing them with larger Bodies.

and induce many People to be fond of this most delightful and instructive Study, when the Difficulties they imagined in it are removed, and they perceive it to be as easy as it is pleasant; when they find themselves able to judge of what they see, not by mere random Guess, but by certain and plain Principles.

C H A P. VIII.

To find the Magnifying Power of Glasses employed in Single Microscopes.

THE Appearance of any Object, as to Magnitude, is according to the Angle it is seen under; or, in other Words, according to the Nearness it can be brought to the Eye: for the less the Distance it can be viewed at is, the more it will appear enlarged.

The naked Eye is unable to distinguish any Object brought exceedingly near it: but looking through a convex Lens, however near the Focus of that Lens be, there an Object may be distinctly seen: and the smaller the Lens is, the nearer will be its Focus, and in the same Proportion the greater must be its magnifying Power.

From

From these Principles, it is easy to find the Reason why the first or greatest Magnifiers are so extremely minute ; and also to calculate the magnifying Power of any convex Lens employed singly in a Microscope. For such as the Proportion of the natural Sight to the Focus of the Lens is, such will be its Power of magnifying. If the Focus of a convex Lens (for Example) be at one Inch, and the natural Sight at eight Inches, which is the common Standard, an Object may be seen through that Lens at one Inch distant from the Eye ; and will appear, in its Diameter, eight Times larger than to the naked Eye. But as the Object is magnified every Way equally, in Length as well as Breadth, we must square this Diameter, to know really how much it appears enlarged ; and we shall then find, that its Superficies is indeed magnified sixty-four Times.

Again : Suppose a convex Lens whose Focus is at one Tenth of an Inch distant from its Center : in eight Inches there are eighty such Tenths of an Inch ; and therefore an Object may be seen through this Lens eighty Times nearer than it can distinctly by the naked Eye. It will consequently appear eighty Times longer, and eighty Times broader, than it does to common Sight ; and as eighty multiplied by eighty makes six thousand and four hundred, so many Times it really appears magnified.

To go one Step farther: If a convex Glass be so small, that its Focus is no more than one twentieth of an Inch distant; we shall find that eight Inches, the common Distance of Sight, contains an hundred and sixty of these twentieth Parts; and, in Consequence, the Length and Breadth of an Object, when seen through such Lens, will each be magnified an hundred and sixty Times; which multiplied by an hundred and sixty, to give the Square, will amount to twenty-five thousand six hundred; and so many Times, it is plain, the Superficies of the Object must appear larger than it does to the naked Eye at the Distance of eight Inches.

Therefore, in a single Microscope, to learn the magnifying Power of any Glass, no more is necessary than to bring it to its true Focus; the exact Place whereof will be known, by an Object's appearing perfectly distinct and sharp when placed there. Then, with a Pair of small Compasses, measure, as nearly as you can, the Distance from the Center of the Glass to the Object you was viewing, and afterwards applying the Compasses to any Ruler with a diagonal Scale of the Parts of an Inch marked on it, you will easily find how many Parts of an Inch the said Distance is: When that is known, compute how many Times those Parts of an Inch are contained in eight Inches, the common Standard of Sight, and

that will give you the Number of Times the Diameter is magnified : squaring the Diameter will give you the Superficies ; and if it be an Object whose Depth or whole Contents you would learn, multiplying the Superficies by the Diameter will shew the Cube or Bulk.

The Superficies of one Side only of an Object can be seen at one View ; and to compute how much that is magnified, is most commonly sufficient. But sometimes it is satisfactory to know how many minute Objects are contained in a larger : as suppose, for Instance, I desire to know, how many Animalcules would make up the Bigness of a Grain of Sand. To answer this, the Cube as well as the Superficies of the Animalcules must be taken into the Account ; as will be shewn in the next Chapter.

As this Treatise is chiefly intended for those who understand but little of such Matters, it may neither be needless nor unacceptable, to give a Table of the magnifying Powers of the convex Glasses commonly used in single Microscopes, according to their different Focus : whereby, upon measuring what the best Distance from the Glass to view the Object is, its Power of magnifying the Diameter, the Superficies, and the Cube of an Object, will be found in one Line.

See the TABLE*.

As this Table is given in round Numbers, it is so clear and easy, that I believe whoever can but divide and multiply a few Figures will readily understand it.

I have taken no Notice of any Magnifier whose Focus is at a greater Distance than the half of an Inch; because Glasses that magnify less than that, may very easily be calculated by the Rules above laid down: nor, when I come to the greatest Magnifiers, have I mentioned any of a shorter Focus than the one hundredth Part of an Inch; since it is so difficult to grind a Lens to a Smallness beyond, or even so minute as this, that perhaps few of my Readers may ever meet with such an one. And though Globules of Glass may be melted so extremely little as to have their Focus at not half this Distance, and consequently their magnifying Powers prodigiously greater; the Use of them is so troublesome, and attended with such Want of Light, such Undistinctness and Uncertainty, that, indeed, they are of very little Service.

The magnifying Powers of the Glasses employed in WILSON'S *Pocket Microscope*, and also of those belonging to the opaque Microscope, are to be calculated in the foregoing Manner. And as People will, no Doubt,
be

To be placed after Page 36.

* A TABLE of the MAGNIFYING POWERS of CONVEX GLASSES, employed in SINGLE MICROSCOPES, according to the Distance of their Focus: Calculated by the Scale of an Inch divided into an Hundred Parts:

Shewing how many Times the Diameter, the Superficies, and the Cube of an Object is magnified, when viewed through such Glasses, to an Eye whose natural Sight is at Eight Inches, or Eight Hundred of the Hundredth Parts of an Inch.

		Magnifies the Dia- meter,	Magnifies the Super- ficies,	Magnifies the Cube of an Object,	
The Focus of a Glass at	$\frac{1}{2}$, or 50	16	256	4,096	Times.
	$\frac{4}{10}$, or 40	20	400	8,000	
	$\frac{3}{10}$, or 30	26	676	17,576	
	$\frac{1}{5}$, or 20	40	1,600	64,000	
	15	53	2,806	148,877	
	14	57	3,249	185,193	
	13	61	3,721	226,981	
	12	66	4,356	287,496	
	11	72	5,184	373,248	
	$\frac{1}{10}$, or 10	80	6,400	512,000	
	9	88	7,744	681,472	
	8	100	10,000	1,000,000	
	7	114	12,996	1,481,544	
	6	133	17,689	2,352,637	
	$\frac{1}{20}$, $\frac{1}{4}$ or 5	160	25,600	4,096,000	
	4	200	40,000	8,000,000	
	3	266	70,756	18,821,096	
	$\frac{1}{50}$, or 2	400	160,000	64,000,000	
	1	800	640,000	512,000,000	

† The greatest Magnifier in Mr. LEEUWENHOEK's Cabinet of Microscopes, presented to the Royal Society, has its Focus, as nearly as can well be measured, at one Twentieth of an Inch Distance from its Center, and consequently magnifies the Diameter of an Object 160 Times, and the Superficies 25,600. But the greatest Magnifier in Mr. WILSON's Single Microscopes, as they are now made, has usually its Focus at no farther Distance than about the Fifth Part of an Inch; whereby it has the Power of enlarging the Diameter of an Object 400, and its Superficies 160,000 Times.

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The Magnifying Power of Glasses. 37

be pleased to know certainly what the Powers of their Glasses are, and consequently what may be expected from them, it would be much better if the *Microscope-Makers* would grind their Glasses according to some settled Standard, and not work by Guess, as they usually do at present, whereby no two Sets of Magnifiers can be supposed exactly alike. Such a Standard, which would afford a very useful Set of Glasses, magnifying one more than another in due Degrees, is, I think, as follows.

*The FOCAL DISTANCES of
Six Magnifiers for Mr. WILSON'S
Pocket Microscope.*

Glas.			Magnifies the Diam.	Magnifies the Superficies
1.	Dist. of the Fo- cus at	$\frac{1}{30}$, or 2	— 400	— 160,000
2.		$\frac{1}{20}$, or 5	— 160	— 25,600
3.		8	— 100	— 10,000
4.		16	— 50	— 2,500
5.		$\frac{3}{10}$, or 30	— 26	— 676
6.		$\frac{1}{2}$, or 50	— 16	— 256

38 *The Magnifying Power of Glasses.*

*The FOCAL DISTANCES of
Four Magnifiers for the Microscope
for Opake Objects.*

Glass.	100 Pts. of an Inch.	Magnifies the Diam.	Magnifies the Superficies.
1. } 2. } 3. } 4. }	Dist. of the Fo- cus at { 8 $\frac{3}{10}$, or 30 $\frac{6}{10}$, or 60 1 Inch	{ 100 26 13 8	{ 10,100 676 169 64
		Times.	Times.

The magnifying Power of the Solar Microscope must be calculated in somewhat a different Manner. For here the Difference between the Focus of the Magnifier, and the Distance of the Screen or Sheet whereon the Image of an Object is cast, is the Proportion of its being magnified. Suppose, for Instance, the Lens made use of has its Focus at half an Inch, and the Screen be placed at the Distance of five Feet; the Object will then appear enlarged in the Proportion of five Feet to half an Inch: and as in five Feet there are one hundred and twenty half Inches, the Diameter will be magnified one hundred and twenty Times; which, multiplied by one hundred and twenty, shews the Superficies to be magnified fourteen thousand and four hundred Times: and by putting

ting the Screen at further Distances, you may magnify your Object to almost what Size you please. But I would advise all who use this Sort of Microscope, to regard Distinctness more than Bigness, and place the Screen just at that Distance where the Object is seen most sharp and clear.

C H A P. IX.

Of the Magnifying Power of Glasses in the Double Microscope.

I Should now shew the Method of computing the magnifying Power of our Double Microscope, as I have done of the Single ones: but a Calculation of the Powers of three combined Glasses would appear so intricate and unintelligible to People unacquainted with Optics (for whose Service chiefly I intend this Treatise) that I believe they will readily excuse my perplexing them with it: and as for the Learned in that Science, they probably will be better pleased to calculate for themselves.

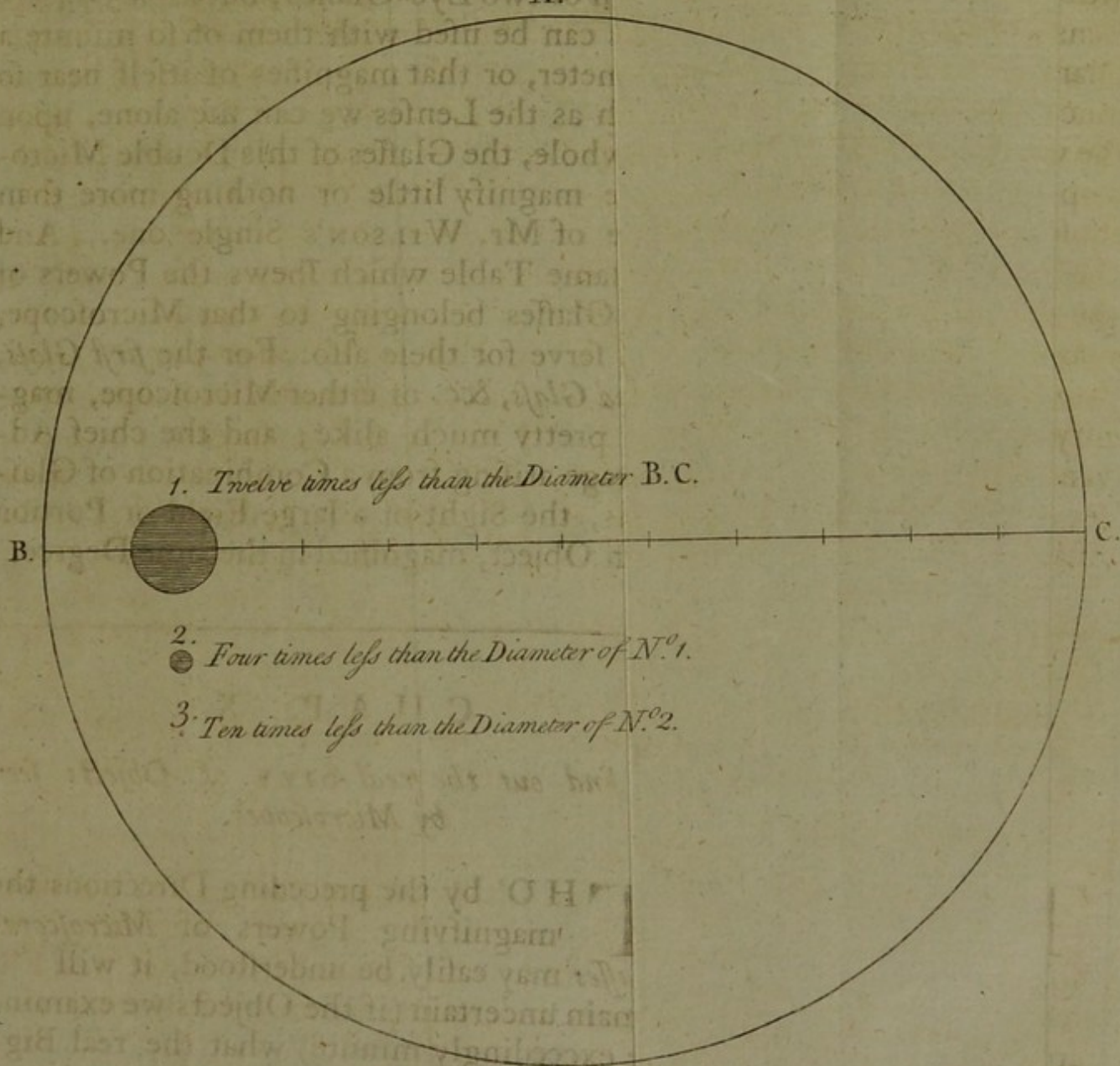
The Double reflecting Microscope, described p. 16. is the only Instrument at present made amongst us for this Purpose, wherein such a Combination of Glasses is employed. Here, indeed, the magnifying Power of the Object-

Object-Lens is greatly increased by the Addition of two Eye-Glasses; but as no Object-Lens can be used with them of so minute a Diameter, or that magnifies of itself near so much as the Lenses we can use alone, upon the whole, the Glasses of this Double Microscope magnify little or nothing more than those of Mr. WILSON's Single one. And the same Table which shews the Powers of the Glasses belonging to that Microscope, may serve for these also. For the *first Glass*, *second Glass*, &c. of either Microscope, magnify pretty much alike; and the chief Advantage arising from a Combination of Glasses is, the Sight of a large Field or Portion of an Object, magnified in the same Degree.

C H A P. X.

To find out the real SIZE of Objects seen by Microscopes.

TH O' by the preceding Directions the magnifying Powers of *Microscope-Glasses* may easily be understood, it will still remain uncertain (if the Objects we examine are exceedingly minute) what the real Bigness of them is. For though we may know they are magnified so many thousand Times, we can make by that Knowledge but a very imperfect Computation of their natural and
true



D.

true Size ; nor can we, indeed, come to any certain Conclusion as to that, but by the Mediation of some larger Object, whose Dimensions we really know. For as Bulk itself is merely comparative, the only Way we can judge of the Bigness of any thing is, by comparing it with something else, and finding out how many Times the lesser is contained in the larger Body. To do this in Microscopical Objects, several ingenious Methods have been contrived ; of which, such as are come to my Knowledge, and are plain and practicable, I shall lay before the Reader.

Mr. LEEUWENHOEK's Way of computing the Size of Salts in Fluids, of the Animalcules in *Semine Masculino*, in *Pepper-Water*, &c. was, by comparing them with the Bigness of a Grain of Sand * ; and his Calculations were made in the following Manner.

* N. B. It is proper to inform the Reader, that wherever, in this Treatise, Microscopical Objects are compared with a Grain of Sand, which commonly was the Measure Mr. LEEUWENHOEK made use of, we must understand it to mean a Grain of coarse *Sea-Sand* (usually called *Scouring-Sand*) which is equal in Bigness to several Grains of our common Inland *House-Sand*, or *Writing-Sand*. But to make our Calculation still more certain, we must suppose them of such a Size, that an hundred of them placed in a Row shall extend an Inch in Length.

He viewed through his Microscope a single Grain of Sand *, which we will suppose to be magnified as the round Figure ABCD. Then observing the Animalcule swimming, or running across it, or coming near it, (which we will imagine to be of the Size 1.) considering and measuring this by his Eye, he concludes, that the Diameter of this Animalcule is less by a twelfth Part than the Diameter of the Grain of Sand: consequently, according to the common Rules, the Superficies of the Grain of Sand is one hundred forty-four Times, and the whole Contents thereof one thousand seven hundred and twenty-eight Times, larger than this Animalcule.

Suppose, again, that he sees among these another and smaller Species of Animalcules; one of which [2.] he likewise measures with his Eye, by the Help of a good Microscope; and computes its Diameter to be five Times, but, to be within Compass, he reckons it only four Times less than the former Animalcule 1. According then to the foregoing Rules, the Diameter of this will be sixteen, and the whole Bulk sixty-four Times less than the Animalcule 1.

If farther, upon a nicer View, he discovers a third Sort of Animalcule [3.] so ex-

* Vide LEEUWEN. *Experim. & Contempl.* Tom. IV. pag. 23.

ceedingly minute that, examining it in the former Manner, he concludes that the Diameter thereof is ten Times smaller than the second Sort: it will then follow, that a thousand of these are but equal in Bigness to one of that second Sort.

The first Sort multiplied by the second, and the second by the third, will plainly demonstrate how many of this third and minutest Sort are requisite to make up the Bulk of a single Grain of Sand: the Process of which is as follows.

First Sort, 1. whose Diameter is less
than that of a Grain of Sand

12 Times.

12

—

144

—

Of the first Sort, 1,728 in a Grain of Sand.

—

Second Sort, 2. whose Diameter is less than
that of the first Sort

4 Times.

4

—

16

4

—

64 in one of the first Sort.

Third

Third Sort, 3. whose Diameter is less than
that of the second Sort

10 Times.

10

100

10

1000 in one of the second Sort.

1728 of the first Sort in a Gr. of Sand.

64 of the 2d Sort in 1 of the first.

6912

10368

110,592

1000 of the 3d Sort in 1 of the 2d.

110,592,000 of the 3d Sort in a Gr. of Sand.

After this Manner the comparative Size
of all Sorts of Objects may very easily be
computed, only substituting (for such as are
less minute) a small Seed, or some other
Body whose Size we are well acquainted
with, in the room of a Grain of Sand.
And, particularly, by the Solar Microscope,
our Calculations may be made with great
Certainty; since the Image of the Object

enquired after, and of the Grain of Sand, the small Seed, or whatever else is thought proper to compare with it, may be really measured by a Ruler, or a Pair of Compasses, and the Difference of their Diameters most exactly found.

The Method Mr. Hooke made use of, to know how much an Object appears magnified, I shall give in his own Words.—

“ Having (says he) rectified the Microscope,
“ to see the desired Object through it very
“ distinctly; at the same time that I look
“ upon the Object through the Glass with
“ one Eye, I look upon other Objects at
“ the same Distance with my other bare
“ Eye: by which means I am able, by the
“ Help of a Ruler, divided into Inches and
“ small Parts, and laid on the Pedestal of
“ the Microscope, to cast, as it were, the
“ magnified Appearance of the Object upon
“ the Ruler, and thereby exactly to measure the Diameter it appears of through
“ the Glass; which being compared with
“ the Diameter it appears of to the naked
“ Eye, will easily afford the Quantity of its
“ being magnified.”—This, for Multitudes of Objects, is a ready and good Way; and I can declare, from my own Experience, that a little Practice will render it exceeding easy and pleasant.

Another very curious Way for this Purpose is described by the ingenious Dr. JURIN,
in

in the 45th Page of his *Physico-Mathematical Dissertations*; the Manner whereof is thus: Wind a Piece of the finest Silver Wire you can get a great many Times about a Pin, or some other such slender Body, so closely as to leave no Interval between the Wire-Threads; to be certain of which, they must be carefully examined with a Glafs. Then, with the Points of a small Pair of Compasses, measure exactly what Length of Pin the Wire covers: and applying the Compasses with that Measure to a diagonal Scale of Inches, you will find how much it is; after which, by counting the Number of Wire-Rounds contained in that Length, you will easily discover the real Thickness of the single Wire. This being known, cut it into very small Pieces, and when you examine an Object, if it be opaque, strew some of these Wires upon it; if transparent, under it; and with your Eye compare the Parts of the Object with the Thickness of such Bits of Wire as lie fairest to your View.

By this Method Dr. JURIN observed, that four Globules of human Blood would generally cover the Breadth of a Wire, which he had found to be $\frac{1}{483}$ th Part of an Inch; and consequently, that the Diameter of a single Globule was $\frac{1}{1940}$ th Part of an Inch. Which was also confirmed by Mr. LEEUWENHOEK's Observations upon human Blood, made with a Piece of the same Wire, sent
to

to him by Dr. JURIN. *Vide Philosophical Transactions*, Numb. 377.

Mr. MARTIN, in his Optics, gives another Way, sufficiently easy and ready on all Occasions. On a circular Piece of Glass, let a Number of parallel Lines be drawn carefully, with the fine Point of a Diamond, at the Distance of one fortieth Part of an Inch from each other. If this be placed in the Focus of the Eye-glass of a Microscope, the Image of the Object will be seen upon these Lines, and the Parts thereof may be compared with the Intervals, whereby its true Magnitude, or Dimensions, may be very nearly known: for the Intervals of these Lines, tho' scarce discernible to the naked Eye, appear very large through the Microscope. A Contrivance of this Kind may also be invented for such Microscopes as a Glass cannot be applied to in the above Manner, by placing it under or behind the Object, which will answer the same Purpose.

Here it will be easy to find what Proportion an Object, or any Part thereof, bears to an Interval between two Lines, and then determine it in Parts of an Inch: for if the Width of an Object appears just one Interval, we shall know it to be just one fortieth Part of an Inch; if half an Interval, the eightieth; if a Quarter of an Interval, the one hundred and sixtieth; if one fifth, only the two hundredth Part of an Inch.

Dr. SMITH has an Invention akin to this, for taking exact Draughts of Objects, viewed in Double Microscopes ; for he advises to get a Lattice made with small Silver Wires, or small Squares drawn upon a plain Glass by the Strokes of a Diamond, and to put it into the Place of the Image formed by the Object-Glass. Then, by transferring the Parts of the Object seen in the Squares of the Glass or Lattice upon similar corresponding Squares drawn on Paper, the Picture thereof may be exactly taken.

There are some other Sorts of Micrometers, or Inventions for measuring the small Objects seen in Microscopes ; but as they are more complex and difficult, I shall not swell this Volume with them.

C H A P. XI.

Of the Area or Portion of an Object seen.

THE visible Area, Field of View, or Portion of any Object seen through a Microscope, is in Proportion to the Diameter and Area of the Lens made use of, and its Power of magnifying, and may be thereby determined : since, if the Lens is extremely small, it magnifies a great deal, and, consequently, a very minute Portion only of an Object

Object can be distinguished through it. For which Reason the greatest Magnifiers never should be employed but for the most minute Objects. — This Consideration will direct how to suit the Magnifiers to the Size of the Objects to be examined, which is of the utmost Consequence in Microscopical Observations ; and may serve to rectify the Mistake of Abundance of People unexperienced in Glasses, who, upon seeing a Mite or a Louse greatly magnified, are apt to cry out with much Surprize, O that we had a Cricket, a Frog, or some other Creature ; how finely that would appear ! Whereas, in truth, such large Objects would entirely cover the Lens, and could not be seen at all.

Microscopes very happily assist us when Objects are so small as to evade our Sight ; but it would be trifling and unnecessary to employ them on such large Things as we can see without their Help.

I shall not trouble the Unskilful with perplexing Calculations about the Area or Field of Objects seen by each Magnifier ; but give this short Rule in general, that it differs not greatly from the Size of the Lens made use of, and that the Whole of any Object, much beyond that Size, cannot conveniently be viewed through it.

There is some Difference, as to the visible Area of an Object, between Single and Double Microscopes ; for the Double shew a larger

Portion of it than the Single, though magnified as much.

Having shewn the Structure and Powers of Microscopes, I proceed now to describe the Manner of chusing, preparing, and applying Objects to them.

C H A P. XII.

Of OBJECTS in General.

PROPER Objects to be examined by Microscopes are (as Mr. HOOKE very judiciously distinguishes) “*exceeding small Bodies, exceeding small Pores, or exceeding small Motions.*”

Exceeding small Bodies must either be the Parts of larger Bodies, or Things the Whole whereof is exceedingly minute; such as small Seeds, Insects, Sands, Salts, &c.

Exceeding small Pores are the Interstices between the solid Parts of Bodies, as in Stones, Minerals, Shells, &c. or the Mouths of minute Vessels in Vegetables, the Pores in the Skin, Bones, &c. of Animals.

Exceeding small Motions are the Movements of the several Parts or Members of minute Animals, or the Motion of the Fluids contained

contained either in animal or vegetable Bodies.

Under one or other of these three Heads almost every thing around us affords Matter of Examination, and may conduce both to our Amusement and Instruction ; as I hope more particularly to shew.

Many, even of those who have purchased Microscopes, are so little acquainted with their general and extensive Usefulness, and so much at a Loss for Objects to examine by them ; that, after diverting themselves and their Friends, some few Times, with what they find in the Sliders bought with them, or two or three more common Things, the Microscopes are laid aside as of little farther Value ; and a Supposition that this must be the Case, prevents many others from buying them : whereas, among all the Inventions that ever appeared in the World, none can perhaps be found so constantly capable of entertaining, improving, and satisfying the Mind of Man.—To evince this, and excite those whose Time and Circumstances permit, to this delightful Study, is the Intention of my writing ; and as Curiosity, the universal Passion of Mankind, may this Way continually be gratified, I hope I shall not write in vain. And if I can hereby induce any to pass those leisure Hours agreeably and usefully in contemplating the Wonders of the

Creation, which otherwise would be spent in tiresome Idleness, or, perhaps, some fashionable and expensive Vice, I shall think these Sheets very happily bestowed.

C H A P. XIII.

Of Examining OBJECTS.

AN Examination of Objects, in order to discover Truth, requires a great deal of Attention, Care, and Patience, together with some considerable Skill and Dexterity (to be acquired by Practice chiefly) in the preparing, managing, and applying them to the Microscope. What little Knowledge in these Matters I may have gained, either from the Accounts of others, or my own Experience, after being conversant many Years therein, I shall readily communicate: in hopes my Pains may clear the Way to Discoveries that will prove of Consequence to the World, and render this Study both desirable and easy.

When any Object comes to be examined, the Size, the Contexture, and Nature of it should be duly considered; in order to apply it to such Glasses, and in such a Manner, as may shew it best. The first Step towards this constantly should be, to view it through a Mag-

a Magnifier that can take in the Whole at once: for by observing how the Parts lie as to one another, we shall find it much easier to examine and judge of them separately, if there be Occasion.—After having made ourselves acquainted with the Form of the Whole, we may divide it as we please, and the smaller the Parts into which it is divided, the greater must be the Magnifiers wherewith to view them.

The Transparency or Opakeness of an Object must also be well regarded, and the Glasses made use of must be accordingly suited thereto; for a transparent Object will bear a much greater Magnifier than one that is opaque; since the Nearness a Glass that magnifies much must be placed at, unavoidably darkens an opaque Object, and prevents its being seen, unless by the Microscope on purpose for such Subjects, described page 27. Most Objects, however, become transparent by being divided into extremely thin or minute Parts. Contrivance therefore is necessary, to reduce them into such Thinness or Smallness as may render them most fit for Examination.

The Nature of the Object, whether it be alive or dead, a Solid or a Fluid, an Animal, a Vegetable, or a Mineral Substance, must likewise be considered, and all the Circumstances of it attended to, that we may apply it in the most convenient Manner. If

it be a living Animal, Care must be taken to squeeze, hurt, or discompose it as little as possible, that its right Form, Posture, and Temper may be discovered. If a Fluid, and too thick, it must be thinned with Water: if too thin, we should let some of its watery Parts evaporate. Some Substances are fittest for Observation when dry, others again when moistened; some when fresh, and some after being kept a while.

Light is the next thing to be taken care of, for on this the Truth of all our Examination depends; and a very little Experience will shew how different Objects appear in one Position and Kind of it, to what they do in another. So that we should turn them every Way, and view them in every Degree of Light, from Brightness even to Obscurity, and in all Positions to each Degree; till we are certain of their true Form, and that we are not deceived. For, as Mr. H O O K E says, in many Objects it is very difficult to distinguish between a Prominency and a Depression; between a Shadow and a black Stain; and in Colour, between a Reflection and a Whiteness. The Eye of a Fly, for Example, in one Kind of Light, appears like a Lattice drilled through with Abundance of Holes; in the Sun-shine, like a Surface covered with golden Nails: in one Position, like a Surface covered with Pyramids; in another,

another, with Cones ; and in other Positions, of quite other Shapes.

The Degree of Light must be duly suited to the Object ; which, if dark, will be seen best in a full and strong Light ; but if very transparent, the Light should be proportionably weak : for which Reason there is a Contrivance, both in the Single and Double Microscope, to cut off Abundance of its Rays, when such transparent Objects are examined by the greatest Magnifiers.

The Light of a Candle, for many Objects, and especially such as are exceedingly minute and transparent, is preferable to Day-light : and for others Day-light is best ; I mean the Light of a bright Cloud. As for Sun-shine, it is reflected from Objects with so much Glare, and exhibits such gaudy Colours, that nothing can be determined by it with Certainty ; and therefore it is to be accounted the worst Light that can be had.

This Opinion of Sun-shine must not however be extended to the Solar Microscope, which cannot be used to Advantage without its brightest Light ; for in that Way we see not the Object itself whereon the Sun-shine is cast, but only the Image or Shadow of it exhibited upon a Screen ; and, therefore, no Confusion can arise by the glaring Reflection of the Sun's Rays from the Object to the Eye, which is the Case in other Microscopes. But then, in that Solar Way,

56 *Of preparing and applying* OBJECTS.

Way, we must rest contented with viewing the true Form and Shape of an Object, without expecting to find its natural Colour, since no Shadow can possibly wear the Colours of the Body it represents.

C H A P. XIV.

Of preparing and applying OBJECTS.

MOST Objects require some Management, in order to bring them properly before the Glasses.—If they are flat and transparent, and such as will not be injured by Pressure, the best Method is to inclose them in Sliders, between two *Muscovy* Talcs or Iinglafs. This Way the Feathers of Butterflies, the Scales of Fishes, the *Farinæ* of Flowers, &c. the several Parts, and even whole Bodies of minute Insects, and a thousand other Things, may very conveniently be preserved. Every curious Observer will therefore have them always ready to receive any accidental Object, and secure it for future Examination: and a Dozen or two of these Sliders, judiciously furnished, are a fine natural History, where we may read delightful Lessons of the high Perfection of God's Works, and his Wisdom in their Contrivance.

In making a Collection of Objects, the Sliders should not be filled promiscuously, but
but

but Care taken to sort the Objects according to their Size and Transparency; in such Manner that none be put together in the same Slider, but what may properly be examined by the same Magnifier: and then the Slider should be marked with the Number of the Magnifier its Objects are fittest for; that is, the most transparent, or minute Objects of all, which require the first Magnifier to view them by, should be placed in a Slider, or Sliders, marked with Number I.; those of the next Degree in Sliders marked with Number II. and so of the rest. This Method will save Abundance of Time and Trouble in shifting the Magnifiers, which, without such Sortment, must perhaps be done two or three Times in overlooking a single Slider *. The Numbers marked upon the Sliders will likewise prevent our being at any Loss what Glass to apply to each.

Small living Objects, such as Lice, Fleas, Gnats, small Bugs, minute Spiders, Mites, &c. may be placed within these Talcs without killing or hurting them, if Care be taken not to press down the Brass Rings that keep in the Talcs: and will remain

* In placing your Objects in Sliders, a convex Glass of about an Inch Focus, to hold in the Hand, and thereby adjust them properly between the Talcs, before you fasten them down with the Brass Rings, will be found very convenient.

58 *Of preparing and applying* OBJECTS.

live even Weeks in this Manner. But if they are larger than to be treated thus, either put them in a Slider with concave Glasses, intended for that Use, and described page 10. or in the Cell, page 19. or else examine them stuck on the Pin, or held between the Pliers; either of which Ways they may be viewed at Pleasure.

If Fluids come under Examination, to discover the Animalcules that may be in them, take up a small Drop with your Pen, or Hair-pencil, and place it on a single Ifin-glass (which you should have in a Slider ready) or else in one of the little concave Glasses, and so apply it. But in case, upon viewing it, you find, as often happens, the Animalcules swarming together, and so exceedingly numerous, that, running continually over one another, their Kinds and real Form cannot be known; some Part of the Drop must be taken off the Glass, and then a little fair Water put to the rest will make them separate, and shew them distinct and well. And this Mixture of Water is particularly requisite in viewing the *Semen Masculinum* of all Creatures: for the Animalcules therein contained are unconceivably minute, and yet crowded together in such infinite Numbers, that unless it be diluted a great deal, they cannot be sufficiently separated to distinguish their true Shape.

But,

But, if we view a Fluid to find what Salts it may have in it, a Method quite contrary to the foregoing must be employed: for then the Fluid must be suffered to evaporate, that the Salts, being left behind upon the Glafs, may more easily be examined.

Another, and indeed the most curious Way of examining Fluids, is, by applying them to the Microscope in exceedingly small capillary Tubes, made of the thinnest Glafs possible. This was Mr. LEEUWENHOEK's Method for discovering the Shapes of Salts floating in Vinegar, Wine, and several other Liquors; and such Tubes should be always ready to use as Occasion requires.

For the Circulation of the Blood, Frogs, Newts, or Fishes, are commonly made use of: and there are Glafs Tubes in the Single Microscope, and a Fish-pan, as well as Tubes, in the Double one, on purpose to confine these Creatures, and bring the proper Parts of them to View: which, in Newts and Fishes, are the Tails, and in Frogs the fine filmy Membrane between the Toes of the hinder Legs. Though, if we can contrive to fasten down the Creature, and bring our Object to the Magnifier, the Circulation cannot possibly be seen so plainly any where as in the Mesentery, or thin transparent Membrane that joins the Guts together; and this Part, by pulling out the Gut a little, may easily be adjusted to the Magnifier.

To

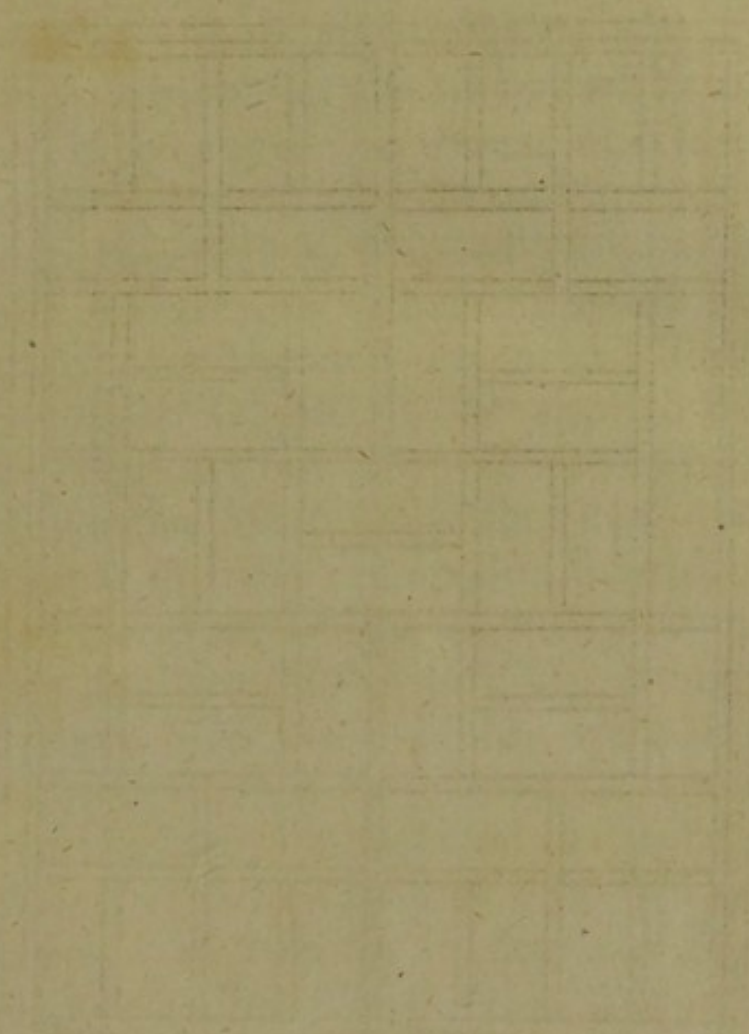
60 *Of preparing and applying* OBJECTS.

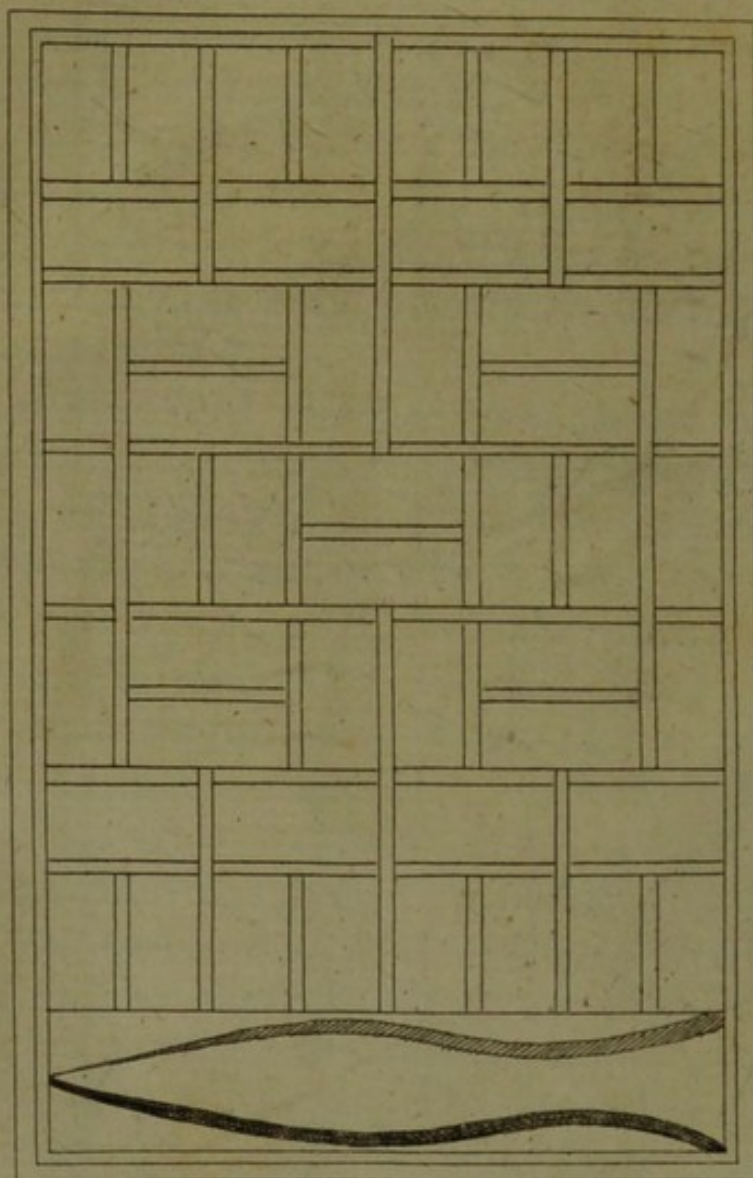
To dissect minute Insects, as Fleas, Lice, Gnats, Mites, &c. and view their internal Structure, requires a great deal of Patience and Dexterity: yet even this may be done in a very satisfactory Manner, by means of a fine Lancet and Needle, if they are placed in a Drop of Water: for their Parts will then be separated with Ease, and lie fair before the Microscope, so that the Stomach and other Bowels may plainly be distinguished and examined.

We should always have ready for this Purpose little Slips of Glass, about the Bigness of a Slider, to place Objects on occasionally; some of which Slips should be made of green, blue, and other different coloured Glass; many Objects being much more distinguishable when placed on one Colour than on another. We should likewise be provided with Glass-Tubes of all Sizes, from the finest Capillaries that can be blown, to a Bore of half an Inch Diameter.

I believe there is no better Way of preserving transparent Objects in general, than by placing them between clear Isinglass in Sliders: but opaque Bodies, such as Seeds, Sands, Woods, &c. require different Management; and a Collection of them should be prepared in the following Manner.

Cut Cards into small Slips, about half an Inch in Length, and the tenth of an Inch broad: wet them half their Length with a
strong





strong but very transparent Gum-water, and with that stick on your Object. As the Spots of Cards are red and black, by making your Slips of such Spots, you will obtain a Contrast to Objects of almost any Colour; and by fixing black Things on the white, white on the black, blue or green on the red or white, and all other coloured Objects on Slips most contrary to themselves, they will be shewn to the best Advantage. These Slips are intended chiefly for the new-invented Microscope for opaque Objects, to be applied between the Nippers: but they will also be proper for any other Microscope that can shew opaque Bodies. A little square Box should be contrived to keep these Slips in, with a Number of very shallow Holes just big enough to hold them. If such Holes were cut through Pieces of that Pasteboard Covers of Books are made of, exactly fitted to the Box, and a Paper was pasted on one Side of each to serve for a Bottom to it, three or four such Pasteboards, stored with Objects, might lie one upon another in the same Box, and contain an hundred or more Slips, with Objects fastened on them, always ready for Examination. It will not be found amiss to provide some Slips larger than others, for the Reception of different-sized Objects: but the Pattern hereto annexed (*Plate VI.*) will better explain my Meaning. The Box should likewise be furnished with a Pair of
Plyers,

Plyers, to take up and adjust the Slips ; and therefore a convenient Place is contrived therein to hold them, as the Plate before you shews *.

C H A P. XV.

Cautions in viewing OBJECTS.

BEWARE of determining and declaring your Opinion suddenly on any Object ; for Imagination often gets the Start of Judgment, and makes People believe they see Things, which better Observations will convince them could not possibly be seen : therefore assert nothing till after repeated Experiments and Examinations, in all Lights, and in all Positions.

When you employ the Microscope, shake off all Prejudice, nor harbour any favourite Opinions ; for, if you do, it is not unlikely Fancy will betray you into Error, and make you think you see what you would wish to see.

Remember, that Truth alone is the Matter you are in Search after ; and if you have been mistaken, let no Vanity seduce you to persist in your Mistake.

* Mr. CUFF, in *Fleet-street*, can supply those who do not care to give themselves the Trouble of making them, with Boxes after this Pattern, which are found by Experience to be extremely useful : He likewise makes and sells all the *Microscopes*, with their *Apparatus*, mentioned in this Treatise.

Pass no Judgment upon Things over-extended by Force, or contracted by Dryness, or in any Manner out of their natural State, without making suitable Allowances.

There is no Advantage in examining any Object with a greater Magnifier than what shews the same distinctly; and therefore, if you can see it well with the third or fourth Glass, never use the first or second; for the less a Glass magnifies, the better Light you will have, the easier you can manage the Object, and the clearer it will appear.

It is much to be doubted, whether the true Colours of Objects are to be judged of, when seen through the greatest Magnifiers: for as the Pores or Interstices of an Object must be enlarged according to the magnifying Power of the Glass made use of, and the component Particles of Matter must by the same Means appear separated many thousands of times farther asunder than they do to the naked Eye, their Reflections of the Rays of Light will probably be different, and exhibit different Colours. And indeed the Variety of Colouring some Objects appear drest in, may serve as a Proof of this.

The Motions of living Creatures themselves, or of the Fluids contained within them, as seen through the Microscope, are likewise not to be determined without due Consideration: for as the moving body and the Space wherein it moves are magnified,

the Motion must probably be so too. And therefore that Rapidity, wherewith the Blood seems to pass along through the Vessels of small Animals, must be judged of accordingly. Suppose, for Instance, a Horse and a Mouse move their Limbs exactly at the same Moment of Time: if the Horse runs a Mile while the Mouse runs fifty Yards (though the Number of Steps are in both the same) we shall readily, I believe, allow the Horse's Motion to be swiftest. The Motion of a Mite viewed though a Microscope, or seen by the naked Eye, is, perhaps, not much less different.

Some People have made false Pretences, and ridiculous Boasts, of seeing, by their Glasses, the Atoms of EPICURUS, the subtile Matter of DES CARTES, the Effluvia * of Bodies, the Emanations from the Stars, and other such like Impossibilities: But let no ingenious and honest Observer give Credit to these romantic Stories, or mis-spend his Time and bewilder his Brains in following such idle Imaginations, when there lies before him an Infinity of real Objects, that may be examined with Ease, Profit, and Delight.

* Dr. HIGHMORE pretends that the Effluvia of the Loadstone have been seen by Glasses, issuing from it in the Form of a Mist: and all the rest of the above Extravagances have been boasted of by others. *Vid. LEEUWEN. Art. Nat. Tom. ii. pag. 348.*

The MICROSCOPE *made Easy* :

O R, A N

A C C O U N T

Of what surprizing

D I S C O V E R I E S

Have been already Made by the

M I C R O S C O P E ;

W I T H

Useful REFLECTIONS on them.

T O G E T H E R W I T H

A great Variety of new EXPERIMENTS and
OBSERVATIONS, pointing out many *uncommon*
Subjects to the Enquiry of the CURIOUS.

P A R T II.

The Microscopical World

OF

ACCIDENTAL
DISCOVERIES

OF WHAT IS

DISCOVERED

IN THE

MICROSCOPICAL

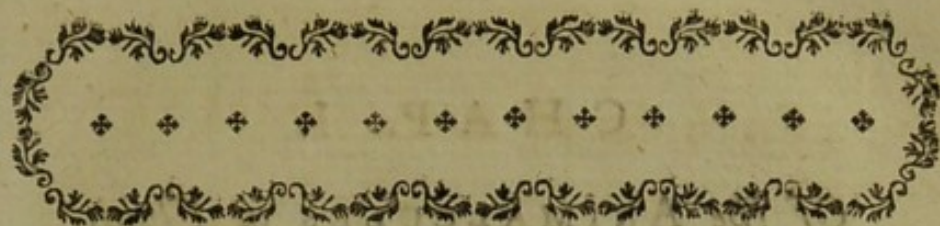
WORLD

WITH REFLECTIONS ON THE

STATE OF THE

ART OF MICROSCOPY, AND
ON THE RAPIDITY OF THE
DISCOVERIES

PART II.



THE
MICROSCOPE
MADE EASY, &c.

PART II.

HAVING described the most useful Kinds of MICROSCOPES made amongst us; shewn how to calculate the *magnifying Powers* of GLASSES, and the real *Size* of OBJECTS; taught the Ways of *preparing*, *examining*, and *preserving* OBJECTS; and given *proper Cautions* in our judging of what we view: I come now to the SECOND PART of my Design, which is, to shew what *surprising Discoveries* have been already made by the MICROSCOPE, with useful *Reflections* on them; and also to set forth a great *Variety* of new *Experiments* and *Observations*, pointing out many *uncommon Subjects* for the Examination of the CURIOUS.

C H A P. I.

Of the ANIMALCULES in Fluids.

THE smallest living Creatures yet known are the Animalcules in Fluids; whereof many Kinds have been discovered by the Microscope of such an exceeding Minuteness, that a Million of them would not equal the Bigness of a large Grain of Sand; and it is probable, there may be numberless Species of a Size much less than these. It is also likely, that there are as many, or even more Kinds of these *Invisibles* (if I may use the Term) than of those whose Size is discernible by the naked Eye. Here, therefore, is Abundance of Scope for Enquiry and Admiration, since every Drop of Water, or other Liquor (excepting Oils and Spirits) either does already, or, upon standing exposed a few Days, will appear full of *living Creatures*, of various Sizes and Forms. Some Kinds of these *Animalcules* seem to be really Fish, and are natural Inhabitants of the Water all their Lives: others live there but occasionally, in the Manner of Gnats, which, from Eggs dropped by their Parents in the Water, become swimming Animals; but after a while shed their skins, appear in a Form that bears no Resemblance to what they

they were before, take Wing, and turn Creatures of the Air.

We may thus account how Water wherein *Pepper, Hay, Oats, Wheat*, or other *vegetable Substances* are infused, will soon become full of Life: for those *minute and invisible little Flies*, which are every where hovering in the Air, and seeking Places to deposit their Eggs, when a Fluid offers well stored with proper Nourishment for their future Offspring, may be supposed to resort to it in Swarms, and lay their Eggs there. These Eggs being soon hatched, the Infant-Brood swim about, and live happily in the Fluid; till, grown to their stated Size, they, in due Time, change their Forms, employ their Wings, and fly away.

The Truth of this I have often experienced; for, after observing some Kinds of *Animalcules* in several Fluids to be grown to a certain Bigness, on a sudden I have found them all gone away, and only a much smaller, and consequently a younger Race, of the same Kinds remaining; which also, when grown to a like Size, have soon after in the same Manner been gone too. Besides, if the Infusion be covered, though with a Muslin or fine Lawn, I have constantly found that few *Animalcules* will be produced therein; but upon taking off the Cover, in a few Days it will be full of Life: which seems to prove, that the Eggs whence these *Animal-*

cules come, must either be deposited by their own Parents, as I above suppose, or be brought along with the Air. And, indeed, both these Ways may possibly be: for as the Eggs of such minute Creatures are lighter than Air, Millions of them may continually float therein, and, being wafted every where indifferently, may perish in Places unsuitable to their Nature, but hatch and thrive when they happen to be lodged in a proper *Nidus* for them. Some People imagine, that the Eggs of these little Creatures are lodged in the *Pepper, Hay*, or whatever else is put into the Water: but, were it so, I cannot think a thin Covering of Lawn, which does not exclude the finer Part of the Air, would prevent their being hatched; and therefore must conclude it a Mistake.

Though Water that stands at Rest, and exposed in the open Air, will, after a few Days, have some *Animalcules* in it, they will be found in no Degree so numerous as when *vegetable Bodies* have been steeped therein: for no Creatures seem able to subsist on mere Water only; and what little Particles besides may accidentally happen in it, can maintain no great Number: but when, by Infusion of the above-mentioned Substances, Water is stored with their proper Food, the Microscope can shew Myriads of *living Creatures* in every little Drop.

As every curious Person will be desirous to view these Wonders with his own Eyes, and communicate them to his Friends, the following Directions for making *Pepper-Water*, &c. to be kept always ready for Observation, may not perhaps be unacceptable.

C H A P. II.

To make PEPPER-WATER, and of the Animalcules found therein.

PUT common Black Pepper, grossly bruised, into an open Vessel, to cover the Bottom of it about half an Inch in Thickness, and pour thereon Rain or River-Water, till it rises above the Pepper an Inch or thereabouts. Shake or stir the Water and Pepper very well together when first you mix them, but afterwards not at all. Expose your Vessel to the Air uncovered, and in a few Days you will perceive a little Pellicle, or Skin, upon the Surface of the Water, reflecting Prism Colours. This Skin, examined by the Microscope, will be found to contain Millions of *Animalcules*, scarce discernible at first, even by the greatest Magnifier, but continually growing bigger till they come to their full Size. Their Numbers too will every Day increase exceedingly,
till

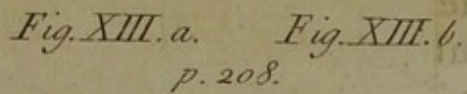
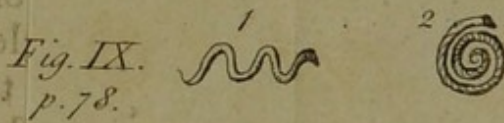
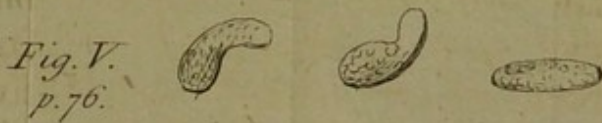
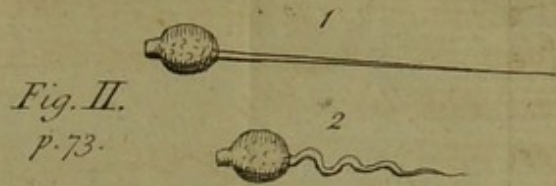
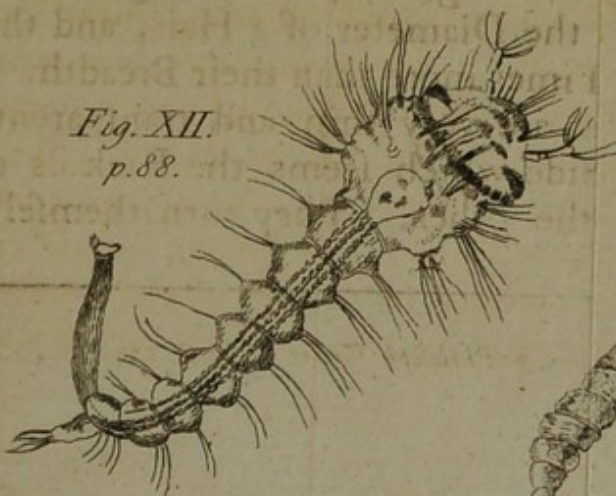
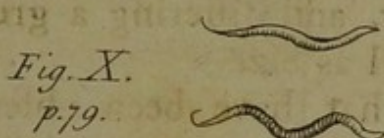
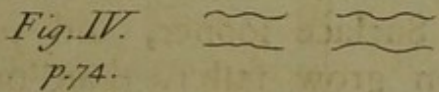
till at length almost the whole Fluid seems alive: though in reality they lie chiefly on the Surface of the Water, and go not deep therein, unless frightened or disturbed; but when that happens, they will sometimes dart down all at once, and not appear again for some time. In warm Weather this Skin rises on the Surface sooner, and you will perceive them grow faster, than in cold: though even in the midst of Winter, if the Water be not frozen, the Experiment will succeed.

About the Quantity of a Pin's Head of this Scum, taken up with the Nib of a new Pen, or a small Hair-Pencil, and applied on a single Ifinglass, first to the third Magnifier, then to the second, and then to the first, will shew several Sorts of *Animalcules* lesser each than other, and differing a great deal in Shape as well as Size.

The Sorts that have been observed in *Pepper-Water* are,

First, The largest Sort of all (represented Plate VII. Fig. I.) † The Length of these is about the Diameter of a Hair, and three or four Times more than their Breadth. Their Bodies are very thin and transparent, but that Side which seems the Back is darker than the other. They turn themselves in

† *Philosoph. Transf.* Numb. 284.



the Water often, and shew both Back and Belly, as 1. 2. Their Edges are fringed, as it were, with a great Number of exceedingly minute Feet, which are chiefly seen about the two Extremities : at one End there are likewise some Bristles longer than the Feet, resembling a Tail. Their Motion is swift; and by their Turns, Returns, and sudden Stops, they seem continually to be hunting about for Prey. They can employ their Feet in running as well as swimming; for upon putting a Hair amongst them, they will often creep along it from End to End, bending in several odd Postures.

Secondly, A pretty common Sort, whose Length is about one Third of a Hair's Breadth, with Tails five or six Times as long, and sometimes more. Fig. II. 1. exhibits one of them with the Tail extended. 2. represents another with its Tail in a Screw-like Form, as they appear very frequently. Sometimes, when they lie still, they thrust out and pull back again a fringed or bearded Tongue; and a Current runs constantly towards them, which is caused, probably, by the nimble Motion of some minute Fins or Legs too fine to be discerned.

Thirdly, A Sort about the Size of the last, but without Tails, appearing sometimes in an oval Shape, as Fig. III. 1. and sometimes a little longer, resembling a Flounder, in the Manner of 2. Their little Feet may be seen

9

plainly

plainly when the Water is just evaporating, for then they move them nimbly. Now and then two of them are seen conjoined, as 3.

Fourthly, Another Sort appear like slender Worms, about fifty Times as long as broad, and whose Thickness is about the one hundredth Part of a Hair. Their Motion is equable and slow, waving their Bodies generally but little in their Progression. They swim with the same Facility backwards or forwards, and being every where of the same Thickness, it is difficult to distinguish which End the Head is placed at. See Fig. IV.

A *fifth Sort* are so amazingly small, that an hundred of them in a Row would not equal the Diameter of a Grain of Sand, and, consequently, a Million of them are but equal to a Grain of Sand in Bigness: their Shape is almost round.

A *sixth Sort* are about the Thickness of the foregoing, but almost twice as long: and, besides these, there are doubtless other Sorts which have not duly been attended to.

It is agreeable enough, while these little Creatures are before the Microscope, to observe the different Effects several Kinds of Mixtures produce among them. For Example, putting to them the smallest Drop imaginable of Spirit of Vitriol upon the Point
of

of a Pin, they immediately spread themselves, and appear to tumble down dead. Dissolved Salt kills them, but with this Difference, that instead of becoming flat, as in the former Case, they shrink into oval Forms. Tincture of Salt of Tartar throws them into convulsive Motions, after which they soon grow faint and languid, and then die without any Change of Shape. Ink kills them as soon as Spirit of Vitriol, but seems to contract them several Ways. Fresh Blood, Urine, and Spittle, kill them in a little while. Sugar dissolved does the same; but thereby some die flat, and others round *.

If the Water be permitted to dry away without any Mixture, some Sorts of the Animalcules will burst, but others not: and if a fresh Drop of Water be put to them, in a little while many of them will revive and swim about again.

* *Philosoph. Trans.* Numb. 203.

C H A P. III.

Of H A Y - W A T E R, &c.

HAY, Straw, Grass, Oats, Wheat, Barley, or any other vegetable Production, being infused in Water, in the Manner advised before; after some Days, a Sort of whitish Scum, or Motheriness, will appear upon the Surface, which, examined by a Microscope, will be found to contain inexpressible Numbers of minute *living Creatures*, of various Sizes, Forms, and Kinds.

And of these some are the same exactly as were just now described in *Pepper-Water*: for it is to be observed, that certain Kinds of these *Animalcules* are met with, universally, in all Waters that have stood any considerable Time exposed to the open Air. The most general among them is an oval Sort of *Animalcule*, somewhat in the Shape of an Emmet's Egg (See Fig. V. Plate VII.) They are extremely nimble, and in a continual swift Motion backwards and forwards: but sometimes they stop on a sudden, and turn round on their own Axis numberless Times with surprising Velocity, first one Way and afterwards the contrary*. This Gyra-

* The Solar Microscope has discovered, that this strange Motion is produced by the Action of a great Number of Legs or Fins, placed in a circular Order.

tion, or Twirling round as it were on a Point, I have taken Notice of in other Kinds also of the Animalcules found in Fluids.

Another pretty common Sort, and in Shape somewhat resembling the foregoing, is shewn (Fig. VI.) Their Motion is very swift, and always with the sharp End foremost, whence one may reasonably suppose it to be the Head. Some of them are clear from End to End, but curiously ribbed in the Manner of a Melon : others are transparent at their small Extremity only, but have their Bottle-end opaque. No Legs or Fins can be discerned in either.

We find another Sort, as long almost as the largest in *Pepper-Water*, which are very brisk and active, and have a Power of contracting or extending themselves as they swim along. At the End that seems to be the Fore-part, several Feet are visible ; but especially when the Water is almost evaporated : for then they shrink into a globular Form, and their Feet standing out may be perceived to move very nimbly. Fig. VII. 1. represents one of these Animalcules at its full Length : 2. shews another of them when contracted.

There is likewise a Species of *Animalcules* whose Bodies are spherical, but pointed somewhat like a Pear, and resembling Bladders filled with Water, wherein a vast Number of dark Particles seem in a continual Agitation.

Agitation. Their Motion is chiefly a revolving one, turning round perhaps above an hundred Times in a Minute, first one Way, and then the contrary; and all this without moving a Hair's Breadth out of their Place. But sometimes they move forward very briskly, turn, return, and fetch a large Compass with several Deviations: keeping, however, throughout their whole Progression, their pointed End always foremost. See Fig. VIII.

I once discovered in the Scum on the Surface of *Hay-Water* a Kind of *minute Serpents*; for so I call them from their Motion, which was like that of a Serpent, and from their coiling up themselves in the Manner Serpents do. I kept this Water some Weeks, and shewed them to several of my Friends; but since that Time have never met with them in any Infusion of the same Sort, or in any other Fluid. Their Manner of moving forward, and also of coiling themselves up, is shewn Fig. IX. 1, 2. They were larger than any of the *Eel-kinds* of *Animalcules*, their Motion very different, and not near so quick. The End that seemed to be the Head was thicker and somewhat more opaque than the other.

Animalcules in the Shape of *Eels* are frequently met with in many of the Infusions I am now mentioning, and likewise in several other Liquors. The Bigness of them
is

is very different, some being an hundred Times larger than others, and probably they may differ also very much in Kind. They have in general a nimble wriggling Motion: but some Sorts of them are more active and vigorous than others.

Vinegar, after standing a few Days uncovered, and especially in the Summer-Season, will frequently abound with a Kind of these *Eels*, large enough to be discerned by the naked Eye: which has encouraged some People erroneously to assert, that the Sharpness of Vinegar is owing to nothing else but the Striking of these Creatures upon the Tongue and Palate with their pointed Tails: whereas it is very certain, that many Times none of them can be discerned even in the fourest Vinegar; and besides, Mr. LEEUWENHOEK has demonstrated, that its Sharpness proceeds only from the pointed and penetrating Figure of the Salts floating in it, as I shall find Occasion to observe more fully by and by.

The Shape of these *Eel-like Animalcules* is delineated *Fig. X.*

Dr. POWER tells us *, That if Vinegar wherein *Eels* abound be but moderately heated at the Fire, they will all be killed, and sink down to the Bottom; but that Cold does them no Injury. For after such

* POWER's *Microscop. Observ.* pag. 35.

Vinegar had been exposed a whole Night to the severest Frost, and was frozen, and thawed, and frozen again, and so several times over, they were as brisk as ever. He likewise informs us, that in cold Weather he put some Vinegar full of these *Eels* into a Glass, and poured thereon about the same Quantity of Oil, which floating on the Vinegar, all the *Eels* would constantly creep up into the Oil when the Vinegar began to freeze ; but upon thawing the Vinegar, they as constantly returned to it again. These are pretty and curious Experiments.

A Drop of Oil of Vitriol, mixed with the Vinegar, kills them in the same Manner as Fire does.

If some Grains of Sand be put among the *Eels* before the Microscope, it will be highly entertaining to see them struggling and embarrassed, as it were, amongst large Stones.

C H A P. IV.

Of EELS in PASTE.

Whoever is desirous to be furnished with *minute Eels* always ready for the Microscope, needs only boil together a little Flour and Water, and make such Paste thereof as Bookbinders commonly use; or it may be bought of them. It should neither be very stiff nor very watery, but of a moderate Consistence. Expose it to the Air in an open Vessel, and prevent its hardening or becoming mouldy on the Surface, by beating it well together when you find any Tendency that Way; for if it grows hard or mouldy, your Expectation will be disappointed. After some Days it will turn sour; and then, if examined attentively, you will discern Multitudes of exceeding small, long, slender, wriggling *Animalcules*, which grow larger daily, till you will be able to see them with the naked Eye.

To promote their coming forward, pour every now and then a Drop of Vinegar on your Paste: and after they are once produced you may keep them all the Year, by putting to them sometimes a little Vinegar or Water, if the Paste becomes too dry, and sometimes a little Supply of other sour Paste; taking Care continually to preserve

the Surface in a right Condition, which will easily be done when it is well stocked with these *Animalcules*; the continual Motion of them preventing any Mouldiness thereon.

A Water-Glass, or some other Glass Vessel, is the most convenient to keep your Paste in; for, by holding it up against the Light, you will oftentimes perceive the *Eels* wriggling themselves above the Surface of the Paste upon the Sides of the Glass, and may be able to take several of them with a Pen or Hair Pencil, much more disengaged from the Paste, and consequently fitter for View, than if you are obliged to examine the Paste itself in order to find them in it.

Apply them to your Microscope upon a single Talc or Icinglass, after having first put on it a very small Spot of Water for them to swim about in. The thicker your Paste is, and the more they are enveloped in it, the greater Proportion of Water will be requisite to dilute it, that they may disentangle themselves, and be rendered distinctly visible.

They are very entertaining Objects examined by any Kind of Microscope, but particularly the Solar one, by which I have magnified them sometimes to an Inch and half, or two Inches in Diameter, with a Length proportionable, and have found them answer exactly the Appearance of such sized Eels. The internal Motion of their Bowels may very plainly be distinguished; and when
the

the Water is dried almost away, and they are near expiring, their Mouths may be seen opening to a considerable Width.

C H A P. V.

Of RAIN-WATER and other Waters.

MR. LEEUWENHOEK says, that at first he could discern no *living Creatures* in Rain-Water; but, after standing some Days, he discovered innumerable *Animalcules* many thousand of Times less than a Grain of Sand, and in Proportion to a Mite as a Bee is to a Horse.

In other Rain-Water, which had likewise stood some Time, he found the smallest Sort he had ever seen; and in a few Days more, met with others eight Times as big as these, and almost round.

In another Quantity of Rain-Water, that had been exposed like the former, he discovered a Kind of *Animalcules* with two little Horns, in continual Motion. The Space between the Horns was flat, tho' the Body was roundish, but tapering a little towards the End, where a Tail appeared four Times as long as the Body, and the Thickness of a Spider's Web. He observed several Hundreds of these within the Space a Grain of Sand would occupy. If they happened on

the least Filament or String, they were entangled in it, and then would extend their Bodies into an oblong Round, and struggle hard to disengage their Tails. He observed a second Sort of an oval Figure, and imagined the Head to stand at the sharpest End. The Body was flat, with several small Feet moving exceeding quick, but not discernible without a great deal of Attention. Sometimes they changed their Shape into a perfect Round, especially when the Water began to dry away. He met also with a third Sort twice as long as broad, and eight Times smaller than the first; yet in these he discerned little Feet, whereby they moved very nimbly. He perceived likewise a fourth Sort, a thousand Times smaller than a Louse's Eye, and which exceeded all the rest in Briskness: he found these turning themselves round, as it were upon a Point, with the Celerity of a Top. And he says there were several other Sorts.

It is common, in Summer-time, for the Water that stands in Ditches to appear sometimes of a greenish and sometimes of a reddish Colour *, which, upon Examination
with

* The Insects that most commonly discolour the Waters are of the *Sbrimp Kind*, called by SWAMMERDAM *Pulex aquaticus arborescens*, from the branching out of their little Horns; they are often so numerous in stagnating Waters, in May or June, at which time they copulate, as to make them

with the Microscope, is found entirely owing to infinite Millions of *Animalcules* crowded together on the Surface of it, and giving it such Appearance. Their Bodies are oval, and transparent at both Ends; but the Middle either green or red, according to the Colour of the Water they are swimming in. This middle Part, viewed with the first or second Magnifier, seems composed of Globules, and bears so near a Resemblance to the Rows or Spawn of Fishes, that it is reasonable to believe it really may be the same: and the more so still, as they are found after some Time perfectly clear and colourless, and therefore may be presumed to have shed their Spawn.

The Water that drains from Dunghills, and looks of a deep brown Colour, is so thronged with *Animalcules*, that it seems to be all alive; and must be diluted with Water before they can be sufficiently separated to distinguish their various Kinds. Amongst these one Sort is found, which I do not remember to have seen elsewhere, and therefore give a Draught of (Plate VIII. Fig. XI.) Their middle Part appears dark, and beset with Hairs, but both Ends of them trans-

them appear of a pale or deep red, and sometimes of a yellow Colour, according to the Colour of themselves. The green Scum so commonly seen on the Top of standing Waters in Summer-time, is nothing but innumerable green *Animalcules*. Vid. DERHAM's *Physic. Theolog.* pag. 178.

parent; their Tails are tapering, with a long Sprig at the Extremity; and their Motion is slow and waddling. This Dunghill-Water abounds also with a Sort of *capillary Eels* that are extremely active.

An Infusion of any *Herb, Grain, Fruit, or Flower*, made in common Water, will be found, after a few Days, to contain some Kinds of *Animalcules* peculiar to itself; and this, tho' astonishing, may be accounted for in a very reasonable Manner; for a little Observation will shew, that every *Herb, Grain, Fruit, or Flower*, is allotted by Providence to be the Food of some particular Sort of Bird, Beast, or Insect, of the visible and larger Kinds; and we may suppose it, in like Manner, when infused in Water, to afford also a proper Nourishment for some or other of those numberless Species of *minute Creatures*, which are *invisible* to the naked Eye, and not to be discovered without a good Microscope. And as to this Particularity of *Animalcules*, I refer the Curious (who have not yet been convinced by Trials of their own) to the Observations of Monsieur JOBLLOT (*Professor Royal of the Mathematics, and of the Royal Academy of Painting and Sculpture at PARIS*) on the various Kinds discovered by him in the several Infusions following: the Pictures of which *Animalcules* he has given, as well as a Description of them. He examined the Infusions of *Pepper*, black,
white,

white, and long; of *Senna*, of *Pinks*, of *Cyanus* or *Bluebottle*, of *Roses*, *Jessamin*, *Raspberry-Stalks*, *Tea*, *Barberries*, *Fennel*, and *Sage*, *Marigold-Flowers*, *sour Grapes*, and *Mellion Rind*; and found different *Animalcules* in them all. *Hay*, new and old, abounded with many Kinds; *Rhubarb*, *Mushrooms*, *sweet Basil*, *Citron-Flowers*, had their particular *Animalcules*. The *Anemomy* afforded some very wonderful *; *Celery* produced many Kinds; *Wheat-Ears* and *Straw* many Kinds; *Straw* of *Barley*, *Rye*, *Oats*, and *Turkish-Corn*, many Kinds; *Oak-Bark*, new and old, afforded great Variety. Some of these Infusions he kept a whole Year round, and observed, not only that each Infusion had *Animalcules* of Shapes quite different from those in others, but likewise that in the same Infusion different Kinds of *Animalcules* appeared at different Times.

N. B. It is highly probable, that the Place where Infusions are made, in a City, or in the Country; exposed to the open Air, or shut up within a House; as also the Season of the Year, and its Temper as to Heat or Cold, may occasion great Differences in the

† Mr. JOBLOT's Draught of the *Animalcules* in this Infusion represents an exact Satyr's Face upon their Backs: I recommend the Trial to the Curious.

Kinds of *Animalcules* to be found in the same Infusions.

We sometimes find in our Infusions of *vegetable Productions*, and in other Waters that have stood awhile uncovered, an Animal much larger than any before described, of a very singular and surprizing Form, as pictured Plate VII. Fig. XII. This little Creature is in its middle State; it lately was a Worm, and will soon become a Gnat. For * Gnats deposit their Eggs in a Kind of slimy Matter on the Surface of the Water, and fasten them to something that may prevent their being washed away, or separated too soon. From these Eggs proceed a Number of minute Worms, which, sinking to the Bottom of the Water, make for themselves Cases or Coverings of fine Sand or Earth, cemented together with a Sort of Glue, but open at both Ends for them to come out of or retire into as they find Occasion. After a Time, quitting these Habitations, and the Figure of Worms, they re-ascend to the Top of the Water in the Shape now before us, shelled all over, with a large Head and Mouth, a Couple of black Eyes, two Horns, several Tufts of Hairs or Bristles on different Parts of the Body, and a Tail with a Brush of Hair at the End of it, which being

* *Spectacle de la Nature*, English Edit. 12mo, pag. 123.
HOOKE'S *Microg.* p. 186.

smear'd over with an oily Fluid, serves like a Cork to keep them above Water; their Heads being sometimes lifted into the Air, and sometimes plunged into the Water, while the Tail slides along the Surface. And if the Oil on the Tail begins to dry, they shed from their Mouth a new Supply upon it, which restores its Ability of steering where they please, without being wetted or prejudiced by the Water. After living in this Manner the Time appointed by Providence, a stranger Change succeeds: for, resigning their Eyes, Horns, and Tail, and casting off their whole Skin, there issues forth a Race of Insects of a quite different Element: the most beautiful and delicate Plumage adorns their Heads; their Limbs are constituted with the finest Texture; they have Wings curiously fringed and ornamented; their whole Bodies are invested with Scales and Hair, and they are actuated by a surprizing Agility: in short, they become *Gnats*, and spring into the Air. And, what is most amazing, a Creature that but a Minute since was an Inhabitant of the Water, would now be drowned if it were plunged therein.

I have been the more particular in my Account of this *Metamorphosis*, as I apprehend many Sorts of the *Animalcules* in Fluids undergo Changes in somewhat a like Manner. I shall only add here, that the little Creature whose Picture I have given,

is a delightful Object for the *Microscope*; its white Heart beating distinctly, and the Motion of all its Intestines being perfectly visible and extraordinary.—Of the *Gnat* I shall speak farther in its proper Place.

The Waters every where abound with Life, and are an endless Subject of Employment for the *Microscope*: Seas, Rivers, Ponds, Ditches, and almost every Puddle can, by its Assistance, present us with living Wonders never before discovered: for such Examinations have as yet been but little attended to, even by People that have got these Instruments, and also a Genius to use them. But I am in hopes this Treatise may excite them to be more industrious, and not suffer a little Difficulty, or a few Disappointments, to discourage them from a Study that can so amply reward their Pains.

In several of * Mr. LEEUWENHOEK'S Letters to the *Royal Society*, we meet with an Account of some surprizing *Animalcules* found adhering to the Roots of the *Lens Palustris*, or *Duck-Weed* (which in Summer-time floats plentifully on the Surface of Ponds and Ditches), as examined by him in a Glass Tube filled with Water. One Sort

* Vid. *Phil. Transf.* Numb. 283, 295, 337.

Pag. 90 Fig. I. p. 91

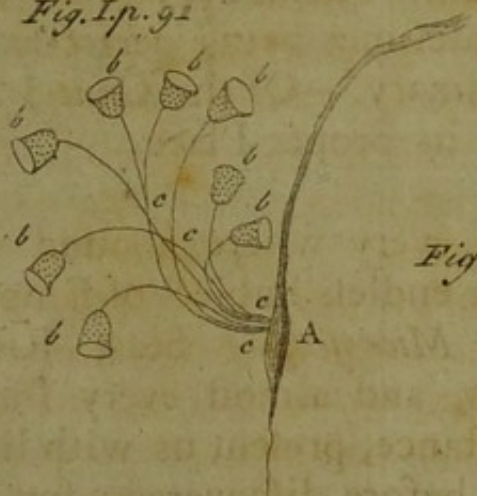


Fig. II. p. 91



Fig. III. p. 91



Fig. V. p. 91



Fig. IV. p. 91



Fig. VIII. p. 93

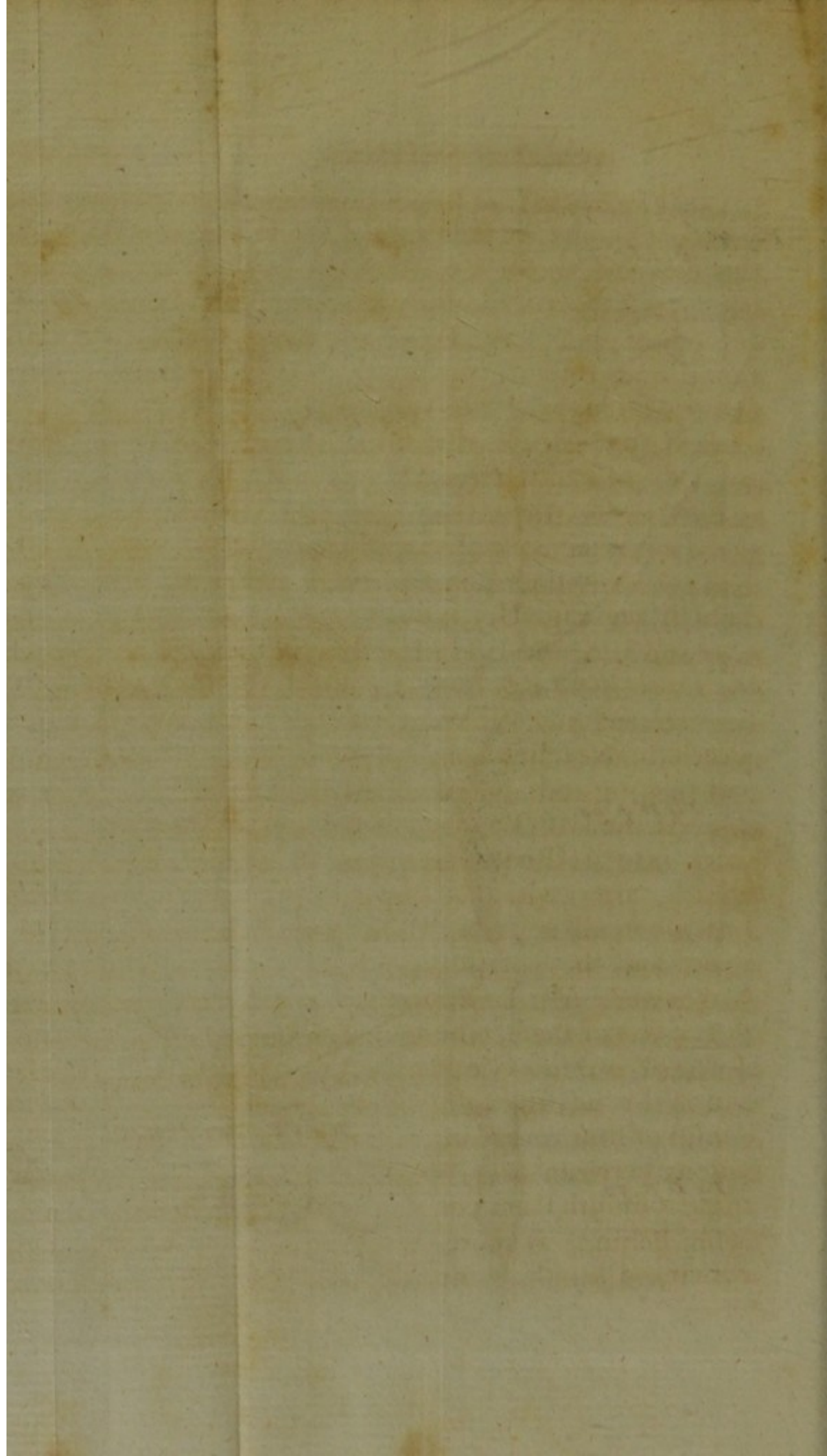


Fig. VII. p. 93



Fig. VI. p. 93





of these was shaped like Bells, with long Tails, whereby they fastened themselves to the Root of these Weeds; and sometimes twenty of these were seen together, gently extending their long Tails and Bodies, and then, in an Instant, contracting them again. See the Draught, Plate VIII. Fig. I.

A, represents a Root of *Duck-Weed*, with the Tails of many *Animalcules* adhering to it.

b b b b, &c. shew their Bell-like Bodies.

c c c c, their long Tails.

Another extraordinary Kind of *Animacule* (which see Fig. II.) appears in a Sheath or Case, *a, b, c*, the End whereof it fastens to the *Duck-Weed* Roots. This little Creature has two seeming Wheels with a great many Teeth or Notches coming from its Head, and turning round as it were upon an Axis, *d, e*. At the least Touch it draws the Wheel-work into its Body, and its Body into the Sheath, after which it appears as Fig. III. But when all is quiet, it thrusts itself out again, and the Rotation of the Wheel-work is renewed. Mr. LEEUWENHOEK took Notice of one of these, whose Case seemed composed of minute Globules (Fig. IV. *a, b.*) and in this he discovered the Wheel-work to consist of four roundish Parts, with little Divisions between each, though only three of those roundish Parts could be seen, the fourth lying behind, as represented Fig. V. This convinced him how much he had been mistaken,

taken, in believing them, from their common Appearances, to be two Wheels, whereas the real Form of this Wheel-work is as at Fig. V.

To find these *Animalcules*, choose *Duck-Weed* that has long Roots; for young Plants with short Roots seldom afford any. Be careful too that they are not covered with a rough Matter, or tending to Decay, as they will often be. Let the Roots sink gently down in a Glass Tube filled with Water, and so apply them to the Microscope. Two or three *Animalcules* will be found sometimes adhering to one Root; and at other times you may examine several, and not be able to meet with any.

In the Water, or slimy Matter, found in Leaden Pipes or Gutters, Mr. LEEUWENHOEK met with various Kinds of *Animalcules*, and, among the rest, with Multitudes that appeared to have a Sort of Wheel-work, turning round somewhat in the former Manner *. These Creatures, when the Water dries away, contract their Bodies into a globular or oval Figure, and reddish Colour, and become fixt in the dry Dirt, which grows as hard as Clay: but whenever a Piece of such Dirt is put in Water, in about half an Hour's Time they open, and by Degrees ex-

* *Phil. Transact.* Numb. 289. LEEUWEN. *Arcan. Nat.* Tom. II. Epist. 149.

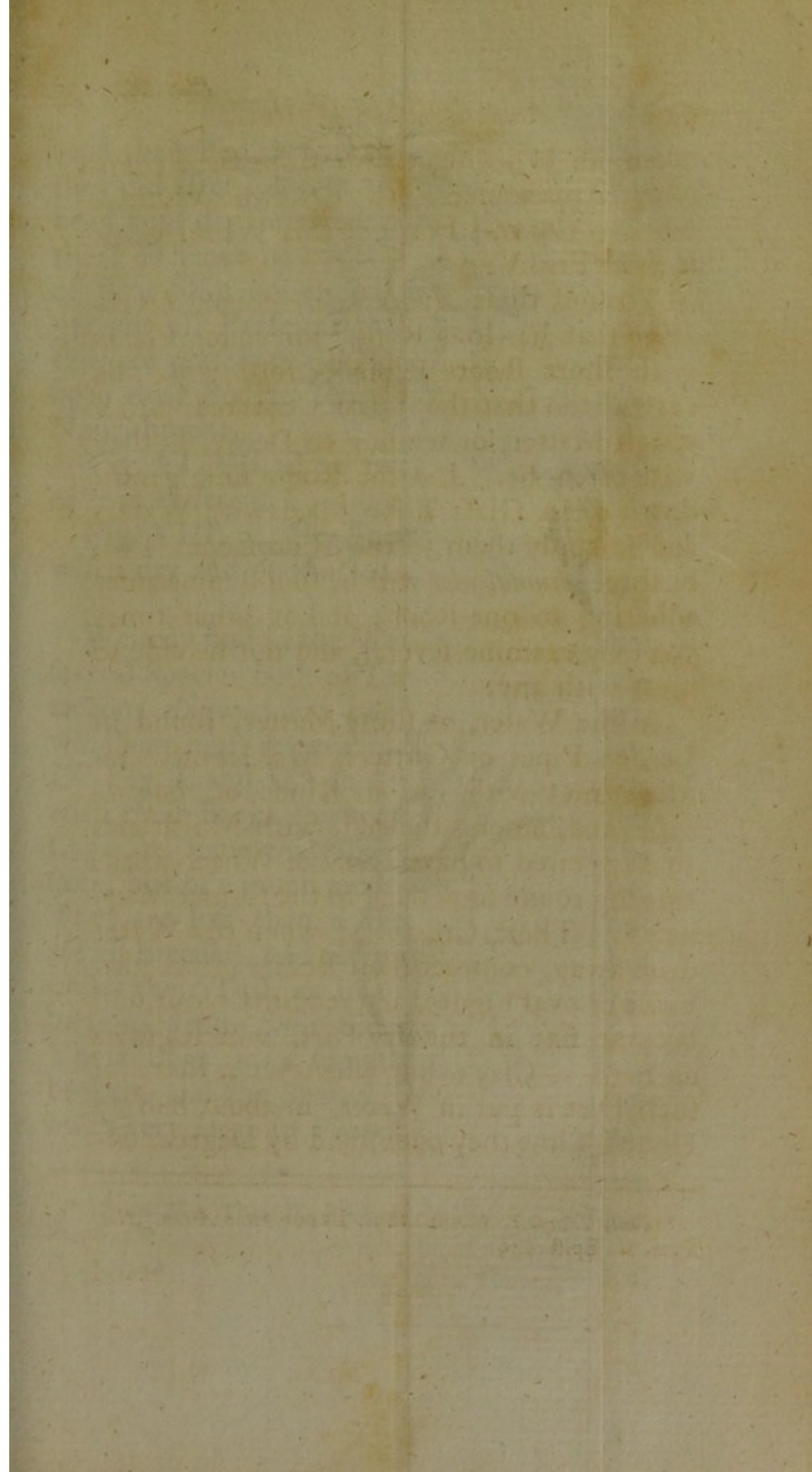


Fig. II. p. 93.



Fig. I. p. 93.

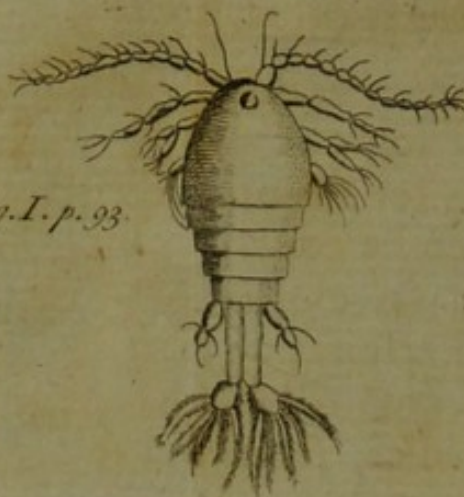


Fig. VII. p. 96.



Fig. VI. p. 96.



Fig. III. p. 94.

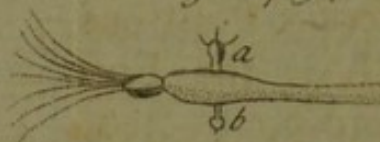


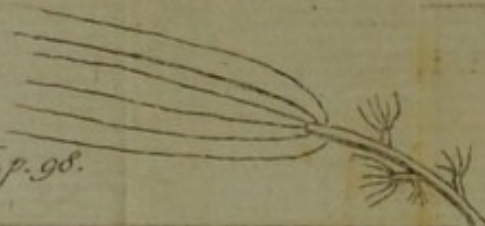
Fig. V. p. 96.



Fig. IV. p. 95.



Fig. VIII. p. 98.



tend their Bodies, and swim about: and this they did after some of this Gutter-Dirt had been kept dry for twenty-one Months together. Whence he concludes, that the Pores of their Skin are closed so perfectly, as to prevent all Perspiration; by which Means they are preserved till Rain falls, when they open their Bodies, swim about, and take in Nourishment.

Fig. VI. VII. shew two of these *Animalcules* in different Positions.

Fig. VIII. is the Form they appear in when dry and contracted.

We may find in the Waters of our Ditches several Species both of Testaceous and Crustaceous *Animalcules*: two of the latter Sort, which are most remarkable, are shewn (Plate IX. Fig. I. and II.) in a swimming Posture, with their Backs towards the Eye. Their Legs are somewhat like Shrimps or Lobsters, but of a much more curious Structure. They are less than a very small Flea, but are all Breeders, and carry their Spawn either under their Tail, or in two seeming * Bags hanging from their Sides, as in Fig. II. These Bags may sometimes be observed broken, and the Spawn (consisting of Globules very large in Proportion to the Crea-

* *Arcan. Nat.* Tom. II. Epist. 121. *Philosoph. Transact.* Numb. 288.

ture) scattered about the Water. There is also a third Sort, as beautiful as the foregoing, but not near so large; its Shape more resembles a Shrimp, and it carries its Spawn as the Shrimp does. These three Species of *Animalcules* appear to have only one Eye, and that placed in the Middle of the Forehead, without so much as the least Trace of even a dividing Line. They are often to be found so transparent, that the Motion of their Bowels is seen distinctly by the *Microscope*, together with a regular Pulsation in a little Part, which therefore we may suppose to be the Heart.

I shall finish this Head with describing a very wonderful Kind of *minute Animal*, the extraordinary Form whereof (about thrice the Bigness it appeared to the naked Eye) whilst in the Water, and fastened to the Root of a Weed, is given Fig. III. This was a large one of the Sort, and had eight Horns; whereas the smaller ones have seldom more than six. It is likewise shewn here as extended to its full Length, but when contracted is not a fourth Part so long. It fixes by the Tail to the Roots or Stalks of Water-Plants. On the upper Side a very small *Animalcule* (*a*) is represented coming out of the other's Body. This was supposed at first to have fastened itself there by some Accident; but, by observing it narrowly,

rowly, it was discovered to be a young one in the Birth; for though it had but four very small Horns when first seen, after sixteen Hours its Horns and Body were grown much larger; and in four Hours more it was quite excluded its Mother's Body. Against this, on the upper Side, appeared a little round Knob, which gradually increased in Bigness, and in a few Hours became pointed at (*b*). Thirteen or fourteen Hours after, it was grown much larger, and also had two Horns. In twenty-four Hours four Horns were seen upon it, one whereof was small, the second larger, and the other two very large, extending and contracting more vigorously than their Fellows. Three Hours afterwards this *Animalcule* likewise fell off from its Mother, and shifted for itself.

The above Account is the Substance of Mr. LEEUWENHOEK's Letter to the *Royal Society, Phil. Trans.* Numb. 283.—And in Numb. 288. we meet with a farther Description of the same *Animalcule* by an *English* Gentleman, whom Mr. LEEUWENHOEK's Relation had put upon hunting after it. He says, he discovered one of them in some clear Water taken out of a Ditch, but with the utmost Attention could find no more therein. It appeared the first Day as in Fig. IV. but he tells us it varied every Moment, and the Knob (*a*), which looks like the

Gut *Cæcum*, was sometimes a little longer. Two or three Days after, he perceived some white Fibres at the Extremity of the Knob; and on the fourth Day it lay extended at full Length, and appeared as in Fig. V. and he was then convinced, that what he imagined an Excrecence, was in Reality a young *Animalcule* of the same Species, issuing from the old one, and having six Horns. Next Day he found it in the Water entirely separated, and about a third of its Parent's Length. The Horns come out like Radii, not from the Extremity, but quite round a small Knob, which probably is the Head: they have a vermicular Motion, and can extend or contract themselves either singly or altogether. The other End is flat, and by that it often fastened to the Bottom or Side of the Glass wherein he kept it. It also contracts and dilates its Body, and can bring both Body and Horns into a small Compass, as in Fig. VI. and Fig. VII. The Horns are perfectly white, the Body yellowish, and not easily discernible by the naked Eye; being, when extended, no thicker than a large Horse-Hair.

MONS. BUFFON, in a Letter to MARTIN FOLKES, Esq. late PRESIDENT of the *Royal Society*, dated at the Garden of *Versailles*, July 18, 1741, sends an Account (as a new Discovery in Natural History) of a Creature
called

called a *Polype* *, found adhering to the *Lens Palustris*; which being cut through the Middle, from the upper Half a Tail proceeds, and from the lower Half a Head: so that one Animal becomes two. If it be divided into three, the middle Part shoots forth a Head and Tail, the upper Part a Tail, and the lower Part a Head; and all three become as perfect Animals as the first. Whence he concludes, that in the boundless Variety of the Works of Providence, every Thing that can be, is.

Another Letter to the same Gentleman, dated at the *Hague*, Sept. 15, 1741, from the Honourable WILLIAM BENTINCK, Esq. says, That a young Man of *Geneva* looking for small Insects in Water, saw some little Things which he took for Plants; but examining them carefully, he perceived some Motions in them, and found them contract when touched. It was a long while, however, before he could determine whether they were Plants or Animals; for he saw several young Shoots coming out upon them, and that as far as four Generations, hanging to one another. But he has since found them

* The Name *Polypus*, or *Many Feet*, is given to several Fishes of the *Star-Fish* or *Cuttle-Fish* Kind, some whereof, besides several Claws, have two long Trunks, which they can extend to a great Distance to seize their Prey: and this *Animalcule*, I suppose, is called *Polype*, from its having somewhat of a like Form.

to eat Insects, and even raw Meat. They fasten themselves by one Extremity to some Plant, or the Side of a Glass, and have at the other End six or eight Horns, where-with they hold their Prey.

Fig. VIII. is taken from a Drawing sent with this Account.

He cut one of these Creatures to see what would become of it, and some Days after found new Arms growing out where others had been cut away. Since that, he has divided them the long Way, the broad Way, oblique, and every Way possible, all with the same Success. He has also gone on subdividing them, and has not found them propagate any other Way than by Shoots, and without Copulation.

Both these Letters seem to mean the same *Animalcule* Mr. LEEUWENHOEK describes: though with farther extraordinary Particulars, which I believe the Curious will judge it worth their while carefully to examine into*.

Upon

* Since the Publication of the above Accounts, such farther Particulars concerning this *Animalcule* have been received both from *Holland* and *France*, in Answer to the ingenious Enquiries of MARTIN FOLKES, Esq. President of the ROYAL SOCIETY, and by him communicated to the said Society, that it would appear an unpardonable Neglect should I take no Notice of them.

The Honourable WILLIAM BENTINCK, Esq. F. R. S. in a Letter from the *Hague*, dated 15th *January*, N. S. 1743, incloses some Observations and Experiments drawn up by Mr. TREMBLEY (the young Gentleman mentioned p. 97. as the first Discoverer of the Singularity of this Insect, who
now

Animalcules in Waters.

Upon the Whole, this *Animalcule* appears to be somewhat of the *Star-Fish* Kind, or between that and the *Sea-Mushroom*, or *Anemone*: which is a little *Animal* found frequently

now resides in *Holland*); and Mr. BENTINCK adds, that he can answer for the Truth of the Facts therein contained, as there is not one of them but what he has seen repeated above twenty times.

Mr. TREMBLEY gives a Drawing of the *Polype*, with eleven Horns, or Arms, and adhering to the Tail by a little Twig; but in all other respects exactly conformable to Fig. IV. and V. Plate IX. The Horns, he says, serve for Legs and Arms; and at the End whence they come out is a Mouth, or Passage into the Stomach, which, extending the whole Length, forms a Body like a Pipe or Gut, open at both Ends. He knows two Species, and has seen some stretch their Bodies to an Inch and half in Length, but that is rare; few, even of the larger Kind, being above nine or ten Lines long: and such can contract themselves to not above a single Line, stopping, if they please, at any Degree, between the utmost Contraction and the utmost Extension. Their Horns differ in Length according to the Species; one Sort can extend them seven Inches: their Number of Horns is also different; but a full-grown *Polype* has seldom less than six.

They do not swim, but crawl, either upon the Ground, on aquatic Plants, Pieces of Wood, Leaves, &c. all which are to be taken from the Bottom, Surface, Edges, or Middle of Ditches (when we hunt after these Animals) and put into a Glass of clear Water; where, after a little Rest, if there be any *Polypes*, they will be seen to extend their Arms, which they contracted upon being disturbed.

Their common Posture is, to fasten their Tails to something, and then extend the Body and Arms into the Water; and they make use of their progressive Motion to place themselves conveniently for this Purpose. Their Arms are so many Snares, stretched out to catch small Creatures in the Water: and when any Insect happens to touch an Arm, it is caught, and conveyed to the Mouth by the contracting of that Arm; or if the Creature struggles, the other Arms assist.

They are voracious Animals: a *Polype* can swallow a Worm whole twice or thrice its own Length. If the Worm come

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Endways, it is swallowed in that Manner; otherwise it goes down double, and makes several Foldings in the Stomach, which distends wonderfully for its Reception. The Worm soon dies there, and after it has been squeezed or sucked, is voided by the Mouth. They eat more or less, seldomer or oftener, as the Weather is hotter or colder, and grow in Proportion to what they eat: they can live whole Months without Food, but waste proportionably to their fasting.

He says, the Account (in the *Philosophical Transactions* before quoted, p. 95.) of the Manner how these Insects multiply, is true and exact; and the more one searches into it, the more evidently it will appear to be done by a true Vegetation. The *Polype* brings forth its Young from the exterior Parts of the Body, and that not always a single young one at once: it is common to see five or six, nay sometimes nine or ten at the same Time; and when one drops off, another comes in its Place.

For two Years, thousands of them have been under his Eye, but he could never observe any thing like Copulation amongst them. And lest it should happen in some secret Manner between the Old and Young, he has several Times cut off a young one from its Parent, and kept it in a Glass alone; notwithstanding which, it bred very plentifully. And that no Copulation might possibly be performed between the young ones themselves, he has cut them off, one by one, as they sprouted out, and has kept each of them alone, and that for seven successive Generations, but without finding any Difference as to their Increase. He has likewise seen a *Polype* bring forth young ones, and those again producing others, before the first has been separated from its Parent. They multiply more or less, in proportion to their Feeding, and the Warmness of the Weather.

But the most amazing Part of Mr. TREMBLEY's Account is, what he tells us concerning his Operations on these Creatures. If one of them be cut in two, transversely, the Fore-part, which contains the Head, Mouth, and Arms, lengthens itself, creeps, and eats, on the very same Day. The Tail-part forms a Head and Mouth at the wounded End, and shoots forth Arms, more or less speedily as the Heat is favourable. In Summer they will be shot out in twenty-four Hours, and the new Head perfected in a few Days.

Cut a *Polype* where or in what Parts you please, transversely, each Part becomes a compleat *Polype*. But being too small an Animal to admit of being divided into many Parts at once,

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once, he first cut one into four Quarters, and let them grow; then divided each Quarter, and proceeded subdividing till he obtained fifty out of one: and has still by him several Pieces of the same *Polype* thus cut above a Year ago, which have produced Numbers of young ones.

If a *Polype* be cut the long Way, through the Head, Stomach, and Body, each Part is half a Pipe, with half a Head, half a Mouth, and some of the Arms at one of its Ends. The Edges of these half Pipes gradually round themselves, and unite, beginning at the Tail-End; and the half Mouth and half Stomach of each becomes compleat. All this he has seen done in less than an Hour; and the two *Polypes* thus formed differed nothing from whole ones, but in having fewer Arms; which Defect a few Days supplied. A *Polype* has been cut lengthways between Seven and Eight in the Morning, and between Two and Three in the Afternoon each Part has devoured a Worm as long as itself.

Cutting a *Polype* lengthways, through the Head and Body, but not quite through the Tail, in a short Time there will be two perfect Heads and Bodies with but one Tail: which Heads and Bodies may, soon after, be again divided in like Manner: and thus, Mr. TREMBLEY says, he has produced a *Polype* with seven Heads and Bodies conjoined with but one Tail. These seven Heads being cut off at once, seven others grew in their stead: and each of the seven Heads so cut off, putting forth a new Body, became a compleat *Polype*.

He cut a *Polype* transversely asunder, and putting the two Parts close together, they united where they had been cut. The Creature eat the next Day, is grown since, and has multiplied. The Fore-Part of one *Polype* united in the same Manner to the Hind-Part of another. This compound Animal eat likewise the next Day, and has since produced young ones from each of the Parts that formed it. But these two Experiments do not always succeed.

It was said before, that the Body of a *Polype* is a Sort of hollow Gut or Tube: this he has found means to turn inside out, as one may turn a Stocking; and has several at present by him, whose Insides remain to be their Outsides; notwithstanding which, they eat, grow, and multiply, as if nothing had been done to them. He has repeated all these Experiments several Times with the utmost Precaution, Assiduity, and Attention; and might appeal, he says, to the Quality and Number of the Persons who have seen them made by him, as well as of those who have made the same themselves.

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He adds, that in the History of the *Polype*, which he has in Hand, all the Methods and Contrivances used by him in his Observations will be described ; but even before its Publication he is ready and willing to communicate any Information that may enable others to perform the like.

Mr. REAUMUR, Fellow of the Royal Academy of Sciences in *France*, declares (in the Preface to the sixth Volume of his *History of Insects* just published at *Paris*) that he has repeated all Mr. TRÉMBLEY'S Experiments, not only by himself, but with Mr. JUSSIEU, and several others of the said Academy, and found them succeed as they had done in *Holland*, of which he gives a general and succinct Account. When first he saw two compleat Animals forming themselves from the Parts of one *Polype* cut asunder, he knew not, he says, how to believe his Eyes ; and he cannot yet behold it without new Amazement, though he has seen it an hundred and an hundred Times. He adds, that the Curious in *France* soon began to try if other Creatures might not be found with the same extraordinary Faculty. That Mr. BONNET soon discovered a slender Water-Worm about one Inch and half long, that had the same Property ; and Mr. LYONETT found another about three Inches long, and the Thickness of the treble String of a Violin, which being cut into thirty or forty Parts afforded the same Phænomena.

Mr. REAUMUR, imagining that some Sea Productions, whose Shape somewhat resembles this *Fresh-Water Polype*, such as the *Urticæ Marinae* and *Star-Fish*, might have the like Faculties, engaged Mr. GUTTARD and Mr. JUSSIEU to make Variety of Experiments on the Coasts of *Poitou* and *Normandy*. They broke and cut *Star-Fish* into several Parts, and had the Pleasure to see the several Parts continue alive, and their Wounds cicatrize and heal : and though they could not stay long enough in the Country to see new Parts shoot forth instead of those cut away, Mr. GERRARD DE VILLARS has seen the *Urticæ*, on the Coasts near *Rochelle*, re-produce all the Parts cut off, and the *Star-Fish* putting forth new *Radii* in the Room of those they had been deprived of. When the Fishermen saw Mr. JUSSIEU tearing and cutting one of these Animals in Pieces, they told him, it was Labour in vain, he could not kill it ; Experience having taught them what Men of Learning had never so much as heard of. Mr. REAUMUR and Mr. BONNET found also some Sorts of Earth-Worms, which being cut in two, each Half had all its Deficiencies re-produced after some Months. Many, indeed, died ;

frequently on the Coast of *Normandy* *. They are seen sticking on the Declivity of Rocks, some red, some green, and some of other Colours ; where they look like Mushrooms while shut and folded up, but like Anemonies when they open and display themselves. There is no opening them by Force without destroying them ; but on Pressure they sometimes eject several young ones of different Sizes : which seems to prove them both Male and Female, and also to be

died ; but as some succeeded, the Miscarriages must be imputed to Want of Care, and not to the Want of such an Ability in these Animals.

It may, perhaps, be expected of me to add here some farther Relation of this extraordinary Creature, as it is well known by many, that for a Year and half past great Numbers of them have been continually under my Examination ; but having lately published whatever I can attest concerning it from my own Knowledge, under the Title of *An Essay towards a Natural History of the POLYPE* (wherein I describe their different Species, the Places where to seek and how to find them, their wonderful Production and Increase, the Form, Structure, and Use of their several Parts, and the Manner they catch their Prey ; with an Account of their *Diseases* and *Cures*, of their amazing *Re-production* after being cut in Pieces, of the best Methods to perform that Operation, and of the Time requisite to perfect the several Parts after being divided : and also full Directions how to feed, clean, manage, and preserve them at all Seasons of the Year : likewise a *Course of real Experiments*, performed by cutting them every Way that can be easily contrived ; shewing the daily Progress of each Part towards becoming a perfect *Polype* ; the Whole explained every where by great Numbers of Figures, and intermixt throughout with Variety of *Observations* and *Experiments*) ; I must refer my Reader to that Essay ; as an Abstract thereof would not only over-swell this Volume, but likewise prove an Injury to those who have bought the former Editions,

* Vid. *Speſtacle de la Nat.* Part II. Dial. 22.

viviparous.

viviparous. If you loosen their Hold, carry them away, and keep them in Water, they will fix themselves to the first convenient Place they find. When the *Sea-Mushroom* is about to open, it raises itself, and thrusts out two little white and striped Bodies like Bladders, round which appears a great Variety of Points or Trunks of different Sizes and Colours; whence some Naturalists have called it the *Sea-Anemone*. This Opening, not unlike the blowing of a Flower, has inclined others to look upon it as a Sort of Plant, or else as partaking both of the Animal and Vegetable Nature. But since all these little Points or Studs are not Leaves, but a Sort of Snouts or Trunks, through which this Creature sucks in its Nourishment, as the *Sea-Urchin* and *Star-Fish* do through their fine Reeds or Prickles, we cannot deny it a Place in the Rank of Animals; and especially after so remarkable a Circumstance (confirmed by ocular Testimony) as that of three or four young ones issuing from the Parent upon squeezing it.

There is a Sort of *Star-Fish*, called by RONDELETIUS, p. 121, *Stella Arborescens*, which, from a Body somewhat like the *Sea-Urchin*, sends out five Branches in Form of a Star: these five divide into ten; those ten again into twenty; the twenty into forty; the forty into eighty; the eighty into one hundred and sixty; the one hundred and
sixty

sixty into three hundred twenty; the three hundred twenty into six hundred forty; the six hundred forty into one thousand two hundred eighty; the one thousand two hundred eighty into two thousand five hundred sixty; the two thousand five hundred sixty into five thousand one hundred twenty; the five thousand one hundred twenty into ten thousand two hundred forty; the ten thousand two hundred forty into twenty thousand four hundred eighty; the twenty thousand four hundred eighty into forty thousand nine hundred sixty; and those again into eighty-one thousand nine hundred twenty.—The farther Divisions could not certainly be traced; tho' probably when the Fish was alive they might have been distinguished much beyond this Number*. All these slender Threads, thro' their whole Length, have minute Claspers issuing from them, and appear very amazing when examined by the *Microscope*.

To conclude this Chapter.—If the smallest living Creatures that have been yet discovered are produced in the Waters, in them we find also the largest and most monstrous. No Bird or Beast comes near the Size of many Kinds of Fishes, nor can the Elephant itself be brought in Comparison with the Whale.

* Vid. *Philosoph. Transact.* Numb. 57.

JOANNES FABER LYNCEUS assures us, that, in the Year 1624, he saw himself a Whale that was cast upon the Shore near *Santa Severa*, about thirty Miles from *Rome*, ninety-one Palms in Length, and fifty in Thickness: its Mouth was sixteen Palms long and ten high, and being opened and kept gaping, a Man on Horseback might therein find Room enough. Its Tongue was twenty Palms, that is, about fifteen Foot in Length. He adds, that four Years before, another Whale was thrown ashore near the Island of *Corfica*, not far from the Coast of *Italy*, which, being a Female, was found big with a Cub thirty Foot long, and fifteen hundred Pounds in Weight. He says, the *Carnea Pinguedo* [Lard or Fat] only of the Parent Whale weighed one hundred and thirty-five thousand Pounds.

Let us now reflect how amazing the Disparity between such a Fish as this, and a minute Animalcule less than the thousandth Part of a Grain of Sand in Bigness! how innumerable must the Kinds of Creatures be that form the Progressions from one Size to the other! and how equally wonderful does the Hand of Providence appear, whether it actuates an enormous Mountain of Matter, or enlivens an Atom!

C H A P. VI.

An Examination of the BLOOD in Animals.

WE cannot employ the *Microscope* to any more useful Purpose than to view the natural Course of the *Blood* within its Vessels, or examine the Contexture of it when extracted from them: for the Preservation or Restoration of the Health of Man may be greatly advantaged by such Enquiries.

By seeing it within the Vessels, we may judge of the Situation, Dimensions, Arrangement, and Ramifications of the *Arteries* and *Veins* through which it passes, together with the general State of the Fluid, the Degree of its Impulse, Progression, or Motion, and the Tendency or Direction of its Current passing through them.

When taken from the Vessels, we can examine it more minutely, and observe all the little Alterations that may happen in the Mixture, Size, Form, and Quality of the Particles composing its more solid or more fluid Parts.

I shall now shew how the *Microscope* may be employed in both these Ways; but think proper to premise a short Account of the *Blood* itself, since our Knowledge of that will the better enable us to make a right Judgment when we come to see it circulate.

C H A P.

C H A P. VII.

*Some Account of the BLOOD, as examined by
the MICROSCOPE.*

HUMAN Blood, and the Blood of Land-Animals, is found by the Microscope to consist of round red Globules floating in a transparent Water and Serum. Each red Globule is made up of six smaller and more transparent ones : and Mr. LEEUWENHOEK has discovered, that each of these again is composed of six Globules still more minute and colourless : so that every common red Globule is compounded of at least thirty-six smaller ones ; and perhaps the Division may still go on much farther *.

The specific Gravity of these Globules is somewhat more than of the Serum wherein they float, as is shewn by their subsiding in Blood extracted from the Veins and at rest : they have also a considerable Attraction to each other, and when brought in Contact, cohere so strongly (unless soon separated again by Motion) as to form a Substance resembling soft Flesh.

It is not difficult to imagine, how six soft and flexible Globules, easily compressible into any Shape, may compose one larger Globule : but to make it the better under-

* *Vid. LEEUWEN. Arc. Nat. Tom. IV. pag. 12.*

stood,

Fig. I. p. 104



Fig. II. p. 104



Fig. III. p. 119

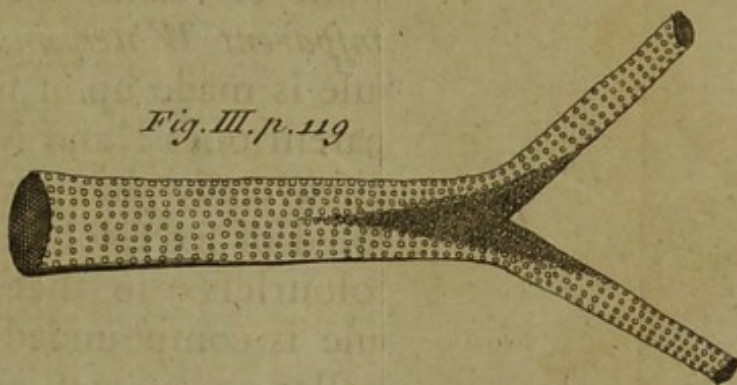


Fig. III. p. 120

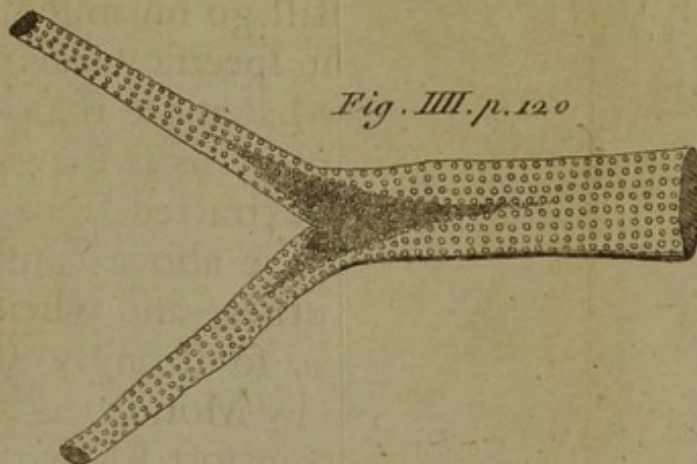
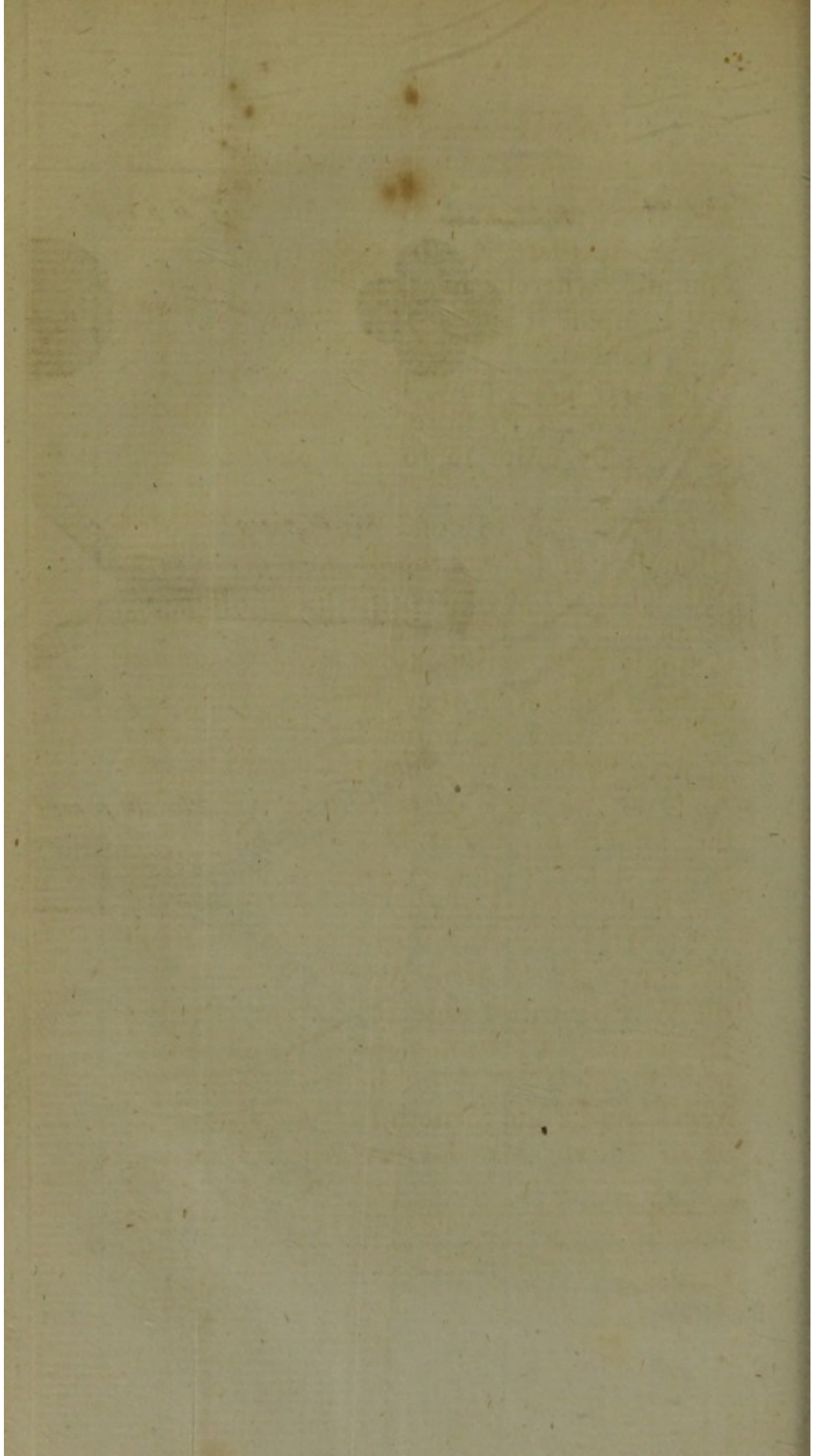


Fig. V. p. 131





stood, I shall borrow two Draughts from Mr. LEEUWENHOEK.

Fig. I. Plate X. shews one such large Globule, wherein five of the smaller Sort that compose it appear in Contact, the sixth lying behind.

Fig. II. shews how, by their mutual Attraction to, or Pressure against each other, they readily unite to form a perfect round Body.

It is also easy to conceive, that these six Globules, and even the more minute ones still whereof they are compounded, may occasionally be separated, in order to pass through such extremely minute Vessels as without Separation they cannot possibly enter; and may re-unite when they meet again in Vessels where they have more Room. And we are very certain, that sometimes they cohere in greater Numbers, and form larger Masses, than are consistent with a free and healthy Circulation.

Mr. LEEUWENHOEK and Dr. JURIN, after the most accurate Admeasurement, by the Way described page 46, agreed, that the Diameter of a common red Globule of human Blood is equal to the * one thousand nine hundred and fortieth Part of the Length of an Inch. Mr. LEEUWENHOEK before

* Vid. *Philosoph. Transact.* Numb. 106.

this had computed that * twenty-five thousand of them were but equal to a Grain of Sand.

Supposing, then, the Blood in People of sound Health to consist of Globules of such Size and Composition as before mentioned, soft, flexible, and easily separable; it must necessarily happen, that a considerable Alteration in any of these Particulars will occasion a morbid State.—Should the Globules, for Instance, be divided too minutely, and not readily again cohere; should they become rigid and unflexible, either when separated or united; or should they coagulate and become inseparable, bad Consequences must ensue.

The great BOERHAAVE says, that Health consists in an equal Motion of the Fluids, and an equal Resistance of the Solids. Now the Fluids move equally when their Force is not greater in one Part than in another; and the Resistance of the Solids is equal when they compress the Fluids every where so equally, that no Sense of Pain arises.

But when the Globules of the Blood cohere in Masses too large, and will not easily be so separated as to pass freely through the

* If the Diameter of one thousand nine hundred and forty Blood-Globules be equal to the Length of one Inch; and if, as *Geometricians* demonstrate, Spheres be to each other as the Cubes of their Diameters, it must necessarily follow, that a Sphere whose Axis is one Inch in Length must be equal to seven thousand three hundred and one millions, three hundred and eighty-four thousand such Globules.

minuteſt Veſſels, the Force of the Fluid muſt there be greater, and conſequently unequal; the Reſiſtance of the Solids muſt alſo be thereby increaſed, and rendered likewise unequal: whence ſome Diſtemper muſt ariſe. If, on the other hand, the Globules are broken, or ſeparated into ſmaller Maſſes than the natural Standard Size, they will take up more Room than they did before; and, being crowded too abundantly into the capillary Veſſels, will occaſion Diſtenſion, Uneaſineſs, and perhaps a partial Stagnation there: whilſt, in the larger Veſſels, the Current rolls along with too great Rapidity, the Force of the Fluids, and the Reſiſtance of the Veſſels, are both rendered unequal, and the Balance between the Solids and Fluids is entirely overturned. None of the Secretions in this State can duly be performed; and unleſs ſome Means be found to reſtore the Equilibrium, the Event muſt ſoon be fatal.

I believe it will be allowed, that where one Perſon dies from a Diſorder in the containing Veſſels, twenty miſcarry by ſome unnatural Alteration in the Fluids that paſs through them: and therefore, if we can find what their natural State is, the Means whereby it may be preſerved in ſuch State, by what Accidents it may be prejudiced, and how it may be reſtored, our Pains will be well employed.

In order to obtain this useful Knowledge, it will be necessary to examine the human Blood and other Juices, frequently, with the *Microscope*, in every Condition, and under every Distemper, as well as in a State of Health: by which we shall have ocular Demonstration of its different Appearances in each State, and of the Changes it undergoes; and by Experiments of various Mixtures with it, may possibly discover by what Means it can be altered from one Condition to another: as from a thin and broken to a more firm and consistent State, and so on the contrary.

Would our learned Physicians, who are best able to judge of such Matters, be induced to take this Method into their Practice, it is reasonable to believe, that in a few Years the Causes of Diseases would be better known, and the Art of Healing brought to a much greater Certainty, than it is at present. An Observation of Mr. LEEUWENHOEK is very well worth regarding: he took Notice, that when he was greatly disordered, the Globules of his Blood appeared hard and rigid, but grew softer and more pliable as his Health returned: whence he infers, that in an healthy Body it is requisite they should be soft and flexible, that they may be capable of passing through the capillary Veins and Arteries, by easily changing their round Figures into Ovals, and also of re-assuming their former Roundness when they come into Vessels where they find larger Room.

Changes are produced in Fluids surprizingly and suddenly, as a very few chemical Experiments will demonstrate: the *Bite of Venomous Creatures*, and *Inoculating* for the *Small-Pox*, shew likewise how minute a Proportion of poisonous Matter will contaminate the whole Mass of human Blood; which can no otherwise be effected but by altering the Solidity, Figure, Size, or Motion of its component Parts or Globules. And it is probable, that in many Cases it may be changed from a morbid to a healthy State, by Ways not less easy, could we be so happy as to find them out: for we cannot reasonably suppose, that the beneficent Author of Nature has given more certain and ready Means of doing Mischief than of doing Good.

Many Distempers might perhaps be cured by an immediate Admission of some Medicine into the Veins, which elude the Power of all that can be taken by the Mouth. For the Stomach, by its Heat, its Action, and a Mixture of its Juices, works such an Alteration in Things before they can be admitted into the Blood, that they are unable to produce the same Effects as if they were received into it simply and unchanged.

Some Trials that have been made already may serve in a great Measure towards confirming the above Supposition. Dr. FABRICIUS injected with a Syphon into the Median Vein of a Soldier's Right Arm, in the Hos-

pital at *Dantzick**, about two Drams of a certain purgative Medicine, which in about four Hours began to operate, and gave the Patient five Stools. His Case was Venereal, and in so terrible a Manner, that there were Nodes on the Bones of his Arm. But by this single Injection, and without any other Medicine, the Protuberances gradually disappeared, and the Disease was quite cured. He likewise injected into the Vein of a married Woman, thirty-five Years old, and troubled from her Birth with Epileptic Fits, a small Quantity of a purging Resin dissolved in an Anti-Epileptic Spirit: this occasioned a few gentle Stools; after which the Fits were less violent every Time than other, and in a short Time returned no more at all.

Dr. SMITH †, of the same City, injected Alteratives into the Veins of three Patients; one was lame with the Gout, another exceedingly Apoplectic, the third afflicted with that strange Distemper called the *Plica Polonica*; and they were all cured by the said Injections.

S. FRACASSATI injected *Aqua Fortis* into the jugular and crural Veins of a Dog, which died immediately. The Blood was found fixed in the smaller Vessels, and the larger Vessels burst. Whereupon he remarks, that as an Apoplexy is caused by a Coagulation of

* *Philosopb. Transact.* Numb. 32.

† *Ibid.* 39.

the Blood, it may probably be cured by some *Dissolvent* injected.—Another Dog, in whose Veins *Oil of Vitriol* was injected, complained a great while, foamed like Epileptics, breathed short, and died. His Blood was fixed and grumous, resembling Soot.—*Oil of Tartar* was injected into a third Dog, who, after much bemoaning, appeared swelled, and died. His Blood was not in the least curdled, but thinner and more florid than common.—This proves too great a Separation, as well as a Coagulation, mortal.

Mr. BOYLE found, that by putting a little *Aqua Fortis*, *Oil of Vitriol*, or *Spirit of Salt*, into warm Blood, it did not only lose its pure Colour and become dirty, but in a Moment was coagulated; whereas urinous Spirits abounding in volatile Salts, such as *Spirit of Sal Armoniac*, mingled with it, did not curdle it, or debase its Colour, but made it redder, kept it fluid, and preserved it a long while from Putrefaction.

As the *Microscope* has informed us of the *Structure of the Blood*, which without its Help could never have been discovered; and as its continual Assistance is needful to examine and distinguish minutely any Changes that may be wrought therein, either for the better or the worse, by Accident or by Medicine; I hope this Discourse will not be judged too long or foreign to my Subject,

since Hints of this Kind may prove highly beneficial to Mankind, if they should be so fortunate to fall into the Hands of those who are inclinable to pursue and improve upon them.

I come now to describe the Manner of bringing the *Blood* to a strict Examination before the *Microscope*, and shall offer such Ways as I have myself experienced; not doubting but the Ingenious will contrive others, as they may find Occasion.

C H A P. VIII.

Of viewing the BLOOD with the Microscope.

TAKE (with the Tip of a Feather, or a soft Hair Pencil) a small Drop of *warm Blood* immediately from the Vein: spread it, as thin as possible, on the clearest single Lens placed on a Slider on purpose, and apply it to the first or second Magnifier: the Globules will then be seen distinctly, and a little Practice will enable to form a Judgment of any Alteration that may happen in the *Size, Figure, Colour, or Appearance* of them. We may also examine the Blood extremely well, by taking up a little of it in a very small capillary Tube of the thinnest Glass, and then placing the Tube before the Magnifier.

If

If a Drop of the same Blood be diluted with warm Water, and applied in either of the above Ways, some of the larger Globules will appear more asunder, and a great many of them will be seen divided into the smaller ones which compose them.

If some of the same Blood be mixed with a little warm Milk, several red unbroken Globules will be seen distinctly; but those that are again separated into their smaller ones will be confounded with the Milk itself, of which the greatest Part is nothing else but Heaps of such like-sized minute Globules.

If we desire to try by Experiment what Alteration any Liquor, either poisonous or medicinal, can produce on the Contexture of the Blood, the Liquor should be blended with it at the very Instant of its issuing from the Vein: for if the Blood be in the least coagulated before such Mixture, no certain Conclusions can be formed. Putting the Vessel into which we receive it into a Basin of Water a little hotter than the Blood, will preserve it longer fluid, and make our Experiment by any Mixture with it succeed the better.—I would also advise, to get your Instrument in perfect Readiness, by adjusting the Magnifier before the Vein is opened; and likewise to make your Observations in a warm Place, lest the Blood become congealed before you can finish your Enquiry.

In all Enquiries of Consequence, it is best to draw the Blood from a large Vein : because what we can gain (by the Prick of a Pin or Needle) from the Finger, or any such Part, issues from some extremely minute capillary Vessels only, and perhaps is not so good a Sample of the Contexture of the whole Mass. Some Trials on both may however not be amiss, to discover what Difference there is between them.

By mingling with the Blood the least imaginable Quantity of the *poisonous Juice* which issues from the Teeth of a *Viper* when enraged, or from any other *Animal, Vegetable, or Mineral*, we shall discover its immediate Effect upon the Globules ; and by considering that the Alteration we observe is wrought in it tho' at Rest, we shall be able to judge and calculate what Consequences must ensue from such a Mixture with the Blood, as it circulates through the Veins of a living Creature.

Mr. WILLIAM COWPER, examining a Solution of *Opium* with the *Microscope*, found its dissolved Particles in the Shape of fringed Globules : whence he concludes, that such Particles circulating in the Mass of Blood, may be so entangled in its Serum, or thicken it in such a Manner, as to retard its Velocity when over-violent, and render its Motion calm and equal ; whereby all painful Sensations

tions will be taken off. And from the same Principles it is easy to account for all its other Effects, and perceive how too great a Number of such fringed Globules must cause a total Stagnation of the Blood, and consequently kill. Vid. *Philos. Trans.* Numb. 222.

Spirits, Oils, dissolved Salts, Tinctures, Essences, and all other chemical Preparations, furnish us with numberless Subjects of Experiment; and are certainly capable of producing the most sudden and amazing Effects either good or bad, if injected into the Blood-Vessels of living Animals: the Causes of which Effects may in a great Degree be discovered and accounted for, by microscopical Observations on Mixtures of them with the Blood when extracted from the Veins.

A little Blood being mixed with about four Times its Quantity of * *Sal Volatile Oleosum*, and viewed through a *Microscope*, there appeared an immediate Separation of the Globules. In about the eighth Part of a Minute some of them were much diminished, and in a Quarter of a Minute many of them were much dissolved, and entirely disappeared. Sometimes twenty Globules were seen near together, which soon lessened to eighteen, then to sixteen, and became fewer and fewer, till only two or three were left. Whence it is probable that *Sal Vo-*

* *Arcan. Nat.* Tom. IV. p. 36.

latile Oleosum taken with the Food, and so carried into the Lacteals and Blood-Vessels, may retain its Power of preventing such Coagulations as would otherwise happen.

The *Urine, Saliva, Semen, Sweat, Fæces Alvi*, and all other *Animal Juices*, are likewise Objects for the Microscope, to be examined either alone, or mixed with the aforesaid Liquors : whence much useful Knowledge may be acquired.

As to Colour in the Blood, a Blackness arises in it from a Deficiency of Serum, as Paleness does from too great an Abundance of it : for it will be always found, that when Globules cohere together in too great Numbers they give a black Appearance. When this therefore is the Case, Means of diluting should be found out and made use of ; since it is absolutely requisite to Health, that the Globules of the Blood should float in a due Quantity of Serum, and be thereby circulated freely through the minutest Vessels ; a contrary State to which has proved the Death of thousands. — Mr. LEEUWENHOEK tells us, that whenever he found his Blood too deep coloured, his Way was to drink four Dishes of *Coffee* in a Morning, in the room of his usual two ; and six Dishes of *Tea* in the Afternoon, instead of three. He drank it as hot as possible, and went on in this Manner till he perceived his Blood grow paler, and consequently its Globules farther separated.

C H A P. IX.

The CIRCULATION of the BLOOD.

IN order to view *the Blood circulating through its Vessels*, we must make use of such *small Creatures* as by their Transparency permit us to look within them, and see what passes there: for, in a Man, or any of the large Animals, the Skin is so opaque that we cannot discern even the fine Blood-Vessels themselves, and much less the Current that runs along them. Our Information, however, will not be greatly different; for the whole Animal Creation is established on one and the same Plan, and the Circulations in the meanest living Creature are carried on through Vessels of a like Structure (in the general), and are accelerated or retarded by the same Causes, as in the noblest.

And, in Truth, as to the Circulations of the Fluids, and the Motions of the Bowels, the Brain, or any of the internal Parts, more Knowledge may be gained by inspecting *Insects* and *small Animals* with the *Microscope*, than by the most skilful and curious Dissections, or anatomical Experiments on larger Subjects. For the Skins of some of these little Creatures are so transparent, that we may see plainly through them the Order and Disposition of the Vessels underneath;
and

and the Coats of these Vessels are, again, of such an amazing Thinness and Delicacy of Contexture, that they are little or no Impediment to our View of the secret, tho' regular, Operations of Nature, and the Laws she acts by when undisturbed and quiet; whereas our Dissections of larger Animals, while alive, may shew her at work, indeed, but in such Confusion, by our breaking in upon her violently, that all her Motions then must be in great Disorder, and consequently incapable of affording any satisfactory Information as to the Circulations.

In this Sort of Creatures too, after viewing as long as we think fit the natural and regular Current of the Blood, as it is carried on in a State of Health; we may, by Pressure, and several other Ways, impede, disturb, and divert its Course; and may find Means, by various Mixtures with it, of inducing a morbid State; and at last, by letting the Creature die before our Glass, we may perceive all the Changes it undergoes, and what occasions the intermitting, vibrating, trembling Pulse of expiring People.

In several of these little Creatures we can not only see the general Course of the Blood, but are able perfectly to distinguish the Figure and Circumstances of the Globules whereof it is compounded, and the Alterations they suffer when they pass out of the larger into the more minute Vessels. For
many

many of the Vessels are so small, that even single Globules cannot possibly find a Passage thro' them without being compressed into oval Shapes : and yet these Vessels are large in Comparison of the finest Vessels of all, to pass through which, the Globules must be divided and subdivided into their smallest and most minute component Globules.

It is amazing to observe how careful Providence has been to prevent the Blood from coagulating, or cohering in Masses dangerous to Life, by the very Disposition of the Vessels it runs through : which, whether separating or uniting, are so contrived as to cause the Globules to come frequently together with a brisk Collision, or striking against each other. The *Arteries*, for Example, which convey the Blood from the Heart to the Extremities of the Animal, and in their Progress continually lessen their Diameters, and divide into smaller Branches almost *ad infinitum* ; in these *Arteries*, I say, at every such Division, many of the Globules of the Blood must rush, with a considerable Force, against an Angle directly in their Way ; whence recoiling back on those immediately behind, they must strike upon one another, and cause a Kind of Commotion, ere the Current can divide readily into the two smaller Branches. See Fig. III. Plate X.—In the *Veins*, which,
on

on the contrary, return back the Blood from the Extremities to the Heart, whose Diameters enlarge as the Tide rolls along, and whose small Branches are continually uniting and making larger Vessels, till at last all their Streams fall into one ; here, at every Conjunction of two Branches, their Currents rush against each other with Violence : by which Concussion unnatural Cohesions are broken or prevented ; and of this the *Microscope* can afford us ocular Demonstration. *Vide Fig. IV.*

C H A P. X.

Of viewing the CURRENT and the CIRCULATION of the BLOOD.

BY the *Current of the Blood*, I mean its *streaming* or *passing on* either *from* or *towards* the *Heart*, through any *Vessel*, whether it be a *Vein* or *Artery*.

By the *Circulation* I would be understood to intend, the *Course* or *Current* of it, *from* the *Heart*, along the *Arteries*, to the *Extremities* of the *Body* : together with its *Return* by the *Veins* from the *Extremities* back again *towards* the *Heart*.

Both these the *Microscope* can bring to View ; but the latter is somewhat more difficult

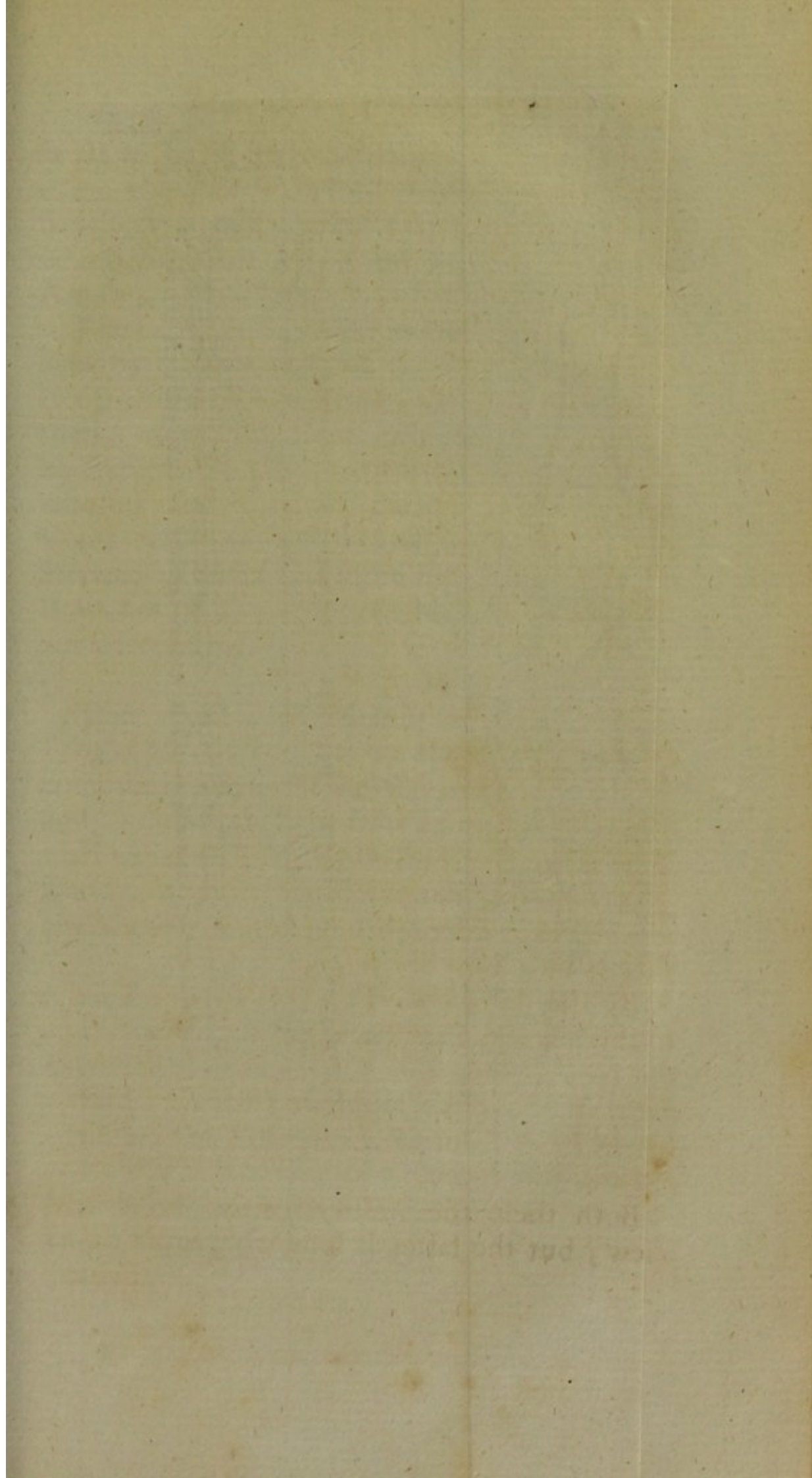


Fig. II. p. 124.

Fig. I. p. 121.

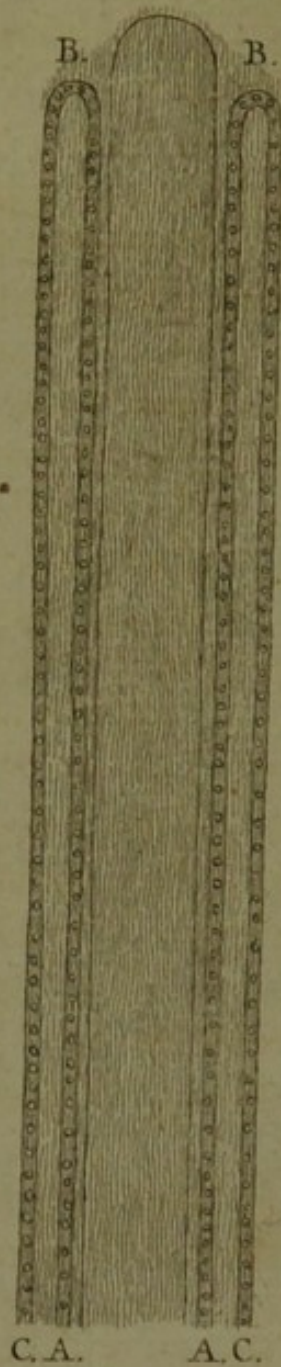
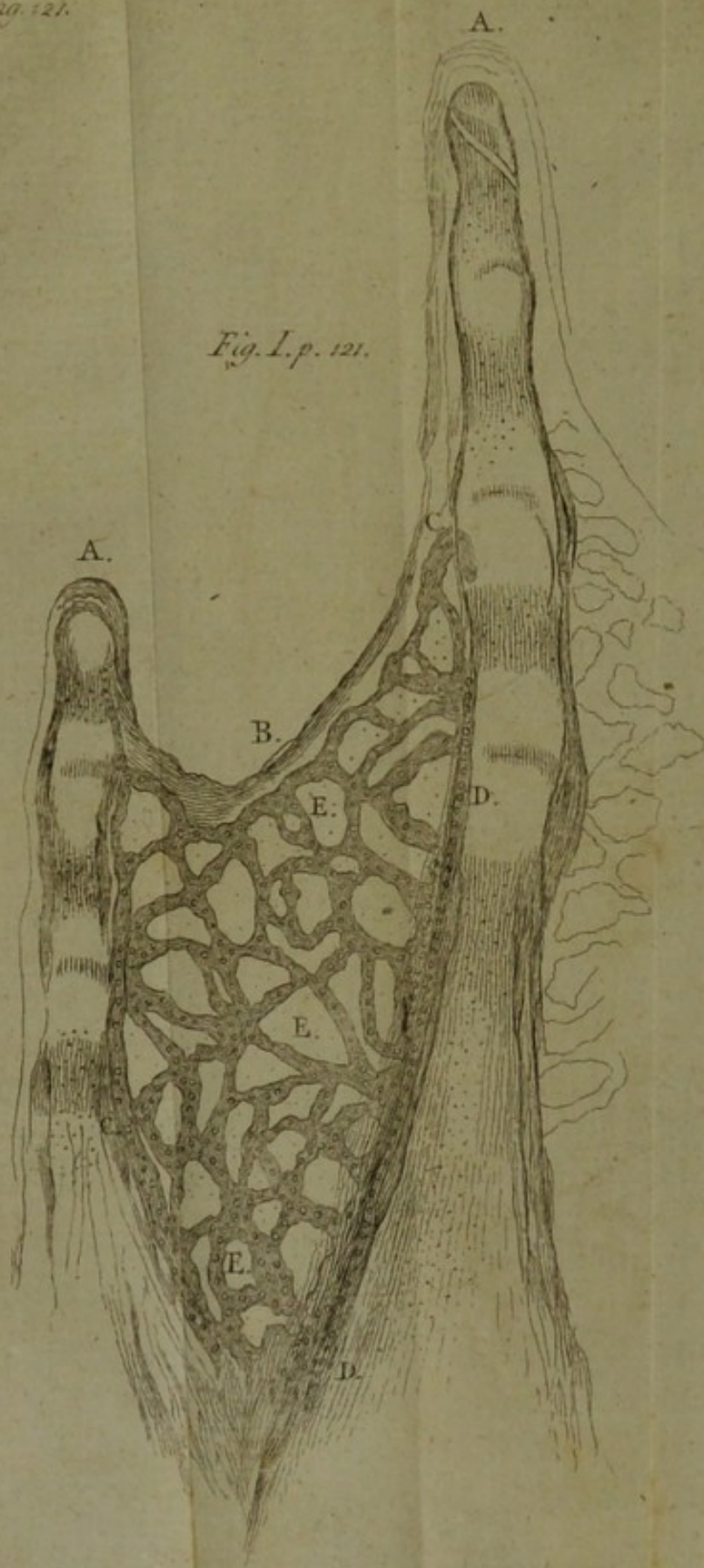
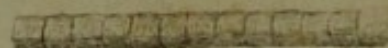


Fig. III. p. 143.



ficult to be assured of than the former ; for when the Vessels before us are extremely small, it is not always easy to distinguish which of them are Veins and which are Arteries.

The larger Arteries are indeed distinguishable by a Protrusion of the Blood at each Contraction of the Heart, then a Stop, and then a new Protrusion, which may plainly be seen continually succeeding one another : whereas the Current passes through the Veins with an equal and unintermitting Stream. But in the more fine and extreme Branches of the Arteries this Difference is not perceivable.

The transparent Membrane between a Frog's hind-foot Toes is the Object most commonly employed for viewing the Current and Circulation of the Blood ; and in this, if well expanded, it may be seen fairly and distinctly, both in the Veins and Arteries, in the Manner represented Plate XI. Fig. I.

A. A. two Toes of a Frog's hinder Foot.

B. the thin Membrane between the Toes extended.

C. C. C. the Trunks of the Arteries.

D. D. the Trunk of a Vein.

E. E. E. Arteries and Veins in the fine Membrane, with the Blood-Globules circulating through them.

The

The Way of applying it to the Microscope was described Page 13, and therefore needs not be repeated here.

The Tails or Fins of small Fishes may likewise be used very commodiously to this Purpose, and present to view great Numbers of Veins and Arteries with the Blood passing different Ways through them.

It is difficult here in *London* to meet with any Fishes alive and proper for this Inspection, except *Eels* and *Flounders*: either of these however will serve exceeding well; but the smaller they are the better.—Put your *Eel* into a Glass Tube filled with Water, after wiping off its Slime, which would obscure your Glass. Then having stopped both Ends, to prevent the Water's running out, apply the Tail or Fin to your Microscope, and you will see the Circulation in a very agreeable Manner. If you put not Water in your Tube, the Sliminess of the Eel will immediately foul the Glass and prevent your Pleasure.

The flat Figure of the *Flounder* will not permit us to put it into a Tube as we do the *Eel*, or view it by every Kind of Microscope: but if a plain Piece of thin Glass be placed over the Hole where Objects are applied to the Double Reflecting Microscope, its Tail may be spread advantageously upon the said Glass: and by setting a Book, or
some-

something else of a proper Height to support the Body of the Fish, it will lie in a very good Position for View, and the Circulation may be seen distinctly.

Eels and *Flounders* live a long While out of Water, and are therefore most useful for this Service here at *London*; but in the Country many Sorts of other small Fishes may be found much more transparent.

Mr. LEEUWENHOEK informs us *, that he saw, with great Admiration, in the utmost Extremities of a very minute Fish's Tail, how the larger Arteries were there divided into the most fine or evanescent ones; and that many of the smallest Veins, returning from the said Extremities, met together at last in some larger Vein. There appeared also in some Vessels such an Agitation of that Blood (which was protruded from the larger Arteries towards the evanescent ones at the very Extremity of the Tail, and returned afterwards through many minute Veins into a large one) as hardly can be conceived. In the larger Arteries he could perceive a continual new Protrusion, or Acceleration of the Blood's Course received from the Heart; but in the smaller Arteries the Motion seemed equable without any

* *Arcan. Nat.* Tom. IV. Epist. 65.

such repeated Propulsion: and though in the minutest Vessels there appeared no Colour, yet in the larger Vein or Artery, though near the End of the Tail, the Blood was plainly red.

We cannot properly call any Vessel an Artery farther than the Pulsation reaches; beyond that, and returning towards the Heart, it must be accounted a Vein: for Veins are only Arteries elongated; but as they frequently divide into Branches that evade Discovery, it is, perhaps, impossible to determine exactly where the Arteries end, and where the Veins begin.

They do not always, however, branch out so extremely fine before their Inosculation or Communication with the Veins; for the same curious Observer tells us, that on each Side the little Gristles, which gave a Stiffness to the Tail of the Fish abovementioned, he could see a very open Communication of the Veins and Arteries; the Blood running towards the Extremities through Arteries, and returning back again through Veins that were evidently a Continuation of those Arteries, and of the same Diameter with them: And this he saw in thirty-four different Places, in as many Arteries, and as many Veins. The Manner whereof, as by him delineated, is shewn, Tab. XI. Fig. II.

A. A.

A. A. represents two Arteries, one of which runs on each Side of a minute Gristle.

B. B. their open Communication with two Veins, C C.

As this whole Fish was not half an Inch in Length, how small must the Tail thereof be, in which, notwithstanding, the Circulation of the Blood was visible in thirty-four Places, and the Current of it in sixty-eight Vessels! and yet these Vessels were very far from being the most minute of all. How inconceivable then must be the Number of its Circulations in an human Body! Nor need we wonder to behold it issuing forth at every Prick of a Pin or Needle. Upon considering this, Mr. LEEUWENHOEK adds, that he is fully persuaded, a thousand different Circulations of the Blood are continually carried round in every Part of a Man's Body that is not larger than the Breadth of his Fore-finger Nail *.

The Tail of a *Newt*, or *Water-Lizard*, applied in a Glass Tube, after the Manner directed for the Eel, affords an entertaining Prospect of the Circulation through Numbers of small Vessels. But nothing can shew it finer than an exceeding small *Newt* † of

* LEEUWEN. *Arcan. Nat.* Tom. pag. 169.

† *Phil. Trans.* Numb. 288.

this Water-Kind, which sometimes may be found less than an Inch long, and so transparent, that the Blood may be seen running in all Directions, not only through the Vessels of the Tail, but throughout the whole Body: And it is particularly delightful, to behold, in the little Toes, the Stream thereof running to the Extremity in one Channel, and returning back again by another. Just below the Head are on either Side three Fins, or somewhat like Fins, which, in swimming, the Creature makes use of to poise and guide its Body: each of these appears by the Microscope divided, like *Polypody*, into many pointed Branches: in any one whereof, as in the Toes, the Blood is seen coming along an Artery to the Extremity, and then immediately returning towards the Heart again through a Vein that lies parallel, and almost close thereto, and with which its Communication is very apparent.—As thirty or forty of these Branchings present themselves before the Eye sometimes at once, with the Blood distinctly circulating in all, they afford a charming Sight: and they may be viewed by the third or fourth Magnifier; for the Globules of the Blood in *Newts* are larger than in any other Creature I have examined, and are fewer in Proportion to the Serum or Water they float along in. To which I may also add, that the Figure of them, as they are
carried

carried along the Vessels, changes in a most surprizing Manner.

In Spring-time, if a little *Frog's Spawn* be kept some Days in a small Quantity of the Ditch-Water wherein you found it, you will be furnished with a Number of exceedingly small *Tadpoles*, which, when first they begin to swim, are almost wholly transparent; and if placed before the Microscope, in a Tube proportionably small, with some Water in it, you will easily discern the Heart and its Pulsation, together with the Blood circulating in every Part of the Body; and, particularly, in the Tail more than fifty Vessels present themselves at one View.

These *Tadpoles* become less clear every Hour, and in a Day or two their Skin grows so opake that the Circulation of the Blood can be seen no longer, unless it be in the Tail, or better still in the Fins, at the joining-on of the Head.

A small *Muscle* taken carefully from its Shell, and placed before the Microscope on an Isinglass, affords a View of many Arteries and Veins, through which the Circulation of the Blood may be very clearly seen: and one great Advantage in this Object is, that it lies always quiet; whereas most other Creatures are difficult to be kept still long enough for Observation. The Motion of the

Blood continues in it six or seven Hours with little Alteration: and, by moistening it now and then with salt Water, may probably be continued much longer.

I can also assure you, from my own repeated Experiments, that if a large *Muscle* be carefully opened, and a Piece of the thin transparent Membrane easy to be found therein be snipped off with a Pair of sharp Scissars, and applied to the Microscope, the Blood will be seen passing through Numbers of Veins and Arteries; and if the Extremity of the Membrane be viewed, the true Circulation, or the Return of the Blood from the Arteries through the Veins, will be shewn in a delightful and satisfactory Manner, and continue for a long Time. There are likewise other transparent Parts of the *Muscle*, where the Passage of the Blood is very discernible: and as *Muscles* are to be got most Times of the Year in *London*, the Knowledge hereof, will, I hope, oblige the curious.

We are told by Mr. LEEUWENHOEK, that in the farthest Joints of the hinder Legs of little *Crabs**; he beheld the Blood circulate through the Arteries and Veins with greater Rapidity than he had ever observed it in any other Creature; and, moreover, that the red Globules thereof were twenty-five

* LEEUW. *Arc. Nat.* Tom. IV, Ep. 84. Again, Ep. 86.

Times fewer in Proportion to its Serum than in any other Land or Water-Animal he had ever before examined.

At the proper Time of Year, exceeding small *Crabs* may be found in great Abundance, under Stones and Brick-bats, on the Shore of the River *Thames*, when the Tide is out : and as many of them are no larger than a little *Spider*, it is highly probable such may be transparent in many Places of the Limbs and Body ; notwithstanding Mr. LEEUWENHOEK found his, which were an Inch broad, opaque every where but in the extremest Joints of the hinder Legs. Perhaps too they may appear more transparent if they are applied to the *Microscope* in a little Tube filled with Water, than if they are viewed dry : for it is observable, that many Objects acquire a Transparency by being wetted, in the same Manner as Paper becomes clear by being rubbed with Oil.

The Blood may be seen circulating in the Legs and Tails of *Shrimps*, especially if viewed in Water ; but then the Water must have a little Salt put thereto, or else they will soon expire. In *Shrimps* the Blood is not red ; which has given Occasion to call them, as well as many other Insects, *exanguis*, or *bloodless* : tho' in reality no living Creature is without Blood ; for animal Life consists in a Circulation of some Fluid through

Arteries and Veins ; and that Fluid, whatever Colour it may be of, is properly to be accounted Blood. In *Grasshoppers* the Globules (which may be seen passing through the Vessels in their Wings) are green ; and yet I am apt to think, Nobody that views them will hesitate to call them, with the Serum wherein they swim, Blood.

In the transparent Legs and Feet of several small *Spiders*, the Current of the Blood may plainly be distinguished both in the Veins and Arteries ; also in the Legs of very small *Punices* or *Bugs* it is remarkably visible, together with an extraordinary Vibration of the Vessels, which I never have observed in any other Creature. In these too, if clear, as they may sometimes be found, the wonderful Motions of all the internal Parts will afford an agreeable Entertainment to the curious, and may be examined as long and as often as they please. For I have kept a *Bug* alive, in a Slider between two Pieces of Icinglass, at least six Weeks together, notwithstanding it was confined so close as to be incapable of stirring : and altho' during that Time it often seemed dead and motionless, when I placed it before the Microscope, a little Warmth would set the Bowels at Work again, and renew the Current of the Blood as briskly as ever.

After

After many Observations made by Mr. LEEUWENHOEK on the Blood of *Cocks, Sparrows, Frogs, Trouts, Perch, Cod, Salmon, &c.* he affirms, that the red Particles in the Blood of *Birds, Fishes, and Water-Animals*, are constantly * flat and of an oval Figure; that is, they are longer than their Breadth, and appear as in Plate X. Fig. V. The serous Part of the Blood in *Fishes* and *Aquatic Animals* is also greatly more, in Proportion to the red Particles, than it is in *Beasts* or *Men*, and the Particles themselves are larger: so that, by being bigger, and swimming farther asunder, they may be seen much better.

Mr. LEEUWENHOEK observed the Blood circulating in the filmy Wings of a *Bat* †, and likewise in its Ears, and found the Globules thereof perfectly round: wherefore, allowing his Assertion, that in *Fishes* and *Birds* they are always flat and oval, we need no longer hesitate how to class this odd Creature; but, notwithstanding its flying, shall pronounce it to be a *Beast*.

He tells us, that *Bats* can see as well by Day as Night: but he supposes the Heat and Dryness of the Day-Air would shrivel up the thin Membranes of their Wings, and consequently stop the Circulations there;

* *Arc. Nat.* Tom. I. Part II. p. 51. Again, Tom. II. Epist. 128. Again, Tom. IV. Epist. 65.

† *Arc. Nat.* Tom. IV. Epist. 67.

whereas

whereas the cool Dews of the Evening render them moist and pliable; which makes them chuse that Time to come abroad.

In viewing several of the Objects here mentioned, one shall often observe the Blood passing through Vessels so minute, that the Globules of it cannot glide along otherwise than single, and squeezed into oblong Forms: yet an hundred of the red Globules of such Blood, if placed close to one another in a Row, would not equal the Length of the Diameter of a large Grain of Sand; and consequently a Million of them exceeds not a Grain of Sand in Bigness*.

The Effects of Heat and Cold upon the Blood are well worth taking Notice of: for as Heat relaxes the Vessels, the Blood finds more Room to move in, its Globules float at greater Distances, and it circulates more freely; whereas Cold so contracts the Vessels, that the Globules are compressed together, and the Blood is impeded, and in some Degree coagulated in the minute Capillary Veins and Arteries of the extreme Parts; as is evident from the Swelling and Blackness of the Hands and Feet when exposed to severe Cold.

* LEEUWEN. *Arc. Nat.* Tom. I. Part I. p. 35.

Before I close this Chapter, I shall briefly communicate some Experiments I had the Pleasure of making last Summer, with my most ingenious and valuable Friend Doctor ALEXANDER STUART, Physician to her late Majesty, in order to view the Circulation of the Blood by the *Solar* or *Camera Obscura Microscope*, which has the Advantage of magnifying Objects beyond any other Sort of Microscope; but must refer the Curious to a more full Account thereof laid by this Gentleman before the *Royal Society*, and which will be published in the *Philosophical Transactions*.

I must first describe a particular Apparatus, invented by the *Doctor* for examining the Circulation of the Blood in *Frogs, Mice, Bats*, or any Creatures of the like Size. In this Contrivance the Looking-glass, Tube, and convex Lens are just the same, and placed in the Hole of a Window-shutter in the same Manner, as described Page 22. But here, instead of using WILSON's little *Pocket Microscope*, he has got the Belly-part of a large Reflecting one fixed horizontally on a Pedestal, at a Height exactly equal to the Tube. This stands on a little Shelf made to support it; and to the Snout thereof, which lies on a Level with the Tube, the Magnifiers are screwed. The Object, being extended and fastened with Strings and Pins on a Frame convenient for the Purpose, is applied

applied between the Tube and the Magnifier; whereby the Sun's Rays reflected from the Looking-glass, through the Tube, upon the Object, pass on through the Magnifier, and exhibit upon the Screen an Image of the Object most prodigiously enlarged. This, I hope, may give some Idea of our Instrument: and now I come to the Application.

Our Object was a *Frog*, whose Limbs being extended and fastened on the Frame, we opened the Skin of the Belly from near the Anus to the Throat; then giving it a little Snip sideways both at the Top and Bottom, by sticking a *Fish-Hook* in each Corner of the Skin, it was easily stretched out before the *Microscope*, and presented on the Screen a most beautiful Picture of the Veins and Arteries in the Skin, with the Blood circulating through them. In the Arteries we could plainly perceive the Blood stopping, and as it were receding a little, at each Dilation of the Heart, and then immediately rushing forwards again at each Contraction; whilst in the Veins it rolled on in a continual Current with inexpressible Rapidity*.

After considering this as long as we thought needful, we opened the *Abdomen*,

* When the Arteries were magnified very much, by removing the Screen to a considerable Distance, the alternate Expansion and Contraction of their Sides were very visible and remarkable.

and extending the Muscles before the *Microscope*, by the same Means as we had done the Skin, we had the Pleasure of viewing their Structure, which we found to consist of Bundles of transparent Strings or Fibres, lying parallel to one another, and joined together by a common Membrane. These Strings or Fibres appeared through their whole Length made up of minute roundish Vesicles, or, in other Words, seemed like Rushes divided the long Way. We could not be certain of any Circulation through the Muscles, though sometimes we imagined we saw a very slow Motion of some transparent Fluid: but the Object growing dry and rigid, obliged us to leave that Enquiry to a farther examination.

We then proceeded to our last Experiment, which was to draw out gently a Part of the *Frog's Gut*, in order to apply the *Mesentery* to the *Microscope*: and herein we succeeded so happily, that I believe the Circulation of the Blood was never before seen in so distinct and fine a Manner. No Words can describe the wonderful Scene that was presented before our Eyes! We beheld the Blood passing through numberless Vessels at one and the same Instant, in some one Way, in others the quite contrary. Several of the Vessels were magnified to above an Inch in Diameter, and the Globules of the Blood rolling through them seemed near as large as
Pepper-

Pepper-Corns ; whilst in many of the minute Vessels only single Globules were able to find a Passage, and that too not without changing their Figure into that of oblong Spheroids. We saw here, likewise, much better than we had done before, the Pulsation and Acceleration of the Blood in the Arteries, in the Manner before described, and could clearly distinguish two or three Vessels lying over one another, with Currents running different Ways. In short, it appeared like a beautiful Landscape, where Rivers, Streams, and Rills of Running Water are every where dispersed.

During this Examination, we took notice of a Vessel extremely minute, issuing from the Side of a larger, and turning backwards from it in a curve Line. We perceived, at unequal Intervals, sometimes one, sometimes two, and sometimes three colourless Globules dropt or squeezed out of the larger Vessels into this minute one, and gliding through it singly and very slowly ; which made the Doctor imagine it might be a *secretory Duct*. We observed, likewise, that as the Animal grew languid and near expiring, the Blood in the Arteries would stop on a sudden, seem as it were coagulating, and then run backwards for some Time ; after which it would again recover its natural Course with a great deal of Rapidity. —A due Consideration of these Appearances might

might possibly account for the Intermissions, Starts, and Irregularities in the Pulse of Persons near the Point of Death.

C H A P. XI.

The Pulsation of the HEART.

THIS wonderful Phenomenon may be seen distinctly in several small Insects, some whereof I shall here mention, with short Directions how to find it.

Divide a *Bee* *, particularly an *Humble-Bee*, near the Neck; and its *Heart*, which is a white pulsing Particle, may be seen beating briskly.

The Head of the *Horse-Fly* † being cut off, just at the setting-on of the Neck, a little Particle (which is the *Heart*) will appear with a Pulsation in it for half an Hour.

The *Grasshopper* ‡ has a green Film or Plate over its Neck and Shoulders, which being raised with a Pin, its *Heart* may be seen beating very orderly for a long While together.

Cut off the Head of that little flying Beetle, known to every Child by the Name of *Lady-Bird* ||, or *Cow-Lady*: erect it per-

* Dr. POWER's *Microscop. Observat.* p. 4. † Ibid. p. 7.
‡ Ibid. p. 24. || Ibid. p. 30.

pendicularly,

pendicularly, and you will see two small black Eyes, each set between three white Plates like polished Ivory, on one Side two small ones, and a large one on the other. Pull off both the crustaceous and filmy Wings which cover a tender black Skin, and removing that Skin, the Pulsation of the *Heart* may be seen beating vigorously for twelve or fourteen Hours.

The *Heart* of a *Snail* * is to be found exactly against the round Hole near its Neck, of a white Colour, and may be seen beating a Quarter of an Hour after Dissection †.

It may also be seen in a *Louse*, as I shall shew when I come to describe that Creature; and I make no doubt the curious and diligent Enquirer will be able to discover it in Multitudes of other little Animals.

The *peristaltic Motion* of the Stomach and Bowels may be seen very distinctly in *Lice*, *Gnats*, *Flies*, &c. and a Multitude of other Insects.

* POWER'S *Microscop. Observat.* p. 36.

† SWAMMERD. *Hist. Generale des Insectes*, p. 77.

C H A P. XII.

Of the muscular or fleshy Fibres of Animals.

THE *fleshy Fibres* of the *Muscles* (according to the Observations of *Monsieur Muys*) are composed of other smaller Fibres or Fibrils, the Size of a slender Hair; five or six hundred of which Fibrils go to the making up of one *fleshy Fibre*, whose Diameter is no more than the twenty-fourth Part of an Inch. Each of these Fibrils is again composed of more than three hundred small transparent *Tubuli*, so extremely slender, that were one of those Blood-Globules (which Mr. LEEUWENHOEK supposes but the millionth Part of a Grain of Sand) divided into twenty-four Parts, even these minute Parts could hardly enter and pass through such exceedingly small Tubes. And yet, that they do enter and pass through them, is evident by the Redness of the Flesh of Animals. We must therefore infer, that the *Tubuli* forming a Fibril are really hollow; that the Extremities of the Arteries open into them, and empty there a Part of their Liquor, which is carried back again by the Veins to the Heart; and that the Globules of the Blood are, for this Purpose, divided into Parts inconceivably small*.

* Vid. *Philosoph. Transact.* Numb. 339.

Mr. LEEUWENHOEK says, each *Muscular Fibre* is composed of many smaller Filaments or Fibrils; which, however minute, he could plainly distinguish to be vascular: for, if he cut across their Length, the Light appeared through the Mouths of the Vessels; but if he cut them ever so little obliquely, no Light was to be seen *. He found also, that each Fibril is invested with a † minute Membrane, which is only a Congeries of Blood-Vessels, conveying Juices and Nourishment thereto, though their Fineness renders them invisible. It is not, however, to be imagined, that each Fibril has its peculiar Membrane: but that all the Membranes together are like a Net finely spread, with a Fibril issuing through each of its Meshes.

This Structure of the Fibres he observed in the Flesh of an Ox and of a Whale; but more plainly in that of a Whale, the Beef-Fibres lying more compact and close. He also found that the Fibres of a Mouse were of the same Thickness as those of an Ox, though thirty thousand Mice are not equal to one Ox in Bigness: whence he concludes, that the different Size of Animals is entirely owing to the greater or less Number and Length of the Fibres ‡.

* *Philosoph. Transf.* Numb. 367.

† GORTER, *Medic. Compend.* p. 58, 59. LEEUW. *Arc. Nat.* Tom. III, p. 58.

‡ *Ibid.* p. 61.

These *fleshy Fibres* appear, through their whole Length, encompassed with circular Wrinkles. If a Thread were twisted about a fine Needle in a Screw-like Form, with spiral Circumvolutions, so that each Thread be distant from another the Diameter of the Needle, it would naturally represent the Manner of these circular Twistings. And this Disposition is wonderfully contrived for the ready *Distension* or *Contraction* of the Fibres: for as a Cord will be distended or contracted *quicker* or *slower* in Proportion to its Length, the same must also be the Case in *Animal Fibres*; and, therefore, on these Principles we may calculate how much more nimbly the Leg of a Mouse can move than the Leg of an Ox.

The Method of viewing the *Muscular Fibres* is, to cut carefully, and with a very sharp Razor or Penknife, a Slice of dried Flesh or Fish, as thin as possible. Lay it on a Piece of Glass, and moisten it with warm Water; which drying soon away, will leave the Vessels open and distinguishable. —It is observable, that the Fibres of Fish are larger than those of Flesh.

That the *Muscular Fibres* are vascular, or made up of little hollow Vessels, is supposed by MALPIGHIVS, BORELLI, GORTER, our own Countryman Mr. HOOKE, who says,
L 2 they

they appeared to him like Strings of Pearls ; and, very lately, by Dr. ALEX. STUART, in his learned and ingenious Treatise *de Motu Musculorum* ; where, from such a Structure, and by the Influx of the nervous Fluid, he accounts, very reasonably, for the elastic Force, the Contraction, the Distension, and all the Actions of the Muscles *. But as these Gentlemen differ somewhat in the Figure of the little Vesicles supposed to make up the muscular Fibres, the Curious will do well to examine, with the *Microscope*, into this Matter, as carefully as possible ; and that by contriving all the Ways they can think of to view the Fibres in living Animals. For, whatever Form the Vessels may have when replete with a nervous or other Fluid, I am afraid, when the Fibres have been dried, or the Vessels collapse together by not being supplied with such Fluid, the true Form and Structure of them can never be fully known.

Our Observations, it is probable, may be made with most Success on *Insects* ; their fleshy Fibres, as Mr. LEEUWENHOEK tells us, being no less visible than those of larger Creatures : which he found by cutting off and examining the fleshy Parts of the Legs of *Flies*, *Gnats*, *Ants* †, &c. in all which he

* *Vid. GORTER de Fabrica & Motu Muscular. STUART de Motu Musc. p. 49.*

† *Arc. Nat. Tom. III. p. 108.*

could plainly distinguish the circular Wrinkles or Circumvolutions encompassing the Fibres, as they are pictured Plate XI. Fig. III.

C H A P. XIII.

Of BONES.

UPON examining of *Bones* with a *Microscope*, their superficial Part is found to consist of a great many small Vessels, and some few of a larger Size: which last, when they come to the Surface of the Bone, appear invested with either a Membrane or bony Substance perfectly transparent. The Inside of the Bone has a spongy or cellular Substance, consisting of long Particles closely united, which are composed of numberless small Vessels, some running lengthways, and others taking their Course towards the Sides of the bony Particles, which, notwithstanding their great Number of Apertures, are extremely hard, and lie some parallel, and others perpendicular, to the Length of the Bone.

Mr. LEEUWENHOEK discovered, once, in a small Bit of a Shin-Bone, four or five Vessels, with Apertures large enough for a Silk to pass through; each whereof seemed furnished with a Valve, disposed in such a Man-

ner as to let out what was contained in the Vessel, but suffer Nothing to return into it*.

“ It may possibly be conceived by some,
 “ says Dr. GREW, that the *Bones*, at least
 “ some of them, are hard at the first: as
 “ Salts and other crystallizing Bodies are as
 “ hard upon the very first Instant of their
 “ Shooting, as they are when grown into
 “ large Crystals. But it is so far evident
 “ that all the *Bones* are soft at the first, that
 “ I am of Opinion, they are originally a
 “ Congeries of as true *Fibres* or *fibrous Ves-*
 “ *sels* as any other in the Body; which by
 “ Degrees harden into Bones, in like Man-
 “ ner as the inmost Vessels of a Plant do in
 “ Time harden into Wood. And as in a
 “ Plant there are successive Additions of
 “ Rings or Tubes of Wood, made out of
 “ Vessels; so in an Animal, it seems plain
 “ that there are Additions successively made
 “ to the Bones out of the *fibrous Parts* of the
 “ Muscles; especially those whitest Fibres
 “ which run transversely, and make the Sta-
 “ men or Warp of every Muscle. So that,
 “ as in the Bark of a Plant, Part of the Ves-
 “ sels are successively derived outward to the
 “ Rind, and Part inward to the Sap, which
 “ afterwards becomes hard Wood; so, in the
 “ Flesh of an Animal, Part of the white
 “ transverse Fibres are successively derived

* *Philosoph. Transf.* Numb. 366.

“ to the Skin (of which it chiefly consists),
“ and Part of them inwardly, making still
“ new *Periosteums* one after another, as the
“ old ones become so many Additions to
“ the Bones *.”

Whoever would examine the *Bones*, must shave off, with a sharp Pen-knife, very thin Pieces, lengthways, crossways, and obliquely, and that from the Inside, Outside, and Middle of the Bone. Apply to the *Microscope* some of these Shavings dry, and others moistened with warm Water, and thus the Vessels will be seen in all Directions. But the best Way of shewing the bony Structure is, by putting the Bones in a very clear Fire till they are red-hot; then taking them out carefully, you will find the bony Cells, tho' tender, perfect and entire: And being now quite empty, they may be viewed with great Ease and Pleasure.

C H A P. XIV.

Of the N E R V E S.

MR. LEEUWENHOEK endeavoured to discover, by his *Microscope*, the *Structure* of the *Nerves*, in the Spinal Marrow

* GREW's Rarities of *Gresham College*, p. 6.

of an Ox; and saw, with great Delight, that minute hollow Vessels, of an unconceivable Fineness, invested with their proper Membranes, and running out in Lengths parallel to one another, make up their Composition. And though some hundreds of these Vessels go to the Formation of the least Nerve that can possibly be examined, he did not only discern the Cavities of them, which he computed to be three Times less than their Diameters, but, in some, perceived the Orifices as plainly as the Holes in a pricked Paper are to be seen when looked at against the Sun. It requires, however, great Dexterity and Expedition to make this Examination with Success; for after a thin Slice of the Spinal Marrow is placed before the *Microscope*, in less than a Minute's Time it becomes dry, and the whole Appearance vanishes*.

The same ingenious Enquirer into Nature examined likewise the Brain of several Creatures, such as an *Indian Hen*, a *Sheep*, an *Ox*, a *Sparrow*, &c. and could there distinguish Multitudes of Vessels, so extremely small, that if a † Globule of the Blood (a Million whereof exceed not a Grain of Sand in Bigness) were divided into five hundred Parts, those Parts would be too large

* *Arc. Nat.* Tom. III. p. 310. 355. 440.

† *Ibid.* Tom. I. Part. I. p. 30.

to pass into such Vessels. He observed farther *, that the Vessels in the Brain of a Sparrow are not smaller than in an Ox; and argues from thence, that there really is no other Difference between the Brain of a large Animal and that of a small one, but only a greater or smaller Number of Vessels; and that the Globules of the Fluid passing thro' them are in both of the same Size.

Though it does not directly relate to *Microscopes*, I hope I may be excused for taking Notice here, that in the Year 1711, Doctor ALEXANDER STUART † made a Discovery, that the Nerves are not elastic, contrary to the Opinion of all preceding *Authors*; and proved it by the following Experiment:
“ Laying a Piece of Twine, about four
“ Inches in Length, parallel to the Nerve,
“ Artery, and Vein of the Inside of the Thigh
“ in an human Subject, and tying these to-
“ gether, above and below, as soon as they
“ were cut out of the Body, and laid on a
“ Board; the Artery and Vein were seen to
“ contract equally, to the Loss of a quarter
“ Part of the Length they had in the Body
“ before Excision; but the Nerve continued
“ of the same Length with the Twine, as
“ in the Body.”

* *Arc. Nat.* Tom. I. Part. I. p. 38.

† Vid. STUART'S *Lectures on Muscular Motion*, in the Year 1738, p. 3.

C H A P. XV.

Of the GENERATION *of* ANIMALS *and*
VEGETABLES.

*E*quivocal or spontaneous Generation, that is, a Production of Plants without Seeds, and of living Creatures without any other Parents but Accident and Putrefaction, however absurd it may seem to us, was an Opinion that prevailed almost universally; till *Microscopes* overturned it, by demonstrating that all Plants have their Seeds, and all Animals their Eggs: whence other Plants and other Animals, exactly of the same Species, are perpetually and unalterably produced.

Nothing seems now more contrary to Reason, than that *Chance* and *Nastiness* should give a Being to Uniformity, Regularity, and Beauty: that two such unlikely Principles should produce, in different Places, Millions of Vegetables of the same Kinds, and alike exactly, even in the most minute Particularities: or, what is yet more amazing, that dead *corrupting Matter*, and blind *uncertain Chance*, should create living Animals, fabricate a Brain, constitute Nerves issuing from it, compose a Contrast of Muscles, furnish out Eyes, Lungs, a Heart, a Stomach, Bowels, and all other Parts useful to such Creatures; and that too not after an awkward, slovenly,

slovenly, variable, undesigning, and unfinished Manner; but with a Contrivance, Dexterity, Elegance, Perfection, and Constancy, beyond the utmost Power of Art to imitate. This, however, was the Opinion, not only of the Ignorant and Illiterate, but of the most learned grave Philosophers of preceding Ages; and would probably still have been taught and believed, had not *Microscopes* discovered the Manner how all these Things are generated, and restored to God the Glory of his own amazing Works *.

The Eye, assisted by a good *Microscope*, can distinguish plainly, in the *Semen Masculinum* of Animals, Myriads of *Animalcules* alive and vigorous; though so exceedingly minute, that it is computed three thousand millions of them are not equal to a Grain of Sand, whose Diameter is but the one hundredth Part of an Inch †. And the same Instrument will inform us, beyond all Doubt, that the *Farinæ* of Vegetables are nothing else but a Congeries of minute *Granula*, whose Shapes are constant and uniform as the Plants they are taken from. And as the

* I would as soon say, that Rocks and Woods engender Stags and Elephants, as affirm, that a Piece of Cheese generates Mites. Stags are born and live in Woods, and Mites in Cheese; but they both owe their Being to that of other Animals. *Spec. de la Nat.* Eng. Edit. 12mo. Vol. II, p. 11.

† Vid. KEIL's *Anat.* 5th Edit. p. 116.

Seeds of Plants are proved, by repeated Experiments, to be unprolific, if the *Farinæ* be not permitted to shed, it has been supposed, that all its *Granula* contain *seminal Plants* of their own Kind.

The Growth of Animals and Vegetables seems to be nothing else but a gradual Unfolding and Expansion of their Vessels, by a slow and progressive Insinuation of Fluids adapted to their Diameters; until, being stretched to the utmost Bounds appointed them by Providence at their Formation, they attain their State of Perfection, or, in other Words, arrive at their full Growth.

It is thought probable, according to this Theory, that in Animals (of the larger and more perfect Kind at least) the *Semen* of the Male being received into the *Matrix* of the Female, some of the *Animalcules* it contains in such Abundance find an Entrance into the *Ovaria*, and lodge themselves in some of the *Ova* placed there by Providence as a proper *Nidus* for them.

An *Ovum* becoming thus inhabited by an *Animalcule*, gets loosened in due Time from its *Ovarium*, and passes into the *Matrix* through one of the *Fallopian* Tubes. The Veins and Arteries that fastened it to the *Ovary*, and were broken when it dropped from thence, unite with the Vessels it finds here, and compose the *Placenta*. The Coats of the *Ovum*, being swelled and dilated by
the

the Juices of the *Matrix*, form the other Integuments needful to the Preservation of the little Animal; which receiving continually a kindly Nourishment from the same Juices, gradually stretches and enlarges its Dimensions, becoming then quickly visible with all the Parts peculiar to its Species, and is called a *Fætus*.

In Plants, which are incapable of removing from Place to Place as Animals can, it was requisite a Repository for their *Farina* should be near at hand, to prevent its being lost: and accordingly we find, that every Flower producing a *Farina* has likewise in itself a proper *Uterus* for the Reception of it: where the *Ova* thereby impregnated are expanded by the Juices of the Parent Plant to a certain Form and Bulk; and then becoming what we call ripe Seeds, they fall to the Earth, which is the natural Matrix for them.

According to the above Supposition, a ripe Seed falling to the Earth is in the Condition of the Ovum of an Animal getting loose from its Ovary, and falling into the Uterus: and, to go on with the Analogy, the Juices of the Earth swell and expand the Vessels of the Seed, as the Juices of the Uterus do those of the Ovum, till the seminal Leaves unfold, and perform the Office of a *Placenta* to the Infant-included Plant; which imbibing suitable and sufficient Moisture, gradually

dually extends its Parts, fixes its own Root, shoots above the Ground, and may be said to be born.

As Discoveries made by the *Microscope*, of infinite Numbers of *Animalcules* in the *Semen Masculinum* of all living Creatures, and likewise of a Regularity and Constancy in the *Farina* of each Species of Vegetables, analogous to the said *Animalcules* in the Animal *Semen*, have been the principal Means of convincing us that all Things are produced by Parents of their own Kind, according to the eternal and unalterable Laws established at their first Creation; I hope this short Account of Generation, before my entering upon those Subjects, will not be judged improper.

C H A P. XVI.

Of the ANIMALCULES in SEMINE MASCULINO.

AT the Beginning of the Year 1678, Mr. NICHOLAS HARTSOEKER of *Rotterdam* declared, in a Treatise of *Dioptrics* by him then published, that it was twenty Years since he first began to examine the *Semen Masculinum* of several living Creatures by the Help of *Microscopes*: that, as
far

far as he knew, he was the first Person who had ever done so; that he had found in such *Semen* infinite Numbers of *Animalcules*, most exceedingly minute, almost in the Shape of Tadpoles or young Frogs; and that he had made this Discovery known to the World in the 30th of the *Ephemerides Eruditorum*, printed at Paris in the same Year 1678.

Mr. LEEUWENHOEK, in the 113th of his Epistles (dated *January* 1678) is very angry at this Claim; and asserts, that he himself first discovered the *Animalcules* in *Semen*; and sent Account thereof to the ROYAL SOCIETY in *November* 1677, as he proves by the *Philosophical Transactions*, published in *December* 1677, and in *January* and *February* 1678. Nay, he farther affirms, that Letters had passed between him and Mr. OLDENBURG on this Subject in 1674. This Dispute concerns us no farther than as it shews about what Time the Existence of these *Animalcules* was first discovered, which some of my curious Readers may perhaps be inquisitive to know.

The general Appearance or Figure of the *Animalcules* in the *Semen Masculinum* of different Kinds of living Creatures is very much the same: that is, the Bodies of them all seem of an oblong oval Form, with long tapering slender Tails issuing therefrom; and as by this Shape they somewhat resemble
Tadpoles,

Tadpoles, they have frequently been called by that Name; though the Tails of them, in Proportion to their Bodies, are much longer than the Tails of *Tadpoles* are: and it is observable, that the *Animalcules* in the *Semen* of Fishes have Tails much longer and slenderer than the Tails of those in other Animals, infomuch that the Extremity of them is not to be discerned without the best Glasses and the utmost Attention: their Bodies are also much smaller.

The general Appearance of them, as above described, is shewn Plate XII. Fig. I.

In the Spring-Season, at the Time that Frogs engender, upon opening the Testicles of a Male, and applying some of the *seminal Matter* before the Microscope, Multitudes of *Animalcules* appeared therein, about * one thousandth Part of the Thickness of the Hair of a Man's Head, as nearly as could be computed: whence it follows, that a thousand Millions of them would be but equal to a Globe whose Diameter is the Thickness of the Hair of a Man's Head. And there seemed to be ten thousand of them at least for each one of the female *Ova*.

The Shape of them is given in the same Plate, Fig. II.

* LEEUWEN. *Arcan. Nat.* Tom. I. Part I. p. 51.

Fig. I. p. 154



Fig. II. p. 154

Plate XII.

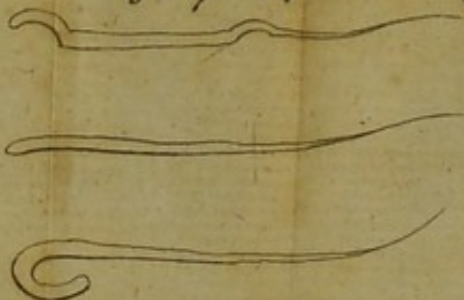


Fig. III. p. 160



Fig. IV. p. 160



Fig. V. p. 161

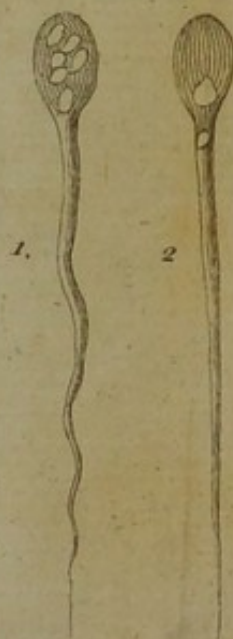


Fig. VI. p. 162

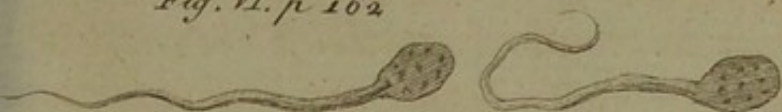
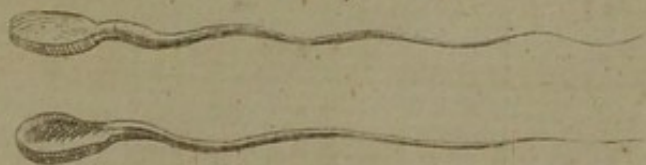
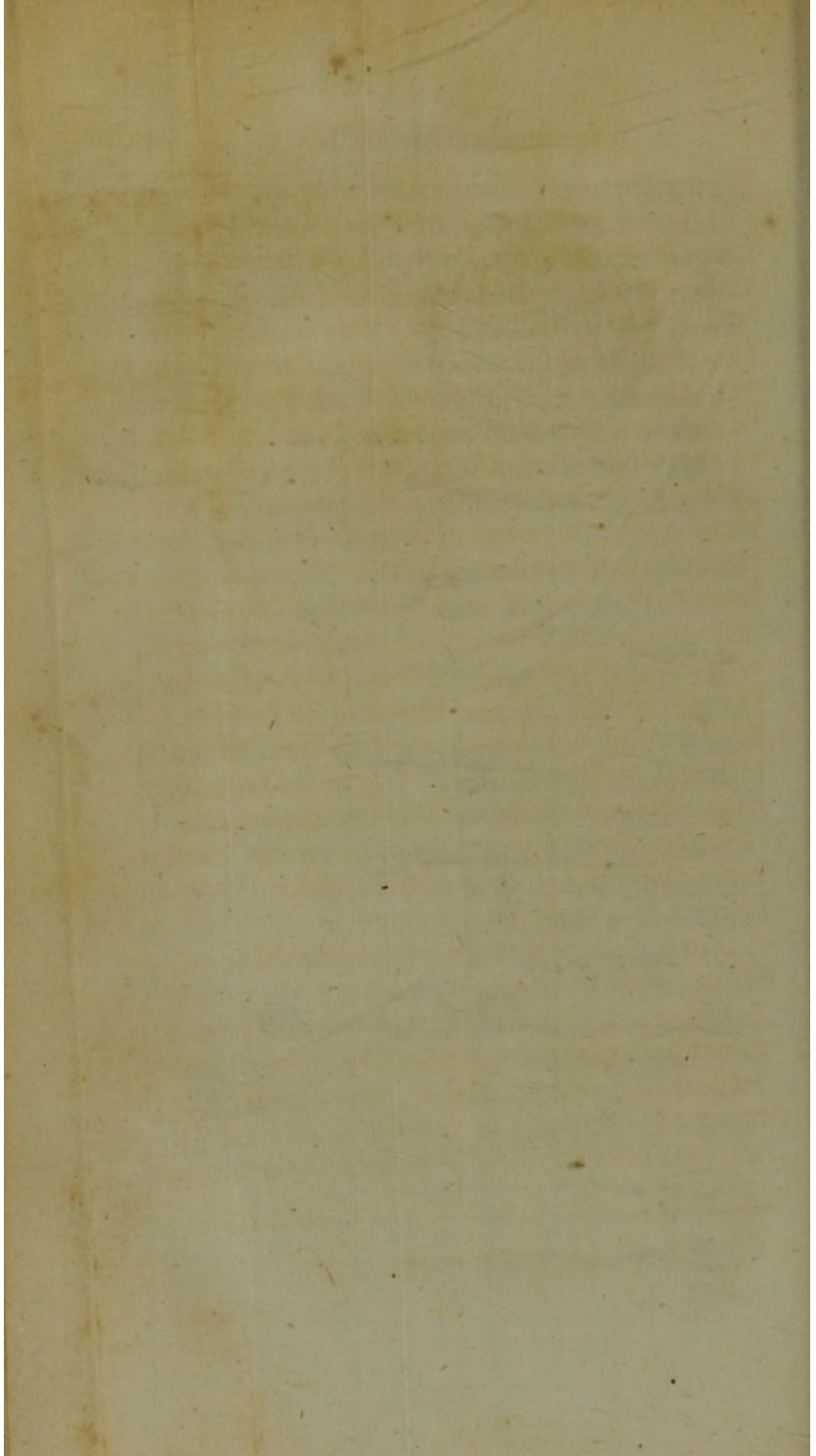


Fig. VII. p. 163





Upon viewing the *Milt* or *Semen Masculinum* of a living Cod-fish with a *Microscope*, such Numbers of *Animalcules* with long Tails were found therein, that at least ten thousand of them were supposed to exist in the Quantity of a Grain of Sand. Whence Mr. LEEUWENHOEK argues, that the Milt of that single Cod-fish contained more living *Animalcules* than there are People alive upon the Face of the whole Earth at one and the same Time: for he computes *, that one hundred Grains of Sand make the Diameter of an Inch; wherefore in a cubic Inch there will be a million of such Sands. And as he found the Milt of the Cod-fish to be about fifteen cubic Inches, it must contain fifteen millions of Quantities as big as a Grain of Sand. Now if each of these Quantities contain ten thousand *Animalcules*, there must be in the Whole one hundred and fifty thousand millions.

Then, to find out, in a probable Manner, the Number of People living upon the whole Earth at one Time; he reckons, that in a great Circle there are five thousand four hundred *Dutch* square Miles; whence he calculates the Surface of the Earth to contain nine millions two hundred seventy-six thou-

* *Arc. Nat.* Tom. I. Par. II. p. 9.

land two hundred and eighteen such square Miles: and supposing one Third of the Whole, or three millions ninety-two thousand and seventy-two Miles, to be dry Land; and of this, two thirds, or two millions sixty-one thousand three hundred and eighty-two Miles, to be inhabited: and supposing farther, that *Holland* and *West-Friesland* are twenty-two Miles long and seven broad, which make one hundred and fifty-four square Miles; the habitable Part of the World is thirteen thousand three hundred and eighty-five Times the Bigness of *Holland* and *West-Friesland*.

Now, if the People in these two Provinces be supposed a million, and if all the other inhabited Parts of the World were as populous as these (which is highly improbable), there would be thirteen thousand three hundred and eighty-five millions of People on the Face of the whole Earth: but the Milt of this Cod-fish contained one hundred and fifty thousand millions of *Animalcules*, which is ten Times more than the Number of all Mankind.

The Number of these *Animalcules* may be computed another Way: for the ingenious Author of *Speſtacle de la Nature* ſays*, that

* Vide *Speſt. de la Nat.* Eng. 12mo. Edit. Vol. I. p. 231.

three curious People counted, with all the Care they were able, as many of the *Eggs* or *Row* of a female Cod-fish as weighed a Dram, and agreed pretty well in the Number, which they wrote down. They then weighed the whole Mafs; and setting down eight Times the Sum of one Dram for every Ounce, which contains eight Drams, all the Sums together produced a Total of nine millions threehundred and thirty-four thousand Eggs*.

Now supposing (as Mr. LEEUWENHOEK does of the *Semen Masculinum* of Frogs) that there are ten thousand *Animalcules* in the Milt for each one of the Female Ova in the Row, it will follow, that since the Female Row is found to have nine Millions three hundred thirty-four thousand Eggs, the whole Milt of the Male may be reckoned to contain ninety-three thousand four hundred and forty millions of *Animacules*: which, though greatly short of the first Calculation, is almost seven Times as many as the whole human Species.

To find the comparative Size of these *Animalcules*, Mr. LEEUWENHOEK placed a

* Four Millions and ninety-six thousand Eggs were computed in the Roe of a *Crab*, each of which received its Nourishment by a Rope from the *Crab's* Body. Vide *Arc. Nat.* Tom. I. Par. II. p. 240.

Hair * of his Head near them, which Hair through his *Microscope* appeared an Inch in Breadth; and he was satisfied that at least sixty such *Animalcules* could easily lie within that Diameter: whence, their Bodies being spherical, it must follow, that two hundred and sixteen thousand of them are but equal to a Globe whose Diameter is no more than the Breadth of such an Hair.

He observed, that when the Water wherewith he had diluted the *Semen* of a Cod-fish was exhaled, the little Bodies of the *Animalcules* burst in Pieces, which did not happen to those in the *Semen* of a Ram; which he imputes to the greater Firmness and Consistency of the latter, as the Flesh of a Land-Animal is more compact than that of a Fish. He likewise takes Notice, that the Tails of those in Fishes are so extremely slender, that he could never be certain of his seeing the very Tips or Extremities of them.

In the Milt of a Jack at least † ten thousand *Animalcules* were discernible in a Quantity not bigger than a Grain of Sand, exactly in Appearance like those of the Cod-fish; and upon putting ‡ four Times as much Water to it, they were perceived to become stronger and brisker, and to swim

* *Phil. Transf.* Numb. 270.
Par. II. p. 2.

† *Arc. Nat.* Tom. I.

‡ *Phil. Transf.* Numb. 270.

as if in Pursuit of Prey, with greater Velocity; though (being viewed in a capillary Tube) their whole Course was no longer than the Diameter of a Hair.

If you would view the *Animalcules* in the Milt or soft Row of Fishes, squeeze out a little of it, and putting the Quantity of a Pin's Head upon a single Ifinglass, dilute it with Rain or River Water, till the little Creatures have sufficient Room to swim about freely, and shew themselves to Advantage; which they can by no means do unless it be made very thin. Or, after you have mixed some Water with it, apply it to the *Microscope* in one of your smallest capillary Tubes; which Way Mr. LEEUWENHOEK informs us he found the most useful for the Examination of the *Semen* of different Creatures. [N. B. * The *Eggs* in the Row, and *Animalcules* in the Milt, of Fishes of one Year old, are as large as in those of the same Species of twenty Years old.]

Upon opening the *Seminal Vessels* of a Cock, squeezing out a small Drop of the *Semen*, and viewing it with a *Microscope*, Legions of *Animalcules* appeared therein, swimming in Crowds together, and crossing one

* *Arc. Nat.* Tom. III. p. 188.

another with as much Briskness and Vigour as if the Cock had been but newly dead, tho' it was killed the Day before : and by several Trials on the *Semen* of other Cocks, it has been found, that the *Animalcules* therein will live many Hours in a capillary Glass Tube. To a slight Observer they seem in the Form of Eels ; but if the greatest Magnifiers be used with due Attention, they will be found shaped as Fig. III. Plate XII.— Their Size is so extremely minute, that a * million of them are supposed not to exceed the Bigness of a Grain of Sand ; and their Tails cannot be discerned without much Difficulty, being ten thousand Times more slender than the Hair of a Man's Hand.

A little of the *Seminal Matter* taken from the Testicle of a Dog abounded with *Animalcules* †, a million whereof would hardly equal a large Grain of Sand : and after some of this Matter had been kept Seven Days in a Glass Tube, several of the *Animalcules* remained alive and vigorous. [Their Form is shewn Fig. IV.]—The *Testicles* of a Hare, though four Days dead, were also exceedingly full of *Animalcules* like those in Dogs, swimming in a clear Liquor, but without Motion.

* *Arc. Nat.* Tom. II. Par. II. p. 369.

† *Arc. Nat.* Tom. I. Par. II. p. 160.

Killing a Female Rabbet immediately after the Coitus, and opening the Uterus thereof, innumerable *Animalcules* were found in a small Drop, taken from the Mouth of the *Fallopian Tube*, where it opens into the Matrix: but none were discerned in the Uterus itself, or farther along the Tube. They had long Tails, and for the most Part * six transparent Globules appeared on the Body of each, as in Fig. V. 1. though some had only one Globule at the End of the Body, and another in the Tail, as Fig. V. 2.

Examining a Drop of *Semen* taken from the Testicles of a Ram, it abounded with *Animalcules* in as great Numbers as the seminal Matter of other Creatures; but with this extraordinary † Singularity, that Multitudes of them swam the same Way together,

* *Arc. Nat.* Tom. I. Par. II. p. 160.

† Mr. LEEUWENHOEK opened the Uterus of an Ewe, which about seventeen Days before had been coupled with a Ram, and in one of the Cornea observed a little *reddish fleshy Substance*, wherein no Shape could be distinguished. He put this in a Glass Tube the Thickness of a Quill, filled with *Oil of Turpentine*, and applied it to his *Microscope*; but could make nothing of it in that Manner. Wherefore he took it from the Tube, and extending it very gently out of the round Figure in which it lay, he perceived extremely plain the Formation of all the *Vertebræ*, with the *Blood-Vessels* and *Ramifications* passing over them, and in two Places could see the *Spinal Marrow*. He could also distinguish not only the Head, but also the Mouth, Brain, and Eyes, the Bigness of two Grains of Sand, and clear as Crystal: He saw likewise

gether, and seemed to have the Inclination of Sheep, to follow their Leader and move in Flocks. Mr. LEEUWENHOEK says, he found so much Pleasure in observing this, that he called in some Neighbours to share it with him.

Their Form was that of Fig. VI.

A Buck being killed in Rutting-time, the * *Vasa Deferentia* were found turgid with a milky Fluid, a Drop whereof, when applied to the *Microscope*, appeared full of *Animalcules* moving very briskly. The greatest Difficulty was to lay them properly before the *Microscope*: for when the Matter is too thick, nothing can be seen but a confused Motion, and when spread thin it dries away immediately; but by diluting it with warm Water, just enough to change its Colour, they were seen distinctly.

The human *Semen* has likewise been viewed by the *Microscope*, and found no less

the Ribs and Intestines; though the whole Creature was no larger than the eighth Part of a Pea.—After this, he opened the Uterus of another Ewe, but three Days from the Coitus; and searching the Liquor coming from it very diligently with a Magnifying Glass, observed a little *Particle* the Size of a Grain of Sand; which examining with an excellent *Microscope*, he with great Pleasure found to be an exceeding minute Lamb lying round in its Integuments, and could plainly discern its Mouth and Eyes. Vid. *Arc. Nat.* Tom. I. Par. II. pag. 165, and 173.

* Vid. *Phil. Transf.* Numb. 284.

plentifully stocked with Life than that of other Animals: for more than ten thousand living Creatures were seen, by Mr. LEEUWENHOEK, moving in no larger a Quantity of the fluid Part thereof than the Bigness of a Grain of Sand; and in the thicker Part they were so thronged together, that they could not move for one another. Their Size was smaller than the red Globules of the Blood, and even less than the millionth Part of a Grain of Sand *. The Bodies of them are roundish, somewhat flat before, but ending sharp behind, with Tails exceedingly transparent, five or six Times longer, and about five Times more slender, than their Bodies. They move themselves along by the violent Agitation of their Tails, in various Bendings, after the Manner that Eels or Serpents swim: and sometimes their Tails are moved thus eight or ten Times in getting forwards the Diameter of a Hair.

Their Shape and Form is shewn Fig. VII.

It is wonderful to consider the Minuteness of these little Animals, and particularly the amazing Slenderness of their Tails: which must, notwithstanding, be furnished with as many Joints as the Tails of larger Creatures, since they are able to move them with great

* *Arcan. Nat.* Tom. II. Par. II. p. 61. 69. 286.

Agility: and, besides, every one of these Joints must be provided with its proper Muscles, Nerves, Arteries, and Veins; and also with Fluids circulating thro' them, and supplying them with Nourishment, Strength, and Motion. In short, the Mind loses itself in contemplating a Minuteness beyond all human Conception; tho' Reason tells us it certainly must be. I remember Dr. POWER has a fine Passage to this Purpose in the Preface to his Experiments: "It has often
" seemed to me (says he) an ordinary Pro-
" bability, and something more than Fancy
" (how paradoxical soever the Conjecture
" may seem), to think, that the least Bodies
" we are able to see with our naked Eyes
" are but *middle Proportionals*, as it were,
" betwixt the *greatest* and the *smallest* Bo-
" dies in Nature; which two Extremes
" lie equally beyond the Reach of human
" Sensation.—For, as on one Side they are
" but narrow Souls, and not worthy the
" Name of *Philosophers*, that think any
" Body can be *too great* or *too vast* in its
" Dimensions: so likewise are they as in-
" apprehensive, and of the same Litter with
" the former, that, on the other Side, think
" the Particles of Matter may be *too little*,
" or that Nature is stinted at an Atom, and
" must have a *Non ultra* of her Subdivi-
" sions."

As

As the *Animalcules* in the *Semen Masculinum* of different Creatures are not much unlike in Shape, it is also observable, that they do not differ in * Bigness according to the Sizes of the Creatures they are taken from; but seem, in this respect, analogous to the *Seeds* of Trees and Plants, whose Size bears very little Proportion to the Bigness of the Trees and Plants producing them. The Seed of an Apple, for Instance, is some thousands of Times smaller than a Cocoa-Nut, tho' the Trees they grow on have not that Disproportion: and the Seeds of Tobacco (whereof a thousand † weigh not above a single Grain) are less beyond Comparison than many Kinds of other Seeds whose Plants are not near so large as Tobacco is. Hence it comes to pass, that *Animalcules* may be discovered in the *Semen* of the smallest Birds, Quadrupeds, and Fishes, nay, and even in Insects too. For Mr. LEEUWENHOEK assures us, he found a *white Matter* he had sometimes squeezed from the hinder Parts of male ‡ Spiders, about the Bigness of a Grain of Sand, to be indeed their *Semen*, by discovering therein prodigious Multitudes of *Animalcules*, which continued living above five Hours, but were so extremely minute that he supposes a thousand Millions of them

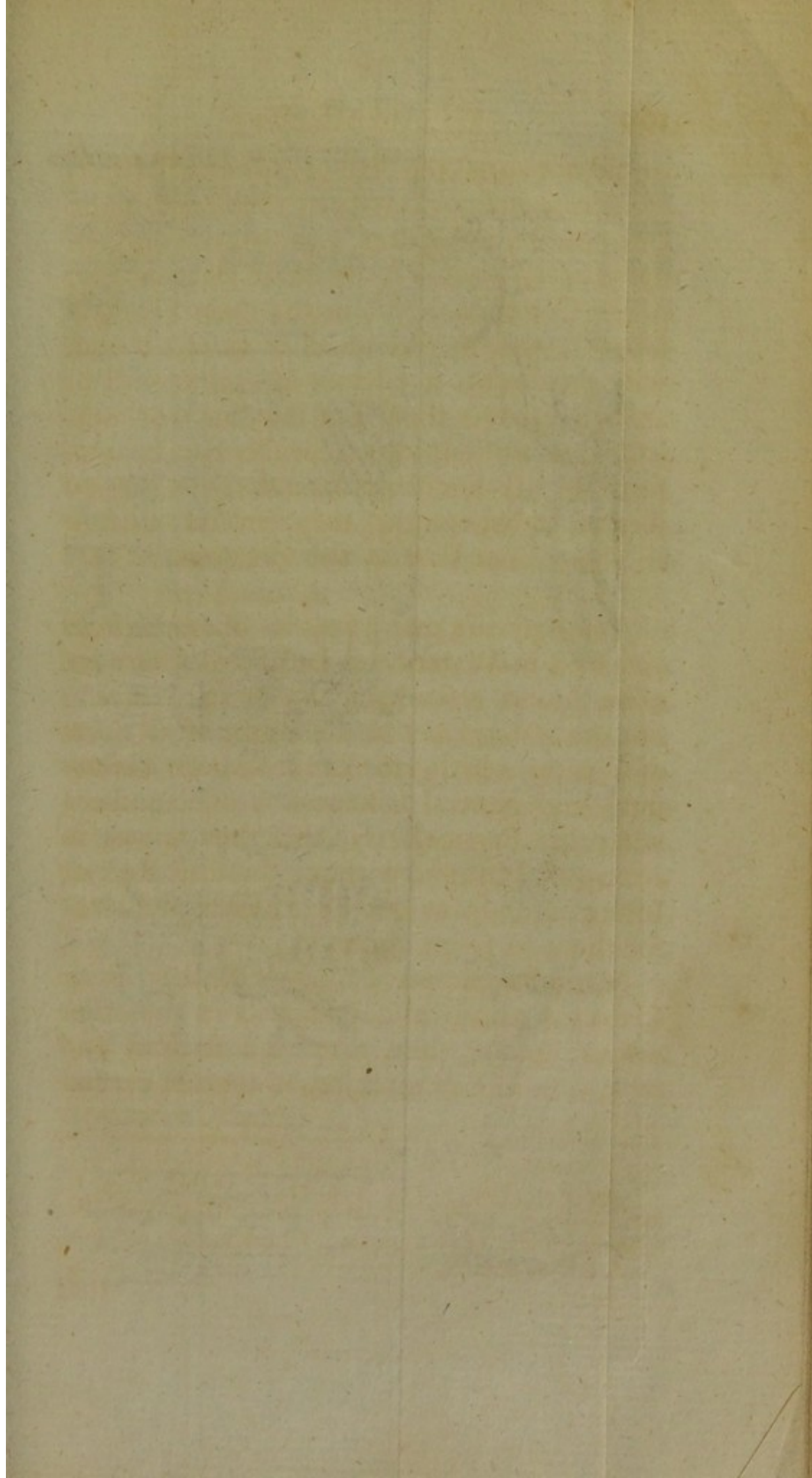
* *Arc. Nat.* Tom. IV. pag. 30. † Dr. POWER'S *Ex-*
perim. pag. 30. ‡ *Philosoph. Transact.* Numb. 279.

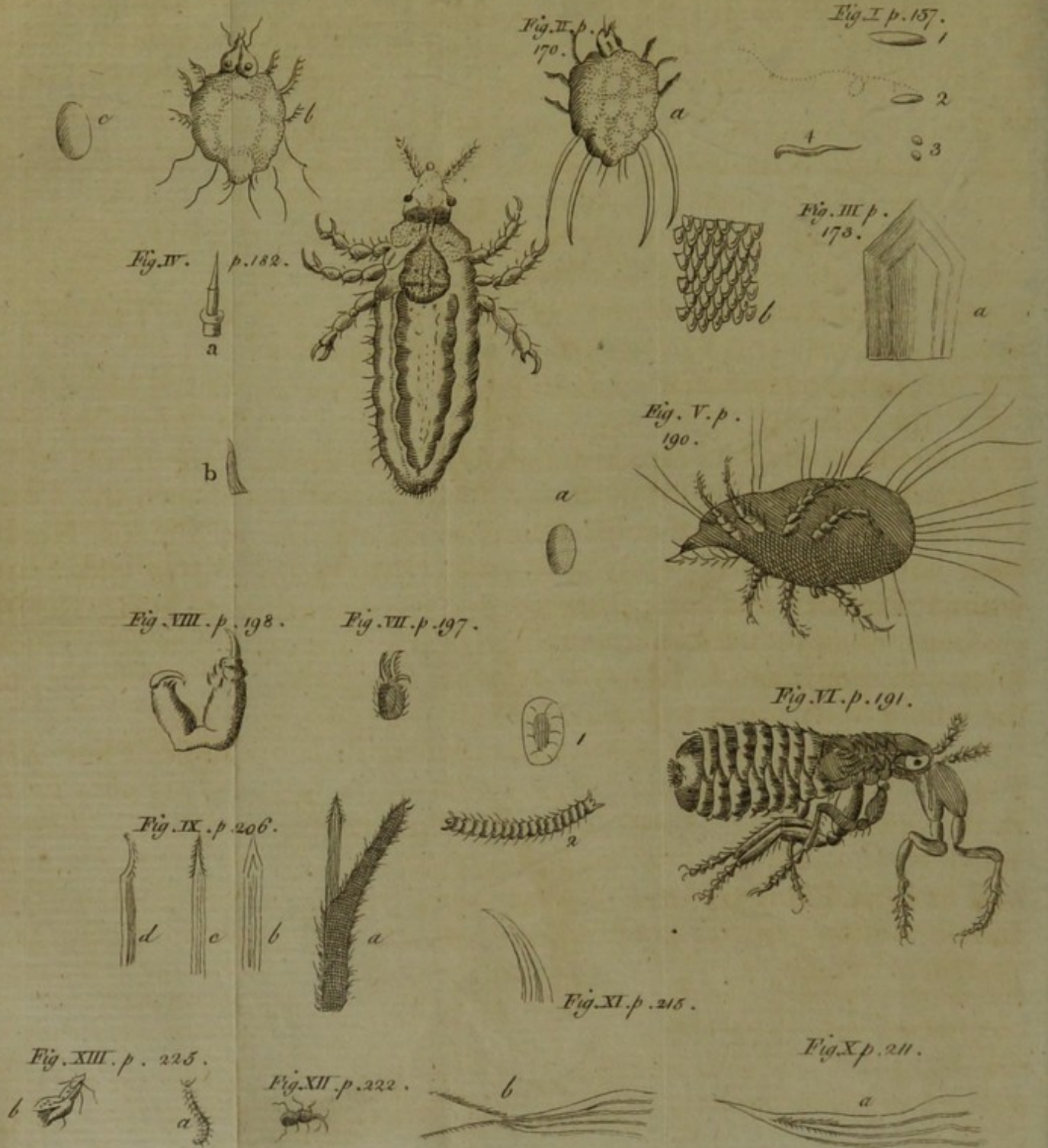
would not equal the Size of a Grain of Millet. He found them likewise in the *Semen* of the Dormouse^a, in Oysters^b, in Silkworms^c, in the *Labella minima*^d, or small Dragon-Fly, in the Common Fly^e, in the male Flea^f, in Gnats^g, and in several other Insects: and, without doubt, a curious Enquirer will be able to discover them in Abundance of Subjects yet unexamined; for Nature is uniform in all her Works, and there is good Reason to believe that they certainly exist in all the animal Part of the Creation.

Amongst the many Species of *Animalcules* observed in Waters and Infusions, there are none found resembling those in *Semine*^h: but the *Animalcules* in the *Semen* of all Sorts of Creatures hitherto examined have a common and general Likeness to one another; with this Particularity, that they appear in continual Motion, without the least Rest or Intermiſſion, provided the Fluid be sufficient for them to swim about in.

Many People have imagined, that *living Creatures* might also be found in the other *animal Juices*: but, after the strictest and most careful Examination, it appears certain

^a *Arc. Nat.* Tom. I. Par. II. p. 27. ^b *Ibid.* Tom. II. Par. I. p. 144. ^c *Ibid.* Par. II. p. 422. ^d *Ibid.* Tom. IV. p. 19. ^e *Ibid.* ^f *Ibid.* p. 20. ^g *Ibid.* p. 22. ^h *Ibid.* Tom. III. p. 294.





that nothing with the least Token of Life is to be discovered by the best Glasses, either in the *Blood, Spittle, Urine, Gall, Chyæ*, or any of the *Humours*, except the *Semen* only.

C H A P. XVII.

Of ANIMALCULES in the TEETH.

THough no *Animalcules* can be found in the *Saliva* or *Spittle*, great Numbers of different Kinds may be discovered in the *whitish Matter* sticking between the Teeth, if it be picked out with a Pin or Needle, mixt with a little Rain-Water and *Spittle* without Bubbles, and applied before the Microscope. And sometimes they are so incredibly numerous, and so full of Motion, that the whole Mass appears alive.

* The largest Sort (shewn Plate XIII. Fig. I. Numb. 1.) move along very swiftly in the *Spittle* or Water; of these there are but few.

The second Sort are more numerous, and have a Motion peculiar to themselves, as represented Numb. 2.

* Vide *Arc. Nat.* Tom. IV. p. 40. Again, Tom. IV. Epist. 75. p. 310.

The third Sort are roundish, and so minute, that a Grain of coarse Sand would equal a million of them in Bigness: they move so swiftly, and in such Multitudes, that they seem like Swarms of Gnats or Flies, and the exact Shape of them is not easy to be distinguished.

Some or all of these three Kinds may be found pretty constantly in the *Matter* taken from between the Teeth of Men, Women, or Children; especially from between the Grinders, even tho' they wash their Teeth continually, and clean them with the utmost Care: but from the Teeth of People that are more careless, the said Matter affords another Sort of *Animalcules* in the Shape of Eels or Worms, as pictured Numb. 4. These move themselves backwards or forwards, with great Bendings of the Body; and force their Way through the minuter *Animalcules* every where around them, with the same Ease as a large Butterfly would break through a Swarm of Gnats. There are likewise, in this Matter from the Teeth, other Sorts of *Animalcules*, whose Motions are so extremely languid, that without long Attention they cannot be distinguished to be alive.

Observation. They all die if Vinegar be applied to them; whence it seems reasonable to conclude, that washing the Teeth and Gums with Vinegar may be a Means of preserving them from these minute Creatures.

C H A P. XVIII.

Of the I T C H.

THE *Microscope* has discovered, what without it could scarce have been imagined, that the Distemper we call the *Itch* is owing to little Insects under the *Cuticula*, whose continual Bitings cause an ouzing of Serum from the *Cutis*, and produce those Pustules or watry Bladders whereby this Disease is known. This was found out by Dr. BONONIO, * who observing that itchy People frequently pull out of their scabby Skin little Bladders of Water with the Point of a Pin, and crack them on their Nails like Fleas, he determined to examine what these Bladders might really be. Wherefore, picking out with a fine Needle a little Pustule from a Place scabbed over, and where there was a severe Itching, he squeezed a thin Matter from it, and perceived a very small white Globule scarcely discernible, which, applying to the Microscope, he found to be a very minute *Animal*, in Shape resembling a Tortoise, of a whitish Colour, but darker on the Back than elsewhere, with some long and thick Hairs issuing from it, very nimble in its Motion, having six Legs, a sharp Head,

* *Phil. Transact.* Numb. 283.

and

and two little Horns; being in Shape as represented by the two Pictures, Fig. II. *a*, *b*. Plate XIII.

This Experiment was repeated on itchy Persons of all Ages, Sexes, and Complexions, and at all Seasons of the Year, and he constantly found the same *Animalcules* in most of the watry Pustules: and though by reason of their Minuteness and Colour (which is the same as the Skin) it is difficult to discern these Creatures on the Surface of the Body, yet he sometimes saw them upon the Joint of the Fingers in the little Furrows of the *Cuticula*, where they first begin to enter with their sharp Heads, gnawing and working in their Bodies, till they are got quite under the *Cuticula*, where they burrow from Place to Place, cause a troublesome and grievous Itching, and force the infected Person to scratch, which only serves to increase the Malady; for, by breaking the little Pustules and some small Blood-Vessels, Scabs, crusty Sores, and such like foul Symptoms ensue: whilst these mischievous *Animalcules* escape the Nails by their Minuteness, and disperse themselves the farther.

Frequently observing these *Animalcules*, he perceived one of them drop a little oblong white Egg, almost transparent, from the hinder Part of its Body: and afterwards he saw many of the same Sort of Eggs; which proves them generated, like other Creatures,
from

from a Male and Female, though he was never able to distinguish the Sex of any he examined.

The Figure of the Egg is shewn c.

We may hence account how this Distemper comes to be so very catching, since these *Animalcules*, by simple Contact, can easily pass from one Person to another, having not only a swift Motion, but clinging to every Thing they touch, and crawling as well upon the Surface of the Body as under the outward Skin; and a few being once lodged, they multiply apace by the Eggs they lay. The Infection may also be propagated in a like Manner by Sheets, Towels, Handkerchiefs, or Gloves, used by itchy People; since these *Animalcules* may easily be harboured in such Things, and will live out of the Body two or three Days.

The Discovery of these *Animalcules* shews the Reason likewise why this Distemper is never to be cured by internal Medicines: but requires lixivial Washes, Baths, or Ointments, made up with *Salts, Sulphurs, Vitriols, Mercury, Precipitate, Sublimate*, or such Kinds of penetrating and corroding Remedies as can powerfully kill these Vermin in the Skin. And if sometimes we find the Disease returns upon us, in a little while after we supposed it quite cured by Unction, it is no great Wonder; since, tho' the Oint-

ment may destroy all the living *Animalcules*, it may not probably kill their Young Ones in the Eggs, laid in Nests in the Skin; which, coming to hatch, may renew the Distemper. For this Reason it is adviseable to continue the Anointing for some Days, even after the Cure seems perfect.

C H A P. XIX.

Of S C A L E S on the Human Skin.

THE *Cuticula*, Scarf-skin, or outward Covering of the Body, is remarkable for its Scales and for its Pores.

Its Scales are a Discovery of the *Microscope*; for being so minute that * two hundred of them may be covered with a Grain of Sand, they could never be discerned by the naked Eye. They are placed as on Fishes, † three deep, that is, each Scale is so far covered by two others, that only a third Part thereof appears: which lying over one another, may be the Cause why the Skin of the Body appears ‡ white; for about the Mouth and Lips, where they only just meet together, and do not fold over, the Blood-

* Vid. *Arc. Nat.* Tom. I. Par. II. p. 208. Again, Tom. IV. p. 46. † Ibid. p. 47. ‡ Ibid. p. 51.

Vessels are seen through, and the Parts look red. The perspirable Matter is supposed to issue between these Scales (which lie over the Pores or excretory Vessels through which the watery and oily Humours perspire), and may find Vent in an hundred Places round the Edges of each Scale * : so that, if a Grain of Sand can cover two hundred Scales, it will be able to cover twenty thousand Places where Perspiration may issue forth.

A Piece of Skin taken from between the Fingers, from the Forehead, Neck, Arms, or any other soft Part of the Body which is not hairy, serves best to shew the Scales ; for where the Skin is callous, they are glewed as it were together.

They are generally of five Sides, as in the Picture, Fig. III. *a*.

Their Disposition on the Skin is shewn Fig. III. *b*.

If they are scraped off with a Penknife, put into a Drop of Water, and so applied to the Microscope, they will be seen to good Advantage.

* *Arcan. Nat.* Tom. IV. p. 48.

C H A P. XX.

The Pores of the Skin.

EVERY Part of the human Skin is full of *excretory Ducts* or *Pores*, which emit superfluous Humours continually from the Mass of the circulating Fluid.

In order to view the *Pores*, cut a Slice of the upper Skin with a sharp Razor as thin as possible: then immediately cut a second Slice from the same Place, which apply to the Microscope, and in a Piece not larger than a * Grain of Sand can cover, innumerable *Pores* will be perceived, as plainly as little Holes pricked by a fine Needle may be discerned if it be held up against the Sun. The Scales of the outer Skin prevent any distinct View of the *Pores*, unless they are scraped away with a Penknife, or cut off in the above Manner; but if a Piece of the Skin between the Fingers, or in the Palms of the Hands, be so prepared, and then examined, the Light will be seen very pleasantly through the *Pores*.

Mr. LEEUWENHOEK endeavours to give some slight Notion of the incredible Num-

* *Arc. Nat.* Tom. II. p. 409, 412.

ber of *Pores* in a human Body. He * supposes there are one hundred and twenty such *Pores* in a Line one tenth of an Inch long ; however, to keep within Compass, he reckons only one hundred. An Inch in Length will then contain a thousand in a Row, and a Foot twelve thousand. According to this Computation, a Foot square must have in it an hundred and forty-four millions : and supposing the Superficies of a middle-sized Man to be fourteen Feet square, there will be in his Skin two thousand and sixteen millions of *Pores*.

To acquire some clearer Idea still of this prodigious Number of *Pores* by our Conception of Time, let us reckon with † MERSENNUS, that each Hour consists of sixty Minutes, and each Minute of sixty Seconds, or sixty Pulsations of an Artery : in one Hour there will then be three thousand and six hundred Pulses ; in twenty-four Hours eighty-six thousand and four hundred ; and in a Year thirty-one millions five hundred and thirty-six thousand. But there are about sixty-four Times as many *Pores* in the Surface of a Man's Skin, and therefore he must live sixty-four Years, ere he will have a Pulsation for every *Pore* in his Skin.

* *Arc. Nat.* Tom. III. p. 413.

† *Ibid.* p. 413.

Dr. NATHANAEL GREW observes, that the * *Pores* through which we perspire are more particularly remarkable in the Hands and Feet; for if the Hand be well washed with Soap, and examined with but an indifferent Glass, in the Palm, or upon the Ends and first Joints of the Thumb and Fingers, innumerable little Ridges parallel to each other, of equal Bigness and Distance, will be found; upon which Ridges the *Pores* may be perceived by a very good Eye, lying in Rows, even without a Glass: but, viewed through a good Glass, every *Pore* seems like a little Fountain, with the Sweat standing therein as clear as Rock-Water; and, if wiped away, it will be found immediately to spring up again.

When we consider the Multitude of Orifices all over the Skin, it is reasonable to imagine, that minute Animals, as Fleas, Lice, Gnats, &c. do not with their slender Instruments make new Perforations, but rather thrust or insinuate them into the Vessels of the Skin, and suck out the Blood, or what other Humour is their proper Aliment.

* *Philosopb. Transf.* Numb. 159.

C H A P. XXI.

Of the LOUSE.

THE *Louse* has so transparent a Shell or Skin, that we are able to discover more of what passes within its Body than in most other living Creatures; which renders it a delightful Object for the Microscope.

It has naturally three * Divisions, namely, the Head, the Breast, and the Belly or Tail-part.—In the Head appear two fine black Eyes, with a Horn that has five Joints, and is surrounded with Hairs, standing before each Eye; from the End of the Nose or Snout there is a pointed projecting Part, serving for a Sheath or Case to a Sucker, or Piercer, which the Creature thrusts into the Skin, to draw out the Blood or Humours it feeds on, as it hath no Mouth that opens: This Piercer, or Sucker, is judged to be † seven hundred times slenderer than a Hair; is contained in another Case within the first, and can be thrust out or drawn in at Pleasure.

The Breast is marked very prettily in the Middle, the Skin thereof transparent, and

* Vid. SWAMMERD, *Hist. Generale des Insectes*, p. 174.

† Vid. *Arc. Nat.* Tom. II. p. 74.

full of little Pits. From the under Part of it proceed six Legs, each having five Joints, their Skin resembling Shagreen, except towards the Ends, where it appears smoother. Each Leg terminates in two hooked Claws of unequal Length and Size, which it uses as we would a Thumb and middle Finger. There are * Hairs between these Claws, as well as over all the Legs.

On the Back of the Tail-part we may discern some † Ring-like Divisions, Abundance of Hairs, and a Sort of Marks that look like the Strokes of a Rod on one that has been whipt. The Skin of the Belly seems like Shagreen, and towards the lower End is clear, and full of little Pits; at the Extremity of the Tail are two little semi-circular Parts, covered all over with Hairs, which serve to conceal the Anus.

When the *Louse* moves its Legs, the Motion of the Muscles (which all unite in an oblong dark Spot in the Middle of its Breast) may be distinguished perfectly: and so may the Motion of the Muscles in the Head be when it moves its Horns. The Motion of the Muscles is also visible in the several Articulations of the Legs. We may likewise see the various Ramifications of the

* Vide SWAMMERD, p. 175.

† Vide *Philosopb. Transf.* Numb. 102.

Veins and Arteries (which are white) with the Pulse regularly beating in the Arteries. But the most surprizing of all is, the peristaltic Motion of the Intestines, continued from the Stomach along all the Guts down to the Anus.

If a *Louse*, when very hungry, be placed on the Back of the Hand, it will thrust its Sucker into the Skin, and the Blood may be seen passing in a fine Stream to the Fore-Part of the Head; where falling into a roundish Cavity, it passes again, in a like Stream, to another circular Receptacle in the Middle of the Head; from thence thro' a smaller Vessel to the Breast; and then to a Gut that reaches to the hinder Part of the Body, where in a Curve it turns a little upwards.—In the Breast and Gut the Blood is without Intermiſſion moved with great Force, especially in the Gut; and that with such a strong Propulsion downwards, and such a Contraction of the Gut, as is amazing: which continual and strong Action of the Stomach and Bowels upon the Food of this Creature, to further its Digestion, is worthy to be considered.—In the upper Part of the crooked ascending Gut just mentioned, the propelled Blood stands still, and seems to undergo a Separation: some of it becoming clear and waterish, while certain
little

little black Particles pass downwards to the Anus *.

If a *Louse* be placed on its Back †, two bloody darkish Spots appear; the larger in the Middle of the Body, and the lesser towards the Tail. In the larger Spot a white Film or Bladder contracts and dilates upwards and downwards from the Head towards the Tail; the Pulse of which is followed by a Pulse of the dark bloody Spot, in or over which the white Bladder seems to lie. This Motion of Systole and Diastole is seen best when the *Louse* grows weak. The white pulsing Bladder seems to be the Heart, for on pricking it the *Louse* instantly dies. In a large *Louse* the Pulsation may be seen in the Back, but the white Film not without turning the Belly upwards. The lower darkish Spot Dr. HARVEY conjectured to be the Excrements in the Guts.

Lice are not *Hermaphrodites*, as has erroneously been imagined, but Male and Female. Mr. LEEUWENHOEK discovered that the Males have ‡ Stings in their Tails, but the Females none: and supposes the smarting Pain they sometimes give arises from their Stinging, when made uneasy by

* Vid. *Philosoph. Transact.* Numb. 102.

† Vid. Dr. POWER's *Observ.* 9.

‡ *Arc. Nat.* Tom. II. p. 77.

Pressure or otherwise; since, if roughly handled, they may be seen to thrust out their Stings; and as he felt little Pain or Uneasiness in the Sucker, or Piercer, though seven or eight were feeding on his Hand at once. The Females lay Eggs or Nits, whence *young Lice* come forth, perfect in all their Members, and undergo no farther Change but an Increase of Size.

Mr. LEEUWENHOEK, being desirous to learn the Proportion and Time of their Increase, put two * Females into a black Stocking, which he wore both Night and Day; and found that in six Days one of them had laid fifty Eggs, and upon dissecting it, saw as many more in the Ovary; whence he concludes, that in twelve Days it would have laid an hundred Eggs. These Eggs hatching in six Days (which he found to be their natural Time) would probably produce fifty Males and as many Females: and these Females coming to full Growth in eighteen Days, might each of them be supposed, after twelve Days more, to lay also an hundred Eggs; which Eggs in six Days farther (the Time required to hatch them) might produce a younger Brood of five thousand †. So that in eight Weeks a *Louse* may see five thousand of its own Descendants; an

* *Arcan. Nat.* Tom. I. p. 78,

† *Ibid.*

Increase hardly credible, were it not proved by Experience.

A *Louse* may be dissected easily in a small Drop of Water, upon a Slip of Glass that can be applied to the *Microscope*; but without Water the Parts are very difficult to divide, and when separated shrivel and dry up immediately. Thus five or six Eggs of a full Size, and ready to be laid, may be found in the Ovary of a Female, with sixty or seventy of different Sizes, but all much more minute, as the Eggs are in the Ovary of a Hen. In the Male the Penis is remarkable, and also the Testes, whereof it has a double Pair; the Sting likewise deserves a curious Examination. These Creatures avoid the Light as much as possible, and are impatient of Cold. The Females, if fasting, appear very white, and even after feeding seem less red than the Males, the Blood not appearing so plainly through their Vessels, from the Multitude of their Eggs.

The Picture of the *common Louse* is given Plate XIII. Fig. IV.

Its Piercer or Sucker is shewn by *a*.

The Sting of the Male by *b*.

There is another Kind of *Louse* found about uncleanly People, which, from its Shape, is called the *Crab-Louse*. The Vermin adhering to and feeding on the Bodies of different Animals, though much unlike
in

in Form and Size, are also commonly called *Lice*. Of these there are numberless Species, several whereof we are obliged to Seignor REDI for giving us the Drawings of, at the End of his Treatise *de Generatione Insectorum*, whence Mr. ALBIN has taken them into his *Book of Spiders*: but few of these have been sufficiently examined by the *Microscope*, and there are great Variety of other Kinds that are yet quite unknown.

Even Insects are infested with Vermin that feed on them and torment them. A Sort of Beetle, known by the Name of the *Lousy Beetle*, is remarkable for Numbers of little Creatures that run about it nimbly from Place to Place, but will not be shaken off. Some other Beetles have Lice also, but of different Kinds.

The *Earwig* is troubled frequently with minute Insects, especially just under the setting-on its Head. They are white and shining like Mites, but much smaller: they are round-backed, flat-bellied, and have long Legs, particularly the two foremost. The same has not been observed on any other Animal.

Snails of all Kinds, but chiefly the large ones without Shells, have many little Insects, extremely nimble, that live and feed upon them.

Numbers of little *red Lice*, with a very small Head, and in Shape resembling a Tortoise,

toise, are often to be seen about the Legs of Spiders. Whilst the Spider lives they cling closely to it, but if it dies they leave it.

Whitish Lice are frequently to be discovered running very nimbly on Humble-Bees: I have seen them frequently on Ants: many Kinds are discoverable on Fishes: KIRCHER says he has found Lice on Fleas; and probably very few Creatures are free from them.

As some may be desirous to know what Kinds of *Lice* * Signor REDI has observed and given *Drawings* of, the following List is inserted to satisfy their Curiosity. Lice found on the Hawk, three Sorts: on the large Pigeon, the Turtle-Dove, the Hen, the Starling, the Crane: on the Moor-Hen three Sorts: on the Magpie, the Heron, the lesser Heron, the Swan, the Turkish Duck, the Sea-Mew, the smaller Swan: on the wild Goose two Sorts: on the Teal, the Kestrel, the Peacock, the white Peacock, the Capon, the Crow, the white Starling: on Sweetmeats and Drugs: on Men two Sorts, namely, the *common Louse* and the

* REDI calls the Vermin on Beasts *Pediculi*, or *Lice*; those on Birds *Pulices*, or *Fleas*. He says every Kind of Bird has its particular Sort of *Fleas*, different from those of other Birds: that all when first hatched are white, but gradually acquire a Colour like the Feathers they live among; yet remain transparent enough for a good *Microscope* to discover the Motions of their Intestines: that the *Crane* has a white Sort, marked as it were with *Arabic Characters*: and that their Size is not proportioned to the Birds they breed upon, for the little *Black-Bird* has *Fleas* as large as the *Swan*.

Crab-Louse: on the Goat, the Camel, the
† *Ass*, the *African Ram*, the *African Hen*:
on the Stag two Sorts, and on the ‡ *Tiger*.

C H A P. XXII.

Of the WOOD-LOUSE.

There is a little Animal, in Shape and Colour like a Louse, that runs swiftly by Starts or Stops, and is commonly found on the Leaves and Covers of Books, or amongst rotten Wood: it is called a *Wood-Louse*, or *Wood-Mite*, and is known almost to every body. The Eyes of this Creature are of a golden Colour, and can be drawn in or thrust out at Pleasure; the peristaltic Motion of the Bowels appears in it distinctly, and, what is still more wonderful, a Motion of the Brain is seen.

I take this to be the Animal Mr. DERHAM calls the *Pediculus Pulsatorius*, or *Death-Watch* (in *Phil. Trans.* Numb. 291.) where he says the *Pediculus Pulsatorius* and the *Scarabæus Sonicephalus* are the only two Insects that make regular clicking Noises like the Beat of a Pocket-Watch.

† ARISTOTLE in his *History of Animals*, and PLINY on his Authority, assert, that *Asses* and *Sheep* are free from Vermin: but REDI proves they are both mistaken as to the *Ass*; and as to the *Sheep*, every Shepherd-Boy is able to confute them.

‡ The *Louse* of a *Lion*, resembles that of the *Tiger* in Shape, but is larger, and of a brighter red. Vid. REDI *Experim. circa Generat. Insect.* p. 312. & seq.

C H A P. XXIII.

Of M I T E S.

BY *Mites* are commonly understood the minute Creatures found in great Abundance in Cheese that is decaying. To the naked Eye they appear like moving Particles of Dust; but the *Microscope* discovers them to be Animals perfect in all their Members, having as regular a Figure, and performing all the necessary Offices of Life in as orderly a Manner, as Creatures that exceed them many millions of Times in Bulk.

They are crustaceous * Animals, and usually transparent. The principal Parts of them are, the Head, the Neck, and Body. The Head is small in Proportion to the Body, with a sharp Snout, and a Mouth that opens and shuts like a Mole's. They have two little Eyes, and are extremely quick-sighted; for if you touch them once with a Pin or other Instrument, you'll perceive how readily they avoid a second Touch. Some have six Legs, and others eight; which proves them of different Sorts, tho' in every respect besides they appear alike. Each Leg has six Joints, surrounded with Hairs, and two little

* Vid. POWER'S Observ. Hook's Microgr. p. 214.

Claws at the Extremity thereof, which can easily take up any thing. The hinder Part of the Body is plump and bulky, and ends in an oval Form, with a few exceeding long Hairs issuing therefrom. Other Parts of the Body and Head are also thinly beset with long Hairs.

These Creatures are Male and Female. The Female lay Eggs; whence (as in Lice and Spiders) the young ones issue forth with all their Members perfect, though most exceedingly minute: but, notwithstanding their Shape does not alter, they cast their Skins several Times before they attain their full Growth.

They may be kept alive many Months between two concave Glasses, and applied to the Microscope at Pleasure; and by often looking at them, many curious Particulars will be discovered. They may thus frequently be seen *in Coitu**, conjoined Tail to Tail; for though the Penis of the Male be in the Middle of the Belly, it turns backwards like that of the *Rhinoceros*. The Coitus is performed with an incredibly swift Motion. Their Eggs in warm Weather hatch in twelve or fourteen Days; but in Wintertime, and cold Weather, not under several

* Vide *Arc. Nat.* Tom. IV. p. 360.

Weeks. It is not uncommon to see the young ones struggling to get clear of the Egg-shell, which sometimes they are a Day about.

The Diameter of a *Mite's* Egg seems equal to the * Diameter of the Hair of a Man's Head; and six hundred such Hairs are about equal to the Length of an Inch. Supposing then a Pigeon's Egg is three Quarters of an Inch in Diameter, four hundred and fifty Diameters of a *Mite's* Egg are but equal to the Diameter of the Egg of a Pigeon; and consequently, if their Figures be alike, we must conclude that ninety-one millions an hundred and twenty thousand Eggs of a *Mite* are not larger than one Pigeon's Egg.

Mites are most voracious Animals; for they devour not only Cheese, but likewise all Sorts of dried Fish or Flesh, dried Fruits, Grain of all Sorts, and almost every thing besides that has a certain Degree of Moisture without being over-wet: nay, they may often be observed preying upon one another. In eating, they thrust one Jaw forwards and the other backwards alternately, whereby they appear to grind their Food; and after they have done feeding, they seem to munch and chew the Cud.

* *Phil. Transf.* Numb. 333. & 284.

These are the Vermin that find a Way into the Cabinets of the Curious, and eat up their fine *Butterflies* and other choice *Insects*, leaving nothing in their Stead but Dust and Ruins. The best Method of preventing this is, to keep the Drawers or Boxes continually supplied with *Camphire*, whose hot and dry Effluvia penetrate, shrivel up, and destroy the tender Bodies of these little mischievous Plunderers.

It must however be remembered, that there are several Species of *Mites*, which differ in some Particulars, though their general Figure and the Nature of them be the same. For Instance, the *Mites* * in Malt-Dust and Oatmeal-Dust are nimbler than *Cheese-Mites*, and have more and longer Hairs. The *Mites* amongst Figs resemble Scarabs, have two Feelers at the Snout, and two very long Horns over them, with three Legs only on each Side, and are more sluggish than those in Malt. Mr. LEEUWENHOEK observed some *Mites* on Figs to have longer Hairs than he had seen on any other Sorts; and upon Examination found those Hairs were spicated, or had other little Hairs issuing from their Sides: whence he imagined they might be jointed at the little Distance where these Hairs come forth. He

* Vide POWER's *Observ.* p. 10.

had also seen the like Hairs on other *Mites*, though very seldom. Mr. HOOK describes a Sort of these Animals, which he terms *wandering Mites* *, as being to be found in every Place almost where they can get Food.

Happening some Years ago to look into an empty white Gallipot, I fancied it was dusty ; but, on a nearer View, perceiving the Particles to move, I examined them by the *Microscope*, and discovered what I had taken for Dust to be Swarms of these *wandering Mites*, which were tempted and brought thither by the Smell of some *Caviere* that had been in the Gallipot a few Days before.

The *Mite* is exceedingly tenacious of Life ; I have kept them in my Glasses Months together, even without Food ; and Mr. LEEUWENHOEK says, one he stuck upon a Pin before his *Microscope* † lived in that Condition eleven Weeks.

The Picture of the *Mite* is shewn Plate XIII. Fig. V.

One of its Eggs appears just by, at *a*.

* Hook's *Microg.* p. 205.

† *Arc. Nat.* Tom. IV. pag. 363.

C H A P. XXIV.

Of the FLEA.

THIS well-known little Creature is covered all over with black hard shelly Scales, Plates, or Divisions, curiously jointed, and folded over one another in such a Manner as to comply with all the nimble Motions and Activity of the Animal. The Scales are curiously polished, and beset about the Edges with long Spikes, in the most beautiful and regular Order possible. Its Neck is finely arched, and much resembles the Form of a Lobster's Tail. The Head is very extraordinary; for from the Snout-part thereof proceed its two Fore-Legs, and between them lies the Piercer or Sucker wherewith it penetrates the Skin of other living Creatures and draws out its Food. It has two large beautiful black Eyes, and a Pair of little Horns or Feelers. Four other Legs are joined on at the Breast, so that it has six in all; which, when it leaps, fold short one within another, and, exerting their Spring all at the same Instant, carry the Creature to a surprising Distance. The Legs have many Joints, are very hairy, and terminate in two long sharp hooked Claws, as may be seen Fig. VI. Plate XIII.

The *Flea's* Piercer or Sucker is lodged between its Fore-Legs, and includes a Couple of Darts or Lancets, which, after the Piercer has made an Entrance *, are probably thrust farther into the Flesh, to make the Blood flow from the adjacent Parts, that it may be sucked up; and seems to occasion that round red Spot, with a Hole in the Center of it, which we commonly call a *Flea-Bite*. This Piercer, its Sheath opening sideways, and the two Lancets within it, are very difficult to be seen, † unless the two Fore-Legs, between which they are usually folded in and concealed from View, be cut off close to the Head: for a *Flea* rarely puts out its Piercer except at the Time of Feeding, but on the contrary keeps it closely folded inwards: the best Way therefore of coming at it is, by cutting of the Head first, and then the Fore-Legs; since in the Agonies of Death it may easily be managed, and brought before the *Microscope*.

Fleas are Male and Female, and lay Eggs as well as *Lice* and *Mites*; but are extremely different in all the Progress of their Lives besides, passing thro' the same Changes exactly as the *Silkworm* does. They deposit their Eggs at the Roots of the Hair of Cats, Dogs,

* Vide *Art. Nat. detect.* Tom. IV. p. 22.

† Ibid. p. 332. *Phil. Trans.* Numb. 249.

and other Animals, sticking them fast there-to by a Kind of glutinous Moisture. When the Eggs hatch, not perfect *Fleas*, but little Worms or Maggots, whose Bodies have several annular Divisions thinly covered with long Hairs, come out of them, and feed on the Juices of the Animal, whereto they closely adhere *. These Maggots are very brisk and nimble; but if touched, or under any Fear, roll themselves up on a sudden in a round Figure, and continue motionless for some Time; after which they slowly open themselves and crawl away, as Caterpillars do, with a lively and swift Motion.

When the Time of their Change approaches, they conceal themselves as much as possible; eat nothing, lie quiet, and seem as if dying: but if viewed with the *Microscope*, will be found, with the Silk or Web that comes out of their Mouth, weaving a Covering or Bag round them, whose Inside is as white as Paper, though without it always appears soiled with Dirt. In this Bag they put on the *Chrysalis* or *Aurelia* Form, and become Milk-white: but two or three Days before they break from this Prison, their Colour darkens, they acquire Firmness and Strength, and as soon as they issue from the Bag are perfect *Fleas*, and able to leap away.

* *Phil. Transf.* Numb. 249.

It has been discovered, by putting the Eggs of *Fleas* in a small Glass Tube, and keeping it constantly warm in one's Bosom, that, in the midst of Summer, they hatch in four Days: then, feeding the Maggots with dead Flies, which they suck greedily, in eleven Days they come to the full Perfection of their reptile State: when the Maggot spins its Bag, and in four Days more changes into a *Chrysalis*; after lying in which Condition nine Days, it becomes a *perfect Flea*. It is then immediately capable of Coition, and in three or four Days lays Eggs. So that in * twenty-eight Days a *Flea* may come from the Egg itself, and propagate its Kind: and their vast Increase will not seem so great a Wonder, if we consider, that from *March* to *December* there may be seven or eight Generations of them. After having laid their Eggs they soon die, as all Creatures do that undergo such like Changes.

By keeping *Fleas* in a Glass Tube corked at both Ends, but so as to admit fresh Air, their several Actions may be observed, and particularly their Way of coupling, which is performed Tail to Tail, the Female (which is much the larger) standing over the Male. They will also be seen to lay their Eggs, not all at once, but ten or twelve in a Day for

* Vid. *Art. Nat.* Tom. IV. p. 325.

several Days successively ; which Eggs hatch in the same Order.

A Dissection of the Flea may be effected after the same Method as that of the *Louse*, that is, in Water : the * Stomach and Bowels, with their peristaltic Motion, may plainly be distinguished, and also the † Testes and Penis, together with Veins and Arteries minute beyond Conception. LEEUWEN-HOEK affirms, that he has likewise discovered innumerable Animalcules shaped like Serpents in the *Semen masculinum* of a Flea.

Two Things in this Creature deserve our Consideration, to wit, its surprising Agility, and its prodigious Strength, whereby it is enabled to leap above an hundred Times its own Length ; as has been proved by Experiments. What vigorous Muscles ! and how weak and sluggish, in Proportion to its own Bulk, is the Horse, the Camel, or the Elephant, if compared with this puny Insect !

A Flea's Egg is shown Plate XIII. Fig. VI. 1.

The *Worm* or *Maggot* proceeding from it, Fig. VI. 2.

* Vid. *Arc. Nat.* Tom. IV. p. 20.

† Again, pag. 335.

C H A P. XXV.

Of SPIDERS.

EVERY body is so well acquainted with the general Form of a *Spider*, even without the Assistance of a *Microscope*, that I shall spend no Time in the Description of it; but proceed to give an Account of some Particulars in this Animal which are discoverable only by that Instrument.

As a Fly (the *Spider's* natural Prey) is extremely cautious and nimble, and comes usually from above, it was necessary the *Spider* should be furnished with a quick Sight, and an Ability of looking upwards, forwards, and sideways, at the same Time: and the *Microscope* shews, that the Number, Structure, and Disposition of its Eyes are wonderfully adapted to serve all these Purposes.

Most *Spiders* have eight Eyes*: two on the Top of the Head or Body (for there is no Division between them, a *Spider* having no Neck) that look directly upwards; two others in Front, a little below these, to discover all that passes forwards; and on each Side a couple more, one whereof points side-

* N. B. *Spiders* Eyes art not pearled.

ways forwards, and the other sideways backwards: so that it can see almost quite round it. All Kinds of them have not, indeed, a like Number of Eyes; for we find ten in some, in others only eight, six, or four; and in the *Field*, *Long-Legs*, or *Shepherd-Spider*, no more than two. But whatever the Number be, they are immoveable and transparent; are situated in a most curious Manner, and deserve the strictest Examination. The best Way of viewing them is, to cut off the Legs and Tail, and bring only the Head-part before the *Microscope*.

All *Spiders* have eight Legs, which they employ in walking, and two Arms or shorter Legs near the Mouth, that assist in taking their Prey. They appear thickly beset with Hair, have each six Joints, and end with two hooked Claws, ferrated, or having Teeth like a Saw on their Inside, whereby they cling fast to any thing; and at a little Distance from these Claws a Sort of Spur stands out, without any Teeth at all. See Fig. VII. Plate XIII.

But the dreadful Weapons wherewith the *Spider* seizes and kills its Prey are a Pair of sharp crooked Claws or Forceps (by some, tho' very improperly, called Stings), in the Fore-part of its Head. The *Scolopendra*, or *Indian Millepes*, and several other Insects, have Weapons of the like Form, and
serving

serving to the same Purpose. These Claws or Pincers stand horizontally; and are, when not made use of, concealed in two Cases contrived for their Reception: into which they fold like a Clasp-knife, and there lie between two Rows of Teeth, that are likewise employed to hold fast its Prey. This Apparatus is better shewn than described: See Fig. VIII.

Mr. LEEUWENHOEK informs us, * that each of these Claws or Pincers has a small Aperture or Slit near its Point, as in a Viper's Tooth; thro' which he supposes a poisonous Juice is injected into the Wound it makes, occasioning Death to Flies and other Insects. But Dr. MEAD, in his most excellent *Essay on Poisons*, believes this to be a great Mistake; having not been able to discern any Exit or Opening, tho' he viewed these Parts several Times with a very good *Microscope*. And he was the more confirmed in this Opinion, by examining a Claw of the great *American Spider*, described by PISO, and called *Nhamdu*, given him by Mr. PETIVER; which being about fifty Times bigger than that of any *European Spider*, if there had been any Slit in it, he doubted not his Glass would have discovered it; but yet he found it to be quite solid. Besides,

* Vid. *Arc. Nat.* Tom. IV. Par. II. p. 319.

“ after

“ after repeated Trials, he plainly saw that
“ nothing dropped out of the Claws, which
“ were always dry while the *Spider* bit ; but
“ that a short white Proboscis was at the
“ same Time thrust out of the Mouth, which
“ instilled a Liquor into the Wound.” And
he farther observes, “ that the Quantity of
“ Liquor emitted by our common Spiders,
“ when they kill their Prey, is visibly so
“ great, and the wounding Weapons so
“ minute, that they could contain but a
“ very inconsiderable Portion thereof, if it
“ were to be discharged that Way.”

Spiders frequently cast their Skins, which may be found in Cobwebs, perfectly dry and transparent ; and from such Skins the Forceps or Claws (for they are always shed with the Skin) may easier be separated, and examined with more Exactness, than in a living *Spider* : for they commonly appear spread out fairly to View, and, by their Transparency, every minute Part is seen with much Distinctness. But neither this Way, nor any other, have I been ever able to discern the Aperture Mr. LEEUWENHOEK speaks of.

The Contexture of the Webs of *Spiders*, and their Manner of weaving them, are farther Discoveries of the *Microscope* ; for that informs us, that the *Spider* has five little
Teats

Teats or Nipples near the Extremity of the Tail, whence a gummy Liquor proceeds; which adheres to any thing it is pressed against; and being drawn out, hardens instantly in the Air, and becomes a String or Thread, strong enough to bear five or six Times the Weight of the *Spider's* Body. This Thread is composed of several finer ones that are drawn out separately, but unite together two or three Hairs Breadth distant from the Body of the *Spider*. The Threads are finer or coarser, according to the Bigness of the *Spider* that spins them. Mr. LEEUWENHOEK computes, that an hundred of the finest Threads of a *full-grown Spider* are not equal to the Diameter of the Hair of his Beard; and, consequently, if the Threads and the Hair be round, ten thousand such Threads are not bigger than such an Hair. He calculated farther, that when *young Spiders* first begin to spin, four hundred of them are not larger than one that is full-grown; and therefore the Thread of such a little *Spider* is smaller by four hundred Times than the Thread of a full-grown one: allowing which, four Millions of a young *Spider's* Threads are not so big as the single Hair of a Man's Beard *.

* *Phil. Transf.* Numb. 272.

The Eggs of some *Spiders* are very pleasant Objects, being round at one End and flattish at the other, with a Depression in the Center of the flattish End, and a yellowish Circle round it. Their Colour is a blueish White, like counterfeited Pearl; and when they hatch, the *little Spiders* come out perfectly formed, and run about very nimbly. The Female deposits her Eggs, to the Number of five or six hundred, in a Bag strongly composed of her own Web, which she either carries under her Belly, and guards with the greatest Care, or else hides in some safe Recess. As soon as the Eggs are hatched, the minute *Spiders* appear very agreeably in the *Microscope*.

It has been before observed, that the Current of the Blood may be seen in the Legs and Body of this Creature; and the judicious Observer will discover many other Wonders in the Dissection and Examination of its several Parts, which it would be tiresome for me to dwell on here. I cannot, however, conclude this Head without pointing out two or three Kinds of *Spiders* as particularly worth Notice.

There is a little *white Field Spider*, with short Legs, found plentifully among new Hay, whose Body appears like white Amber, with black Knobs, out of each where-
of

of grow Prickles like Whin-Pricks. Some have fix, some eight Eyes, that may be distinctly seen, quick and lively: each Eye has a Violet-blue Pupil, clear and admirable, furrounded by a pale yellow Circle *.

The *wandering* or † *hunting Spider*, who spins no Web, but runs and leaps by Fits, has two Tufts of Feathers fixt to its Fore-Paws, which well deserve being placed before the *Microscope*: the Variety and Beauty of Colouring all over this little Creature afford likewise a most delightful View.

The ‡ *Long-Legs, Field, or Shepherd-Spider* is a most wonderful Creature: It has two Fore-Claws at a great Distance from the Head, tipped with Black like a Crab's, that open and shut in the Manner of a Scorpion's, and are Saw-like, or indented, on the Inside.—Cut all the Legs from this *Spider*, and place it before the *Microscope*, and you will discover, that the Protuberance on the Top of the Back is furnished with two fine Jet-black Eyes.

The little *red Spider* that creeps on the Barks of Trees should also not be neglected.

* Dr. POWER's *Microscop. Observat.* p. 13.

† HOOK's *Microg.* p. 200.

‡ Ibid. p. 14.

C H A P. XXVI.

Of the G N A T.

THE Production of this Creature is from an *Egg*, deposited by its Parent upon the Waters, which first becomes a *Worm* or *Maggot*, then a very odd *aquatic Animal* (described page 88.) and afterwards a *Gnat*.

The particular Beauties of it cannot possibly be discovered without the *Microscope*; but by the Assistance of that Instrument, it appears to be adorned by Nature in a more extraordinary Manner than most other living Creatures are. Its Tail-part is covered over with Feathers, most exquisitely disposed in Rows of different Colours, but yet perfectly transparent. The Breast * (which is crustaceous) is bedecked with little stiff Hairs or Bristles, instead of Feathers; and from thence six hairy Legs proceed, with six Joints to each, and at the End two little Claws. The Feet are all over feathered in a Manner resembling the Scales of Fishes, with Abundance of little black Hairs amongst them, appearing stubborn like Hogs Bristles. Its Wings are encompassed with a Furbelow of long Feathers: and the Veins or Ribs that

* SWAMMERD. *Hist. Generale des Insectes*, p. 108.

serve to strengthen them are also either feathered or scaled. Between these Ribs an exceeding thin transparent Membrane is extended, full of little black sharp-pointed Hairs, that are ranged every where with the utmost Regularity. But as there are * different Sorts of Gnats, their Wings are also very different, some having a Border of long Feathers, others of short ones, and others none at all: the Rib-work of the Wings, likewise, in some is feathered, in some scaled, and in some beset with Prickles.

But the most wonderful Part of this Creature is its Head; as it contains the Horns, the Sting or Sucker, and the Eyes. The Horns of the *brush-horned* or *Male Gnat* are a most charming Object: it has two Pair, one whereof is surrounded, at little Distances, with long Hairs issuing out circularly; each Circle lessening more than other as it stands nearer the Extremity of the Horns: and the Whole together exactly representing the Figure of the Plant called *Equisetum* or *Horse-tail*. The other Pair is longer and much thicker than the foregoing, and hairy from End to End. In the *great-bellied* or *Female Gnat*, the first Pair of Horns, though of the

* MR. DERHAM observed near forty different Species of Gnats about the Place where he lived, which was *Upminster* in *Essex*. Vide *Physico-Theology*, p. 378.

same Figure as the Male's, has Hairs not near so long, and the second Pair is shorter than the first by at least three Parts in four.

The *Piercer*, *Sting*, or *Sucker*, is a Case covered with long Scales, that lies concealed under the * *Gnat's* Throat when not made use of. The Side opens, and four Darts are thrust out thence occasionally; one whereof (minute as it is) serves for a Sheath to the other three. The Sides of them are extremely sharp, and they are barbed or indented towards the Point, whose Fineness is inexpressible, and scarcely to be discerned by the greatest Magnifier. When these Darts are thrust into the Flesh of Animals, either successively or in Conjunction, the Blood and Humours of the adjacent Parts must flow to and cause a Tumour about the Wound, whose little Orifice being closed up by the Compression of the external Air, can afford them no Outlet. When a *Gnat* finds any tender juicy Fruits or Liquors, she sucks up what she likes through the outer Case, without using the Darts at all: but if it is Flesh that resists her Efforts, she stings very severely, then sheaths her Weapons in their Scabbard, and through them sucks up the Juices she finds there. The Pain they cause

* Vide *Hist. of Nat. Eng.* 12mo. Edit. Vol. I. p. 124.

is only while they are entering, and continues not when the *Gnat* is sucking: nor is its Stinging out of Revenge, but from mere Necessity to obtain a proper Sustenance.

The *Gnat's* four Darts are shewn Plate XIII. Fig. IX. *a. b. c. d.*

A *Gnat's* Eyes, which form the greatest Part of its Head, are pearled, or composed of many Rows of little semicircular Protuberances ranged with the utmost Exactitude. What these Protuberances are, and the Purposes whereto they serve, will be explained when we come to treat of the *Eyes* of *Insects*.

The Motion of the Itneftines may be seen in the transparent Parts of this Animal; and upon Dissection many curious Discoveries may be made. Mr. LEEUWENHOEK says, he found in the * *Semen* of the Male numberless *Animalcules* smaller than those in Fleas, and in the Female a surprizing Quantity of Eggs. And, indeed, the Spawn of this Insect is amazingly great in Proportion to its Size, being seen floating on the Waters (though always fastened to something to prevent its swimming away) sometimes above an Inch in Length, and half a quarter in Diameter; the Eggs (each of which has a little

* LEEUWEN. *Arc. Nat.* Tom. IV. p. 22.

black Speck) being placed in exact Order, and kept together by a Sort of Jelly or glewy Matter, which the minute Maggots, when hatched, carry down with them to the Bottom, and thereby cement together the small Particles of Earth or Sand that form their Cells or Cafes.

C H A P. XXVII.

Of the OX-FLY, or GAD-BEE.

ANOTHER Creature that undergoes a like Change, is the *Ox-Fly*, *Dun-Fly*, or *Gad-Bee*, an Insect very troublesome to Cows and Horses.

This, like the Gnat, has a long Proboscis, with a sharp Dart or Darts sheathed therein. The Use of these Darts is to penetrate the Flesh of Animals, and feed on their Blood; whereas the Proboscis can only serve to suck the Juices, Honies, or Dews, from Fruits, Flowers, or the Leaves of Plants: and Providence seems to have kindly furnished it with this two-fold Instrument, that if one Sort of Provision fails it may be able to subsist on the other. It is worth Enquiry, whether *Lice*, *Fleas*, *House-Bugs*, &c. are not also provided for the same Purpose.

The Eggs of this Insect are deposited in the Waters, and produce an extraordinary Kind of little *Worm* or *Maggot*, the Extremity of whose Tail is incircled with moveable Hairs, which, being expanded on the Surface of the Water, enable it to float along, as * in Plate VII. Fig. XIII. *a*. When it would descend towards the Bottom, these Hairs are made to approach each other in an oval Form, and inclose a little Bubble of Air; by Means whereof it is able to rise again: and if this Bubble escapes, as sometimes it will, the Insect immediately squeezes out of its own Body another like Bubble to supply the Place thereof. The *Maggot*, as descending, is shewn Fig. XIII. *b*. Its Snout has three Divisions, whence three little pointed Bodies are thrust out, in continual Motion, like the Tongues of Serpents.

These *Maggots* are frequently to be met with in Water taken from the Surface of Ditches. The Motion of their Intestines is perfectly singular and distinguishable, and they are Objects well deserving our particular Observation.

* Vid. SWAMMERD. *Hist. Generale des Insectes*, p. 148.

C H A P. XXVIII.

Of the STINGS of INSECTS.

THE *sharp* and *penetrating Instruments* wherewith the Tails of Bees, Wasps, Hornets, Ants, and some other Insects are armed, I distinguish by the Name of *Stings*; being Weapons given them by Nature to defend themselves and offend their Enemies: whereas the *Trunk* or *Proboscis* which Gnats, Fleas, Lice, and many other Kinds carry in their Mouth, though it may be equally sharp, is not intended as an Instrument of Revenge, but for procuring and sucking in their Food; and therefore when such Creatures bite or sting us, as we term it, we must not imagine they do so out of Anger, but from Necessity. Squeeze or strike a Bee or Wasp, it instantly puts forth its *Sting*; but no Provocation can urge a Flea or Gnat to bite: on the contrary, when disturbed or hurt, they draw in their *Proboscis* instead of thrusting it out, and never make use of it but when they think themselves perfectly safe and quiet. There is besides this farther Difference: a *Sting injects* a venomous Liquor into the Wound it makes; but a *Proboscis sucks* or *draws out* the Blood and Humours from it.

As the Structure and Contrivance of most Stings are nearly alike, by describing one the rest will be understood. I shall, therefore, give a brief Account of the *Sting* of a *Bee*, as discovered by the *Microscope*.

C H A P. XXIX.

Of a BEE'S STING.

THE *Sting* of a *Bee* is a horny Sheath or Scabbard that includes two bearded Darts. This Sheath ends in a sharp Point: near the Extremity whereof a Slit opens, through which, at the Time of Stinging, two *bearded Darts* are protruded beyond the End of the Sheath; one whereof, being a little longer than the other, fixes its Beard first; but the other instantly following, they penetrate alternately deeper and deeper, taking hold of the Flesh with their Hooks, till the whole Sting becomes buried in the Wound: and then a venomous Juice is injected, thro' the same Sheath, from a little Bag at the Root of the Sting, which occasions an acute Pain, and a Swelling of the Part, continuing sometimes several Days. This is best prevented by enlarging the Wound immediately, to give it some Discharge.

The two Darts lie within the *Sting*, as in Plate XIII. Fig. X. *a*.

When thrust out, they appear as in Fig. X. *b*.

Mr. DERHAM says, he counted in the *Sting* of a *Wasp* eight Beards on the Side of each Dart, somewhat like the Beards of Fish-hooks; and I have observed the same Number in that of a *Bee*. When these Beards are struck deep in the Flesh, if the wounded Person starts before the *Bee* can disengage them, she leaves her *Sting* behind sticking in the Wound: but if he has Patience to stand quiet till she brings the Hooks close down to the Side of the Darts, she withdraws her Weapon, and the Wound becomes much less painful. A *Wasp* is not so liable as a *Bee* to leave its *Sting* behind, the Beards of it being rather shorter, and the Animal stronger and more nimble*.

To view the *Sting* of a *Bee* by the *Microscope*, cut off the End of its Tail, and then touching it with a Pin or Needle, it will thrust out the *Sting* and *Darts*, which may be snipt off with a Pair of Scissars and kept for Observation. Also if you catch a *Bee* in a Leather Glove, its *Sting* will be

* Vid. DERHAM's *Phys. Theol.* p. 241. *Spec. de la Nat.* Dial. VI.

Sting * ; which convinced him that *ÆLIAN* says true, where he asserts, that the Perforation in a *Scorpion's Sting* is small beyond the Possibility of being seen. And such a Drop he frequently saw afterwards, in the Progress of his Experiments, on the *Stings* of several *Scorpions*, at the Time of their Striking : which Drop entering the Wound, produced the most fatal Effects †.

What a virulent and surprizing Poison must this be ! that in so very minute a Quantity can contaminate the whole Mass of the Fluids, and bring on sudden Death, not only in Man, and other smaller Creatures, but even in Lions, Camels, and Elephants, as we are assured it will ! How subtle, how penetrating, how divisible, must the component Particles of this little Speck of Venom be ! and how strong a Proof it affords, that the greatest Changes imaginable may be wrought in the human Body, by the Admixture of different Liquors with the Blood even in the smallest Quantities !

* Vid. *REDI de Gener. Insect.* p. 127.

† Mr. *LEEUWENHOEK* discovered an Opening on each Side of the *Sting* for the Emission of this Poison ; which he supposes is not discharged till the *Sting* is buried in the Wound. Vid. *Arc. Nat.* Tom. II. p. 167.

C H A P. XXXI.

Of the POISON of a VIPER.

THE Mischief done by the *Viper*, or any other Serpent, is not effected by Means of a Sting (for what is darted out of its Mouth, and by the Vulgar supposed a Sting, is nothing but the Tongue of the Animal, and perfectly harmless): but its *Teeth* are the dreadful Weapons wherein the Poison lies; and its *Bite* is all we need to fear.

Dr. MEAD, in his most valuable Essay on the *Poison of the Viper*, has described these Teeth and their Poison so much better than it is possible for me to do, that I shall beg Leave to borrow the chief I have to say from him.

The poisonous *Fangs* or great *Teeth* are crooked and bent: they are hollow from the Root a considerable Way up, not to the very Point (which is solid and sharp to penetrate the better), but to within a little Distance of it; as may be seen by splitting a Tooth through the Middle. This Cavity ends in a visible Slit resembling a Nip or Cut of a Pen. See Plate XIII. Fig. XI. The Poison is ejected through this Slit from a Bag at the Root of the Teeth, into which it is discharged by a Duct just behind the Orbit of the Eye, from

from a conglomerated Gland that separates it from the Blood.

The venomous Juice of the *Viper* may be got by enraging it till it bites on something solid. This Juice the Doctor put carefully on a Glass Plate, and examined it by the *Microscope*. Upon the first Sight, he could discover nothing but a Parcel of small Salts nimbly floating in the Liquor: but in a very short Time the Appearance was changed, and those saline Particles were now shot out as it were into Crystals of an incredible Tenuity or Sharpness, with something like Knots, here and there, from which they seemed to proceed: so that the whole Texture did in a Manner represent a Spider's Web, though infinitely finer and more minute; and yet withal so rigid were these pellucid Spicula or Darts, that they remained unaltered upon his Glass for several Months. And, by considering the necessary Effects of such Spicula in the Blood, this learned Physician accounts very reasonably for all the Symptoms usually succeeding the Bite of this Animal.

GALEN says, the *Mountebanks* of his Time used, with some Kind of Paste, to stop the Perforations in the Teeth of *Vipers*, whereby they kept in the Venom; and then would suffer themselves to be bit, pretending their Antidotes prevented any ill Effects.

C H A P.

C H A P. XXXII.

Of the S N A I L.

THE * *Snail* has four Eyes, at the End of optic Nerves, sheathed in her Horns, which she can draw in or thrust out, turn or direct, as she finds most convenient.

When the Horns are out, cut off nimbly the Extremity of one of them, and placing it before the *Microscope*, you may discover the black Spot at the End to be really a *Semiglobular Eye*.

The Dissection of this Animal is very curious; for the *Microscope* does not only shew the Heart beating just against a round Hole near the Neck, which seems the Place of Respiration; but also the Liver, Spleen, Stomach, Veins, Arteries, Guts, Mouth, and Teeth. The Guts are green, from the Creature's eating Herbs, and branched all over with fine capillary white Veins. The Mouth is like a Hare's or Rabbet's, with four or six *Needle-Teeth* resembling those of *Leeches*, and of a Substance like Horn.

Snails are all *Hermaphrodites*, having both Sexes united in each Individual. They lay their Eggs with great Care in the Earth;

* Vide POWER's *Observ.* p. 38. LISTER, *Exerc. Anatom. Cochli.*—*Spect. de la Nature*, Dial. XI.

and the young-ones come out, when hatched, with Shells completely formed, and of a Minuteness proportionable to their own Size. These little Shells enlarge, as the *Snails* advance in Growth, by the Addition of new Circles, of which Circles they always continue to be the Center.

Cutting off a *Snail's* Head, a *little Stone* appears, * which from its diuretic Quality is of singular Service in gravelly Disorders. Immediately under this *Stone* the beating Heart is seen, with its Auricles, which are membranous ; all of a white Colour, as are also the Vessels issuing therefrom. This *little Stone* seems intended to serve instead of a Breast-Bone, which most other Creatures have.

It is very remarkable, that *Snails* discharge their Excrements at an Opening in the Neck, that they breathe there, and that both their Male and Female Parts of Generation are situated near the same Place. The Male Part is very long, and in Shape resembles the *Penis* of a Whale.

* *Vid.* SWAMMERD. *Hist. Generale des Insectes*, p. 77.

C H A P. XXXIII.

Of the common FLY.

THE common *Fly* is adorned with Beauties not to be conceived without a *Microscope*. It is studded from Head to Tail with Silver and Black, and its Body is all over beset with Bristles pointing towards the Tail. The Head of it contains two large Eyes, encircled with Borders of Silver Hairs; a wide Mouth, with an hairy Trunk or Instrument to take in its Food: a Pair of short Horns, several stiff black Bristles, and many other Particulars discoverable by the *Microscope**. Its Trunk consists of two Parts, folding over one another, and sheathed in the Mouth. The Extremity thereof is sharp like a Knife, for the Separation of any thing. The two Parts can also be formed occasionally into a Pair of Lips for taking up proper Quantities of Food; and by the *Fly's* sucking in the Air, they become a Kind of Pump, to draw up the Juices of Fruits or other Liquors.

Some *Flies* are much lighter coloured and more transparent than others, and in such the Motion of the Guts may be seen very

* *Spectacle de la Nat.* Dial. VII.

distinctly, working from the Stomach towards the Anus; and also the Motion of the Lungs, contracting and dilating themselves alternately. Upon opening a *Fly*, numberless Veins may likewise be discovered, dispersed over the Surface of its Intestines: for the Veins being blackish, and the Intestines white, they are plainly visible by the *Microscope*, though two hundred thousand Times slenderer than the Hair of a Man's Beard. According to * Mr. LEEUWENHOEK, the Diameter of four hundred and fifty such minute Veins were about equal to the Diameter of a single Hair of his Beard; and consequently two hundred thousand of them put together would be about the Bigness of such an Hair.

In most Kind of *Flies* the Female is furnished with a moveable Tube at the End of her Tail, by extending of which she can convey her Eggs into convenient Holes and Receptacles, either in Flesh or such other Matters as may afford the young-ones proper Nourishment. From the Eggs come forth minute Worms or Maggots, which after feeding for a while in a voracious Manner, arriving at their full Growth, become transformed into little brown *Aurelias*;

* *Arc. Nat.* Tom. II. p. 77.

whence,

whence, after some Time longer, they issue perfect Flies.

It would be endless to enumerate the different Sorts of *Flies* which may continually be met with in the Meadows, Woods, and Gardens; and impossible to describe their various Plumes and Decorations, surpassing all the Magnificence and Luxury of Dress in the Courts of the greatest Princes. Every curious Observer will find them out himself, and, with Amazement and Adoration, lift up his Eyes from the Creature to the CREATOR.

C H A P. XXXIV.

Of the WEEVIL, or CORN-BEETLE.

THE *Weevil* and the *Wolf* are two Kinds of small Insects that do Abundance of Mischief to many Sorts of Grain, by eating into them and devouring all their Substance.

The *Weevil* is somewhat bigger than a large Louse of the Scarab Kind, with two pretty jointed tufted Horns, and a Trunk or Piercer projecting from the Fore-part of its Head. At the End of the Trunk (which is very long in Proportion to its Body), are a Sort of Forceps or sharp Teeth, wherewith it gnaws its Way into the Heart of the

Q₂

Grain,

Grain, either to seek its Food or deposit its Eggs there.

By keeping these Creatures in Glass Tubes, with some few Grains of Wheat, their Copulation has been discovered, and likewise their Manner of Generation, which is thus.—* The Female perforates a Grain of Wheat, and therein deposits a single oblong Egg, or two Eggs at most (a Grain of Wheat being unable to maintain above one or two of the young Brood when hatched), and this she does to five or six Grains every Day for several Days together. These Eggs, not above the Size of a Grain of Sand, in about seven Days produce an odd Sort of *white Maggots*, which wriggles its Body pretty much, but is scarce able to move from Place to Place, as indeed it has no Occasion, being happily lodged by its Parent where it has Food enough. This *Maggot* turns into an *Aurelia*, which in about fourteen Days comes out a *perfect Weevil*.

As many People are unacquainted with the *Weevil*, a Picture of it is given Plate XIII. Fig. XII.

Weevils when in the Egg, or not come to their perfect State, are often devoured by Mites.

* *Vide* LEEUWEN. Epist. de sexto Augusti 1687. ad Reg. Societ.

C H A P. XXXV.

Of the WOLF.

TH E *Wolf* is a little white *Worm* or *Maggot* that infests Granaries and Corn-chambers, and unless proper Care be taken will do unspeakable Damage.—I call it a *Worm* or *Maggot*, because under that Form it does the Mischief, though in its perfect State it is really a small *Moth*, whose Wings are white, spotted with black Spots.

This little *Maggot* has six Legs; and, as it creeps along, there issues from its Mouth an exceeding fine Thread or Web, by which it fastens itself to every Thing it touches, so that it cannot fall. Its Mouth is armed with a Pair of reddish Forceps, or biting Instruments, wherewith it gnaws its Way, not only into Wheat and other Grain, but perforates even wooden Beams, Boxes, Books, and almost any thing it meets with.

Towards the End of Summer, this pernicious Vermin (in Corn-chambers infested with them) may be seen crawling up the Walls in great Numbers, in Search of proper Places where they may abide in Safety during their Continuance in their *Aurelia* State: for when the Time of undergoing a Change into that State approaches, they for-

fake their Food, and the little Cells they had formed of hollowed Grains of Corn, clotted together by Means of the Web coming from their Mouths, and wander about till they find some Wooden Beam, or other Body to their Mind, into which they gnaw Holes with their sharp Fangs, capable of concealing them : and there enveloping themselves in a Covering of their own Spinning, soon become metamorphosed into dark-coloured *Aurelias* *.

These *Aurelias* continue all the Winter unactive and harmless : but about *April* or *May*, as the Weather grows warm, they are transformed anew, and come forth *Moths* of the Kind above described. They may then be seen in great Numbers taking little Flights, or creeping along the Walls ; and, as they eat nothing in their Fly-state, are at that Time not mischievous. But they soon copulate and lay Eggs (shaped like Hen's Eggs, but not larger than a Grain of Sand), each Female sixty or seventy, which, by Means of a Tube at the End of her Tail, she thrusts or insinuates into the little Wrinkles, Hollows, or Crevices, of the Corn ; where, in about sixteen Days, they hatch, and then the *Plague* begins : for the minute *Worms* or *Maggots* immediately perforate the Grain

* Vide LEEUWEN. *Experiment. & Contempl.* Epist. 71.

they were hatched upon, eat out the very Heart of it, and with their *Webs* cement other Grains thereto, which they likewise scoop out and devour, leaving nothing but Husks and Dust, and such a Quantity of their Dung as shews them to be more voracious Insects than the *Weevil*.

The watchful Observer has two Opportunities of destroying this Vermin, if they happen to be got among his Corn. One is, when they forsake their Food and ascend the Walls, which they will sometimes almost cover: the other, when they appear in the *Moth State*. At both these Times they may be crushed to Death against the Walls in great Numbers by clapping Sacks upon them. But they may still be exterminated more effectually, if, closing up all the Doors and Windows, the Corn-chamber be filled with the Fumes of *Brimstone*, by leaving it burning on a Pan of Charcoal, without giving it any Vent for twenty-four Hours. Great Caution however must be used, to open the Windows and Doors, and let all the Fumes be entirely gone before any body enters the Place afterwards, for Fear of Suffocation. The Fumes of *Sulphur* are in no wise hurtful to the Corn, or give it any Taste.

The Picture of the *Wolf* in its Reptile State (when it goes by that Name) is shewn Plate XIII. Fig. XIII. a.

226 *Of the pearly Eyes of Insects.*

Its Appearance when transformed into a *Moth* is seen Fig. XIII. *b*.

Old Corn is less subject to these devouring Insects than Corn that is new; for its Skin being more hard and dry it is much more difficult for the *little Maggots* when first hatched to penetrate*.

C H A P. XXXVI.

Of the pearly Eyes of † INSECTS.

THE *Eyes of Insects* are amazing Pieces of Mechanism, whose Structure and Disposition, without the Assistance of the *Microscope*, would for ever have been unknown to us.—*Beetles, Dragon-flies, Bees, Wasps, Ants, common Flies, Butterflies*, and many other *Insects*, have two Crescents, or immoveable Caps, composing the greatest Part of the Head, and containing a prodigious Number of little *Hemispheres* or round *Protuberances*, placed with the utmost Regularity and Exactness in Lines crossing each other, and resembling Lattice-work. These

* I call this Insect the *Wolf* from the *Latin Name* *Lupus*; given, I suppose, for its Voraciousness.

† Vide *Spectacle de la Nature*, Dial. VIII. *Hook's Microg.* p. 108. *LEEuw. Arc. Nat.* Tom. III. Part. II. p. 41. Again, p. 424. *DERHAM's Phys. Theol.* 364.

are a Collection of *Eyes*, so perfectly smooth and polished, that like so many Mirrors they reflect the Images of all outward Objects. One may see the Figure of a Candle multiplied almost to Infinity on their Surfaces, shifting its Beam into each Eye, according to the Motion given it by the Observer's Hands: and as other Creatures are obliged to turn their Eyes to Objects, this Sort have some or other of their Eyes always ready directed towards Objects on whatever Side they present themselves. In short, all these little *Hemispheres* are *real Eyes*, having in the Middle of each a minute transparent *Lens* and *Pupil*, through which Objects appear topsy-turvy as through a convex Glass: This becomes also a *small Telescope* when there is a just focal Distance between it and the *Lens* of the *Microscope*. It is also reasonable to believe, that every *Lens* has a distinct Branch of the Optic Nerves administering to it: and yet, that Objects are not multiplied, or appear otherwise than single, any more than they do to us, who see not an Object double though we have two Eyes.

Every Man almost that has seen a *Microscope* has been entertained with a View of these *minute Eyes*, and yet very few perhaps have well considered either the Nature or the Number of them. Mr. Hook computed fourteen thousand *Hemispheres* in the
two

two Eyes of a *Drone*, viz. seven thousand in each Eye. Mr. LEEUWENHOEK reckoned six thousand two hundred thirty-six in a *Silk-Worm's* two Eyes when in its Fly-State; three thousand one hundred eighty-one in each Eye of a *Beetle*; and eight thousand in the two Eyes of a *common Fly*. The *Libella*, *Adder-Bolt*, or *Dragon-Fly*, is the most remarkable of all the Insects we know for its large and fine *pearly Eyes*; which, even with a common Reading-glass, appear like the Skin we call Shagreen. Mr. LEEUWENHOEK reckons in each Eye of this Creature twelve thousand five hundred forty-four *Lenses*, or, in both, twenty-five thousand eighty-eight; placed in an hexangular Position, each *Lens* having six others round it; which is also the Order most common in other Eyes. He likewise observed in the Center of each *Lens* a minute transparent Spot, brighter than the rest, and supposed to be the *Pupil* through which the Rays of Light are transmitted upon the *Retina*. This Spot had three Circles surrounding it, and seemed seven Times less than the Diameter of the whole *Lens*. We see here, in each of these exceedingly minute *lenticular Surfaces*, as much Accuracy in the Figure and Polish, and as much Contrivance and Beauty, as in the Eye of a Whale or an Elephant: and how delicate, how exquisitely delicate, must the *Filaments* of the *Retina* be which serve to

to each of these, since the whole Picture of Objects painted thereon must be Millions of Times less than the Images of them pictured on the human Eye!

If we cut off the *Eye* of a *Dragon-Fly*, of a *Drone*, or a *common Fly*, and with a Pencil and some clean Water wash out all the Vessels, those Vessels may be examined by the *Microscope*, and the Numbers of them will appear wonderful and surprizing; and then if the outward Covering be dried carefully, so as not to shrink, it will be rightly prepared for making Experiments with the *Microscope*: and, upon viewing it, we shall perfectly distinguish the numerous *Protuberances* or *Hemispheres*, divided from one another, with a small Light issuing between them, and six Sides to each. Mr. LEEUWENHOEK, having prepared an Eye in this Manner, placed it a little farther from his *Microscope* than when he would examine an Object: so as to leave a right and exact *focal Distance* between it and the *Lens* of his *Microscope*; and then looking through both, in the Manner of a *Telescope*, at the Steeple of a Church, which was two hundred ninety and nine Feet high, and seven hundred and fifty Feet from the Place where he stood, he could plainly see, through every little *Lens*, the whole Steeple, inverted, tho' not larger than the Point of a fine Needle: and then directing

directing his View to a neighbouring House, he saw, through Abundance of the little *Hemispheres*, not only the Front of the House, but likewise the Doors and Windows ; and was able to discern distinctly whether the Windows were shut or open.

There can be no Doubt, that *Lice*, *Mites*, and Multitudes of other *Animalcules* much smaller still than they, have Eyes contrived and fashioned to discern Objects some thousands of Times less than themselves : for so the minute Particles they feed on, and many other Things necessary for them to distinguish and know perfectly, must certainly be.—What a Power then of magnifying are such Eyes endued with ! and what extraordinary Discoveries might be made, were it possible to obtain Glasses through which *we* could see as *they* do !

C H A P. XXXVII.

Of the Antennæ, Feelers, or Horns of
I N S E C T S.

THE *Horns* of *Insects* have been thought by many designed only to clean their Eyes, by wiping off any Dust that may fall thereon : but as we constantly observe them performing

performing that Office with their Fore-legs, it is certain their *Horns* must be intended for some other Purpose. And since they are perpetually feeling before them with their *Antennæ* as they walk along, * Mr. DERHAM very reasonably imagines them absolutely necessary to search and find out their Way. For as their Eyes are immoveable, so that no Time is required for their turning them to Objects, there is no Necessity that the *Retina*, or *Optic Nerve*, should occasionally be brought nearer to, or removed farther from the *Cornea*, as it is in other Animals; which would require Time: but their *Cornea* and *Optic Nerve* being always at one and the same Distance, and fitted only to see distant Objects; they would be insensible of, and apt to run their Heads against Bodies very near them, were they not assisted by their *Feelers*.

And that this, rather than wiping the Eyes, is the chief Use of the *Feelers*, is farther manifest from the *Antennæ* of the *Flesh-Fly*, and many other Insects, which are short and strait, and incapable of being bent down to, or extended over the Eyes: as also from others enormously long, such as those of the *Capricorni* or *Goat Chafers*, the *Cadew Fly*, and divers others both *Beetles* and *Flies*.

* DERHAM'S *Physico-Theol.* p. 365.

The lamellated *Antennæ* of some, the clavellated of others, the Topknots or Tufts like *Dandelion* Seeds, the branched, the feathered, and divers other Forms of Horns of the *Beetle*, *Butterfly*, *Moth*, *Gnat*, and many Kinds beside, are surprizingly beautiful when viewed thro' a *Microscope*. And in some these *Antennæ* distinguish the Sexes: for in the *Gnat-kind* all those with Tufts, Feathers, or Brush-horns (of which there are great Varieties), are *Males*: those with short single-shafted Horns are *Females*.

C H A P. XXXVIII.

Of the WINGS of INSECTS.

THERE is such infinite Variety in the Contexture, Formation, Disposition, and Ornaments of the *Wings of Insects*, according to their different Wants and Ways of Life, that nothing but a curious Observation can make us have any true Conception of it. Some Wings are filmy, as those of *Dragon-Flies*; others are stuck over with short Bristles, as in *Flesh-flies*: some are Films covered with short Feathers, like the Tiles of a House, as in *Butterflies* and *Moths*; others have divided Wings, as the *grey* and *white* feathered

feathered Moth. The Wings of many Sorts of *Gnats* are adorned with Rows of Feathers along their Ridges, and Borders of Feathers round their Edge. Some again have Hairs, and others Hooks, placed with the greatest Regularity and Order. All of the Scarab Kind have *Elytra*, or *Cases*, into which their Wings are folded and preserved until they want to employ them. Some of these Cases reach almost to the Extremity of the Tail, as in most Kinds of *Beetles*; and others are very short, as in the *Ear-Wig*. Many of them are likewise extremely beautiful when brought before the *Microscope*.

All these Kinds of *Wings* have certain bony Parts or Ribs, that give them Strength, along the Sides of which run large Blood-Vessels, branching out into numberless Divisions, and conveying Nourishment to the intermediate Parts: for tho' no Circulation can be discerned in them, it being probably extremely slow, we can scarce doubt that there must be continually a Supply of Juices to the Quills, Hairs, or Bristles, wherewith they are armed or ornamented.

As to Motion, *Wings* that are filmy move faster than those covered with Feathers. Mr. Hook observes, that in the Wings of some minute Flies there are many hundreds, if not thousands of Vibrations in a Second, and supposes them the swiftest Vibrations in the

the World: whence he reflects very ingeniously, on the Quickness of the Animal Spirits, that serve to supply this Motion.

Those conversant in *Microscopes* need not be informed, that the beautiful Colours on the Wings of Butterflies and Moths are owing to elegant minute Feathers ending in Quills, and placed with great Exactness in orderly Rows; as, when rubbed off, the Holes they come from shew: but few, it may be, have much observed the great Variety of their Make, not only in Moths and Butterflies of different Sorts, but even in those taken from different Parts of the same Wing; insomuch that it is pretty difficult to find any two of them exactly alike.

Rub these Feathers gently off, with the End of your Finger or Pen-knife; and, breathing upon a single *Talc* in one of your *Sliders*, apply it to the Feathers, which seem only like a fine Dust, and they will immediately adhere to it: then placing it before the *Microscope*, if they are not perfect, or lie not to your Mind, wipe them off, and put on others in the same Manner, till you get those you like: then cover them with another *Talc*, and fasten it down with a Wire, that you may preserve them for future Examination. Look at them with the *third* or *fourth*, then with the *second*, and at last with the *greatest Magnifier*.

The

The Wing of a *Midge* is a most curious Object, and so indeed is every Part of that minute Insect. The Wing of the little *Plume Moth* is composed of several distinct Quills, like those of Birds. There are also Wings folded up in the little Cases on the Backs of *Earwigs*, very pretty to examine. But no more need be said of Wings, since every body must be sensible the great Variety of them is an endless Subject of Enquiry and Admiration.

C H A P. XXXIX.

Of the Balances or Poises of Insects.

MOST Insects having but two Wings, are provided with a little *Ball* or *Bladder* under each, set at the Top of a slender Foot-stalk, which is moveable every Way at Pleasure. With these they *balance* themselves in Flight as a *Rope-Dancer* does with his Pole leaded at each End; and if one of them be cut off, the Creature flies for a while very awkwardly, as if over-heavy on one Side, and falls at last to the Ground. These Bladders being hollow may serve likewise to produce the Noise many Sorts of *Flies* make, by striking their Wings against them, and be a Means of finding out one another. In some

Creatures they stand alone, but the whole Fly Tribe have little Covers or Shields under which they lie and move. Insects that have four Wings balance themselves with the two lesser ones, and as they want not, have none of these little Poises. The *Microscope* may probably find out still farther Beauties, Contrivances, and Uses for them than have been yet discovered.

C H A P. XL.

Of the SCALES of FISHES.

THE Scales or outside Coverings of Fishes are formed with surprizing Beauty and Regularity; and, in different Kinds of them, exhibit an endless Variety in Figure and Contexture. Some are longish, some round, some triangular, some square, and some or other of all Shapes we can well imagine. Some again are armed with sharp Prickles, as those of the *Pearch*, *Soal*, &c. Others have smooth Edges, as of the *Codfish*, *Carp*, *Tench*, &c. There is likewise a great Variety even in the same Fish; for the Scales taken from the Belly, the Back, the Sides, the Head, and all the other Parts, are very different from one another. And, indeed, for Variety, Beauty, Regularity, and the

the Order of their Arrangement, the Scales of Fishes bear a near Resemblance to the Feathers on the Bodies and Wings of Moths and Butterflies.

These *Scales* are not supposed to be shed every Year *, nor during the whole Life of the Fish; but to have an annual Addition of a new *Scale*, growing over and extending every Way beyond the Edges of the former, in proportion to the Fish's Growth; somewhat in the same Manner as the Wood of Trees enlarges yearly by the Addition of a new Circle next the Bark. And as the Age of a Tree may be known by the Number of Ringlets its Trunk is made up of, so in Fishes the Number of Plates composing their *Scales* denote to us their Age. It is also probable, that as there is a Time of Year when Trees cease to grow, or have any farther Addition to their Bulk, the same Thing happens to the *Scales* in Fishes; and that afterwards, at another Time of Year, a new Addition, Increase, or Growth, begins. Somewhat like this in Birds and Beasts their Feathers and Hairs demonstrate.

Mr. LEEUWENHOEK took some *Scales* from an extraordinary large *Carp*, forty-two Inches and a half long, and thirty-three and a quarter in the Round, *Rynland Measure*,

* Vid. LEEUWEN. *Epist. Physiol. Epist.* 24 Maii, 1716.

which were as broad as a Dollar. These he macerated in warm Water to make them cut the easier: and then cutting obliquely through one of them, beginning with the first-formed and very little *Scale* in the Center, he, by his *Microscope*, plainly distinguished forty *Lamellæ* or *Scales*, glewed as it were over one another; whence he concluded, that the Fish was forty Years of Age*.

It has generally been imagined, that an *Eel* has got no *Scales*; but if its Slime be wiped clean away, and the Skin be examined by a *Microscope*, it will be found covered with exceeding small *Scales*, ranged in a very orderly and pretty Manner; and I believe few Fishes, unless such as have Shells, are to be found without *Scales*.

The Way of preparing *Scales* is to take them off carefully with a Pair of Nippers, wash them very clean, and place them in a smooth Paper, between the Leaves of a Book, to make them dry flat, and prevent their shrivelling up. Then place them between your Talcs in Sliders, and keep them for Examination.

The *Snake*, the *Viper*, the *Slow-worm*, the *Lizard*, the *Eft*, &c. afford a farther Variety of *Scales*.

* *Arc. Nat.* Tom. III. pag. 214.

C H A P. XLI.

Of the O Y S T E R.

I N the clear Liquor of an *Oyster* many little round living *Animalcules* have been found, whose Bodies being conjoined, formed spherical Figures, with Tails, not changing their Place but by sinking towards the Bottom, as being heavier than the Fluid: these were seen sometimes separating, and presently afterwards coming together and joining themselves again. In other *Oysters* *Animalcules* of the same Kind were found, not conjoined, but swimming by one another, whence they seemed in a more perfect State, and were supposed by Mr. LEEUWENHOEK to be the *Animalcules* in the *Row* or *Semen* of the *Oyster* *.

A *Female Oyster* being opened, incredible Multitudes of minute *Embryo-Oysters* covered with little Shells perfectly transparent were plainly seen therein, swimming along slowly: in another they were found of a brownish Colour without any apparent Life or Motion. Monsieur JOBLOT kept the Water running from *Oysters* three Days, and it appeared full of young *Oysters* that swam about

* *Arcan. Nat.* Tom. II. Par. I. p. 52. Again, p. 145.

nimbly, and increased in Bignefs daily. A Mixture of Wine, or the very Vapour of Vinegar, killed them.

In the Month of *August* Oysters are fupposed to breed, becaufe young-ones are then found in them. Mr. LEEUWENHOEK opened an Oyster on the fourth of *August*, and took out of it a prodigious Number of minute Oysters all alive, and swimming briskly in the Liquor, by the Means of certain exceeding small Organs extending a little Way beyond their Shells, which he calls their Beards. In these little Oysters he could distinguish the joining of the Shells: and perceive some that were dead, with their Shells gaping, and as like large Oysters in Form as one Egg is like another.

As for the Size of these Embryo-Oysters, he computes, that one hundred and twenty of them in a Row would extend an Inch; and, consequently, that a globular Body, whose Diameter is an Inch, would, if they were also round, be equal to one Million seven hundred and twenty-eight thousand of them. * He reckons three or four thousand are in one Oyster, and found many of the Embryo-Oysters among the Beards, some fastened thereto by slender Filaments, and

* Vide *Arc. Nat.* Tom. IV. p. 513.

others lying looſe. He likewiſe found other *Animalcules* in the Liquor five hundred Times ſmaller than Embryo-Oyſters.

C H A P. XLII.

Of the LIGHT on OYSTERS.

IT is not very uncommon to ſee on the Shells of Oyſters, when in the Dark, a *ſhining Matter*, or *blewiſh Light*, like the Flame of Brimſtone, which ſticks to the Fingers when touched, and continues ſhining or giving Light a conſiderable Time, tho' without any ſenſible Heat*. Monſ. AUXAUT obſerved this *ſhining Matter* with a *Microſcope*, and diſcovered it to conſiſt of three Sorts of *Animalcules*. The firſt whitish, having twenty-four or twenty-five Legs on each Side, forked; a black Speck on one Part of the Head; the Back like an *Eel* with the Skin ſtripped off. The ſecond Sort red, reſembling the common *Glow-worm*, with Folds on its Back, but Legs like the former, a Noſe like a Dog's, and one Eye in the Head. The third Sort ſpeckled, a Head like a *Soal*, with many Tufts of whitish Hairs on the Sides thereof. He ſaw alſo ſome much larger and greyiſh, having a

* Vid. *Phil. Tranſ.* Numb. 12.

great Head, two Horns like a Snail's, and six or eight whitish Feet: but these shined not.

As the Bodies of Lobsters and some other Kinds of Fishes, tainted Flesh, rotten Wood, and other Substances, are sometimes found to shine with a Light resembling the foregoing, may it not probably proceed from the same Cause, namely, from *Animalcules*? Some have also supposed, that the *Ignis Fatuus*, *Will-in-a-Wisp*, or *Jack-a-Lanthorn*, is nothing else but a Swarm of minute flying Insects, that emit Light around them in the Manner Glow-worms do: and, indeed, the Motions and several other Circumstances of this Sort of Fire (if I may so term it) seem favourable to such Opinion.

The Curious will judge it proper to examine this Matter carefully, and to them it is submitted.

C H A P. XLIII.

Of the M U S C L E.

I Have observed already, in the 127th Page of this Treatise, that a *Muscle* is a most delightful Object for the *Microscope*; and that, in the transparent Membrane which immediately appears on opening of the Shell,
the

the Blood may be seen circulating through an amazing Number of Vessels, even in the smallest Particle of it that can be applied for Examination.

Mr. LEEUWENHOEK, in several that he dissected, discovered Numbers of *Eggs*, or *Embryo-Muscles*, in the *Ovarium*, appearing as plainly as if he had seen them with the naked Eye, lying with their sharp Ends fastened to the Strings or Vessels whereby they receive Nourishment. These minute *Eggs*, or *Embryo-Muscles*, are, in due Time, laid or placed by the Parent in a very regular and close Order on the Outside of the Shell: where, by Means of a glewy Matter, they adhere very fast, and continually increase in Size and Strength, till, becoming perfect *Muscles*, they fall off and shift for themselves, leaving the Holes where they were placed behind them. This Abundance of *Muscle-Shells* viewed by the *Microscope* can shew. Sometimes two or three thousand of these Eggs adhere to the Shell of one Muscle; but it is not certain they were all fixed there by the Muscle itself, for they frequently place their Eggs on one another's Shells. The fringed Edge of the Muscle, which Mr. LEEUWENHOEK calls the Beard, has in every the minutest Part of it such a Variety of Motions as is inconceivable: for being composed of longish Fibres, each Fibre has on both Sides a vast many moving Particles,

cles, which one would almost imagine to be *Animalcules* *.

The Threads or Strings, which we term the Beard, are composed of a Glew which the Muscle applies by the Help of its Trunk to some fixed Body, and draws out as a Spider does its Web, thereby fastening itself, that it may not be washed away. If Muscles be put into Salt and Water, we may have the Pleasure of seeing them perform this Work, and fasten themselves to the Sides or Bottom of the Vessel we place them in.

Cockles, Scallops, Limpets, Periwinkles, and Abundance of other Shell-fish, are Objects that have as yet been very slightly examined by the *Microscope*; and therefore the serious Enquirer into Nature's secret Operations may here be certain of discovering Beauties which at present he can have no Conception of.

* *Phil. Trans.* Numb. 336. *Arc. Nat.* Tom. II. p. 19. &c.
Tom. IV. p. 423, &c.

C H A P. XLIV.

Of H A I R S.

THE *Hairs* of Animals are very different in their Appearance before the *Microscope*, and can furnish out a great Variety of pleasing Observations. MALPIGHI discovered them to be tubular, that is, composed of a Number of extremely minute Tubes or Pipes, in his Examination of a Horse's Mane and Tail, and in the Bristles of a Boar. These Tubes were most distinguishable near the End of the Hairs, where they appeared more open : and he sometimes could reckon above twenty of them. In the Hedge-hog's Prickles, which are of the Nature of Hairs, he perceived these Tubes very plainly, together with elegant medullary Valves and Cells.

There are also in the *Hairs* of many Animals, in some transverse, in others spiral Lines, somewhat of a darker Colour, running from Bottom to Top in a very pretty Manner. A * Mouse's Hairs are of this Sort ; they appear as it were in Joints like the Back-bone, are not smooth but jagged on the Sides, and terminate in the sharpest Point imaginable. Hairs taken from a

* Vid. *Arc. Nat.* Tom. III. p. 47.

Mouſe's Belly are leaſt opaque, and fitteſt for the Microſcope.

The *Hairs* of Men, Horſes, Sheep, Hogs, &c. are compoſed of ſmall, long, tubular Fibres or ſmaller Hairs, encompassed with a Rind or Bark; from which Structure a ſplit Hair appears like a Stick ſhivered with beating. They have Roots of different Shapes in different Animals, become lengthened by Propulſion, and are thicker towards the Middle than at either End.

Hairs of *Indian* Deer are perforated from Side to Side: our *Engliſh* ones ſeem covered with a Kind of ſcaly Bark. The Whiſkers of a Cat, cut tranſverſely, have ſomewhat in the Middle like the Pith of Elder. * The Quills of Porcupines or Hedge-hogs have alſo a whitish Pith in a Star-like Form: and a human Hair cut in the ſame Manner ſhews a Variety of Veſſels in very regular Figures.

Hairs taken from the Head, the Eye-brows, the Noſtrils, the Beard, the Hand, and other Parts of the Body, appear unlike, as well in the Roots as in the Hairs themſelves, and vary as Plants do of the ſame *Genus*, but of different *Species*.

* Hook's *Microg.* p. 157.

C H A P. XLV.

Of the FARINA of FLOWERS.

THE *Farina*, or *mealy Powder*, found on the little pendant Tops of almost every Flower, is somewhat so analogous to the *Semen* of Animals, that it deserves the strictest and most attentive Examination.

This Powder, whose Colour is different in Flowers of different Kinds, was imagined, by former Ages, to be a mere excrementitious and unnecessary Part of the Plant: but the *Microscope* here also has made surprizing Discoveries, by shewing, that all the minute Grains of this Powder are regular, uniform, and beautiful little Bodies, constantly of the same Figure and Size in Plants of the same Species, but in different Kinds of Plants as different as the Plants themselves.

It was impossible to observe this Order and Configuration of the *Farinæ*, without concluding, that Providence, which never acts in vain, must intend a nobler Use for Bodies so regularly formed, than to be dissipated by the Winds and lost. This Reflection drew on farther Examination; and farther Examination, by the Help of the same Instrument, soon discovered, that this Powder is produced and preserved with the utmost Care,

Care, in Vessels wonderfully contrived to open and discharge it when it becomes mature: that there is likewise a *Pistil*, *Seed-Vessel*, or *Uterus*, in the Center of the Flower, ready to receive the minute Grains of this Powder, as they either fall of themselves, or are blown out of their little Cells. And Experience, founded on numberless Experiments, proves, that on this depends entirely the Fertility of the Seed: for if the *Farina-Vessels* be cut away before they open and shed their Powder, the Seed becomes barren and unproductive.

This *Farina* is therefore judged to be the Male Seed of Plants, and every little Grain of its Powder may possibly contain in it a minute Plant of the Species whereto it belongs.—It is wonderful to observe the various Contrivances Nature employs to prevent this Powder from being unprofitably dispersed, and to assist its Entrance into the proper *Pistil*, *Seed-Vessel*, or *Uterus*, prepared for it. The Tulip, for Instance, which stands upright, has its *Pistil* shorter than the *Farina-Vessels*, that the Powder may fall directly on it; but in the Martagon, which turns downwards, the *Pistil* is longer than the said Vessels, and swells out at its Extremity, to catch the *Farina* hanging over it as it sheds.

A Mind

A Mind inquisitive into Nature's hidden Beauties will find inexpressible Delight in examining and considering the endless Variety discoverable in the *Farinæ* of numberless vegetable Species. In that of the Mallow, each little Grain appears to be an opaque Ball with Prickles issuing from it on every Side. The Sun-Flower *Farina* seems composed of flat circular minute Bodies, sharp-pointed round the Edges; the Middle of them appears transparent, and exhibits some Resemblance of the Flower it proceeds from. The Powder of the Tulip is exactly shaped like the Seeds of the Cucumbers and Melons. The *Farina* of the Poppy appears like Pearl-Barley, with a Furrow, as in that, reaching from End to End. That of the Lily is a great deal like the Tulip.

I will not anticipate the Pleasure of the Curious, or take up their Time in describing more of the *Farinæ*, which every Flower they come at presents to their Examination; but advise them, not to neglect the Vessels that contain it, for they will find Beauties in them also sufficient to reward their Pains.

Gather your *Farina* in the Midst of a sun-shiny dry Day, when all the Dew is off: be careful not to squeeze or press it, but shake or else gently brush it off with a soft Hair Pencil upon a Piece of clean white Paper.

per. Then take a single Talc or Isinglass between your Nippers, and, breathing on it, apply it instantly to the *Farina*, which the Moisture of your Breath will make adhere to it. If too great a Quantity of Powder seems sticking to your Isinglass, gently blow off a little; if there be not enough, breathe on it again, and touch the *Farina* with it as before. Then put your Glass into the Hole of a Slider, and apply it to the *Microscope*, to see if the little Grains are spread according to your Liking; and when you find they are, cover them cautiously with another Talc, which fasten down with a Brass-wire; but let not the Glasses press hard upon the *Farina*, for that will destroy its true Figure, and represent it different from what it is.

A Collection of the most remarkable *Farinae* thus preserved must be a lasting Entertainment to those who study Nature: to such I also recommend a diligent Examination of the little Cells that contain the *Farina*, and likewise of the *Pistils* or *Uteri*, and other Parts of Generation in Flowers. Let them only begin with the Arch-Angel, or blind Nettle with a white Flower, or even with the common Mallow, and they will discover Beauties impossible to be described. And as every other Flower has Organs for the same Purpose, though of a different Form and Structure, here are
Wonders

Wonders in Abundance for the *Microscope* to discover, and happy the Man who can find most Leisure to explore these Worlds as yet unknown!

I shall add only one Observation more before I leave this Head, which is, that as the *Animalcules* in *Semine* differ not in Bigness according to the Size of those Animals whence the Semen comes: so the *minute Grains* composing the *Farinae* of Vegetables are not bigger or less in Proportion to the Size of the Plants producing them, but are often the direct contrary; as we find by the *Farina* of the little creeping Mallow, the Globules of which are larger than those of the lofty gigantick Sun-flower.

C H A P. XLVI.

Of SEEDS.

EACH Seed includes a Plant: that Plant, again, Has other Seeds, which other Plants contain: Those other Plants have all their Seeds; and Those More Plants, again, successively inclose.

Thus, ev'ry single Berry that we find,
Has, really, in itself whole Forests of its Kind.
Empire and Wealth one Acorn may dispense,
By Fleets to sail a thousand Ages hence:
Each Myrtle-Seed includes a thousand Groves,
Where future Bards may warble forth their Loves.

So ADAM'S Loins contain'd his large Posterity,
All People that have been, and all that e'er shall be.

Amazing Thought ! what Mortal can conceive
Such wond'rous Smallness !—Yet we must believe
What Reason tells : for Reason's piercing Eye
Discerns those Truths our Senses can't descry.

I hope to be excused for borrowing the Lines above from a little *Poem* of my own, called *The Universe*, published some Years ago ; as they contain a Supposition, which, however chimerical it may appear at first, will, if duly considered, be found, perhaps, not only possible, but even highly probable: MALPIGHI, LEEUWENHOEK, HOOKE, GREW, and several others bear Witness, that the *Microscope* has discovered minute Plants not only in the larger Seeds, such as the Walnut, Chesnut, Acorn, Beechnut, Seed of the Lime, Cotton-Seeds, Pease, &c. but also in the smaller of Radish, Hemp, Chervil, Scurvy-grass, Mustard, and Multitudes of other Seeds. About two Years ago, I likewise had the Honour to present the Dissection of a Seed of the *Gramen tremulum*, or *trembling Grass*, with an Account thereof, to the *Royal Society*, wherein a perfect Plant appeared, with its Root, sending forth two Branches, from each of which several Leaves or Blades of Grass proceeded. Thus far our Sight, assisted by the *Microscope*, is able to discover : and as that Instrument convinces

convinces us, that Nature in her Operations is in no wise confined to our Conceptions of Bigness, but acts as freely in the minute Fabric of a Mite, as in the bulky Compass of a Whale or Elephant; nay, that she rather seems to wanton in her Skill, by giving a greater Number of Limbs, and more numerous Ornaments, to the minute Creatures than to the larger ones. When these Things, I say, are seen and reflected on, it is easy to conceive the rest.

Most Kinds of Seeds must be prepared, in order to discover the minute Plants they contain, by steeping them in warm Water till their Coats can be separated and their seminal Leaves opened without Laceration: tho' some new Sorts may better be dissected dry. But Seeds, even without any Preparation, are exceeding pretty Objects, and afford infinite Varieties of Figure, Colour, and Decoration.

The Seeds of Strawberries rise out of the Pulp of the Fruit, and appear themselves like Strawberries when viewed.

Poppy Seeds (and what we call Maw-Seeds, which come from *Germany*, and are produced by a Kind of Poppy) in Shape resemble little Kidneys, but have Furrows or Ridges on their Surfaces curiously disposed with regular Sides and Angles. From these Seeds a Dust may be shaken, that looks agreeable enough when brought before the

Microscope; having nearly the same Appearances as the Surfaces of the Seeds, with the Advantage of being transparent. This Dust is really the fine Membranes that lay between the Seeds; which, by the Pressure of the Seeds against them, have received Marks corresponding to the Ridges or Furrows on the Seeds themselves.

Seeds of the lesser Moonwort, of Tobacco, Lettuce, Thyme, Chervil, Parsley, and a thousand others, afford a delightful Entertainment.

The Ancients imagined the capillary Plants and many other Kinds to produce no Seeds at all, and their Mistake could never have been rectified by the naked Eye: but the Microscope has discovered, that all the several Species of Fern, Harts-tongue, Maiden-hair, &c. are so far from being barren in this respect, that they are amazingly fruitful: that the Seed-Vessels are on the Backs of the Leaves, and that the Dust which flies off when we meddle with them, is nothing but their minute Seeds. These Seed-Vessels appear to the naked Eye like a black or brown Scurf on the Back Side of the Leaf; but, when viewed by the Microscope, resemble little circular Tubes, divided into many Cells containing Seeds. When the Seed is ripe the Vessels fly open with a Spring, and spirt the Seeds out on every Side, in the Form of Dust: and if at that Season some of the Leaves are put in a Paper Cone, and that

that be held to the Ear, the Seed-Vessels may be heard to burst with a considerable Noise. Some of these minute Vessels contain at least an hundred Seeds, invisible to the naked Eye.

It would be tedious to enumerate the Beauties of Seeds, since every transient Observer must be sensible of their great Variety: but I believe I shall be excused if I take Notice of the Powder or Seed of the *Fungus Pulverulentus* or *Puff-Ball*, which, when crushed, seems to the naked Eye like a Smoke or Vapour; but when examined by one of the greatest Magnifiers (for else it cannot be distinguished) it appears to be infinite Numbers of little Globules of an Orange Colour, somewhat transparent, whose Axis is not above the fiftieth Part of the Diameter of a Hair: so that a Cube of a Hair's Breadth Diameter would be equal to an hundred and twenty-five thousand of them. This was the Powder of a *Fungus* bigger than two Fists; but in another Sort, the Size of a small Apple, the Globules were of a darker Colour, and had each a little Stalk or Tail*. These are evidently so many *minute Puff-Balls*, furnished with Stalks or Tails to penetrate easily into the Ground: and the Mischief they do

* Vide *Phil. Transf.* Numb. 284. and DERHAM'S *Phys. Theol.* p. 418.

the Eyes is probably owing to their sharp Stalks that prick and wound them *.

C H A P. XLVII.

Of LEAVES.

THE *Leaves* of Trees or Plants are full of innumerable Veins and Ramifications, that convey the perspirable Juices to the Pores, for their Discharge. Whether or no there be any Circulation in them is still a Matter of Doubt; but as their Juices, when let out, immediately break, coagulate, and become a stiff Jelly, it seems probable there may be some Circulation, which prevents the same Effect in the Vessels. The sudden shrinking, closing, and opening of Flowers, the raising and sinking the Heads of Poppies, &c. the vermicular Motions of the Veins of Plants when exposed to the Air, seem also to imply somewhat like Sensation. The *Microscope* may perhaps be of Service to discover much more on these Subjects than we yet know.

* A *Puff-Ball* being burst near the Eyes of a Boy of twelve Years old, by an unlucky Play-fellow, and the Dust thereof flying into them, occasioned such Swelling, Inflammation, and intense Pain, with a continual Discharge of Water, that he could not open them for several Days; and did not recover his Sight in less than a Fortnight, though all the Remedies that could be thought on were applied. Vide JON. MUYS, *Præf. Chirurg. Ration. Observ. I.*

Mr. LEEUWENHOEK, tearing to Pieces a Leaf of the Species of *Box* called *Palma Cereris*, that he might examine it the better, computed one Side of it to be furnished with an hundred seventy-two thousand and ninety Pores; and as the other Side must have as many, the whole Number of Pores in a single Leaf of *Box* will be three hundred forty-four thousand one hundred and eighty.

The Leaves of *Rue* seem full of Holes like a Honey-comb; all the Kinds of *St. John's Wort* appear likewise stuck full of Pin-holes to the naked Eye; but the *Microscope* shews, that the Places where those Holes seem to be are really covered with an exceeding thin and white Membrane.

The Back Side of the Herb *Mercury* looks as if rough-cast with Silver, and the Ribs full of white round transparent Balls, like numberless Grapes, fastened by slender Footstalks.

A *Sage Leaf* appears like Rug or Shag, full of Knots tasseled with Silver Thrums, and embellished with fine round crystal Beads or Pendants, fastened by little Footstalks.

The Backside of a *Rose Leaf*, but especially of *Sweet Briar*, looks diapered with Silver*.

Every Body knows that the Leaves of *Stinging Nettles* are thick set with sharp

* Dr. POWER's *Microscop. Observ.*

Prickles, that penetrate the Skin when touched, and occasion Pain, Heat, and Swelling : which Symptoms were imagined formerly to ensue from the Prickles being left in the Wounds they make. But the *Microscope* discovers something much more wonderful in this common Vegetable, and shews that its Prickles are formed and act in the same Manner as the Stings of living Animals. For every one of them is found to be a rigid hollow Body, terminating in the most acute Point imaginable, with an Opening near its End. * At the Bottom of this Cavity lies a minute Vessel or Bag, containing a limpid Liquor, which, upon the least touching of the Prickle, is squirted thro' the little Outlet ; and, if it enters the Skin, produces the Mischiefs before-mentioned by the Pungency of its Salts. Hence it comes to pass, that when the Leaves of *Nettles* are considerably dried by the Heat of the Sun, they sting but very little : whereas such as are green and juicy produce violent Pain and Inflammation. But the quite contrary to this would happen, if the Symptoms were only owing to the Breaking of the Prickles in the Flesh : since when dry they must be more brittle, as well as more rigid, than when they abound with Juice.

* Hook's *Microg.* pag. 142. *Arc. Nat.* Tom. I. Par. III. p. 107.

Quere, Are there any Valves in the Vessels of Vegetables, as in those of Animals, to let the Juices pass, but hinder their Return?

C H A P. XLVIII.

Of SALTS in General.

IT is I think agreed, that all Bodies have their *Salts*, from whose different Configurations and Impressions many wonderful Changes are effected both in Solids and Fluids, in Things animate and inanimate. Saline Particles striking upon the Nerves of Animals excite the Sensations of Taste and Smell; and as their Forms and Degrees of Impulse are almost infinitely diversified, the Sensibility of Pain or Pleasure arising therefrom must be varied almost infinitely, according to the greater or less Delicacy of the Organs they strike upon.—It is therefore of great Consequence to discover what we can about them.

The *Microscope* shews, that *Vinegar* owes its Pungency to Multitudes of floating oblong quadrangular Salts, each of which, tapering from its Middle, has two exquisitely sharp Ends. These Salts, being inexpressibly
 9 minute,

minute, can hardly be discovered, unless a Drop or two of Vinegar be exposed for some Hours to the Air, that the more watery Part may evaporate, before we attempt to view them.

Their Shape appears, Plate XIV. Fig. I.

If *Crabs Eyes* are infused in *Vinegar*, after the Effervescence is over, the Shapes of the *Salts* will be found quite altered; their sharp Points seem broken off, and they appear in different square-like Forms, as at Fig. II.

In Wines of several Kinds the *Salts* are distinguishable, of various Figures, many of them resembling those in *Vinegar*, but with Ends much more obtuse: some are shaped like a Boat, some like a Spindle, others like a Weaver's Shuttle, and others square: there are also infinite Varieties of other Forms.

The *Salts* of Sugar candied are shewn, Fig. III.

Vegetable Salts are to be extracted by burning the Wood, Stalks, or Leaves of any Tree or Plant; throwing the Ashes into Water; then filtering, and setting the Liquor to crystallize in a cold Place. Their Oils also, when examined, present Abundance of *Salts*.

The *Salts* of Minerals or Metals are to be come at by quenching them, when red hot, in Water, then filtering, evaporating, and crystallizing.

Fig. I. p. 260.

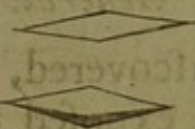


Fig. II. p. 260.



Fig. III. p. 260. Plate XIV.

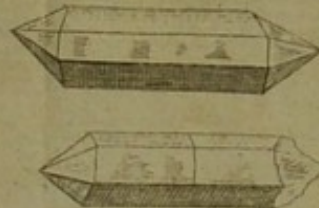


Fig. IV. p. 263.

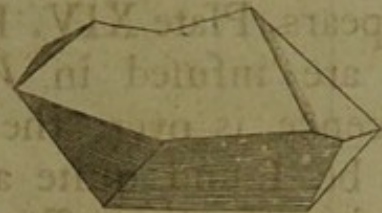


Fig. V. p. 263.

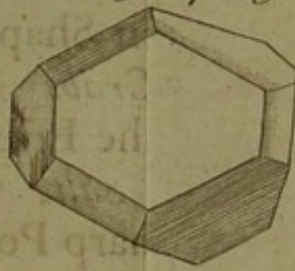


Fig. VI. p. 263.

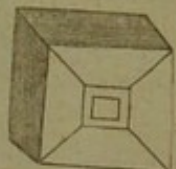
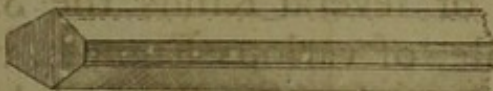


Fig. VII.



VII. p. 264.

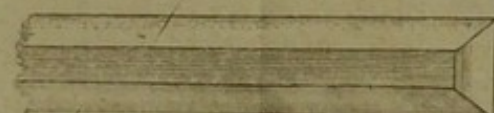


Fig. VIII. p. 265.

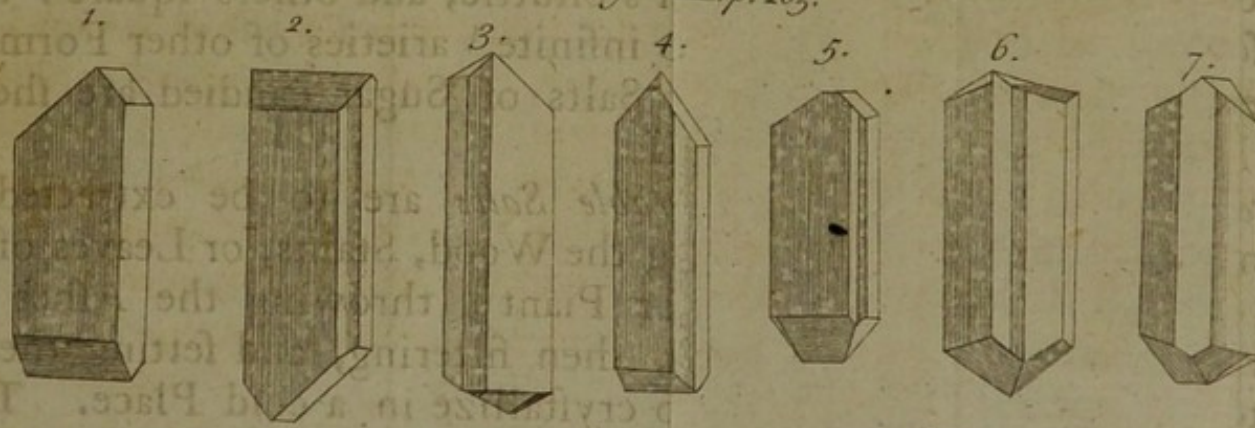


Fig. IX. p. 265.



Fig. X. p. 265.



Fig. XI.



XI. p. 265.



Pretty Salt for Observation are, Pot-Ash,
 English and Russian: Salt of Wormwood,
 Saccharum Saturni, Salt of Tartar, Salt of
 moniac, Salt of Marsh-mallows, Salt of Amber,
 &c. They should be examined first in their
 dry or crystallized State, and afterwards dis-
 solved in a very small Quantity of some
 transparent Fluid.

The same found in all Bodies, when sepa-
 rated by Fire, seem as so many Pores or
 Nails*, penetrating their Pores, and fasten-
 ing their Parts together; but as Pores or
 Nails, when too large or too numerous,
 serve only to split or rend a Body; Salt, by
 the same Means, sometimes break, separates,
 and dissolve, instead of joining and making
 fast. They indeed are merely Instruments
 and can no more act upon or force them-
 selves into Bodies, than Nails can without the
 Stroke of a Hammer; but they are either
 driven on by the Pressure of other Bodies, or
 by the Spring of the Air impelling them.
 As Salt enters the Pores of all Bodies, Water
 maintains between the Particles of Salt; se-
 parates or dissolves, and sustains them in its
 Intervals, till, by being in a State of Rest,
 they precipitate, and form themselves into
 Masses. By this dissolving Power, Water

Pretty *Salts* for Observation are, Pot-Ash, *English* and *Russian* : Salt of Wormwood, *Saccharum Saturni*, Salt of Tartar, Salt Armoniac, Salt of Hartshorn, Salt of Amber, &c. They should be examined first in their dry or crystallized State, and afterwards dissolved in a very small Quantity of some transparent Fluid.

The *Salts* found in all Bodies, when separated by Fire, seem as so many Pegs or Nails *, penetrating their Pores, and fastening their Parts together : but as Pegs or Nails, when too large or too numerous, serve only to split or rend asunder ; *Salts*, by the same Means, oftentimes break, separate, and dissolve, instead of joining and making fast. They indeed are merely Instruments, and can no more act upon or force themselves into Bodies, than Nails can without the Stroke of a Hammer ; but they are either driven on by the Pressure of other Bodies, or by the Spring of the Air impelling them. As *Salts* enter the Pores of all Bodies, *Water* insinuates between the Particles of *Salt* ; separates or dissolves, and sustains them in its Interstices, till, by being in a State of Rest, they precipitate, and form themselves into Masses. By this dissolving Power, *Water*

* Vid. *Spectacle de la Nat.* Dial. XXVI.

becomes

becomes the Vehicle of *Salts*, and conveys them into the Pores of Bodies, where it leaves them to execute their proper Office.

Most Sorts of *Animal* and *Vegetable Salts* are likewise probably dissolved by the Juices of the Stomach, before they enter the Blood, or they would occasion great Mischiefs: and the Difficulty of dissolving some *mineral Salts*, or breaking off their Points in the same Manner, may be the Reason of their dreadful Effects.

C H A P. XLIX.

Of SALTS in Mineral Waters.

THE *Microscope* may be of singular Service to determine, by ocular Examination, what Kinds of *Salts* our medicinal Springs are charged with; whence to form a Judgment in what Cases their Waters may be drank to Advantage.

The four Kinds of *fossile Salts* best known are, according to Dr. * LISTER, *Vitriol*, *Alum*, *Salt-petre*, and *Sea-salt*: whereto he adds a fifth, less known, though more

* Vid. LISTER, de Fontibus Medicatis Angliæ.

common than any, namely, *Calcarious Salt*, or *Nitre*.

Green Vitriol is produced from the *Iron Pyrites*. When mature and perfect, its Crystals are always pointed at each End, and consist of ten Planes with unequal Sides: that is, the four middle Planes are Pentagons, and each of the sharp Ends is made up of three triangular Planes, as *Plate XIV. Fig. 4.*

Alum burnt, dissolved in Water, and strained, affords Crystals whose Top and Bottom are two sexangular Planes, the Sides round, which appear composed of three Planes that are likewise sexangular, and three double quadrangular ones, placed alternately. So that every perfect Crystal consists of eleven Planes, namely, five sexangular, and six quadrangular, *Fig. V.*

The Water of our Inland *Salt-Springs* affords Crystals of an exact cubical Form, one Side or Plane whereof seems to have a particular Clearness in the Middle, as if some Deficiency were in that Place; but the other five Sides are white and solid. See *Fig. VI.*

Sal Gem, dissolved, shoots into the like cubic Crystals.

Sea-water boiled to Dryness, and its Salt dissolved again in a little Spring-water, gives Crystals also that are cubical, but remarkably different from those last described: for in the Crystals of *Sea-salt* all the Angles of the Cube are seemingly cut off, and the
Corners

Corners left triangular : (See Fig. XI. XI.) whereas the *Salts* of our *Inland Springs* have all their Corners sharp and perfect, as Fig. VI.

Nitre, or *Salt Petre*, throws itself into long slender sexangular Crystals, whose Sides are Parallelograms. One End constantly terminates either in a pyramid-like Point, or else in a sharp Edge, according to the Position of the Sides of two unequal Planes. The other End is always rough, and appears as if broken. Fig. VII. VII.

The most general, tho' least noted of all the *fossile Salts* among us, is a Kind of *Wall* or *calcareous Nitre*, or *Lime-salt*, which may be collected from the Mortar of ancient Walls ; and is, as Dr. LISTER supposes, what a great Part of the Earth and Mountains consist of *. Its Crystals are slender and long, the Sides of them four unequal Parallelograms: their Point at one End is formed of two Planes with triangular Sides ; the other End terminates in two quadrangular

* We are well assured, that in *France* it is the common Practice for those who have the Superintendency of the King's *Salt-Petre* Works, to amass vast Quantities of the Mortar and Rubbish taken from old Buildings : whence, by proper Management, they extract Abundance of this *calcareous Nitre*. And when they have got all they can from it, by letting it lie together for some Years, it becomes impregnated anew, and affords almost as much as it did at first.

Planes: though both Ends are seldom to be found unbroken.—Of this Salt some is seen with five Sides, and all the other Varieties may be found in it, which are shewn *Fig. VIII. 1. 2. 3. 4. 5. 6. 7.*

Unripe or imperfect *Vitriol* is a white Salt, whose Crystals are Cubic Rhomboides: as *Fig. IX.*

The Crystals of our Inland *Salt-springs*, not yet arrived at Maturity and Perfection, are formed like *Fig. X.*

The Particles of each of these particular *Salts*, either in falling one upon another, or uniting on one common Base, form themselves into Masses, which are invariable, and always of the same regular Figure: but it is best to examine them in the smallest Masses, their Shape being there most perfect and distinct.

CHAP. L.

Miscellaneous DISCOVERIES and OBSERVATIONS.

IT has been urged by some, in Behalf of spontaneous Generation, that Worms are found in the human Bowels, of a Figure seen no where else; and therefore that they must be generated there, spontaneously, by the Slime and Heat of the Intestines: for if they proceed from Parents of their own Kind
without

without the Body, and get into it by Accident, either in the Egg or any other State, where are those Parents found?—This seems a very strong Objection; but the *Microscope*, I believe, can enable us to answer it.

Worms found in the human Body are of three Kinds, namely, the *Ascarides*, or little short slender *Maggots*, so nearly resembling a Sort frequently met with in warm moist Places, under rotten Wood, &c. that they may reasonably be supposed the same.—The *Teretes rotundi*, or long round *Worms*, which are evidently the Species of Earth-worms, found commonly in Dunghills and Hot-beds; whose Degree of Warmth is pretty equal to that of the human Bowels. And the *Lati, Fasciæ, Tape-worms*, or *Joint-worms*, which are broad, flat, full of Joints, and sometimes of a monstrous Length, extending many Yards along the Intestines.—This is the Animal said to be found no where else; but the *Microscope* has very happily discovered Worms of the same Figure exactly, and different in Size only, in the Intestines of *Eels*, so fixt as not to be removed without great Difficulty, but contracting and dilating themselves very agreeably*. They are of an incredible Length in comparison of their Breadth, and when contracted become

* *Arc. Nat.* Tom. IV. p. 367.

fix Times broader than when extended. There are *Tape-worms* likewise in the Bowels of a *Turbut*, tho' shorter than those in *Eels*, and with a Head not quite the same. They are fixed to the Guts by a Kind of Hooks which they have in their Mouths, and are not to be got off, but by holding the Tail with one Hand, and separating the Head from the Intestines with a Needle.

Having found these *Worms* in the Intestines of Fishes, let us now consider how they could get there. And it is probable they are naturally Water Animals, whose Eggs or young-ones getting into the Stomach with the Water or the Food, become hatched or nourished there. In the same Manner they may also be introduced into the Stomach of other Animals: and their Difference of Size in one or the other may arise from the different Degrees of Heat, and the Kinds of Nourishment they meet with.—Three other Sorts of *Worms* are also found in the Intestines of *Eels*. *Carp* are likewise subject to Worms which make them very lean, and so is the *Trout*.—There are two Sorts of *white Worms* in the *Whiting*; and the *Microscope* may discover them perhaps in every other Kind of Fish: nor can we wonder at it, when we reflect how liable Fishes must be to swallow the Eggs or young-ones of whatever Insects are Inhabitants of the Waters.

2. There are frequently, in the *Livers* of Sheep, *Animalcules* shaped like the Seed of a Gourd, or rather like a small thin Myrtle-Leaf with a very short Foot-stalk. Their Colour is whitish, but numberless branching Vessels or minute Canals of a greenish Yellow are dispersed every where about them; and a round Hole or Mouth appears near the Stalk End. These Creatures are found often in the *Gall-Bladder*, and in every Part of the *Liver*; where, forming themselves little Cells, they abide in a Liquor that is seemingly Blood mixt with Gall*.

3. In the *Head* of *Stags*†, *Worms* or *Maggots* are most commonly to be met with, lodged in a Cavity under the Tongue, near the *Vertebræ* where the Head joins on to the Neck. Their Shape is partly cylindrical, being flat underneath, but rounded on the upper Side; in Colour white, with many semi-annular Rings beset with darkish Hairs. On the Head are a Couple of exceeding small white Horns, which are thrust out or drawn in like a Snail's; and under them two minute Claws, black, hard, and sharp, exciting much Itching, and thereby great Uneasiness. They move along by fixing these Claws, and

* Vid. REDI de Generat. Insect. p. 302.

† Ibid. p. 307.

then dragging up their Bodies to them. The End where their Excrements are discharged has a little Opening, with two black Spots resembling a Half-moon. Twenty or thirty are usually found in one Head, of the Size of very large Maggots.

4. Like to the foregoing, especially towards the Tail, but smaller, less vigorous, and not so hairy, are certain *Maggots* found in the * *Heads* of Sheep. Their white Bodies are marked across with black Lines (particularly the largest of them); and two black Spots at the Anus, which form a Half-moon in the Worms of Deer, compose in these a complete Circle. They abide most commonly in a hollow Part of the *Os Frontis*, near the Insertion of the Horns; but are sometimes found even in the Nostrils, and in the Cavities round the Roots of the Horns. Sometimes too they get higher up into the Head, and make the Sheep run mad. They are less numerous than those in Deer, being seldom more than ten or fifteen.

5. Early in the Spring Season, we shall frequently find sticking to Pales of Wood, especially very old ones, and sometimes to Walls of Brick or Stone, a Sort of *little Worm* or *Maggot*, inclosed in a Case about the Big-

* Vid. REDI *de Gener. Insect.* p. 309.

ness of a small Barley Corn. If this Case be viewed with the *Microscope*, it appears covered all over with a most delicate Sort of Moss, intermixed with fine Sand or Earth. At the sharpest End there is a little Hole, thro' which the Excrements are discharged; and at the other a larger Opening, where the Creature puts out its Head, and fastens itself to the Pales or Wall. The included Animal is all black, about two Lines of an Inch long, and three Quarters of a Line broad. Its Body has several Ringlets folding over one another. Its Head is large, flat, and polished, resembling Tortoise-shell, with some Hairs issuing from it; and near thereto, on each Side, are three Legs. The Mouth is large, and in continual Motion, and from it proceeds a slender Thread or Web: the Eyes are black and round. This is a pretty Object, and changes I believe to some Sort of minute Fly, tho' I have not had an Opportunity of making the Experiment.

6. Nothing is more common, in the Beginning of Summer, than to see the Leaves of Peaches, Nectarines, and Cherries, curled up and blighted: which Leaves on Examination are found covered with *little Insects**,

* MONS. DE LA HIRE calls these *Pucerons*, or *little Fleas*, and instances them as Insects that come from *walking* to *flying* without passing through the *Aurelia* State: which they do by casting off their Skins, as a little Observation will shew.

some blackish, others green ; some winged, and others without Wings. These Creatures bring forth their Young alive and perfect ; and if their Bodies be opened, several perfect Embryos will be seen therein.—It remains a Doubt, whence, and by what Means, these Insects are conveyed upon the young sprouting Leaves, which at the same Time are always covered with a glutinous and honey-like Moisture : but we may hope diligent Observations will discover this Secret to us. Trees in this Condition are visited by Multitudes of *Ants* ; which hurt not the Trees, as some erroneously conjecture, but do them Service, by devouring this Vermin that infests them.

7. The *Ant* itself is an Object well worth our Notice, being a Creature of a very singular Structure. The Head large, adorned with two pretty Horns, each having twelve Joints. Its Eyes are protuberant and pearled : it has Jaws saw-like or indented, with seven little Teeth that exactly tally, opening side-ways, and able to gape very wide asunder ; by the Help whereof it is often seen grasping and transporting Bodies of three or four Times its own Bulk and Weight. It is naturally divided into the Head, the Breast, and the Belly or Tail ; each of these Parts joining to the other by a very slender Ligament. From the Breast-part, three Legs come forth on either Side. The Tail is armed

with a Sting, which the Animal uses only when provoked; but then a poisonous Liquor is conveyed by it into the Wound, occasioning Pain and Swelling. The whole Body is cased over with a Sort of Armour, so hard as scarce to be penetrated by a Lancet, and thick set with shining whitish Bristles. The Legs, &c. are also covered with Hairs, but much smaller and of a darker Colour.

Upon opening an *Ant-Hill*, we shall see them carrying in their Mouths, and securing with great Solitude, small whitish Bodies, usually called their Eggs. These, however, are not Eggs, but *Ants* in their *Aurelia State*, each encompassed with an Integument of its own spinning. We might have conjectured this from their Largeness in Proportion to a perfect *Ant*; but the *Microscope* fully proves it, by discovering to us their real Eggs, of an oblong oval Figure, about the Size of a Grain of Sand *: ninety whereof would not extend the Length of an Inch, nor an hundred and seventy be equal in Bigness to one of these *Aurelia* inclosed in its Case. These minute Eggs produce *Maggots*, which, after a Time, spin themselves Coverings, become *Aurelias*, and then *Ants*. The Parents Affection for their Young in the *Aurelia State* is so strong, that when Danger threatens they instantly run away with them, and will

* Vid. LEEUWEN. Epist. ad Reg. Soc. 9 Sept. 1687.

sooner die than leave them. There are several Sorts of *Ants* differing both in Size and Colour; and towards the End of Summer many of them are seen having four Wings. These, SWAMMERDAM says, are Males*.

The *French Academy* has published a curious Account of *Ants*, whence I shall abstract some few Particulars. Every *Ant's* Nest (it tells us) has a straight Hole leading into it, about the Depth of Half an Inch; which, afterwards, runs sloping downwards to the public Magazine, where the Grains they collect are stored up: and this is a different Place from that where they rest and eat.— Their Corn, being kept under Ground, would shoot and grow, did they not prevent it by biting out the *Germen* or *Bud* before they lay it up; but this they constantly do: for if their Corn be examined, no *Bud* will be found therein; nor, if sowed in the Earth, will it ever vegetate. Was it, however, to lie continually in the Ground, the Moisture would occasion it to swell and rot, and make it unfit for Food. But these Inconveniencies they find Means to remedy by their Vigilance and Labour in the following Manner.

They gather very small Particles of dry Earth, which they bring out of their Holes

* Vid. SWAMMERD. *Hist. Generale des Insectes*, p. 183.

every sunshiny Day, and place them in the Heat. Every one of them brings in her Mouth a Particle of this Earth, lays it by the Hole, and then goes to fetch another; so that in a Quarter of an Hour a vast Number of such small Particles of dried Earth are heaped round the Hole. Their Corn is laid upon this Earth when under Ground, and covered with the same. When these Particles of Earth are brought out, they fetch out their Corn likewise, and place it round this Earth, making two Heaps about the Hole, one of dry Particles of Earth, and the other of Grains of Corn. Last of all, they fetch out the Remainder of their dry Earth whereon the Corn was laid. They never go about this Work unless the Weather be clear, and the Sun very hot; but when both are favourable, they perform it almost every Day.

The Author of this Account had found a Nest of *Ants* in a Box of Earth standing out from a Window two Stories high; whence they made Excursions both upwards to the Top of the House, where some Corn lay in a Garret; and downwards into a Garden, which the Window overlooked. The Situation of this Nest obliged them to go up or down a great Way before they could possibly meet with any thing; but he found, notwithstanding, that none of them ever returned empty, but every one brought a Grain
of

of Wheat, Rye, or Oats, a small Seed, or even a Particle of dry Earth, if nothing else could be got. Some travelled to the farther End of the Garden, and, with prodigious Labour, brought heavy Loads from thence. It required four Hours, as he learned by frequent Observation, to carry a pretty large Grain or Seed from the Middle of the Garden to the Nest; and he computed therefrom, that an *Ant* works as hard as a Man who should carry a heavy Load twelve Miles a Day.

The Pains these *Ants* took to carry Grains of Corn up a Wall to the second Story, climbing all the Way with their Heads downwards, must be exceeding great. Their Weariness was shewn by their frequent Stops at the most convenient Places; and some appeared so fatigued and spent, they could not reach their Journey's End: in which Case, it was common to see the strongest *Ants*, which had carried home their Load, come down again and help them. Sometimes they were so unfortunate to fall down with their Burdens when just in Sight of Home: but when this happened, they seldom lost their Corn, but carried it up again.—He saw one, he says, of the *smallest Ants* carrying a large Grain of Wheat with incredible Pains. When she came to the Box where the Nest was, she and her Load together tumbled back to the Ground. Going down to look for her, he found she had recovered
the

the Grain, and was ready to climb up again. The same Misfortune befel her three Times; but she never let go her Hold, nor was discouraged; till at last, her Strength failing, she was forced to stop, and another *Ant* assisted her to carry home her Load to the public Stock.

How wonderful is the Sagacity of these Insects! How commendable their Care, Diligence, and Labour! How generous their Assistance of one another for the Service of the Community! How noble their public Virtue, which is never neglected for the Sake of private Interest! In all these Things they deserve our Notice and Imitation.—A contemplative Mind will naturally turn its Thoughts from the Condition and Government of *Ant-hills* to that of *Nations*; and reflect, that *superior Beings* may possibly consider Human Kind, and all their Solitudes and Toils, Pride, Vanity, and Ambition, with no more Regard than we do the Concerns of these little Creatures.

8. Among Pinks, Roses, and Sun-flowers, there is to be found, almost constantly, a *little, long, nimble Insect*, smaller than a Louse, sometimes creeping, and sometimes leaping. It appears in the *Microscope* bodied like a Wasp, with six or seven annular Divisions: it has two fair long black and yellow Wings; two Horns, each rising from a knobbed Root;

Root ; two black Eyes, and fix Legs. It is so tender, the least Touch kills it, but a very pretty Object.

9. A little *Insect* is constantly found in the *Froth* (or *Cuckow-spit* as some call it) that hangs on the Leaves of Rosemary, Lavender, &c. It creeps first, then leaps, and at last flies. It has six Feet, with two blackish Claws at the End of each ; a long *Proboscis* to suck up its Food, two Horns, and a Pair of darkish red pearly Eyes. The Tail ends in a Stump, but by its annular Divisions can be thrust out or drawn in at Pleasure.

10. There is a pretty *yellow Insect* on Sycamore Leaves, with six Legs, running very nimbly. The Eyes are red, prominent, and pearly ; the Horns are slit, and forked at the Ends. At first it has no Wings, but near the Shoulders are two little Protuberances, whence two long Wings come forth, when it turns into a Fly or Locust. It is hairy towards the Tail.

11. A small *white oblong Insect* sticks to the Ribs on the Back Sides of Rose-tree Leaves, towards the End of Summer, which turns into a little yellow Locust that skips about the same Tree. In both States it is a pretty Object.

12. There

12. There is also a greenish *Grasshopper* or *Locust*, on Gooseberry-Leaves, Sweet-Bryar, and Golden Mouse-Ear, in *April* and *May*, with four Legs, two black Eyes, a Pair of curious Horns, and many other Beauties.

13. In the Water of Ditches there are frequently Numbers of *Water-Spiders*, not larger than a Grain of Sand; they are very voracious, hunting about continually for Prey; and may be seen by the Microscope catching and devouring other minute Animalcules. Some have eight, some ten Legs, and *Antennæ* jointed like *Equisetum* or Horse-Tail.

14. Likewise in standing Waters we may often meet with slender *Eels* or *Worms*, about the third of an Inch, and sometimes more, in Length. They are full of Joints from End to End, at large Distances from one another; have a sharp Head like an *Eel*, a large Mouth, and two fine black Eyes. The Tail terminates in a Tuft of Hairs of a very curious Structure; the Motions of the Intestines are seen distinctly, and the whole Animal is a delightful Object.—The Blood-red *Jointed Worm*, very common in stagnant Waters, is also well deserving our Observation.

15. The

15. The *Crane-fly*, called by ALDROVAND *Culex maximus*, by SWAMMERDAM *Tipula terrestris*, and by the common People *Father-long-legs*, affords, in every Part of it, agreeable Subjects of Examination: but the Feet are more particularly surprizing; for, upon dissecting them in a Drop of Water, the fleshy Fibres contract and distend, in a Manner not to be imagined without seeing it, and continue their Motions three or four Minutes. Mr. LEEUWENHOEK found it constantly in the Feet of this Creature, but not in those of any other Insect *. The Intestines are also very curious, consisting of numberless Vessels and Organs, which may be seen as plainly by the Microscope, as the Bowels of larger Animals can by the naked Eye †. The Tails both of the Male and Female are of an extraordinary Structure: that of the Female ends in a sharp Point, wherewith she perforates the Ground, and deposits her Eggs under the Grass in Meadows.

16. The *Multipes*, or *Scolopendra*, has a very long slender Body; its Mouth is armed with a Pair of sharp Forceps, and in hot Countries (where they are of a large Size)

* *Arc. Nat.* Tom. III. p. 119. † Tom. IV. p. 351.

its Bite is venomous : but our smaller ones seem not mischievous. One I examined had fifty-four Joints, and from every Joint a Leg issued on each Side, which, with two others at the End of the Tail, larger than the rest, made in all one hundred and ten. When the Creatures move along, these Legs follow one another very regularly, making a pretty Kind of Undulation, not to be described, and giving the Body a swifter Progression than one would expect, where so many Feet take so many short Steps, in turn, one after another. There are several Sorts of these Insects, different in Shape, and in Number of Legs, which the Curious will be pleased to examine *.

17. There is an extraordinary Sort of *Caterpillar*, of a middle Size, having four Tufts of yellowish white Hair, like little Brushes, of an equal Height, standing upright on its Back : below these, from each Side, issues a Bunch of dark-coloured Hairs of different Lengths, the Extremities of which are black. Two more Bunches of the same Form rise from the Head like Horns, and another still from the Top of the Tail. Every Hair in these Bunches,

* LEEUWENHOEK says, the *Indian Millipes* has eight Eyes like the *Spider*. *Quere*, Have *English* ones so too?

when viewed through the *Microscope*, resembles a *Peacock's Feather*, and is a delightful Object. The Inquisitive will find abundance more Wonders in this amazing Creature, and, indeed, in most Sorts of *Caterpillars*.

18. The *Silk-worm* is a Creature every Part whereof, either in the *Worm* or *Fly State*, deserves our particular Attention: but as both MALPIGHI and LEEUWENHOEK have examined it with great Skill, and published their Observations with anatomical explanatory Drawings, I shall refer the Curious to them, and to their own Enquiries; only advising such as shall engage in a farther Examination, not to neglect the *Skins* these Animals cast off three Times before they begin to spin: for the Eyes, Mouth, Teeth, Ornaments of the Head, and many other Parts, may be discerned better in the *cast-off Skins* than in the real Animal. A due Observation of the Changes of this Creature, from the *Caterpillar* to the *Nymph*, *Aurelia*, or *Chrysalis*, and thence to the *Moth* or *Butterfly State*, will give a general Notion of the Changes all *Caterpillars* undergo, though some little Differences may be in the Manner. SWAMMERDAM says, the *Butterfly*, by a judicious Examination, may be traced and discerned under
each

each of these Forms, which are only different Coverings or Dresses for it.

19. The Tail of the *Male Silk-worm* being squeezed, Animalcules were found in the *Semen* * four Times as long as broad; their Backs thicker than their Bellies, like the Shape of a Trout. Their Length was supposed to be about half the Diameter of a Hair. This I experienced myself, on the 8th Day of *August*, in the Year 1742, when taking a *Male Silk-worm*, that was just then come forth in its *Moth-state*, and giving its Tail several little gentle Squeezes, in about a Minute's Time a small Drop of a brownish white Liquor was squirted briskly from it on a Talc I held to receive it: and diluting this with a little Water warmed in my Mouth for that Purpose, I was very much surprized and pleased to observe the numberless Animalcules it contained, swimming about, alive and vigorous.—

N. B. Whoever would make this Experiment, must do it before the *Moth* has been coupled with the Females; for nothing is to be got from it afterwards, as I have found by several Trials.

20. The *Proboscis* of a *Butterfly*, which winds round in a spiral Form, like the Spring

* Vid. LEEUWEN. *Arc. Nat.* Tom. I. Par. II. p. 422.

of a Watch, serves both for Mouth and Tongue, by entering into the Hollows of Flowers, and extracting their Dews and Juices. The Shape and Structure of it will be found very surprizing.

21. The *Legs* and *Feet* of *Insects* are wonderful in their Structure and Contrivance, according to their different Circumstances and Necessities of Life, and afford a pleasing Variety of Objects. It is pretty to observe, not only the sharp hooked Claws, but also the skinny Palms of some Flies, &c. which enable them to walk on Glass and other smooth Surfaces, even with their Bodies hanging downwards, by means of the Pressure of the Atmosphere: others again have a Sort of Sponges, which preserve their Claws from being broken or blunted by striking against hard Bodies, as the Claws of Cats, &c. are, by soft fleshy Protuberances at the Bottoms of their Feet.

22. The *Nymph* of the *Clothes-moth*, which (from being often found scudding among Books and Papers) Mr. Hook calls the silver-coloured Book-worm, is covered with thin transparent Scales, from whose Surfaces a Multiplicity of Reflections of Light make the Animal appear in Colour like a fine Pearl. It has six Legs, runs by Starts and Stops, and has three Horns at the Ex-

tremity of the Tail. As this Description is sufficient to make it known, I shall leave the Curious to examine its Beauties, and not anticipate their Pleasure. *Vide* Hook's *Microg.* p. 208.

23. On the Leaves of Orange Trees, Fig Trees, Willows, and many other Trees and Plants, there are various Kinds of minute *Insects*, as yet but little known, inclosed in Tubercles or Swellings.

24. The *Eggs* of *Insects* are remarkable for their different Figure and Colour, and for the particular Regularity and Exactness wherewith they are frequently placed. We shall sometimes find a Sort cemented round a Twig of the Sloe Tree, or Damson Tree, as if fastened there by Art, and ranged merely for the Sake of Beauty. The Variety of them is inconceivable, and to be sought for as well in the Waters as elsewhere; as those will be convinced who will take the Pains to examine, in the Spring, the Water-Cresses, Brook-lime, and other Water-plants, on the Back of whose Leaves infinite Numbers of *minute Eggs* may frequently be discovered, appearing to the naked Eye only as a Slime.

25. In Cellars, on the Corks of Bottles, there are three or four Sorts of very surprizing *Insects*.

26. The

26. The *Lungs* of a *Frog*, blown up and dried, will assist us to discover the true Structure of that Bowel.

27. *Cochineal*, which comes from *New Spain*, and is so valuable for its Use in dying *Scarlet*, *Crimson*, and *Purple*, has been asserted by some to be a Seed or Grain, and by others, an Insect; but the *Microscope* determines these Disputes, by shewing plainly, after steeping it in Water twenty-four Hours, an oval Body, Scales, Legs, and a pointed Trunk: in short, the whole resembles our *Cow-lady*. Many Eggs may be discovered upon opening their Bodies: and if you burn them, let their Ashes stand two or three Days in Water, then filter and evaporate, their Salts may be distinctly seen.

28. The *Feathers* of *Birds* afford Variety of Beauty, and differ greatly from one another, not only in their general Colour and Form, but in the Structure of each particular Part; as every body must be sensible, who examines those of the Ostrich, the Peacock, the Eagle, the Swan, the Parrot, the Owl, and all the numerous Species of Birds. Their Quills too deserve our Attention: and our Observations on them will be assisted by reading the 36th Observation in Mr. HOOK's *Micrography*, p. 168; and also Mr. LEEU-

WENHOEK's *Experiments*, in the 4th Tome of his Writings, p. 323.

29. *Mosses* of all Kinds are agreeable Objects, and appear, by the *Microscope*, to be as perfect in their Leaves, Flowers, and Seeds, as the largest Plants or Trees. Those, particularly, that grow on the Rocks and Coasts of the Sea, exhibit amazing Beauties.

30. *Sponge* is reckoned a *Plant-Animal*, and appears composed of minute Vessels resembling Veins and Arteries.

31. Decayed Fruits, moist Wood, damp Leather, stale Bread, and Abundance of other Things, contract what we call *Mouldiness*; which the *Microscope* discovers to be nothing else but innumerable minute *Plants*, bearing Leaves, Flowers, and Seeds, and increasing in a Manner almost incredible: for in a very few Hours the Seeds spring up, arrive at full Maturity, and bring forth Seed themselves; so that a Day produces several Generations of them. There are many Sorts of these microscopical *Plants*, very different in Size and Appearance: Some of the Mushroom Kind, others resembling Bulrushes, and others again bearing vast Quantities and great Varieties of Fruit. Other Kinds are likewise found in great Abundance on the Surface of Liquors, when they are what we term *Mothery*.

32. The

32. The *Air-vessels*, *Sap-vessels*, and *Pores* of *Wood*, are wonderful in their Figure, Number, and Disposition; as plainly appears by shaving off the thinnest Slices possible, lengthways, crossways, and obliquely, and bringing them to view. Fir and Cork are the readiest for this Purpose: but all other Kinds of Wood, tho' with somewhat more Trouble, may be rendered fit to be examined. In a Piece of Cork, no longer than the eighteenth Part of an Inch, sixty Cells were numbered in a Row; whence it follows, that one thousand and eighty are in the Length of an Inch; one million an hundred sixty and six thousand four hundred in an Inch square; and in a Cubic Inch, one thousand two hundred fifty-nine millions seven hundred and twelve thousand*.

In the *Pith* of Trees and Plants, cut so as to become transparent, the Vessels may be discerned distinctly. The Pores of Wood may likewise be seen advantageously in *Charcoal* and *Small-coal*.

33. There are many Sorts of Sand; some gathered on the Sea-shore, or on the Shores of Rivers, and others found within Land. The Grains of each Sort differ much in Size,

* Hook's *Microg.* p. 114.

Form, and Colour: some are opake, others transparent; some have rough Surfaces, and others are quite smooth*. These Varieties are very agreeable to examine by the *Microscope*, which shews, in some of the shining Kinds, Grains having all Numbers of Sides and Angles, and so finely polished, that no Diamond is more exquisitely beautiful. On others, grotesque Figures, or Representations of Landscapes, Buildings, Plants, and Animals, at once surprize and please.

34. In order to examine *Diamonds* † with the greater Exactness, Mr. LEEUWENHOEK broke a small one between two Hammers, and placing the Pieces before his *Microscope*, in the Sun-shine, he saw many sparkling Flames issue from them, with a continual Coruscation in some, like a faint Lightning. Then viewing them in the Shade, he observed, among other pretty Appearances, a little Flame that seemed to dart from each Particle of the Diamond: and it was a glorious Sight to behold Multitudes of sparkling Flames, most of a bright Fire-colour, and others greenish, flashing faintly and like Lightning at a Distance. In other Pieces of the *Dia-*

* Vid. *Phil. Transf.* Numb. 289. Hook's *Microg.* p. 80.

† Vid. *Phil. Transf.* Numb. 374.

mond, the *Lamellæ*, or *Layers*, composing it, were very plainly to be distinguished.

35. In striking Fire with a Flint and Steel, little Particles of Steel are struck off, and melted into Globules by the Collision; as will be evident upon making the Experiment over a Sheet of white Paper, and viewing what falls into it through the Microscope. Mr. Hook first made the Trial, and found that a black Particle, no bigger than a Pin's Point, appeared like a Ball of polished Steel, and strongly reflected the Image of the Window near which he examined it *. It is also entertaining enough to separate the melted Iron Particles from the Particles of Stone, which sometimes are vitrified, by Means of a Knife that has been touched by a Loadstone.

36. Kind Nature has supplied the Seeds of Dandelion, Thistles, and many other Plants, with a Down, that serves instead of Wings to convey them to distant Places. The Figures of such Down, in different Plants, are very different when looked at thro' Glasses; some appearing plain and smooth, others rough and thorny, and others again with little Hooks or Claspers to catch hold of any

* Hook's *Microg.* p. 25. 44. 46.

Thing. Peaches, Quinces, and some other Fruits, have likewise a soft Down, which is worth examining, as well as the Hairs on many Sorts of Leaves, Fruits, and Seeds.

37. There is a very fine Down, or Hair, called *Cowage*, or *Cow-itch*, growing on a Sort of hairy Kidney-bean that comes from the *East-Indies*. The Pods, about three Inches long, resemble a *French-bean*, and are covered with this Down, or Hair, which is very stiff for its Bigness, causes Pain and Inflammation if rubbed on any Part, and when viewed by a Microscope appears like Multitudes of Needles.

A Sort of *curling Horns*, rising out of the Middle of some Carnations and Pinks, are exceeding pretty Objects.

38. The *Flakes of falling Snow* are various in their Configurations, and extremely beautiful, if examined before they melt: which may easily be done by making the Experiment in the open freezing Air. DESCARTES, Dr. GREW, Mr. HOOK, Mr. MORTON, Dr. LANGWITH, and others, have given us several of their different Star-like Forms: and Dr. STOCKE, of *Zealand*, has lately communicated to the *Royal Society* some new Figures unobserved before.

The Configuration of the Particles of Dew may perhaps be likewise well worth observing.

Plumous

Plumous Alum, Talcs of different Kinds, Asbestos, Marcasites, and all Sorts of Minerals and Fossils, afford a Variety of agreeable and curious Objects.

Æthiops Mineral, Calomel, Mercurius dulcis, and all other Mercurial Powders, are found, when examined by the Microscope, to be full of minute Globules of crude and unaltered Mercury.

Common Salt dissolved in Water exhibits infinite Numbers of quadrangular Bodies.

Toads, Frogs, and Newts, are killed by rubbing Salt upon their Backs *; Snakes, Vipers, Rattle - Snakes, &c. by drawing through their Skin, with a Needle, a Thread dipped in Oil of Tobacco : and Mercury is a mortal Poison to Ants.

It would be an endless Task to point out half the Objects fit to be examined by this useful and entertaining Instrument, which supplies us, as it were, with Eyes infinitely more penetrating than our own ; and discovers Wonders to us which we should be unable to conceive without it. The foregoing are a few only among those that are most curious ; but every Creature, every Plant, and Fruit, and Flower, every Drop of Wa-

* Hook's *Microg.* p. 144.

ter, and every Particle of Matter, if carefully examined, will afford us new Instruction and Delight.

C H A P. LI.

*The Works of ART and NATURE
compared together and considered.*

BEFORE this Treatise is concluded, it will not perhaps be thought unprofitable to examine some of the finest and most exquisite Performances of human Art, and compare them with the Productions of Nature: as such a Comparison must tend towards humbling the Self-conceit and Pride of Man, by giving him a more reasonable and modest Opinion of himself; and at the same Time may in some Degree conduce towards improving his imperfect Conceptions of the SUPREME CREATOR.

Upon examining the *Edge* of a very keen *Razor* by the Microscope, it appeared as broad as the Back of a pretty thick Knife; rough, uneven, full of Notches and Furrows, and so far from any Thing like Sharpness, that an Instrument as blunt as this seemed to be, would not serve even to cleave Wood*.

* Hook's *Microg.*

An exceeding small *Needle* being also examined, the Point thereof appeared above a Quarter of an Inch in Breadth ; not round, or flat, but irregular and unequal ; and the Surface, though extremely smooth and bright to the naked Eye, seemed full of Ruggedness, Holes, and Scratches. In short, it resembled an Iron Bar out of a Smith's Forge *.

But the *Sting of a Bee*, viewed through the same Instrument, shewed every where a Polish most amazingly beautiful, without the least Flaw, Blemish, or Inequality ; and ended in a Point too fine to be discerned : yet this is only the Case, or Sheath, of Instruments much more exquisite contained therein, as before described, Page 210.

A small Piece of exceeding fine *Lawn* appeared, from the large Distances and Holes between its Threads, somewhat like a Hurdle or Lattice, and the Threads themselves seemed coarser than the Yarn wherewith Ropes are made for Anchors.

Some *Brussels Lace*, worth five Pounds a Yard, looked as if it were made of a thick, rough, uneven Hair Line, intwisted, fastened, or clotted together in a very awkward and unartful Manner.

* *Phil. Transf.* Numb. 324. *Specif. de la Nat.* Eng. Edit. 12mo. Vol. I. p. 8.

But a *Silkworm's Web*, being examined, appeared perfectly smooth and shining, every where equal, and as much finer than any Thread the best Spinster in the World can make, as the smallest Twine is finer than the thickest Cable. A Pod of this Silk being wound off, was found to contain nine hundred and thirty Yards : but it is proper to take Notice, that as two Threads are glewed together by the Worm through its whole Length, it makes really double the above Number, or one thousand eight hundred and sixty Yards : which being weighed with the utmost Exactness, were found no heavier than two Grains and a Half *. What an exquisite Fineness is here ! and yet this is nothing when compared with the Web of a small Spider (see Page 200), or even with the Silk that issued from the Mouth of this very Worm, when but newly hatched from the Egg.

The smallest *Dot*, *Tittle*, or *Point*, that can be made with a Pen, appears, when viewed by the Microscope, a vast irregular Spot, rough, jagged, and uneven all about its Edges, and far enough from being truly round. The finest and minutest *Writing*, such as the Lord's Prayer in the Compass of a silver Penny, or other such like curious

* Ibid. p. 50.

Performance, done by the most able Master, seems, when brought to Examination, as shapeless, uncouth, and barbarous, as if written in *Runic Characters*. But the little Specks on the Wings or Bodies of Moths, Beetles, Flies, and other Insects, are found, when magnified, to be most accurately circular : and all the other Lines and Marks about them appear regularly and finely drawn, to the utmost Possibility of Exactness.

Dr. POWER says, he saw a golden Chain at TREDESCANT's, of three hundred Links, not more than an Inch in Length, fastened to, and pulled away by, a Flea. And I myself have seen very lately, near *Durham-Yard* in the *Strand*, and have examined with my *Microscope*, a Chaise (made by one Mr. BOVERICK, a Watch-maker) having four Wheels, with all the proper Apparatus belonging to them, turning readily on their Axles ; together with a Man sitting in the Chaise ; all formed of Ivory, and drawn along by a Flea without any seeming Difficulty. I weighed it with the greatest Care I was able, and found the Chaise, Man, and Flea, were barely equal to a single Grain. I weighed also, at the same Time and Place, a Brass Chain made by the same Hand, about two Inches long, containing two hundred Links, with a Hook at one End, and a Padlock and
Key

Key at the other; and found it less than the third Part of a Grain *.

We are told, that one OSWALD NELINGER † made a Cup of a Pepper-corn, which held twelve hundred other little Cups, all turned in Ivory, each of them being gilt on the Edges, and standing upon a Foot: and that, so far from being crowded or wanting Room, the Pepper-corn would have held four hundred more.

These are some of the nicest, most curious, and surprizing Works of Art: but let us examine any of them with a good Microscope, and we shall immediately be convinced, that the utmost Power of Art is only a Concealment of Deformity, an Imposition upon our Want of Sight; and that our Admiration of it arises from our Ignorance of what it really is.

This valuable Discoverer of Truth will prove the most boasted Performances of Art to be as ill-shaped, rugged, and uneven, as

* I have seen, since my writing the above (made by the same Artist) a Quadrille Table with a Drawer in it, an Eating Table, a Side-board Table, a Looking-glass, twelve Chairs with Skeleton Backs, two dozen of Plates, six Dishes, a dozen Knives and as many Forks, twelve Spoons, two Salts, a Frame and Castors, together with a Gentleman, Lady, and Footman, all contained in a *Cherry Stone*, and not filling much more than half of it.

† *Ephem. German. Tom. I. Addend. ad Observ. 13.*

if they were hewn with an Ax, or struck out with a Mallet and Chiffel. It will shew Bungling, Inequality, and Imperfection in every Part, and that the Whole is disproportionate and monstrous. Our finest Miniature Paintings appear before this Instrument as mere Daubings, plaistered on with a Trowel, and entirely void of Beauty, either in the Drawing or the Colouring. Our most shining Varnishes, our smoothest Polishings, will be found to be mere Roughness, full of Gaps and Flaws.

Thus sink the *Works of Art*, when we become enabled to see what they really are!—But, on the contrary, the nearer we examine, the plainer we distinguish, the more we can discover of the *Works of Nature*, even in the least and meanest of her Productions, the more sensible we must be made of the Wisdom, Power, and Greatness of their Author.—Let us apply the *Microscope* where we will, nothing is to be found but Beauty and Perfection. View we the numberless Species of Insects that swim, creep, or fly around us, what Proportion, Exactness, Uniformity, and Symmetry shall we perceive in all their Organs! what a Profusion of Colouring! Azure, Green, and Vermilion, Gold, Silver, Pearls, Rubies, and Diamonds; Fringe and Embroidery on their Bodies, Wings, Heads, and every other Part! How rich the Glow!
how

how high the Finishing! how inimitable the Polish we every where behold!—Search we yet farther, and examine the Animalcules, many Sorts whereof it would be impossible for an human Eye unassisted to discern; those breathing Atoms, so small they are almost all Workmanship! in them too we shall discover the same Organs of Body, Multiplicity of Parts, Variety of Motions, Diversity of Figures, and particular Ways of Living, as in the larger Animals.—How amazingly curious must the internal Structure of these Creatures be! The Heart, the Stomach, the Entrails, and the Brain! How minute and fine the Bones, Joints, Muscles, and Tendons! How exquisitely delicate beyond all Conception the Arteries, Veins, and Nerves! What Multitudes of Vessels and Circulations must be contained within this narrow Compass! And yet all have sufficient Room to perform their different Offices, and neither impede nor interfere with one another.

The same Order, Regularity, and Beauty, will appear likewise among *Vegetables*, if brought to Examination. Every Stalk, Bud, Flower, or Seed, displays a Figure, a Proportion, a Harmony, beyond the Reach of Art. There is not a Weed, not a Moss, whose every Leaf does not shew a Multiplicity of Vessels and Pores disposed most curiously for the Conveyance of Juices to support
and

and nourish it, and which is not adorned with innumerable Graces to embellish it.

The most perfect *Works of Art* betray a Meanness, a Poverty, an Inability in the Workman; but those of *Nature* plainly prove, the Hand that formed them was absolute Master of the Materials it wrought upon, and had Tools exactly suitable to its Design. Every Hair, Feather, or Scale, even of the meanest Insect, appears rounded, polished, and finished to the highest Pitch; and shews the abundant Riches, Munificence, and Skill of its Maker.

But some may possibly enquire, to what Purpose Providence has bestowed such an Expence of Beauty on Creatures so insignificant; and then cry out, *What is all this to us?* — My Reply is, that the Beauty and Elegance which adorn them are evident and convincing Proofs of their not being so insignificant as we presumptuously suppose they are; for such Beauty must be given them, either for their own Sake, that they themselves may be delighted with it; or else for ours, that we may observe in them the amazing Power and Goodness of the Creator. If the former be the Case, we must allow them to be of Consequence in the Account of their Maker, and therefore deserve our Regard; and if the latter, it is really our Duty to take Notice of and admire them. But

for whatever Reason God has been pleased to bestow Existence on them, and to clothe them with Beauty, what he has judged worthy himself to create, is not, surely, below us to examine and consider. The same Hand that formed the Whale, the Elephant, and the Lion, has likewise made the Louse, the Gnat, and the Flea.

C H A P. LII.

Some reasonable Reflections on Discoveries made by the Microscope.

THE Use of the *Microscope* will naturally lead a thinking Mind to a Consideration of *Matter*, as fashioned into different Figures and Sizes, whether Animate or Inanimate : it will raise our Reflections from a Mite to a Whale, from a Grain of Sand to the Globe whereon we live ; thence to the Sun and Planets ; and, perhaps, onwards still to the fixt Stars and the revolving Orbs they enlighten, where we shall be lost amongst Suns and Worlds in the Immensity and Magnificence of Nature.

Our Ideas of Matter, Space, and Duration, are merely comparative, taken from ourselves and Things around us, and limited to certain Bounds ; beyond which if we endeavour to extend them, they become very indistinct. The Beginnings and Endings,
excessive

excessive Greatness or excessive Littleness, of Things, are to us all Perplexity and Confusion.

“ Let a Man try to conceive the different Bulk of an Animal which is twenty, from another which is an hundred Times less than a Mite ; or to compare, in his Thoughts, the Length of a thousand Diameters of the Earth with that of a million, an he will quickly find that he has no different Measures in his Mind adjusted to such extraordinary Degrees of Grandeur or Minuteness. The Understanding, indeed, opens an infinite Space on every Side of us ; but the Imagination, after a few faint Efforts, is immediately at a Stand, and finds itself swallowed up in the Immensity of the Void that surrounds it. Our Reason can pursue a Particle of Matter thro’ an infinite Variety of Divisions, but the Fancy soon loses Sight of it, and feels in itself a Kind of Chasm, that wants to be filled with Matter of a more sensible Bulk. We can neither widen nor contract the Faculty to the Dimensions of either Extreme. The Object is too big for our Capacity, when we would comprehend the Circumference of a World ; and dwindles to Nothing when we endeavour after the Idea of an Atom *.”

* *Spectator*, Numb. 420.

The minute Size of microscopical Animalcules, and the little Space they occupy, when compared with ourselves and the Room we fill, may possibly increase our Pride and Folly, and make us imagine ourselves of mighty Consequence in the Creation. But if we carry our Thoughts upwards, and compare the Body of a Man to the Bulk of a Mountain, that Mountain to the whole Earth, the Earth to the Circle it describes round the Sun, that Circle to the Sphere of the fixt Stars, the Sphere of the fixt Stars to the Circuit of the whole Creation, and the whole Creation itself to the infinite Space that is every where diffused about it, we shall find ourselves sink to Nothing.——

“ * Were the Sun, with all its planetary
 “ Worlds, utterly extinguished and annihi-
 “ lated, they would no more be missed in
 “ the grand Universe than a Grain of Sand
 “ upon the Sea-shore: the Space they pos-
 “ sess is so exceeding little, in comparison
 “ of the Whole, that it would scarce make
 “ a Blank in the Creation. The Chasm
 “ would be almost imperceptible to an Eye
 “ that could take in the whole Compass of
 “ Nature, and pass from one End of the
 “ Creation to the other.” What then is

* Vide *Spectator*, Numb. 565.

the mightiest Monarch that ever lived!
What is the whole Race of Man!

A Mite upon a Cheese is as large and considerable, in Proportion, as a Man upon the Earth: the little Insects feeding on the Leaves of Peach-Trees and Cherry-Trees, are no ill Representation of Oxen grazing in large Pastures: and the minute Animalcules in a Drop of Water swim about with as much Freedom as Whales do in the Ocean:—All have equal Room in Proportion to their own Bulk.

The Term or Duration of Life, in different Creatures, is likewise comparatively long or short, according to the Number, Quickness, or Slowness of Ideas presenting themselves successively to the Mind. For, when the Ideas succeed one another swiftly, and many of them are crowded into a narrow Compass, the Time, however short it may be, will seem long in Proportion to the Number of Ideas passing through it: on the contrary, when the Ideas are but few, and follow one another very slowly, a long Time will appear short, in Proportion to their slow Succession, and the Smallness of their Number.

“ It is evident, says Mr. LOCKE, to any
“ one who will but observe what passes in
“ his own Mind, that there is a Train of
“ Ideas, which constantly succeed one ano-
X 3 “ ther

“ ther in his Understanding, as long as he
 “ is awake. Reflection on these Appear-
 “ ances of several Ideas one after another in
 “ our Minds, is what we call *Duration*.
 “ For whilst we are thinking, or whilst we
 “ receive successively several Ideas in our
 “ Minds, we know that we do exist : and
 “ so we call the Existence, or the Conti-
 “ nuation of Existence of ourselves, or any
 “ Thing else commensurate to the Succession
 “ of any Ideas in our Minds, the *Duration*
 “ of ourselves, or any such other Thing
 “ co-existing with our Thinking *.”

From these Principles it is manifest, that
 one Day may appear as a thousand Years,
 and a thousand Years but as one Day : by
 which Means, the Lives of all Creatures, for
 aught we know, may seem to themselves
 nearly of the same Duration. It is at least
 probable, that something like this may
 really be the Case as to the Inhabitants of
 this our Earth : for as the same Functions
 or Offices of Life, namely, to be born, seek
 proper Sustenance, increase in Bulk, arrive
 at full Maturity, propagate the Kind, and
 die, are equally performed by all ; they who
 perform them in a few Months, Days, or

* Vide Locke on *Human Understanding*, Chap. XIV.

Hours *, may be supposed, from the Number and swift Succession of Ideas suited to all these Purposes, to live as long, according to

* SWAMMERDAM has published, in *Low Dutch*, a curious Account of what he calls the *Ephemeron*; a Fly which, he tells us, lives but five Hours. This Insect is found about all the Mouths of the *Rhine*; and, according to his Drawings and Descriptions, seems to be a Species somewhat between our *May-Fly* (bred from the *Cadew Worm*) and the *Libella* or *Dragon-Fly*. It has four Wings, two whereof are shorter than the other; a Pair of small Horns, six Legs, and two very long straight Hairs issuing from the Tail. They are seen, he says, flying near the Surface of the Water, about Midsummer, for three succeeding Days, but no longer in one Season. They eat nothing; and their only Business is to generate, and drop their Eggs upon the Water: which Eggs, sinking to the Bottom, produce a Kind of *Worms* or *Maggots*, that soon hollow themselves Cavities in the Clay, where they abide three Years; growing each Year about an Inch in Length. When the *Worm* is come to its full Growth, it rises to the Surface, about six o'Clock in an Evening; lays its Eggs, and dies about ten o'Clock the same Night.

I am surprized that SWAMMERDAM should say, the Life of this Creature is no more than five Hours, when his own Account plainly proves that it really lives three Years: for it is certainly as much alive in the *Worm State*, as when afterwards it becomes a Fly.—Truth should be every Body's Pursuit; and for the Sake thereof I have endeavoured to clear up the general Mistake as to this Fly, which is frequently produced, upon SWAMMERDAM's Authority, as the most remarkable Instance we know of the Shortness of Life.—But tho' this Insect happens to live much longer than was imagined, I make no Doubt, there are some among the numberless Species of Beings, whose natural Lives are as short as this was supposed to be: such too are most likely to be found amongst the very minute Kinds. For as those *exceeding small Plants*, invisible to the naked Eye, which compose what we call *Mouldiness*, spring up, bear Fruit, and die in a few Hours; we may reasonably suppose the Lives of some *exceedingly small Animals* to be of as short a Duration.

their own thinking, as other Creatures do, where the same Train of Ideas proceed more slowly, and take up many Years.

As the Microscope discovers almost every Drop of Water, every Blade of Grass, every Leaf, Flower, and Grain, swarming with Inhabitants, all of which enjoy not only Life but Happiness; a thinking Mind can scarce forbear considering that Part of the Scale of Beings which descends from himself to the lowest of all sensitive Creatures, and may consequently be brought under his Examination. “ Amongst these, some are raised so little above dead Matter, that it is difficult to determine whether they live or no: others, but one Step higher, have no other Sense besides Feeling and Taste: some, again, have the additional one of Hearing, others of Smell, and others of Sight *.

It is wonderful to observe, by what a gradual Progression the World of Life advances through a prodigious Variety of Species, before a Creature is formed that is complete in all its Senses: and, even amongst these, there is such a different Degree of Perfection in the Senses which one Animal enjoys beyond what appears in another, that tho’ the Sense in different Animals be distinguished

* Vide *Spectator*, Numb. 519.

by the same common Denomination, it seems almost of a different Nature. If, after this, we look into the several inward Perfections of Cunning and Sagacity, or what we generally call Instinct, we find them rising in the same Manner, imperceptibly, one above another, and receiving additional Improvements according to the Species in which they are implanted.

This Progress in Nature is so very gradual, that the whole Chasm, from a Plant to a Man, is filled up with divers Kinds of Creatures, rising one over another by such a gentle and easy Ascent, that the little Transitions and Deviations from one Species to another are almost insensible. And the intermediate Space is so well husbanded and managed, that there is scarce a Degree of Perception which does not appear in some one Part of the World of Life. Since then the Scale of Being advances by such regular Steps so high as Man, we may by Parity of Reason suppose, that it still proceeds gradually upwards thro' numberless Orders of Beings of a superior Nature to him: as there is an infinitely greater Space and Room for different Degrees of Perfection between the Supreme Being and Man, than between Man and the most despicable Insect."

Mr. LOCKE's Thoughts upon this Subject are very curious: "That there should", says he,

he, “ be more Species of intelligent Creatures
“ above us, than there are of sensible and
“ material below us, is probable to me from
“ hence, that in all the visible and corporeal
“ World we see no Chasm, no Gaps. All
“ quite down from us the Descent is by ea-
“ sy Steps and a continued Series of Things,
“ that in each Remove differ very little one
“ from the other. There are Fishes that
“ have Wings, and are not Strangers to the
“ airy Region; and there are some Birds that
“ are Inhabitants of the Water, whose Blood
“ is as cold as Fishes’, and their Flesh so like
“ in Taste, that the Scrupulous are allowed
“ them on Fish-Days. There are Animals
“ so near a-kin to Birds and Beasts, that
“ they are in the Middle between both.
“ Amphibious Animals link the Terrestrial
“ and Aquatic together: Seals live at Sea
“ and at Land; and Porpoises have the warm
“ Blood and Entrails of a Hog: not to
“ mention what is confidently reported of
“ Mermaids or Sea-men.—There are some
“ Brutes that seem to have as much Know-
“ ledge and Reason as some that are called
“ Men; and the Animal and Vegetable
“ Kingdoms are so nearly joined, that if
“ you will take the lowest of one and the
“ highest of the other, there will scarce be
“ perceived any great Difference between
“ them. And so on till we come to the
“ lowest

“ lowest and the most inorganical Parts of
“ Matter, we shall find every where that
“ the several Species are linked together, and
“ differ but in almost insensible Degrees.
“ And when we consider the infinite Power
“ and Wisdom of the Maker, we have Reason
“ to think, that it is suitable to the
“ magnificent Harmony of the Universe,
“ and the great Design and infinite Goodness
“ of the Architect, that the Species of Creatures
“ should also, by gentle Degrees, ascend
“ upwards from us towards his infinite
“ Perfection; as we see they gradually
“ descend from us downwards. Which, if
“ it be probable, we have Reason then to
“ be persuaded, that there are far more Species
“ of Creatures above us than there are
“ beneath; we being in Degree of Perfection
“ much more remote from the infinite
“ Being of God, than we are from the lowest
“ State of Being, or that which approaches
“ nearest to Nothing.”

Every Creature is confined to a certain Measure of Space, and its Observation stinted to a certain Number of Objects: but some move and act in a Sphere of a wider Circumference than that of others, according as they rise above one another in the Scale of Existence. This Earth is the Spot appointed for Man to dwell and act upon: he
stands

stands foremost of all the Creatures here, and links together Intelligences and Brutes. The Sphere of his bodily Action is limited, confined, and narrow; but that of his Mind is vast, and extensive beyond the Bounds of Matter. Formed for the Enjoyment of intellectual Pleasures, his Happiness arises from his Knowledge; and his Knowledge increases in Proportion as he discovers and contemplates the Variety, Order, Beauty, and Perfection of the Works of Nature: whatever, therefore, can assist him in extending his Observations is to be valued, as in the same Degree conducive to his Happiness.

What we know at present, even of Things the most near and familiar to us, is so little in Comparison of what we know not, that there remains a boundless Scope for our Enquiries and Discoveries; and every Step we take, serves to enlarge our Capacities, and give us still more noble and just Ideas of the Power, Wisdom, and Goodness of the Deity.

The Universe is so full of Wonders, that perhaps Eternity alone can be sufficient to survey and admire them all: perhaps, too, this delightful Employment may be one great Part of the Felicity of the Blessed.—When the Soul shall become divested of Flesh, the Pleasures of Sense can be no more: and if,

by

by a continued Habit, any Longings after them shall hang about it, such Longings must create a proportionable Degree of Wretchedness, as they can never possibly be gratified. But if its principal Delight has been in the Contemplation of the Beauties of the Creation, and the Adoration of their Almighty Author, it soars, when disembodied, into the celestial Regions, duly prepared for the full Enjoyment of intellectual Happiness.

TO THEE, eternal self-existing CREATOR of the UNIVERSE! whose Will is Nature's Law! Omniscient, Omnipresent, All-Bountiful, and Gracious! TO THEE be paid, by all thy CREATURES, Thanksgiving and Adoration, till Time shall be no more!

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