Pl. 1.

THE *NEW UNIVERSAL* SINGLE MICROSCOPE,

Invented, Made and Sold by

GEORGE ADAMS

at Tycho Brahe's Head in Fleet Street,

LONDON.

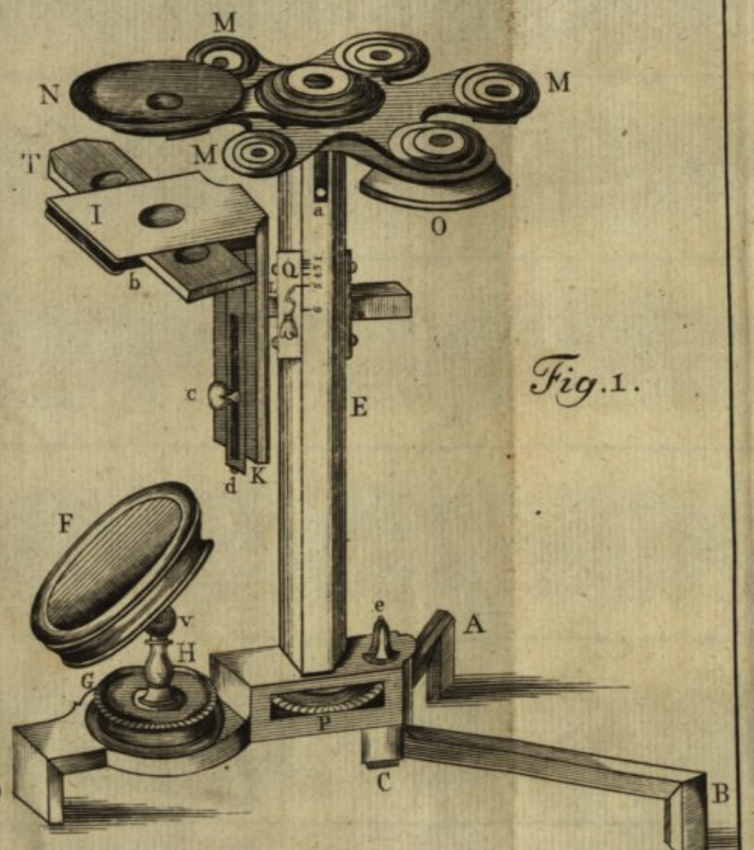

Fig. 1.

Front.g the Title Page.

Micrographia Illuſtrata,

OR,

The Knowledge of the MICROSCOPE *Explain'd:*

Together with an ACCOUNT of

A *New Invented*

UNIVERSAL, Single *or* Double,

MICROSCOPE,

Either of which is capable of being applied to an Improv'd

SOLAR APPARATUS.

This TREATISE contains a Deſcription of the Nature, Uſes, and Magnifying Powers of MICROSCOPES in general; together with full Directions how to prepare, apply, and examine, as well as preſerve, all Sorts of minute Objects:

Alſo an ACCOUNT of

The principal MICROSCOPICAL DISCOVERIES, that have hitherto been mentioned by the moſt celebrated AUTHORS, together with a great Variety of new Experiments and Obſervations.

The WHOLE being, as it were,

A NATURAL HISTORY of a Multitude of Aerial, Terreſtrial, and Aquatick Animals, Seeds, Plants, *&c.*

To which is added,

A TRANSLATION of Mr. JOBLOTT's Obſervations on the Animalcula, that are found in many different Sorts of Infuſions;

AND

A very particular ACCOUNT of that ſurpriſing Phænomenon, *The Freſh Water Polype*, tranſlated from the *French* Treatiſe of Mr. *Trembley*.

This WORK is compiled for the Aſſiſtance of thoſe, who are deſirous of ſurveying the extenſive Beauties of the minute Creation;

And is illuſtrated with 65 Copper-Plates, curiouſly engrav'd, which contain above 560 Pictures of MICROSCOPIC OBJECTS.

By *GEORGE ADAMS*,

Mathematical, Philoſophical, and Optical Inſtrument-Maker, at *Tycho Brahe's Head*, in *Fleet-Street*.

The Second Edition.

LONDON:

Printed for, and Sold by the AUTHOR, and by *Samuel Birt*, in *Ave Mary Lane*.

MDCCXLVII.

OR,

The Knowledge of the MICROSCOPE Explain'd:

Together with an Account of

A New Invented

UNIVERSAL, Single or Double,

MICROSCOPE,

Either of which is capable of being applied to an Improv'd

SOLAR APPARATUS.

This TREATISE contains a Description of the Nature, Use, and Magnifying Powers of Microscopes in general; together with full Directions how to prepare, apply, and examine, as well as preserve, all sorts of minute Objects:

Also an Account of

The principal MICROSCOPICAL Discoveries, that have hitherto been mentioned by the most celebrated Authors; together with a great Variety of new Experiments and Observations.

The Whole being as it were,

A NATURAL HISTORY of a Multitude of Aerial, Terrestrial, and Aquatick Animals, Seeds, Plants, &c.

To which is added,

A TRANSLATION of Mr. LOBLOTT's Observations on the Animalcula, that are found in many different Sorts of Infusions;

AND

A very particular Account of that surprising Phænomenon, The Rock Water Polypus, translated from the Parisian Treatise of Mr. Trembly.

This WORK is compiled for the Affiftance of thofe, who are defirous of furveying the exact Beauties of the minute Creation;

And is illuftrated with 25 Copper-Plates, curioufly engrav'd, which contain above 300 Figures of Microfcopic Objects.

By GEORGE ADAMS,

Mathematical, Philofophical, and Optical Inftrument-Maker, at Tycho Brahe's Head, in Fleet-Street.

The Fourth Edition.

LONDON:

Printed for, and Sold by the Author, and by Samuel Dilly, in Poultry Lane.

MDCCLXII.

INTRODUCTION.

THE *Study of Nature, or in other Words, a ſerious Contemplation of the Works of God, is certainly one of the moſt pleaſing and uſeful, as well as moſt extenſive Kinds of Knowledge. It is indeed the great, and proper Object of our rational Faculties; for ſurely we cannot employ our Reaſon better, than in endeavouring to make ourſelves acquainted with the glorious Works of that Being, to whoſe Goodneſs we owe it.*

Natural Philoſophy is now ſo greatly improv'd in all its ſeveral Branches, that few Perſons, who have had the Happineſs of a liberal Education, are wholly unacquainted with the Value of it. But ſtill the Generality of Mankind are guilty of one very great Miſtake, for they are apt to form an abſolute Judgment of the Works of Nature, from outward Appearances only; and ſo imagine, that the moſt grand and magnificent Parts of the Creation, are always

always moſt perfect, and for that Reaſon moſt worthy of our Regard. The Splendour of the Sun is viſible to every Eye, and we need only look upwards in order to be convinced, that nothing leſs than infinite Power and Wiſdom, could firſt create the Univerſe. What, but an Almighty Hand, could raiſe ſuch a glorious Canopy as that of the Heavens, ſo richly adorned with Stars? Or ſtretch out ſuch a ſpacious Area, as this terraqueous Globe on which we tread, and ſail; and which is furniſh'd with every Thing that is neceſſary for our Support or Happineſs? And indeed theſe great Truths are ſo very obvious to the loweſt Capacities, that few Perſons pretend to diſpute them; but then it muſt likewiſe be own'd, that Men are generally apt to confine their Attention to the moſt ſhining Parts of Philoſophy, and ſo treat every Thing elſe with Coolneſs and Indifference, and even ſome Degree of Contempt. But ſurely a true Philoſopher is one, who diligently purſues the Study of Nature, in all its ſeveral Branches; who can behold with Admiration her nobleſt Productions, and yet view with Pleaſure the ſmalleſt of her Works; in ſhort one, who thinks every thing excellent, that owes its Formation to her ſkilful Hand. Nor is this a forced and imaginary Deſcription, but a real Character; and we need only take a tranſient View of ſome of thoſe Creatures, with which all Parts of the Earth are ſo plentifully ſtored, in order to be convinced of the Juſtneſs of it. For whether we regard their Elegance, and Beauty; or conſider their Fitneſs to anſwer thoſe Purpoſes, for which they were deſigned; in both theſe Reſpects we ſhall find,

find, that the ſmalleſt Creatures are perfect in their Kind, and carry about them as ſtrong Marks of infinite Wiſdom and Power, as the greateſt. How many curious Animals inhabit the Air, and what Numbers traverſe the deep Waters. The whole Earth is full of Life; there not being a ſingle Tree, Plant, or Flower, but what affords Food and Shelter to a Species of Inhabitants peculiar to itſelf. And then if we call in the Aſſiſtance of Art, what a new Scene of Wonder opens to our View? What an infinite Variety of living Creatures preſent themſelves to our Sight? Indeed their extream Minuteneſs may at firſt ſeem a juſt Argument for that low Opinion, which the Vulgar are apt to entertain of them; however, if we examine them with Cloſeneſs and Attention, we ſhall ſoon diſcover their divine Original. We ſhall then ſurvey with Admiration the wonderful Art and Mechaniſm of their Structure; wherein ſuch a Number of Veſſels, Fluids, and Movements, are collected into a ſingle Point; and That often inviſible to the naked Eye. What a Profuſion of the richeſt Ornaments, and gayeſt Colours, are frequently beſtowed upon one little Inſect; and yet there are Millions of others, that are as beautiful and wonderful in their Kind. Some are covered with ſhining Coats of Mail; others adorned with Plumes of Feathers; and all compleatly furniſh'd with thoſe Weapons, that are moſt proper for defending themſelves, as well as attacking their Enemies. In ſhort, the more we enquire into Nature, the more excellent ſhe appears, and we ſhall conſtantly find, that the Beauty of her Works will gradually riſe in Proportion to our Knowledge of them. There is no ſuch Thing as Meanneſs in

any

any of her Productions; ſome indeed may be more grand, and happen to ſtrike our Senſes more ſtrongly than others, but all are perfect in the higheſt Degree.

If then a ſerious Contemplation of the Works of God, may juſtly be conſider'd as an excellent Kind of Knowledge, and worthy of our Purſuit; and if all thoſe Works, though different in Degrees of Splendour, are ſtill perfect; it is hoped, that an humble Attempt to improve, and encourage the Study of any Branch of Natural Philoſophy, will not be unacceptable to the Publick. And ſince the Knowledge of the Microſcope has always been look'd upon as no inconſiderable Branch of Natural Philoſophy, and as that Part of it has more particularly fallen within the Compaſs of the Author's Studies, he has ventured to make it the Subject of the following Treatiſe; a Subject, which has ſo often employ'd the moſt learned Men, that it can hardly ſtand in Need of an Apology for the Choice of it.

Having ſaid thus much with Regard to the Science, I ſhall now beg Leave to ſay ſomething of the Inſtrument itſelf; and then make Haſte to acquaint the Reader with what he is to expect in the following Sheets.

The Microſcope is an Inſtrument ſo curious and entertaining, and ſo generally eſteemed amongſt the learned Part of the World, that one great Reaſon of its being ſo much diſregarded by Men of Leiſure and Fortune, muſt be owing to the Difficulty of uſing ſome of thoſe, which have been hitherto invented. Beſides, many Perſons have neglected the Microſcope, from an Apprehenſion, that a good Degree of Knowledge in Opticks would be neceſſary to their Underſtanding even the experimental Part of it; where-

as

as nothing more is really required, than good Eyes, good Glaſſes, and a well-conſtructed Inſtrument; with theſe Helps, a common Underſtanding, and a little Practice, will be ſufficient to carry us through this Branch of Natural Philoſophy.

Others, again, have conſider'd the Microſcope as an Inſtrument, which is perhaps capable of affording a little Amuſement, or even raiſing our Wonder for a Moment, but is indeed of no real Service. However, this is an Objection that reflects more upon the Author of it, than the Inſtrument; and therefore does not ſeem to deſerve the Ceremony of an Anſwer. Some alſo have laid aſide the Microſcope, after a little Uſe, merely from a Want of knowing what Objects to examine, and where to find them; as well as how to prepare and apply them.

I hope the Reader will find, that I have, in ſome Meaſure, ſurmounted all theſe Difficulties. For, firſt, I have given a clear and accurate Deſcription of my new invented Univerſal Microſcope; which comprehends all the ſeveral Uſes of other Microſcopes, in one Apparatus; a Circumſtance that deſerves a very particular Conſideration. For Microſcopes have been generally conſtructed ſo, as chiefly to excel in a ſingle Inſtance; ſome having been adapted for viewing Opake, and others for Tranſparent Objects; but none capable of ſhewing both in the ſame exact Manner. I have therefore endeavoured to contrive my Univerſal Microſcope ſo, as to render it capable of doing every Thing that can be expected from ſuch a Kind of Inſtrument. I have likewiſe ſhewn how it may be applied to an improved Solar Apparatus; in which Application of it, there is a particular Contri-

vance

vance for confining Frogs, Mice, Bats, &c. in order to view the Circulation of the Blood in the Meſentery, and other Parts of thoſe Animals.

Next I have proceeded to give a Deſcription of all the different Sorts of modern Microſcopes, that have been hitherto invented; ſo that any Gentleman, who is willing to purchaſe, may readily comprehend their ſeveral Uſes, and by comparing them together, be enabled to form a true Judgment of their Value.

I come now to acquaint the Reader with what he is to expect in the following Sheets, and this I ſhall do in a very few Words.

And here I muſt be ſo ingenuous as to confeſs, that my Book contains rather a faithful Collection of every Thing that has hitherto been mention'd by the beſt Writers upon Microſcopes, than Matters of my own Invention. However, I can truly ſay, that my ſincere Endeavours have not been wanting, in order to range theſe Materials under their proper Heads, as well as to enlarge upon them, where it was requiſite, in the moſt plain and intelligible Manner. I have likewiſe attempted a Tranſlation of two very valuable Pieces; the one containing Mr. JOBLOT's *Obſervations upon the Animalcula, that are found in many different Sorts of Infuſions; the other Mr.* TREMBLEY's *Account of the freſh Water Polype; neither of which, I believe, has hitherto appeared in our Language.*

As to the Copper-Plates, I have taken particular Care to have them copied from exceeding good Drawings, and then engraved in the very beſt Manner; and in order to prevent, as much as poſſible, any Inaccuracy, I always

obſerved

observed the following Method: When I had a Mind to make a Drawing of any Object, I placed it in my Universal Microscope, and applied it to an improved Solar Apparatus; by which Means the Object was thrown upon a large Sheet of white Paper, and magnified to a Degree, that cannot be conceived by those, who have never seen the Experiment. I then took my Pencil, and went over every Line of the Object, with all imaginable Care and Exactness, 'till I had finished a compleat Drawing of it; and this being fixed in the Camera Obscura, and so reduced, according to the strictest Rules of Perspective, to a Size proper for my Book, I drew from it the Pattern, which was sent to my Engravers. And indeed I have been so extreamly careful with Respect to the Copper-Plates, that no Expence has been wanting, in order to their being engraved in the very best Manner. It is for this Reason that I am obliged to raise the Price of my Book much higher, than I ever intended, or even desired; however, as it is not a Matter of Choice, but absolute Necessity, I hope the Publick will be so indulgent, as to take it into their Consideration.

As my Microscope has had the good Fortune to meet with a favourable Reception from many Gentlemen of Distinction and Learning in ENGLAND, *as well as several Parts of* EUROPE; *I thought an accurate Description of it would not be disagreeable to those, who had been pleased to honour me with their Custom. This was my sole Intention in sitting down to write, but I quickly found myself engaged much deeper, than at first I designed; and at length began to believe, that a Collection of the most valuable Materials that could be met with in*

the beſt Writers upon Microſcopes, might perhaps be pleaſing, as well as uſeful to the Publick. I was greatly aſſiſted in this Undertaking, by being allowed a free Acceſs to one of the fineſt Libraries in ENGLAND, *belonging to a noble Perſonage, whoſe Name I am not permitted to mention, but whoſe Goodneſs upon this, and all other Occaſions, I ſhall conſtantly acknowledge with the higheſt Reſpect and Gratitude. I ſhall only add, that I have neither ſo much Ambition, nor Vanity, as to preſume to reckon myſelf among the Number of thoſe learned Men, who have wrote upon this Subject. My Profeſſion indeed muſt neceſſarily afford me a good deal of Inſight into ſeveral Branches of Natural Philoſophy, and I cannot reproach myſelf with having wilfully neglected any Opportunity of Improvement, but ſtill I am fully ſenſible, that my Book muſt have many Defects; however, I rely very much upon the Candour of the Reader, and ſo ſhall beg Leave, without farther Ceremony, to throw my Mite into the publick Treaſury.*

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SECT.

CHAP. XXXIV.

CHAP. XXXV.

SECT.

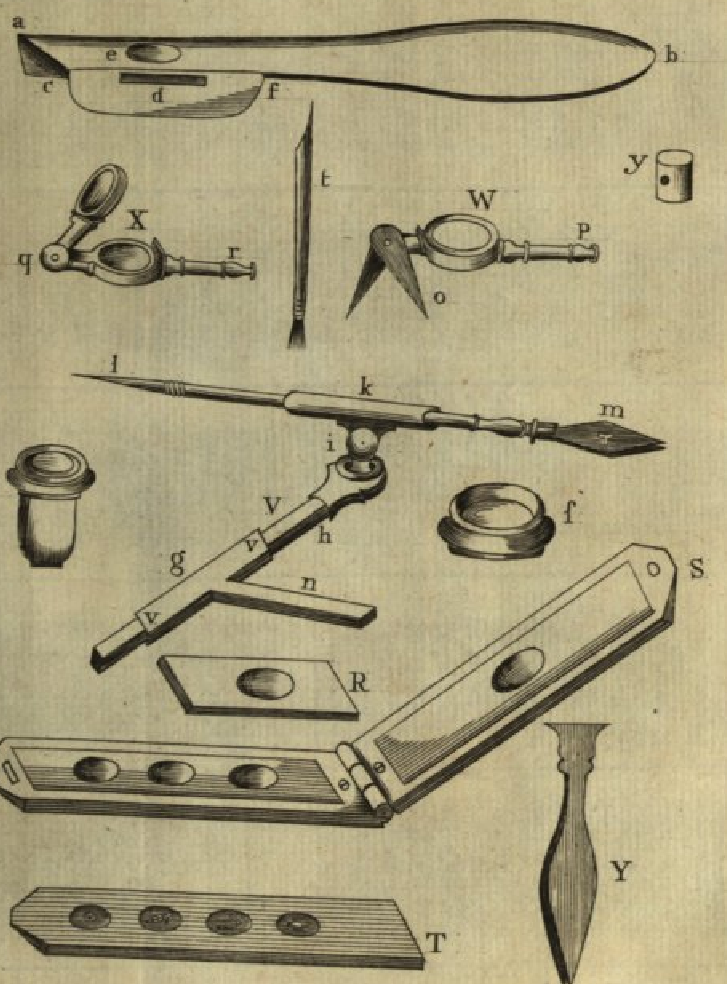
CHAP.

ERRATA.

Page 98, Line 24. for *Bindings*, read *Windings*.
Page 127, Line 16. read *Anemony*.

Pl. 2.

Fig. 2.



Front. Page. 1.

CHAP. I.

Containing the Deſcription and Uſe of a New Univerſal Single Microſcope, invented, made and ſold by GEORGE ADAMS, *at* Tycho Brahe's *Head, in* Fleet-Street, LONDON.

IT hath long been the Deſire of the Curious and Inquiſitive Part of Mankind, to have a Microſcope which would be Portable and Univerſal, that is to ſay, ONE ONLY *Inſtrument*, by which all Sorts of minute Objects might be obſerv'd.

I ſhall here preſent the Reader with a Deſcription of One, which comprehends all the wiſh'd-for Advantages, becauſe it contains a *ſufficient (tho' ſmall, yet all that's neceſſary) Apparatus*, to perform the Effects of all the various Sorts of Microſcopes, (and ſome of them very elaborate ones too) that have been heretofore invented; nay, I can go farther, and ſay alſo of ſome others that have been ſince attempted.

It is capable of obſerving all thoſe very minute Animals, which walk or crawl upon the Earth, Trees, Flowers, *&c.* thoſe which fly in the Air, and the Animalcula that ſwim in prepared Liquors, and in thoſe which have had no Preparation; it may alſo be very advantagiouſly employed in examining the Circulation of the Blood, *&c.* in the Inſide of larger Animals, and likewiſe in the Diſcoveries of the minute Particles of Minerals, Plants, *&c.* wherein may be perceived what amazing and ſtupendious Contrivances, exact and perfectly uniform Proportions, the great Author of Nature hath endowed thoſe very minute Parts of the Creation with, which are ſo extreamly ſmall, as to eſcape the beſt Eyes deprived of this Aſſiſtance of human Art.

This MICROSCOPE is made either of *Braſs* or *Silver*, and is compoſed of *ſix* double Convex *Lens's*, of different Foci.

Repreſented, as put together for Uſe in Fig. 1.

When it is firſt taken out of its Box, the two Legs A, B, are to be turn'd about upon the Joint C, till they make an equilateral Triangle with

 the

the fixed Leg D, then will the Pillar E, be ſupported in a perpendicular Poſture.

F, is an illuminating Glaſs, for reflecting the Light of the Sky, the Sun, or a Candle, upon the Object: Its Support H, is to be put into a Hole, in the Center of the round Piece G.

The Object-Bearer I, with its Springs b, and Slider K, has a ſquare Stem behind the Slider, which is to be put into a Hole at L, in the upright Pillar E.

M, M M, is a ſcollop'd Plate, which contains the ſix Magnifiers, number'd from 1 to 6, the leaſt Number being the greateſt Magnifier; in the Center, and on the Underſide of this Plate, is a ſhort Cylinder, with a ſmall Steel Pin near the End of it. This Cylinder is to be placed in the Top of the Pillar E, in ſuch a Manner that the aforeſaid Steel Pin may go into the Slit at æ.

N, a black Eye Piece, hollowed out to defend the Eye from the Side Rays of Light, under which the Magnifiers may be turn'd round at Pleaſure; ſo that in this Apparatus there is no Trouble in changing the Magnifiers, they being ſo contrived as to be ſucceſſively brought under the Eye-Piece N.

O, is a reflecting Speculum of Silver, or other Metal, highly poliſhed; which when an opake Object is to be viewed, muſt be placed under the Eye-Piece N. By which Means, the Light thrown upon it from the Mirrour F, will be by it collected and reflected back again upon that Surface of the Object next the Eye; which will then be ſo ſtrongly illuminated, as to be examined with Eaſe and Pleaſure.

This removes the Inconvenience of having the dark Side of an Object next the Eye, that having been hitherto an unſurmountable Obſtruction to the making Obſervations on opake Objects, with any conſiderable Degree of Exactneſs. For in all other modern Contrivances generally known, when a large Magnifier is uſed, the Nearneſs of the Inſtrument to the Object, unavoidably overſhadows it ſo much, that its Appearance is render'd obſcure and indiſtinct; although many Ways have been tried to throw Light upon an Object from the Sun, the Sky, or a Candle, by a Convex Lens, placed on the Side thereof, yet this refracted Light falls on the Object ſo obliquely, that it rather ſerves to give a confuſed Glare, than to afford a clear and perfect View.

P, is an adjuſting Screw, by the turning of which an Object placed between the Object carrying Plate I, and Springs b, is readily raiſed or depreſſed; until it is brought into the exact Focus of the Magnifier.

1, 2, 3, 4, 5, 6, are Marks on the Pillar E, to ſhew the reſpective Diſtances of the Object from the Magnifiers, according as each Glaſs magnifies more or leſs. — For Inſtance, if you uſe the 5th Magnifier, firſt

firſt place it under the Eye-Piece N, and then with your Finger and Thumb turn the Screw P, till the Finger of the Hand which is engraved on the Sliding-Piece Q, points to the Mark 5 on the Pillar; then will the Object be very near its exact Diſtance from the Magnifier; ſo that by a Turn or two of the Screw P, either backwards or forwards, to be found by Trial, you may ſoon fit it exactly to your Eye.

The Object carrying Plate I, and Steel Springs b, are capable of holding Ivory Sliders; or other Contrivances of different Thickneſſes, by unſcrewing the little Screw c, and with your Nail preſſing down the Slider K, by the Button d, the Steel Springs will then be ſo ſeparated from the Plate I, as to receive any other Part of the Apparatus; and may be there made faſt by tightening the Screw c.

e, A Nut, by the ſcrewing of which, the Joint C may be tightned, if at any Time it ſhould wear eaſy.

The Plate numbered Fig. 2. *repreſents the Apparatus belonging to the Univerſal Single Microſcope*, Fig. 1. *and alſo to the Univerſal Double Microſcope, repreſented by* Fig. 3. Whereof,

a, b, f, Is a Contrivance to confine a ſmall Fiſh, by putting its Tail under a Spring on the Inſide at c, and tying the Body of the Fiſh to the long Part b, f, the two extreme Ends of the Tail, may be drawn through the Slits d, d, on each Side, that the Middle of the Tail may lie flat: Then put the End æ of this Fiſh-pan between the Object carrying Plate I, and Springs b, of Fig. 1, or Fig. 3, (they being firſt opened to a proper Thickneſs to receive it,) in ſuch a Manner, that the Hole e, under which the Tail of the Fiſh is placed, may lie nearly under the Center of the Hole f, in the Object carrying Plate I. In this Poſition, the Magnifiers may be all ſucceſſively turned over the Object: And the Circulation of the Blood examined from the leaſt to the greateſt Magnifier, with Eaſe and Pleaſure. It may alſo be ſeen in the Webb between the Toes of a Frog's hind Foot, which is to be placed under the Spring at c, and its Body tied with a Tape to the Part b, f.

R, is a Piece of Glaſs to be placed as Occaſion requires, either upon the Surface of the Object carrying Plate I, or between it and the Springs b; its Uſe is to hold any accidental Object that may offer; ſuch as the Animalcules in Fluids, (which may be very commodiouſly examined in this Manner) Duſts, Cryſtals of Salts, the Farina of Vegetables, *&c.*

S, S, A jointed Slider, containing two flat Glaſſes, with Cavities ſunk in them, deſigned for confining any ſmall Object without cruſhing or deſtroying it; ſuch as Aquatics, or any other live Inſects, as Fleas, Buggs, Lice, *&c.* and is alſo to be placed between the Object carrying Plate I, and Springs b, which muſt be ſet wider to receive it as before directed.

T, is an Ivory Slider with four Holes, wherein to place different Objects between two Pieces of *Muſcovy* Talcs, and is alſo to be applied between the

the Object carrying Plate I, and Springs b, ſee Fig. 1, with the Ivory Slider T, applied to it.

V with its Socket g, ſliding Steel Bar h, Joint i, and its ſpringing Tube k, through which runs a Steel Wire; one End whereof terminates in a ſharp Point l, and the other hath a Pair of Plyers m, ſoldered to it: The Joint i having a twofold Motion for the readily placing the Parts of an opake Object before the Magnifier.

The Point or Plyers, are to be thruſt into, or take up, and hold any Inſect or Object; either of them may be turned under the Magnifier, as beſt ſuits the Purpoſe.

When this Apparatus is uſed, the ſquare Stem n, of the Socket g, muſt be put on to the Pillar E, at the Hole L, Fig. 1, and 3, (the Object Plate I, with its Springs b and Slider K being firſt removed,) it is repreſented as applied to the Microſcope at Figure 3.

W is a round Object Plate, one Side black and the other white, for rendring Objects the more viſible, by placing them if black upon the white, and if white upon the black Side. A Steel Spring o turns on each Side to make any Object faſt, and a hollow Pipe p iſſues from the Object Plate which may be ſcrew'd upon the ſliding Wier's Point l. y is another black and white Object-Plate, to be ſtuck on the aforeſaid Wires Point for opake Objects.

X is a ſmall Braſs Box, with a Joint at q and a Glaſs on each Side, its Uſe is to confine any living opake Object for Examination. This Box alſo hath a Pipe r, to ſcrew over the End of the ſliding Wire l.

Y, a Pair of Plyers or Forceps, to take up any Object, and manage it with Conveniency.

Z, a ſmall Ivory Box, with Iſinglaſs, to be placed when wanted, in any of the Ivory Sliders.

ſ, Is a ſeventh Magnifier, ſet in Ivory, to be held in the Hand or laid in the black Eye-piece N, for viewing any large Object.

t, 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 to put it upon the Glaſs R.

When a tranſparent Object is to be examined, thruſt the Ivory Slider which contains the Objects, between the Object carrying Plate I, and the Steel Springs (they being firſt opened to receive the Thickneſs of the Slider) and obſerve always to put that Side of the Slider where the Braſs Rings are, fartheſt from your Eye: Then turn the Magnifier you intend to uſe under the Eye-piece N, and ſet the Finger of the Hand on the ſliding Piece Q, to the Mark anſwering the Number of the Magnifier.

The Microſcope being placed on a Table near the Window, direct the Mirrour F towards the Sky, and then looking through the Eye-piece N upon the Object, placed next under the Plate I, turn the illuminating Glaſs

F, ſo about upon its Support H, and Joint v, till the Light is reflected upwards to the Object.

If it ſhould then happen not to be at its due Diſtance from the Magnifier, turn the Screw P at the ſame Time you are looking at the Object, till it be made to fit your Eye; which you will then know by its appearing perfectly diſtinct and clear.

I muſt here obſerve that the Screw P is to be turned as your Hands and Arms are reſting upon the Table, which is a Conveniency to be met with in no other Microſcope. All others requiring the Obſerver to raiſe his Body and Arms in adjuſting the Object to fit his Sight; which is not only very troubleſome but tireſome too; eſpecially if it requires any conſiderable Attention. Whereas in this new univerſal Microſcope a leaning Poſture is ſufficient, and conſequently the eaſieſt of all others for microſcopick Obſervations.

When an opake Object is to be view'd, place the reflecting Speculum O exactly under the Eye-piece N; Fig. 1, and fix your Object either on the Point of the Sliding Wire l, in the Plyers m, in the Braſs hollow Box X, or on the Object Plate W, as may be moſt convenient according to the Nature of it; then apply this whole Apparatus mark'd V, to the Microſcope, by putting its Stem n into the Hole L of the Pillar E: The Object carrying Plate being firſt removed. See Fig. 3. where this Apparatus is applied to the Microſcope. The Microſcope being placed upon a Table near the Window, direct the illuminating Glaſs to the Light, ſo as to throw it upon the Speculum O, then looking through the Eye-Piece N, and that Magnifier you judge fitteſt for the Object you would examine; by the Aſſiſtance of the Steel Bar h, ſliding in its Socket g, the Point and Plyers ſliding in their ſpringing Socket k, together with the double Motion of the Joint i. The Object may be turn'd about, rais'd or depreſs'd, brought nearer to the Magnifier, or put farther from it, till you hit the true focal Diſtance, and the Light be reflected ſtrongly on the Object from the Speculum O. The Screw P, will alſo greatly aſſiſt in adjuſting the Object to fit your Sight. In this Manner an opake Object will be ſhewn ſurprizingly diſtinct and clear.

It is always beſt to view an Object at firſt with one of the leaſt Magnifiers, by which Means, you may examine the whole, or a large Part thereof at once, and then gradually to inſpect the ſeveral particular Parts, by ſucceſſively turning the larger Magnifiers, under the Eye-Piece N, and thereby gain a true Idea of the Whole and all its Parts. Altho' the greateſt Magnifiers can ſhew but a very ſmall Portion of an Object at once: Yet by gently moving the Slider that contains the Object, and ſometimes gently turning the Magnifier backwards or forwards within the Limits of the Hole in the Eye-Piece N, or if it be an opake Object by ſliding the Steel Bar h backwards or forwards in its Socket g, the Eye will regularly

larly ſurvey it all: And if any Part ſhould be out of Diſtance, it may be eaſily rectified by turning the Screw P, one Way or the other.

In uſing the firſt Magnifier in the Single Microſcope, the Object is requir'd to be brought ſo near the Glaſs, as almoſt to touch it; therefore particular Care muſt be taken not to ſcratch it by rubbing the Slider, *&c.* againſt it; a few Turns of the Screw P will eaſily prevent it, and give it Room.

The Objects may be changed in the Sliders for any other you think proper, by taking out the Braſs Rings which keep in the Glaſſes where the Objects lie, with the Point of a Penknife; and if you turn the Slider, the Talcs will fall out: After which you may put what you pleaſe between them, and replace the Rings.

CHAP. II.

Containing the Deſcription and Uſe of a New Univerſal Double Microſcope, invented and made by GEORGE ADAMS, *at* Tycho Brahe's *Head, in* Fleet-Street, LONDON.

THIS Microſcope is compoſed of three double convex Lens's, two of which are placed in the Body thereof at a and b, and the Magnifier at g, ſix of which belong to this Microſcope, and are fixed in a ſcollop'd Plate M, M, M, moveable about a Center at f, by which Means either of them may be readily turn'd under the other two Glaſſes, as at g, whereby the Trouble of ſearching out for different Magnifiers is remov'd.

The Body of the Microſcope is ſupported by the Arm T, having a circular Collar, whereinto it may be ſcrewed, or from whence it may be eaſily taken; this Arm proceeds from the upper Part of the ſliding Socket T, f.

The aforeſaid Socket T, f, together with the ſcollop'd Plate M M M, and the Body of the Microſcope; may be moved up or down the ſquare Bar R S, which is divided into as many Parts (1, 2, 3, 4, 5, 6.) as there are Magnifiers of different Foci; ſo that the Diſtance of the Object from the Object-Glaſs may be found without any Trouble, by ſetting the Finger of the Hand engrav'd upon the Socket, to the correſpondent Number of the Magnifier (then, under the Body of the Microſcope) on the Bar R S, and fixing it there by Help of the Screw *b*. But as it is ſcarce exactly enough determined this Way, the Object may be brought nearer to, or removed farther from the Magnifier at Diſcretion, by a Turn or two of the Screw P. Remembering at the ſame Time, the upper Hand is ſet to any Number

Number on the ſquare Bar, to place the Index on the Piece Q, to the Flower-de-luce on the upright Pillar E.

O, is a reflecting Speculum highly poliſhed, which muſt be placed at R, when an opake Object is to be viewed, on which a direct Light becomes reflected from the aforeſaid Speculum.

The ſquare Bar R S, fits into the Top of the upright Pillar E, and may be made faſt thereto by the Screw at æ.

The Object-Bearer I, Ivory Slider, illuminating Glaſs F, with its Support H, and round Piece G, and the Apparatus V, with its Nippers and ſliding Wire, *&c.* having been ſufficiently deſcribed in the foregoing Chapter, I ſhall refer the Reader to that for the Uſes thereof, and alſo for a Deſcription of the Apparatus, which is exactly the ſame as that repreſented in Fig. 2. and its Uſes and Application to this Univerſal Double Microſcope, the very ſame as in the foregoing Univerſal Single One.

I have alſo adapted to either of theſe two New Microſcopes, a particular Apparatus for confining Frogs, Mice, Bats, *&c.* in order for viewing the Circulation of the Blood in the Meſentery, or any of the tranſparent Skins, which will by and by be fully deſcribed.

It remains therefore only to ſhew how theſe two New Microſcopes are beſt illuminated by Candle-Light, which is by letting the Rays of Light tranſmitted from the Candle, firſt paſs through a Glaſs Globe *, filled with Water before they fall on the illuminating Glaſs F, and if that ſhould prove too glaring, as it ſometimes does, interpoſe between the Globe and Microſcope, a Piece of thin oil'd Paper, by which Means moſt Sorts of Objects may be view'd as well by Night, as in the Day-Time.

Either of the foregoing new invented Univerſal Microſcopes, may be applied to the ſolar Apparatus, and may be had at my Shop ſeparate or together. They are very portable, and neatly packed up in ſmall Caſes.

After having given a Deſcription of the new invented Univerſal Microſcope, in both its Forms, that is to ſay, either ſingle or double; it is convenient to ſay ſomething concerning the Uſes thereof. And here I muſt inform the Reader, that my Curioſity and Deſire of rendering this Inſtrument as perfect as poſſible, hath engaged me to find out Methods, which might fully ſatisfy thoſe who are willing and deſirous of prying into the minute Receſſes of Nature, and repeat the Experiments and Obſervations related in the following Natural Hiſtory.

In order therefore to obſerve Flies, and other Inſects of the like Bulk, ſtick them upon the ſliding Wires Point, or pinch ſome Part of them between the Nippers, and apply them under the reflecting Speculum O.

I have already ſhewn that Lice, Fleas, Ants, and other Animals of the ſame Size may be obſerved alive, by being confined between the two

* For the Want of a Jeweller's Globe, a common globular Decanter, filled with clear Water, will anſwer the ſame End.

Glaſſes

Glaſſes S, S, Fig. 2. They may alſo be pinch'd by the Breach between the Nippers m of the Apparatus V, Fig. 2. by which Means you will have the Pleaſure of obſerving all the external Parts of their Bodies, and may ſometimes ſee other Animals running too and fro upon them, which feed on and torment them; theſe are called Lice of the Louſe, and Fleas of the Flea. They may alſo be placed between two *Muſcovy* Talcs, as at T, Fig. 2. in an Ivory Slider.

Mites of Cheeſe, and their Eggs, Lice of Birds, and the Inſects which infeſt Pears, Apples, *&c.* may be fixed upon the black and white Object-Plate, with a little Gum-Water, if they are opake, or if tranſparent, they may be ſtuck to the Object-carrying Glaſs R, Fig. 2. with Gum Water; by which Means you may examine them with the greateſt Magnifier, and with Satisfaction and Delight view their internal Structure and the Periſtaltick Motion of their Bowels, *&c.*

All the other Sorts of little crawling Animals, which are ſo very ſmall that one can hardly touch them without deſtroying their Lives, are beſt glewed as it were upon the Point of a fine ſewing Needle, dipped in Turpentine. (The Needle being firſt made faſt to the End of a ſhort Bit of Stick by Way of Handle to it) If you do but juſt touch the Back or Side of any one of theſe minute Animals therewith, it will ſtick ſo faſt thereto, as not to be able to remove itſelf; by which Means they may be examined with Eaſe and Pleaſure. The ſewing Needle muſt be held between the Nippers m, of the Apparatus V, Fig. 2. and ſo placed before the Magnifier, either of Fig. 1, or 3. any Part of the Animal may be turn'd before the microſcopick Lens, by twiſting the Handle of the ſewing Needle, as you find Occaſion.

Hairs, Wings of Flies, ſmall Feathers of Birds, *&c.* are beſt perceived, and eaſieſt examined, when placed between two *Muſcovy* Talcs, in an Ivory Slider.

All Sorts of inanimate Objects, ſuch as Grains of Sand, Seeds of Plants, Farina of Flowers, *&c.* may be commodiouſly examined, upon the Object-carrying Glaſs R, Fig. 2. if they are tranſparent; or if they are opake, ſtrew them lightly on one of the black and white Object Plates W or y, and apply them to the Microſcope, under the reflecting Speculum o.

To preſerve any of theſe tranſparent Objects, place them in an Ivory Slider, between two *Muſcovy* Talcs, and the opake ones being thinly ſtrewed upon ſome of thoſe Holly Slips of different Colours (hereafter deſcribed in Chap. 10.) the Slips being firſt wetted with Gum-Water.

In the Manner laſt mentioned, Objects of a larger Size may be preſerved, ſuch as the Heads and ſcaly Wings, *&c.* of curiouſly colour'd Flies, and may be conveniently placed before the Microſcope, by pinching the End, or any other Part of the Slip between the Nippers *m*, of the Apparatus V, Fig. 2.

To examine the Animalcula in Fluids, thruſt the Point of an Hair Pencil,

THE
NEW UNIVERSAL DOUBLE
MICROSCOPE
Invented, Made and Sold by
GEORGE ADAMS
at
Tycho Brahe's Head
in Fleet Street
LONDON.

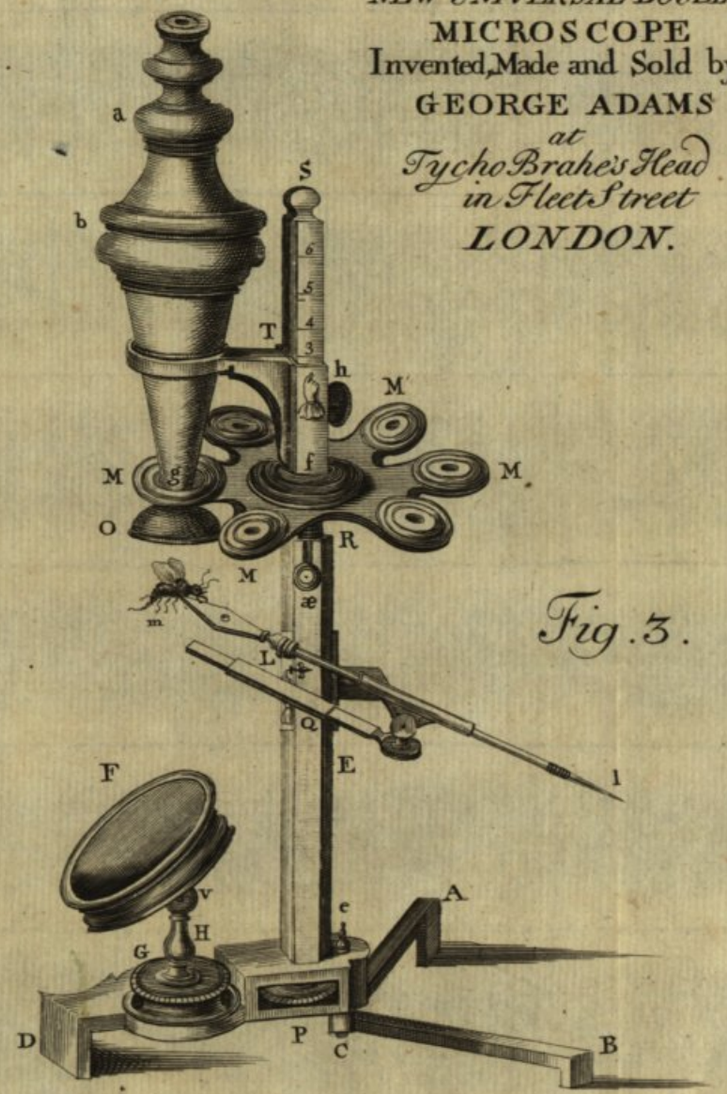


Fig. 3.

T. Bowles sc.

Fig. 4.

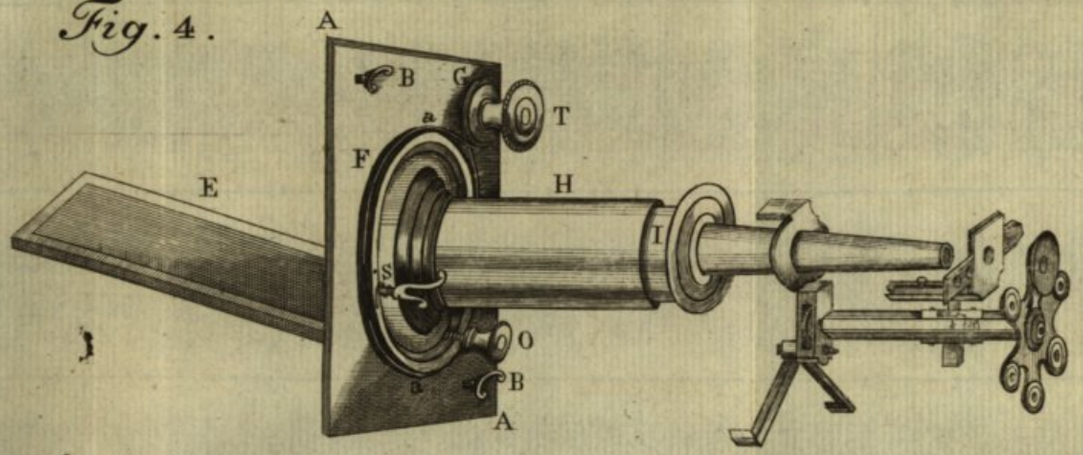
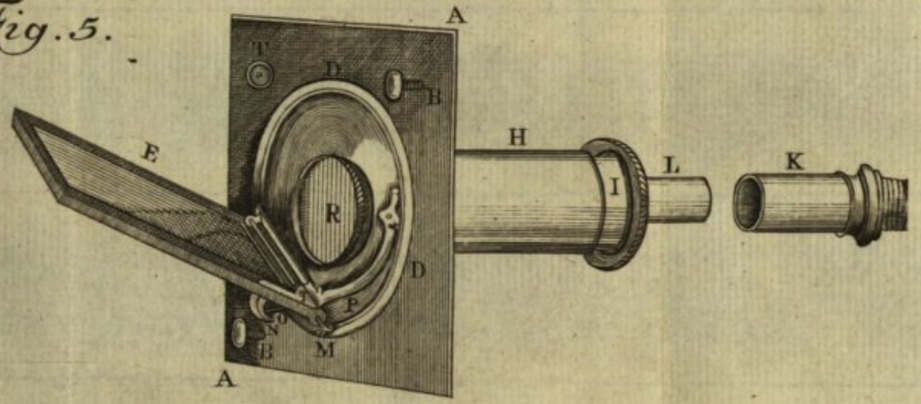


Fig. 5.



cil, or rather the Point of a Pin about one Tenth of an Inch under the Surface of the Liquor, and near the Sides of the Veſſel, that a little of it may may be taken up and placed in the Hollow of the Object-carrying Glaſs R, Fig. 2. which ſhould be no more than to form a Drop about $\frac{1}{10}$ of an Inch in Diameter, and that will be a Kind of Lake or Pond, in which you may diſcover a ſurprizing Quantity of extremely minute fiſh-like Animalcula of different Sizes, Figures, and Motions.

I have already ſhewn how to apply the Tail of a ſmall Fiſh, and the Foot of a Frog, to the Fiſh-Pan a, b, f, Fig. 2. in order to ſhew the Circulation of the Blood. And ſhall by and by explain another Method which I have contrived, for viewing the Circulation of that Purple Tide in Animals of a larger Size.

The Eaſe and Readineſs with which every minute Object may be applied to this Inſtrument, hath render'd it the moſt univerſal and commodious of any other of the preſent Sorts, for by this one Inſtrument, all the particular Uſes of every other Sort are obtained with leſs Trouble, and conſequently more Satisfaction to the Obſerver.

CHAP. III.

Of the Improved Solar, or Camera Obſcura Microſcope.

THIS moſt ſurpriſing Contrivance, is compoſed of a Looking-Glaſs, a Tube, and the *Univerſal Microſcrope*, Fig. 1, or 3, and as it depends entirely on the Sun-ſhine, is to be uſed in a Chamber, from whence all the Light muſt be excluded, except what paſſes through the aforeſaid Tube.—A Picture of the whole Apparatus put together, is ſhewn Fig. 4. and the other Side of the Solar Apparatus by itſelf, Fig. 5.

Whereof A, A, in both the Figures, is a ſquare Braſs Plate, thro' which two Screws B, B, paſs; their Screw-Nuts are ſeen at B, B, Fig. 4. and the Head of their Screw Pins at B, B, Fig. 5. A large Hole, $4\frac{3}{4}$ Inches Diameter, muſt be cut in the Window-Shutter, which is ſomewhat bigger than the Circle D D, Fig. 5. And then applying the ſquare Plate thereto, bore thro' it two other ſmall Holes, anſwerable to thoſe in the Plate at B and B. Put the Screw-Pins thro' theſe laſt made Holes in the Shutter, and with their Nuts, ſcrew the ſquare Plate faſt thereto, the Looking-Glaſs being without the Window.

In the Middle of the ſquare Plate A A, is made a circular Hole to receive the flat Braſs Ring D, D, on one Side, and on the other Side a narrower Ring F, whoſe Edge, which projects a little beyond the Hole, is turn'd

into a ſhallow Groove a a, wherein runs a ſilken Line, which by twiſting round, and then croſſing over a Braſs Pulley G, performs an eaſy Motion for turning round the flat Wheel D, D, and all the Parts thereto affixed.

H, is a Braſs Tube, that ſcrews into the Middle of the two Braſs Rings D D, and F, and becomes a Caſe for the leſſer Braſs Tube I, to be drawn backwards or forwards in.

K, is a ſhort Tube of Braſs, which fits into the Foot D of the Univerſal Microſcope, Fig. 1, or 3. the illuminating Glaſs F, and the round Piece G, being firſt taken out to make Room for its Reception. The Tube K, fits over another ſhort Tube L, which is ſolder'd to the End of the inner Tube I, and is diſtinctly ſeen in Fig. 5.

E, is a Looking-Glaſs of an oblong Figure, ſet in a Frame of poliſhed Braſs, and fixed to the broad Ring D, D, Fig. 5. by Means of a long Steel Screw M, going through a Joint at the Bottom of the Frame, and may be ſcrew'd in, or taken out at Pleaſure. At the Bottom of the Looking-Glaſs Frame, is fixed a circular Piece of Braſs N, againſt which the End of the Screw O preſſes, in order by ſcrewing it to elevate the Glaſs, which is depreſſed on its being diſcharged; by the Force of a ſtrong Spring P, acting againſt a Bracket, fixed to the Side of the Looking-Glaſs Frame.

R, a convex Lens, whoſe Focus is about 12 Inches, fixed at the outward End of the Tube H, to collect the Sun's Rays, and throw them ſtrongly upon the Object.

S, Fig. 4. is a Steel Pin, having one End of the ſilk String faſtened to it, by the Turning of which, the String may be tightened, if at any Time it ſhould be too ſlack; the other Extremity of its being tied by a Knot to the Ring F.

When this Microſcope is uſed, the Room muſt be made as dark as poſſible; for on the Darkneſs of the Room, and the Brightneſs of the Sun-ſhine, you are to expect a perfectly clear and diſtinct Image.

The Looking-Glaſs being put thro' the Hole in the Window-Shutter, and the ſquare Plate A, A, faſten'd thereto by its Screw Pins C, C, and Nuts B, B, as before directed. Screw the Tube H into the Middle of the Plate and Rings, and the double convex Lens R on its Outſide. Then adjuſt your Looking-Glaſs to the Altitude and Situation of the Sun, by Means of the Screw O, and the Silk-Line with its Pullies F and G, the firſt of theſe raiſes or depreſſes the Looking-Glaſs, and the latter by turning the Boſs T, inclines it to either Side; by which compound Motion, the Glaſs is ſo readily managed, as to be brought into a right Direction for throwing the Sun's Rays thro' the double convex Glaſs R, and Tube H, upon a Paper-Screen, placed about 5 or 6 Foot Diſtance from it; and

to

to form thereon a round Spot of Light, which is a Proof of your Glaſs being rightly adjuſted; but this 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 perfectly round Spot of Light, but if it be on either Side of you, it may be obtained even when the Sun is in the ſouthern Tropick.

Being thus far prepared, ſcrew the Tube K into the Foot D of the *Univerſal Microſcope*, Fig. 1. or Fig. 3. and ſlip it over the ſmall End L of the inner Tube I, (all which is repreſented as done and ready for Uſe in Fig. 4.) and pull out the ſaid Tube I, more or leſs, as the Object is capable of ſuſtaining the Sun's Heat. Dead Objects may be placed within about an Inch of the Focus of the double convex Lens R, which Diſtance muſt be ſhortened for living Creatures, or they will ſoon be killed.

If the Light falls not exactly right, you may readily direct it thro' the Axis of the Microſcopick Lens; and there keep it during the Time of your Examination, by the Help of the Screw O, and Boſs T, following the Sun's Motion.

The Objects are to be managed and brought to their true focal Diſtance, by obſerving the Directions given in Chap. I. in the Deſcription of the *Univerſal Microſcope*, Fig. 1, that is, they may be placed between the Object-carrying Plate I, and Springs b, ſtuck upon the Point, or held in the Nippers, and adjuſted to their exact Focus, by the Screw P, *&c.*

The moſt uſeful Magnifiers in the ſolar Microſcope, are the 4th, 5th, or 6th.

Having taken Notice of a Screen to throw the Images of Objects upon; ſuch a Screen is uſually made of a Sheet of the largeſt Elephant Paper, ſtrain'd on a Frame, which ſlides up and down on a round mahogany Pillar, in the Manner of ſome Fire Screens. A larger Sort are compoſed of ſeveral Sheets of the ſame Paper paſted together on Cloth, and let down with a Roller from the Ceiling in the Manner of a large Map.

There are many Conveniencies in this, which no other Microſcope has, for as it ſhews Objects larger than any other Way, there is Reaſon to hope that further Diſcoveries will be made by it. Beſides this particular Property it hath, that Numbers of People may view an Object at the ſame Time, and may point to the different Parts thereof, and by diſcourſing on what they ſee, may underſtand each other better, and more probably find out the Truth, than when they are obliged to look one after another. Beſides the weakeſt Eyes may uſe it without the leaſt Straining or Fatigue. By this Means alſo, an Object may be outlined exactly, and thereby a Drawing of whatever is curious be eaſily obtained.

CHAP. IV.

The Deſcription of the Screw-Barrel, or Mr. WILSON's *Single Pocket Microſcope.*

THIS Microſcope of Mr. *Wilſon*'s, is an Invention of many Years ſtanding, and was in ſome Meaſure laid aſide, till Dr. *Liberkun* introduced the ſolar Apparatus, to which he applied it, there being no other Inſtrument at that Time would anſwer his Purpoſe ſo well; ſince which Time it has been revived, and eſteemed the beſt, tho' very troubleſome in moſt Caſes.

The Body of the Microſcope is repreſented by A B, A B, Fig. 6. made either of Silver, Braſs, or Ivory.

C C, 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; on which may be placed, as Occaſion requires, one of the two concave Pieces of thin Braſs, with Holes of different Diameters in the Center of them, to cover the ſaid Glaſs, and thereby diminiſh the Aperture, when the greateſt Magnifiers are uſed.

E, 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.

F, a Piece of Wood or Braſs, arched in the Manner of the ſaid Plate, and faſtened thereto.

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

H, a ſpiral Spring of Steel between the ſaid End G, and the Plates of Braſs E, intended to keep the Plates in a due Poſition, and counter act againſt the long Screw C.

I, a ſmall turn'd Handle for the better holding the Inſtrument, to ſcrew on and off at Pleaſure.

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

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

M, is a flat Slip of Ivory, called a Slider, with four round Holes thro' it, wherein to place Objects between two *Muſcovy* Talcs.

Six

Six 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.

There is alſo a Braſs Slider, not expreſſed in the Figure, to confine any ſmall Object, that it may be viewed without cruſhing or deſtroying it.

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

O, a little Hair Bruſh or Pencil, wherewith to take up and examine a ſmall Drop of Liquid.

P, is a Tube of Glaſs, to confine living Objects, ſuch as Frogs, Fiſhes, *&c.* in order to diſcover the Circulation of the Blood.

When you would view an Object, thruſt the Ivory Slider in which the ſaid Object is placed, between the two flat Braſs Plates; obſerving always to put that Side of the Slider where the Braſs Rings are fartheſt from the Eye. Then ſcrew in the magnifying Glaſs you intend to uſe, at the End of the Inſtrument G, and looking through it againſt the Light, turn the long Screw C C, till your Object is brought to the true focal Diſtance, which you will know by its then appearing perfectly clear and diſtinct. The Way of examining any Object accurately, is to look at it firſt thro' a Magnifier, that will 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 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 C C 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 C C, will eaſily prevent this Miſchief, by giving it Room enough.

How to change the Objects in the Ivory Sliders, has been ſhewn in the firſt Chapter.

The Circulation of the Blood may be eaſieſt ſeen in the Tails or Fins of Fiſhes, in the thin Membrane between the Toes of a Frog's hind Foot, or beſt of all in the Tail of a Water-Newt. 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 its hind Foot, as wide as you are able. When your Object is ſo adjuſted,

ed, that no Part thereof can intercept the Light from the Place you intend to view, unſcrew the long Screw C C, and thruſt your Tube into the arched Cavity quite thro' the Body of the Microſcope; then ſcrew it to the true focal Diſtance, and you'll ſee the Blood paſſing along its Veſſels with a rapid Motion.

Make Uſe of the third and fourth Magnifiers for Frogs, or Fiſhes; but for the Tails of Water-Newts, the fifth or ſixth will do; the firſt or ſecond Magnifier cannot well be employed to this Purpoſe, for the Thickneſs of the Tube, wherein the Object is placed, will ſcarce admit its being brought ſo near to the focal Diſtance of the Magnifier.

This Single Microſcope of Mr. *Wilſon*'s, has ſometimes been 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 Addition of the following Contrivance.

The beſt Light for viewing Objects, is a clear Sky-Light, the Sun ſhining on any white Thing, or the Reflection of its Rays from a Looking-Glaſs; which laſt is found to be full as ſtrong as any, and much more convenient for Uſe, particularly in examining Liquids; for if you hold this Microſcope up to to receive the Light from the Sky, your Liquid ſubſides, and is ſoon loſt; but when placed in a perpendicular Poſition, ſo as the Rays of Light may be thrown from a Glaſs, fixed beneath it, you view it with more Eaſe, and leſs Inconvenience. For the Application of which obſerve,

CHAP. V.

A Contrivance for fixing Mr. WILSON*'s Pocket Microſcope, and reflecting Light to it by a Mirrour.*

A B C, Fig. 7. is a Braſs Scrole, which, for the better Conveniency of Carriage, is ſo order'd, as to take into three Parts, and put into the Draw upon which it ſtands, with its reflecting Mirrour, and *Wilſon*'s Pocket Microſcope.

The Top-Part of the Scrole is taken off at B, by unſcrewing half a Turn of the Screw; then lift it up, and it comes out of the Socket. The lower Part unſcrews at C, and the Baſe unſcrews at E.

The Mirrour lifts out at F, which with the Scrole lie in one Partition of the Box.

To apply this Scrole to Uſe, fix the Body of the Microſcope to the Top thereof, by the Screw A, as in Fig. 7. by ſcrewing it in the ſame Hole as the Ivory Handle.

The Braſs or Ivory Slider being fixed as before deſcribed, and the Microſcope placed in a perpendicular Poſition; move the reflecting Glaſs D in ſuch a Manner, as to caſt the Light of the Sky, the Sun, or a Candle, directly upwards, through the Microſcope; by which Means it is made to anſwer moſt of the Ends of a double reflecting Microſcope, hereafter to be deſcribed.

It is alſo rendered more uſeful for viewing opake Objects, by ſcrewing the Arm Q, Fig. 6. into the Body of the Microſcope, at G, then ſcrewing into the round Hole R, that Magnifier, which you think will beſt ſuit your Object; and put the concave Speculum S, on to the Outſide of the Ring R, you will find in the Body of the Microſcope, between the Wood or Braſs F, and the End of the Male Screw C C, a ſmall Hole U, through which ſlide the long Wire T, which has a Point at one End, and Forceps at the other, that may be uſed occaſionally, as your Object requires: When you have fixed this, and your Object on it, turn the Arm R, which is performed by two Motions, till the Magnifier is brought over the Object; it may be then adjuſted to the true Focus, by turning the Male Screw C C, in the ſame Manner as before deſcribed. It muſt alſo be turned exactly over the Speculum, by twiſting the upper Part of the Scrole to one Side, till your Object, and the two Speculums, are in one Line, as will be found by Trial, and then fix it by the Screw B, at which Time the upper Surface of the Object will be ſo exceedingly enlightened by the Light reflected upward from the Mirrour, to the concave Speculum, as to be ſeen as clear and diſtinct as any tranſparent one.

CHAP. VI.

Of the Manner of applying Mr. WILSON*'s Pocket Microſcope, to the Solar Apparatus.*

THE Solar Apparatus having been already deſcribed in the 3d Chap. it remains only to ſhew how Mr. *Wilſon*'s Pocket Microſcope, is to be applied to it.

After having fixed the Apparatus to the Window-Shutter, and adjuſted it to the Altitude and Situation of the Sun, ſo as to form a round Spot of Light on the Screen.

Screw the Tube H, Fig. 5. into the Middle of the Plate and Rings, taking Care not to alter the Looking-Glaſs; then ſcrewing the Magnifier you chooſe to employ, to the End of your *Wilſon*'s Microſcope, at G, Fig. 6. In the uſual Manner, take away the Lens D, at the other End thereof,

thereof, and place a Slider, containing the Object to be examined between the thin Braſs Plates E.

Things being thus prepared, ſcrew the Body of the Microſcope A B, by the Screw D, Fig. 6. to the ſhort Braſs Tube K, Fig. 5. which ſlip over the ſmall End L of the Tube I, and pull out the ſaid Tube I, more or leſs, as the Object is capable of enduring the Sun's Heat.

The ſhort Tube K, which your Microſcope is ſcrew'd to, enables you by ſliding it backwards or forwards on the other Tube L, 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.

For the Screen, and all the other Particulars, See Chap. 3.

CHAP. VII.

Of the Microſcope for Opake Objects.

A, Fig. 8. is a fixed Arm, through which paſſes a Screw B, the other End whereof is faſtened to the moveable Arm C.

D, is a Nut fitted to the ſaid Screw, which when turned, will either ſeparate or bring together the two Arms A C.

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

F, a Piece of Braſs turning round in a Socket, whence proceeds a ſpringing Tube, moving on a Rivet, through which runs a Steel Wire, one End of which finiſhes in a Point G, and the other End hath a Pair of Plyers R ſolder'd to it; theſe are either to thruſt into, or to take up and hold any Object; and may be turned round as required.

I, a Ring of Braſs, with a female Screw fixed on an upright Piece of the ſame Metal, which turns on a Rivet, that it may be ſet at a due Diſtance when the leaſt Magnifiers are uſed; and ſerves 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 to fit the Braſs Ring I, which may be ſcrewed into the ſaid Ring at Pleaſure.

Four of theſe concave Specula of different Depths, are fitted to four Glaſſes of different magnifying Powers; to be uſed as Objects to be examined may require. The greateſt Magnifiers have 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, upon the white, and if white, on the black Side. A Steel Spring N, turns down on

Fig. 6.

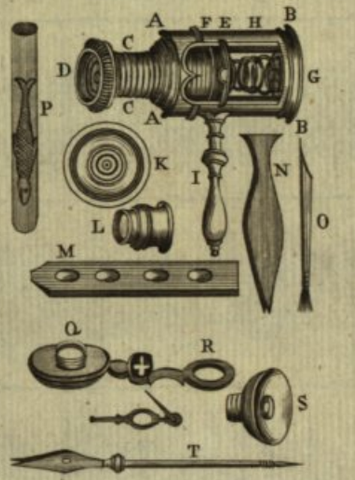
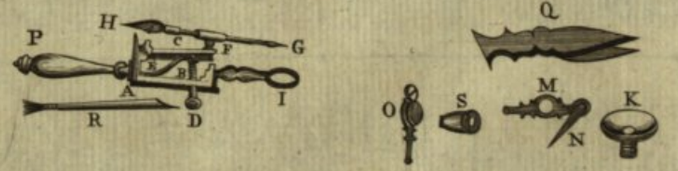


Fig. 7.

Fig. 8.



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on each Side to make any Object faſt; and iſſuing from the Object Plate is a hollow Pipe to ſcrew it on the Needles 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 at G.

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

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

R, a ſoft Hair Bruſh to clean the Glaſſes or Specula.

When you would view any Object, ſcrew the Speculum with the Magnifier you intend to uſe, into the Braſs Ring I, place your Object either on the Needle G, in the Plyers 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 appear very diſtinct and clear.

CHAP. VIII.

A Deſcription of the Double Microſcope, commonly, though very improperly, called the Reflecting Microſcope.

A B C, Fig. 9, is the Body of this Microſcope, in which ſlides C D, the inner Tube, that contains all the Glaſſes. The Eye Glaſs is at E, the broad middle plano convex Glaſs at F, and the Object Glaſs being ſet in a Button at G, is ſcrew'd upon the End of the narrower Tube I, which being fixed in the Baſe of the inner Tube, paſſes freely through a Hole in the Baſe of the outer.

The Buttons that contain the ſeveral Object Glaſſes are number'd 1, 2, 3, 4, 5, and the Convexity of the inner Tube, is alſo marked with dotted Circles number'd 1, 2, 3, 4, 5, in order to bring that Circle to coincide with the Mouth of the outer Tube, whoſe Number is the ſame as that of the Object Glaſs then made uſe of: But if the Object does not then appear quite diſtinct, ſlide, or rather twiſt the inner Tube gently, higher or

lower, or turn the Screw of the Magnifier gradually till the Object appears diſtinct. The greateſt Magnifiers are known by their having the ſmalleſt Apertures.

The Baſe B C of the outer Tube is ſupported by three Braſs Pillars on Scroles, fixt on a Mohogany Pedeſtal H K, in which is a Drawer L, to hold the Magnifiers and other Parts of the Apparatus. A little below the Object-Glaſs is fixed a Plate M, like a Stage between the Pillars.

N, three ſmall braſs Circles with Holes thro' the Middle of them which are to be placed over the Hole in the Middle of the Stage, and then the Ivory Slider O may be put between the two uppermoſt, which are preſſed together by a ſpiral ſpringing Wire lodged between the two undermoſt. The two outermoſt being held together by four ſmall Pillars paſſing through four Holes in the Circumference of the middle Circle.

P, is a Fiſh-pan to faſten a ſmall Fiſh on, to ſee the Circulation of the Blood, its Tail being ſpread acroſs the oblong Hole at the ſmalleſt End; then by ſhoving the Button inwards through a Slit made in the Stage, a ſmall Braſs Spring under the Stage will keep it ſteady; for viewing it the Tail may be brought exactly under the Magnifier, by turning the Pan on the Button, or by ſhoving it inwards or outwards along the Slit in the Stage.

All tranſparent Objects are well illuminated in this Microſcope, either by Candle or Sky-Light reflected upwards from a concave Looking Glaſs R, placed in a Frame upon the Center of the Pedeſtal. While you are viewing the Object through the Microſcope, turn this Concave upon its horizontal Poles a b, and you will ſoon find out that Poſition of it wherein it reflects the moſt Light through the Hole c upon the Object.

Opake Objects when laid upon the Plate s, which is on one Side black Ebony, and on the other a Piece of white Ivory, being laid over the Hole c, in the Stage may be illuminated by the Light of the Sun-ſhine or a Candle tranſmitted through a double Convex Lens a, which by turning on two Screws, e, d, and the Foot of it put into the Hole f of the Stage. The Candle muſt be placed in a Line drawn from the Object through the Middle of this Lens at ſuch a Diſtance to be found by Trial as will form the ſmalleſt Spot of Light upon the Object Plate. By Day-light this Glaſs is of no Service.

T, an Ivory Cone to ſcrew on to a male Screw under the Center of the Stage: Its Uſe is to intercept ſome Part of the oblique Rays when the firſt and ſecond Magnifiers are uſed.

V, a Glaſs Tube to put a ſmall Frog or Newt in, to ſee the Circulation of the Blood. When the Object is well expanded on the Inſide of the Tube, ſlide it over the Hole c, in the Center of the Stage; and bring that Part of the Object you would examine directly under the Magnifier.

W,

W, a Cell, containing a concave and a plain Glaſs, is to confine Fleas, Lice, Mites, or any ſmall living Objects, and being placed over the Middle of the Stage may be viewed with Eaſe.

X, a plain circular Glaſs to be placed over the Center of this Stage to lay any Objects on that may at any Time offer, and a looſe concave Glaſs being laid with its hollow Side downwards, will eaſily confine any living Inſect.

Y, a long Steel Wire with its Pliers and Point to hold or ſtick Objects on, ſlips backwards and forwards in a ſhort Braſs Tube, which by the Button fits into the Hole of the Stage, and then it may be conveniently managed under the Magnifier.

O, a flat Piece of Ivory called a Slider with four round Holes through it, and Objects placed in them between *Muſcovy* Talcs.

Z, a little round Ivory Box to hold Iſinglaſs for the Sliders.

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

J, a Pair of Nippers to take up any Object to be examined.

N. B. When the Body of this double Microſcope is made of Braſs, it is ſupported with a ſingle Pillar, to which is fixed a ſliding Bar, an adjuſting Screw, and a concave Speculum for opake Objects, *&c.* But as this Apparatus comes to double the Price of that juſt deſcribed, and being not at all better for Uſe, I have omitted a drawing thereof.

CHAP. IX.

Of a Single or Double Microſcope, what, how it magnifies, and why.

A Single Microſcope is only a very ſmall Globule of Glaſs, or a double convex Lens, whoſe focal Diſtance is very ſhort. The former being at preſent diſus'd, I ſhall confine myſelf only to a Deſcription of the Nature and magnifying Powers of the latter.

A thin Piece of Glaſs bounded on one Side by a poliſhed plane Surface, repreſented by the Line E F, Fig. 10, 11, and on the other Side by a ſmall Portion of a poliſhed ſpherical Surface, repreſented by the Arch A C B; or bounded on both Sides by ſpherical Surfaces A C B E D F, Fig. 12, 13, 14. is called a Lens, or ſimply a Glaſs; and by Mathematicians is conceived to be generated or deſcribed by turning the Figure A C B F D E round about the Line C D, drawn through the Middle of it, perpendicularly to both its Sides.

This Line produced is therefore called the Axis of the Lens; and paſſes through G and H, the Centers of its Surfaces.

The Points C D, where it cuts the Surfaces, are called the Vertexes of the Lens, and the middle Point between them is called its Center.

The 10th Figure repreſents a plano Convex, the 11th a plano Concave, the 12th a double Convex, the 13th a double Concave, and the 14th a concavo Convex, or a Meniſcus Lens.

As Rays of Light are thrown out and diſperſed in all poſſible Directions from every Point of a luminous Body; ſo as they illuminate other Bodies upon which they fall, they are alſo inceſſantly thrown back from, or tranſmitted through every Point of theſe Bodies. For the Points of opake and tranſparent Bodies ſo enlighten'd, are viſible to the Eye, at any Point of Space, and in any Point of Time, as well as the Points of the luminous Body that enlightened them. The numberleſs Rays which flow from all viſible Bodies, called Objects, are conſidered as conſiſting of ſo many phyſical Points, and theſe Points are conceived to radiate all Manner of Ways.

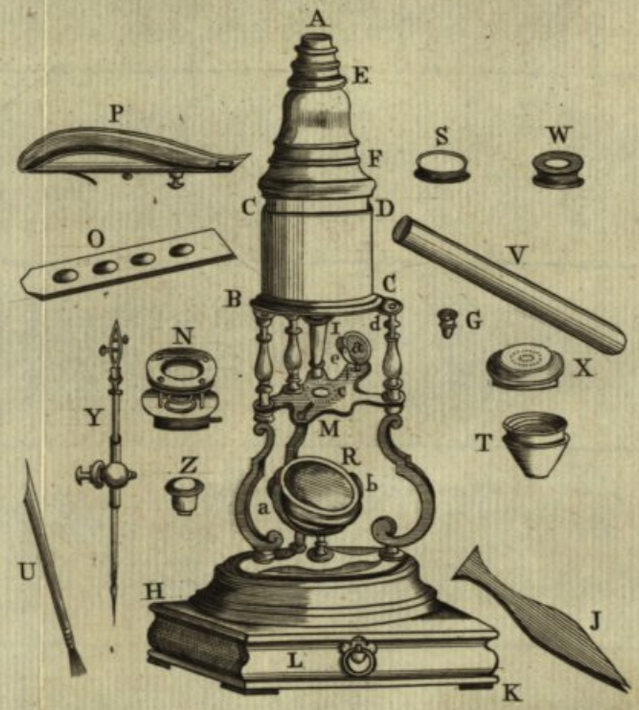
The Point Q, Fig. 15. from which Rays diverge, or towards which they converge (being made to go back towards the ſame Point, though they may never meet at it) is called the Focus. And in both Caſes, any Parcel of theſe Rays, as Q B C, or Q B A conſidered a-part from the reſt, is called a Pencil of Rays; and theſe Rays are ſaid to belong to that Focus, whether they be near at Hand, or at an immenſe Diſtance; and in the latter Caſe, the Rays are called, and conſider'd as parallel, or equi-diſtant from each other; becauſe the Difference of their Diſtances at any two given Places is inſenſible, * as thoſe from the Sun, and other vaſtly diſtant Objects. A B, Fig. 16. repreſents ſuch parallel Rays, which falling upon the Lens C D, are made to approach nearer and nearer together in their Progreſs; tending to one certain Point, where they all unite. Thus the Rays proceeding from the Lens C D, to the Point E, are called converging Rays; and the Point E their Focus, where they croſs, and continually recede from each other as they paſs along. So that thoſe Rays flowing from the Point E, towards F G, are called diverging Rays.

Let A B, Fig. 17. be a double convex Lens, E F the Object at its Focus C; G, the Eye very near the Lens E F, the Rays coming from the Object, will, after their Refraction, fall parallel † upon the Eye, and conſequently make diſtinct Viſion. For the Fabrick of the Eye having its focal Diſtance juſt at the Bottom of it, upon the Retina, requires that the Rays from each ſingle Point, ſhould fall nearly parallel, in order to be there collected; that is, that the Baſis of each Cone of Rays, flowing from every

* *Smith's* Opt. *p.* 6. † *Greg.* Opt. 170.

Point

Fig. 9.



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Point of an Object, which Baſis is the Pupil of the Eye, ſhould bear ſo ſmall a Proportion to the Length of the Cone, as that theſe Cones may be looked upon as little Cylinders. The Diſtance requiſite for diſtinct Viſion, is not limited to a Point, but is indulg'd in larger Bounds; becauſe Nature has furniſh'd us with the Power of contracting the Pupil, as the Object comes nearer; and ſo diminiſhing the Baſis of each Cone in Proportion, and conſequently of preſerving diſtinct Viſion; but this is only to a certain and that no very great Degree.

Therefore a minute Object E F, ſeen diſtinctly thro' a ſmall Glaſs Lens A B, by the Eye put cloſe to it, appears ſo much greater than it would to the naked Eye; placed at the leaſt Diſtance E D, from whence it appears ſufficiently diſtinct, as this latter Diſtance E D, is greater than the former E C; for having put your Eye cloſe to the Glaſs A B, in Order to ſee as much of the Object as poſſible at one View, remove the Object to and fro till it appears moſt diſtinctly, ſuppoſe at the Diſtance C E, then conceiving the Glaſs A B, to be removed, and a thin Plate A B, with a Pin-hole in it, Fig. 18. to be put in its Place, the Object will appear diſtinct, and as large as before when ſeen thro' the Glaſs, only not ſo bright. For if the Hole be ſo ſmall as to admit but a ſingle Ray, from every diſtinct Point of the Object, theſe Rays will fall upon the Retina, in as many other diſtinct Points, * and will make a diſtinct Picture †; and when the Pencils of Rays fall upon a thin Lens, their Axis go ſtrait thro' the Middle of it, and conſequently will proceed to the ſame Points upon the Retina, as when they paſſed thro' the Hole. Now ſuppoſing the Lens to have ſuch a Figure, that the Rays of every Pencil ſhall be refracted by it, and by the Eye together, to thoſe very Points of their Axis which touch the Retina, the Picture will ſtill be diſtinct; and will be the ſame in Magnitude and Poſition as before. The only Difference in the Effects, between the Hole and Lens, will be in the Degree of Brightneſs upon the Retina. And in this latter Caſe, the Object appears ſo much greater than it does to the naked Eye, at the Diſtance E D, either with the Pin-hole, or without it; as the Angle C E F, is greater than the Angle A D E, or as the latter Diſtance is greater than the former.

Since the Interpoſition of the Glaſs has no other Effect than to render the Appearance diſtinct, by helping the Eye to increaſe the Refraction of the Rays in each Pencil, it is plain, that the greater apparent Magnitude is entirely owing to a nearer View than could be taken by the naked Eye. If the Eye be ſo perfect, as to ſee diſtinctly by Pencils of parallel Rays falling upon it, the Diſtance C E of the Object from the Glaſs, is then the focal Diſtance of the Glaſs.

* *Greg.* Opt. *p.* 171.. † *Smith*, Opt. *p.* 37.

Now

Now if this *focal* Diſtance of the *Lens*, be $\frac{1}{5}$ of an Inch, and if the Diſtance E D be 8 Inches from the Object, the uſual Diſtance at which we view minute Objects, the apparent Image, or Diameter of the Object, may be ſaid to be ſo much magnified, as thoſe 8 Inches exceed the little Space C E, or the *focal* Diſtance of the *Lens* A B, which is at the Rate of 40 to 1. Therefore the leſs the *focal* Diſtance of the little *Lens* is, the greater will its Effects be in dilating the Image of a ſmall Object; (for if its *focal* Diſtance be yet ſmaller, ſuppoſe $\frac{1}{200}$ of an Inch; the Diameter or Length of an Object will appear 160 Times longer thro' ſuch a *Lens*, than to the naked Eye, at 8 Inches; its Surface 15600 Times greater, and the Solidity or Bulk would be magnified to 2,496,000 Times) inſomuch that its *focal* Diſtance may be ſhortened, till it is reduced to an infinitely ſmall *Spherule*. Tho' there are ſome Inconveniencies which here offer themſelves, and forbid our going beyond certain Limits; for theſe ſmall *Spheres* are inferior to little Lens's, on this Account, that for the ſame Degree of magnifying, the *Lens's* are three Times more diſtant from the Object than the *Spheres*, the Effects of which are thus demonſtrated. Let there be a Glaſs *Sphere*, Fig. 19. whoſe Center is A, and Axis B D, in which, produced on both Sides, the Eye is placed at H, and the Object at C, each of the Diſtances B H, D C, being taken equal to half the Radius A B, and conſequently the Point C is the *Focus*, where Rays falling parallel to the Axis B D, upon the Sphere at B G, are after Emmerſion collected. Wherefore an Object placed at C, will ſend Rays upon the Sphere, which will, after Refraction, be received parallel by the Eye, and conſequently make diſtinct Viſion. But if we take the Point L, ſuch that L B may be equal to the Radius A B, the Point L is the *Focus*, towards which parallel Rays, after Refraction, at the firſt Surface D E tend in their Paſſage through the Sphere, and from which they are diverted after Refraction at their Emmerſion, and collected at H. Make E F parallel to the Axis, and comprehending the Portion of the Object C F, and draw the right Line F H. The Ray F E being refracted at E, proceeds according to E L, and being again refracted at G, goes on to meet the Eye at H, wherefore the Line C F is ſeen under the Angle B H G, and would appear to the naked Eye under the Angle C H F, which is but half the former Angle.

Becauſe B L is double to B H, the Angle B H G is double to B L G, but H L is parallel to F E, and to be looked upon as equal to it, or to the right Line D C; becauſe C F is to be a Line very ſmall, with Reſpect to the Diameter of the Sphere. Therefore the Angle B H G is alſo double of the Angle C H F, and conſequently equal to the Angle C A F. From whence it is plain, that to the Eye placed at H, the Line C F will appear under the ſame Angle, in which it would appear to the naked Eye, ſeeing from the Point A. Whence if the Diameter of the little Sphere B D, were $\frac{1}{12}$ of an Inch, we ſhould have A C equal to $\frac{1}{100}$ of an Inch; which

is

is to the Diſtance of 8 Inches in the Proportion of 1 to 128, ſo that the Magnitude of the Object will be increaſed 128 Times.

But if K E, the *focal* Diſtance of the *Lens* M N, Fig. 20. be equal to the right Line A C of the laſt Figure; we have ſhewn, that by this Means the Object L P would be ſeen in the ſame Magnitude, as if the Eye were placed at K, without the *Lens*; nor in uſing this *Lens* will the apparent Magnitude be any Ways changed, in whatſoever Part of the Axis K E, produced, the Eye be placed. Therefore, 'tis plain the ſame Degree of magnifying, and the ſame Effect every Way is performed equally by the *Lens* M N, Fig. 20. and the little *Sphere* B D, Fig. 19. and it is alſo manifeſt, that the Diſtance K L, is equal to thrice D C, Q E D.

If an Object A B be placed in one *Focus* of a *Lens* M N, Fig. 21. and the Eye in the other *Focus* D; ſo much of the Object as is equal to the Diameter of the *Lens*, will be ſeen by the Eye, for the Rays A M and B N, which flow from the Object to the Extremities of the *Lens*, proceed from thence converging, till they meet at D the *Focus*; muſt neceſſarily paſs from the Object to the *Lens*, parallel to the Axis, and therefore parallel to each other. Conſequently that Part only of the Object A B, ſeen by the Rays M D, and N D, will be equal to the Diameter of the *Lens* M N.

If the *Lens* be covered with a thin Plate, and only the Part m n, Fig. 21. be left open, then only ſo much of the Object a b, as is equal thereto, will be perceived by the Eye. For as A B is equal to M N, or a b to m n; the Angle M D N, or m D n, is the Meaſure under which Part of the Object A B, or m n appears to the Eye at D.

In order to ſee a larger Portion of an Object than the *Lens*, or its *Aperture*; the Eye muſt be placed nearer the *Lens*, than its *Focus*; for, let the two *Foci* of the *Lens* M N, Fig. 22. be H and G. Let an Object A B be placed in the laſt *Focus*, larger than the *Lens*. The Rays proceeding from the Extremities A B of the Object, towards the *Lens*, will, after Refraction, unite in the Point C, between the Lens M N, and its Focus H. Therefore if the Eye be placed at C, its Field of View or Portion of an Object, will be greater than the *Lens* M N.

If E F be a Portion of an Object leſs than the *Lens*, the Rays E M, E N, produced to the Extremities of the *Lens*, will after Refraction unite in a Point D, farther diſtant from the *Lens*, than the *Focus*. From whence it appears, that if the Eye be placed farther from the *Lens* than its *Focus*, it cannot ſee any Part of an Object ſo large as the *Lens*, but always ſmaller.

Therefore, in the *Univerſal Single Microſcope*, I have contrived the Manner of fixing the Magnifiers, which are *Double Convex Lens's*, ſo as to admit the Eye to be placed almoſt cloſe to them, by which Means we always ſee a Portion of an Object larger than the Aper-

ture of the Lens. And in this Way of uſing ſingle Lens's, microſcopick Objects appear exceedingly diſtinct and clear, and are in all Reſpects far preferable to the Double Microſcopes, which are compos'd of three convex Glaſſes.

Upon the *Apertures* of *Microſcopes*, all their Effects and Virtue entirely depend. It is therefore to be obſerved, that in ſingle *Lens's*, if their *focal* Diſtance be about $\frac{1}{4}$ an Inch, or greater, there will be no Occaſion for limiting the *Aperture*, in order to make diſtinct Viſion; becauſe the very Narrowneſs of the Pupil of the Eye excludes as many of thoſe Rays which diſturb Viſion, as is neceſſary, and as much as they would be excluded, if the *Lens* were made to have a leſs *Aperture*. But in ſmaller *Lens's*, where this Limitation of the *Aperture* is neceſſary, the Rule is, that the Diameters of thoſe Apertures ſhould be in the ſame Proportion with the *focal* Diſtances of their reſpective *Lens's*, in order to have the Object ſeen by both equally diſtinct. But the *Light* or *Brightneſs* will be in a duplicate Proportion of thoſe *focal* Diſtances *; ſo that the more convex the *Lens* is, the greater indeed, but then the more obſcurely will the Object be ſeen.

In my *Univerſal Microſcope*, I have contrived the black Eye-Piece N, in ſuch a Manner, as to receive any *Lens*, whoſe *Aperture* wants no Limitation, and have taken Care to limit all the Apertures of the ſix Magnifiers, ſo as to admit as much Light as poſſible, without deſtroying diſtinct Viſion, an Advantage which few of the modern Microſcopes have.

In order to find the magnifying Power of any *Lens*, we need only find its exact *focal* Diſtance in 100th Parts of an Inch (which is eaſily done by ſetting a minute Object in the Microſcope, ſo as to appear perfectly clear and diſtinct; this Diſtance meaſured on a Scale of an Inch, divided into 100 Parts, will give its true focal Length;) and by computing how many Times thoſe Parts are contained in 8 Inches, we ſhall have the Number of Times the Diameter of an Object is magnify'd to, and that Number multiplied into itſelf, will produce the Magnitude of the Superficies, which Product, multiplied by the Diameter, will ſhew the Solidity or magnified Bulk.

It was with theſe Sorts of ſingle Microſcopes, that the famous Mr. *Leeuwenhoeck* made ſuch wonderful Diſcoveries; and it was this Conſideration which induced me to contrive an Apparatus that ſhould make theſe ſingle Microſcropes eaſy in Uſe, to thoſe Gentlemen whoſe Curioſity leads them to ſearch into the *minute Receſſes* of *Nature*, and thereby be taught to contemplate and adore the wonderful and ſurprizing Contrivance of *Nature's* ALMIGHTY *Architect*.

* *Gregory's* Opt. *p.* 184.

Of

Of Double Microſcopes.

A double Microſcope is compoſed of two convex Glaſſes, placed at E and L, Fig. 23. the Glaſs L next the Object P Q is very ſmall, and very much convex, and conſequently its focal Diſtance L F is very ſhort; the Diſtance L Q of the ſmall Object P Q, is but a little greater than L F; ſo that the Image p q may be formed at a great Diſtance from the Glaſs, and conſequently may be much greater than the Object itſelf. This Picture p q being viewed through a convex Eye-Glaſs A E, whoſe focal Diſtance is q E, appears perfectly diſtinct. Now the Object appears magnified upon two Accounts, firſt, becauſe if we view its Picture p q with the naked Eye, it would appear as much greater than the Object at the ſame Diſtance, as it really is greater than the Object, or as much as L q is greater than L Q; and ſecondly, becauſe this Picture appears magnified through the Eye-Glaſs, as much as the leaſt Diſtance, at which it can be ſeen diſtinctly with the naked Eye, is greater than q E, the focal Diſtance of the Eye-Glaſs. For Example, if this latter Proportion be 5 to 1, and the former of L q to L Q, be 20 to 1, then upon both Accounts the Object will appear 5 times 20, or 100 times greater than to the naked Eye.

To fit theſe Microſcopes to ſhort-ſighted Eyes, the Glaſſes E and L muſt be placed a little nearer together; ſo that the Rays of each Pencil may not emerge parallel, but may fall diverging upon the Eye; and then the apparent Magnitude will be alter'd a little, but ſcarce ſenſibly.

In the laſt Example, let us ſuppoſe the Eye-Glaſs E A to be 1 Inch $\frac{6}{10}$ Focus, which will be found exactly 5 times in 8 Inches, the Diſtance at which the ſame Object would be ſeen diſtinct by the naked Eye. Therefore this Eye-Glaſs magnifies 5 times; and if the Object Lens L, has for its Focus L Q $\frac{1}{4}$ of an Inch, and the Picture be formed at P q, whoſe Diſtance L q is 5 Inches, the Picture will be magnified 20 times; becauſe the Diſtance L Q $\frac{1}{4}$ of an Inch is contained 20 times in L q, 5 Inches; and this Picture magnified 5 times greater (as appears above) by the Eye-Glaſs E A, and therefore 5 times 20, that is 100 times.

The Length being magnified 100 times, the Surface of Objects will be magnified 10000 Times, and their Solidity or Bulk 1000000 times.

Altho' we can readily, by this Method, find out the magnifying Powers of the ſeveral Sorts of Microſcopes, yet our Notions of the comparative Smallneſs of any minute Object, muſt be aſſiſted by a larger one, whoſe Dimenſions we know, and by finding how many Times the leſſer is contain'd in the greater; which ſhall be the Subject of the remaining Part of this Chapter.

* *Smith*'s Opt. *p.* 41.

Mr. *Hook*'s Method of computing the Magnitude of Objects, ſeen in the *Microſcope*, was, after he had adjuſted the *Microſcope*, to ſee the Object very diſtinctly: At the ſame Time that he look'd upon the Object thro' the Glaſs with one Eye, he looked upon other Objects at the ſame Diſtance with his other bare Eye, by which Means he was able, by the Help of a *Rule* divided into Inches and ſmall Parts, * and laid on the Pedeſtal of the *Microſcope*, to caſt up, as it were, the magnified Appearance of the Object upon the Rule, 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 magnifying. This Method is very eaſy to thoſe Perſons who can accuſtom themſelves to ſuch a Practice, I mean of obſerving two Objects at the ſame Time, one of them with one Eye by direct Viſion, and the other by refracted Viſion, through the Glaſs. It is indeed a Method I have practiſed with Succeſs to eſtimate the magnifying Power of Teleſcopes for many Years.

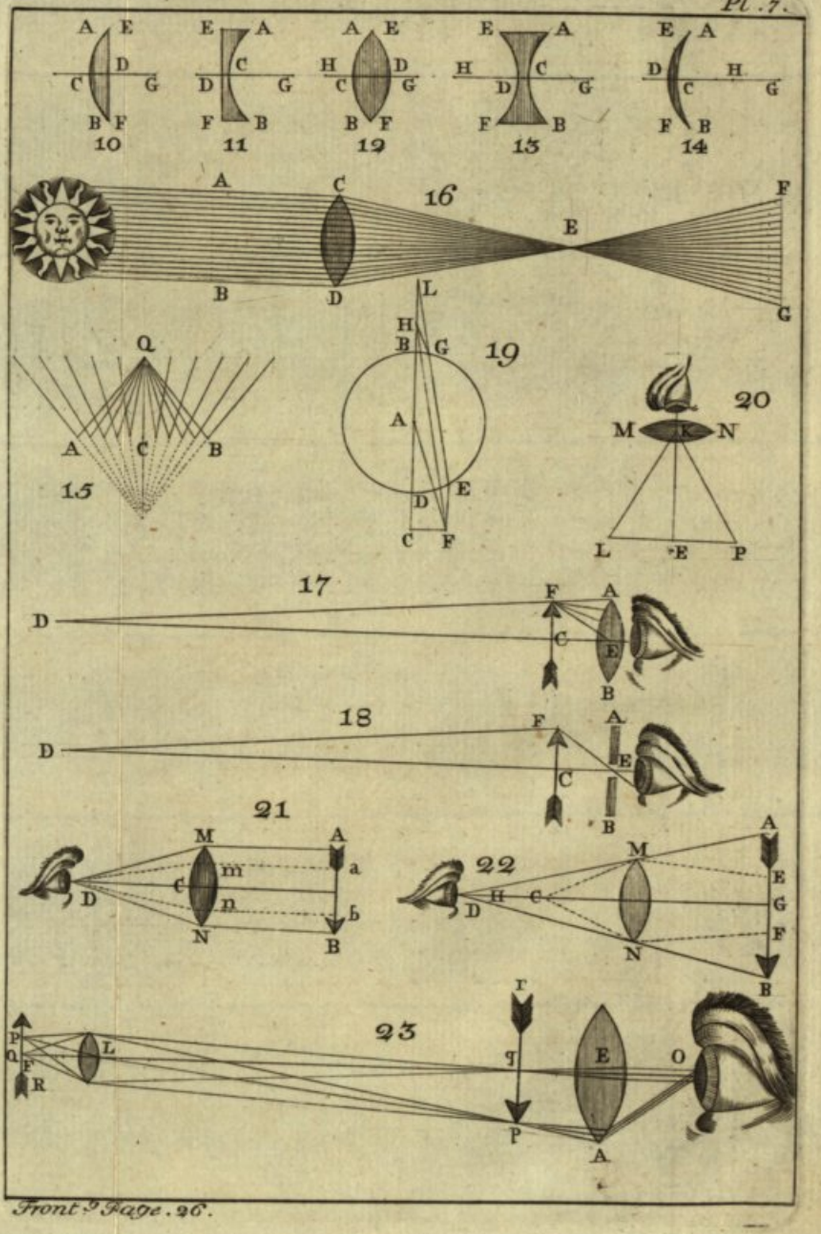
The Method Mr. *Leuwenhoek* made uſe of to compute the Size of Animalcules in Water, in *Semine Maſculino*, the *Salts* in Fluids, *&c.* was by comparing them with a Grain of Sand, one hundred of which laid in a Row, will but juſt equal an Inch in Length. Then conceiving one ſingle Grain of Sand, magnified to the Bigneſs of Fig. 24. A B C; and ſeeing an Animalcule ſwimming, or running by, or acroſs it, the Magnitude of Figure D. The Axis of which he eſtimates by his Eye, and concludes it to be a twelfth Part of the Axis D C of the Grain of Sand. From whence it follows by the common Rules, that the Figure of the Body or Sphere A B C, is 1728 times larger than the Sphere D.

Alſo amongſt the reſt, he ſees a ſecond Species of Animalcules E, the Diameter of which, by the Help of a very good *Microſcope*, he alſo meaſures, and eſtimates it to be a Fifth; but leſt he ſhould exceed, ſets it down to be only four times leſs than the firſt Animalcule D; therefore according to the former Rules, the Animalcule D is 64 times larger than that of E. Likewiſe upon a cloſer View, he ſees a third Species of Animalcules F, ſtill leſs than the ſecond, whoſe Diameter he meaſures by Eſtimation as before, and judges it to be 10 times leſs than the Diameter of the Animalcule E. Therefore the Animalcule, Fig. E, is 1000 times bigger than that of F.

In multiplying the firſt Sort by the ſecond, and that again by the third, will plainly ſhew how many of theſe laſt are required to fill a Sphere no bigger than a Grain of Sand, *viz.*

* Preface to *Hook*'s *Mycographia*, printed *Anno* 1675.

Diame-



Front.d Page. 26.

Diameter of D 12 times less than a 12 Grain of Sand.

144
12

1728 in a Grain of Sand.

Diameter of E 4 times less than 4 that of D.

16
4

Sort D. 64 in one of the first of Sand.

1728 of the first Sort D in a Grain
64 of the second Sort E in one of the first Sort D.

6912
10368

of Sand.

110,592 of the 2d Sort E in a Grain
1000 of the 3d Sort F in one of the 2d.

110,592,000 of the 3d Sort F, contained in a Sphere no bigger than a Grain of Sand *.

The third Sort F, whose Diameter is less than that of E, 10 times 10

100
10

1000 in one of the 2d Sort.

The ingenious Dr. *James Jurin*, in his excellent Dissertation on *Physico Mathematical Subjects*, *Pag.* 45. has taught us a more accurate and ready Way of measuring microscopick Objects; as follows,

He first twists a very fine silver Wire a great many times upon a slender Pin, so closely as to leave no Interval between the Wreaths, which he carefully examines by a magnifying Glass; then he takes the Interval of the outermost Wreaths, between the Points of a Pair of fine Compasses, and applies this Extent to a diagonal Scale of Inches, and by dividing this Measure of that Extent by the Number of Wreaths therein contained, he obtains the Thickness of the Wire itself. Then cutting it into very small Bits, and scattering them upon the Object-Plate, he places the Object upon them, if transparent; or the Wires upon the Object, if it be opake; and by the Eye he compares the Parts of the Object, with the Thickness of those Wires that happen to lie contiguous to them.

Thus he observed, that 4 Globules of human *Blood* would generally cover the Breadth of a Wire, which he had found to be $\frac{1}{445}$ Part of an Inch, and by Consequence, that the Diameter of a single Globule was $\frac{1}{1940}$ Part of an Inch, which was also confirm'd by Mr. *Leeuwenhoek*'s Observations upon human Blood, made with a Piece of the same Wire transmitted to him from Dr. *Jurin*. *Philos. Transf.* N° 377.

This Method of Dr. *Jurin*'s gave Rise to another which I have contrived, that is, a Method of straining a few of these small Silver Wires, in

* *Vide Leeuw. Exp. & Contemp. Tom.* IV. *Page* 23.

form

form of a Lattice; in ſuch a Manner, that the Diſtances between the Wires are exactly equal to the Diameter of the Wire itſelf. By which Means having a Wire, whoſe Diameter is a certain known Part of an Inch, we may be able to meaſure a very ſmall Animalcule, *&c.* and be more exact in our Calculations, than by either of the former Methods. For by placing this Lattice of Wires, cloſe under a *Muſcovy* Talc, upon which the Object may be placed, if it be tranſparent, or placing the Lattice over the Object, if it be an opake one. And when the Object is adjuſted to the Magnifier, the Parts thereof may be eaſily compar'd with the Number of Wires and Intervals, and their true Magnitude, or Dimenſions very nearly known, or if I obſerve the Diameter of an Object to be juſt the ſame with one Wire, or an Interval, I know it is the 560th Part of an Inch, ſuppoſing the Wire of that Size. If half that Width, the 1120th Part of an Inch; if one Quarter of the Width, the 2240th Part of an Inch, and ſo on *ad infinitum.*

Or thus, if an Object cover but the 6th Part of the Diameter of a Wire or Interval, it will be but 3360th Part of an Inch in Diameter, which multiplied into itſelf, will ſhew the Superficies to be the 11,289,600th Part of an Inch, and that Product multiplied by the firſt Number will ſhew the Solidity to be the 37933,056,000th Part of an Inch, and thus may the Minuteneſs of any Object be exactly determined.

However, this laſt Method, tho' infinitely better than any other in Practice amongſt us, is ſtill deficient on this Account; if the Object be conſiderably leſs than the Diameter of one ſingle Wire or Interval between the Wires, we are obliged to eſtimate, or gueſs its Proportion to that Diameter or Interval; but if the Object be no ſmaller than one fourth Part of ſuch Interval, the Eye is able to determine that to the utmoſt Exactneſs poſſible.

I have, therefore, to remove this Deficiency, invented a particular and curious Micrometer, applicable both to ſingle and double Microſcopes, but particularly adapted to my *Univerſal Microſcope*, deſcribed Fig. 1, and 3.

The magnifying Power of the ſolar Microſcope, is found by reckoning how many Times the focal Diſtance of the Magnifier is contain'd between it and the Diſtance of the Screen, or Sheet, upon which the Image of an Object is caſt. For Inſtance, let us ſuppoſe the *Focus* of the *Lens* in Uſe, to be $\frac{1}{4}$ of an Inch, and the Screen ſet at the Diſtance of ſix Feet, and as the focal Length of the Lens will be contained 288 times in the Screen's Diſtance, the Diameter of an Object is magnified in the Proportion of 288 to 1. The Superficies 82,944 times, and its Solidity, or Bulk 23,887,872 times, and by removing the Screen farther off, the Object may be magnified to almoſt what Size you pleaſe.

CHAP.

CHAP. X.

Of chuſing, preparing, preſerving, and applying Objects to the Microſcope.

WE muſt be very curious in chuſing ſuch *Objects* as are proper for the MICROSCOPE, which are either ſmall Parts of larger Bodies, or exceeding ſmall Inſects, *Salts*, *Sands*, *Seeds*, *Farina* of *Flowers*, &c. or the Interſtices between the ſolid Parts of *Bodies*, as *Minerals*, *Shells*, the *Air Veſſels* in *Vegetables*, *Pores* in the *Bones*, *Skin*, &c. of *Animals*, or the Motion of the ſeveral Parts of minute Animals, or of the *Fluids* in *Animal* or *Vegetable Bodies*.

The greateſt Care imaginable ſhould be taken in preparing *Objects* for an Examination; otherwiſe the beſt ſkill'd in magnifying Glaſſes may be miſled, if they give too ſudden a Judgment on what they ſee, without aſſuring themſelves of the Truth by repeated Experiments.

If *Objects* are flat and tranſparent, the beſt Method is to incloſe them between two *Muſcovy* Talcs, in an Ivory Slider, as the *Farina* of *Flowers*, *Scales* of *Fiſhes*, *Wings* of *Butter* and other *Flies*, &c. the Bodies of *minute Inſects*, &c. By this Method, every Virtuoſo may always have ready two or three Dozen of theſe *Ivory Sliders*, furniſhed with the moſt curious *Objects*; which will be a moſt delightful natural Hiſtory of the ſurprizing Beauty, Perfection, and Contrivance, we find in the Works of Nature.

In collecting *Objects* for the Ivory Sliders, Care ſhould be taken to put thoſe into the ſame Slider, which are of the ſame Degree of Tranſparency and Size; that they may all be viewed with the ſame Magnifier. There is a convex Glaſs of about an Inch Focus to hold in the Hand, in the Caſe with my *New Univerſal Microſcope*, by the Help of which you may adjuſt the *Objects* properly between the Talcs, before you fix them down with the Braſs Rings; the Number of the Magnifier may be alſo marked on each Slider its *Objects* are fitteſt for. Many ſmall living Objects may be placed in this Manner between the Talcs, ſuch as *Mites*, *ſmall Spiders*, *Lice*, *Fleas*, &c. without being killed or hurt, and will remain alive ſeveral Days in this Manner. But for preſent Examination, theſe as well as larger *Objects*, may be put into the *Glaſs Slider* V, Fig. 2. deſcribed Page 4, and deſigned for that Uſe, or in the jointed Cell X, Fig. 2. Page 4, or elſe ſtick them upon the Pin l, or pinch them between the Nippers m of the Apparatus V. Fig. 2.

The *Animalcula* in *Fluids*, may be examined in a ſmall Drop, taken up with a Pen or Hair Pencil, and placed in the Glaſs Slider before deſcribed, Page 3, or on the ſingle Glaſs Slider R, Fig. 2. if in viewing them you find them (as is often the Caſe) ſo exceedingly numerous, that by

by their continual running over one another, their Shape cannot be diſtinguiſhed: Some Part of the Drop muſt be taken off the Glaſs, and a little fair Water put to the reſt, which will ſeparate, and make them appear diſtinct. It is neceſſary thus to dilute, with fair Water, the *Semine Maſculinum* of all Animals; otherwiſe their Shape cannot be diſcovered, they are ſo crowded together in ſuch infinite Numbers.

If *Salts* in *Fluids* are to be view'd, you muſt let the Fluid evaporate, that the Salts may be left behind upon the Glaſs, and be more eaſily examined.

For viewing the *Circulation* of the *Blood* in the Tails of *Fiſhes*, in *Frogs*, *Newts*, &c. they are ſometimes put into Glaſs Tubes, but my *Univerſal Microſcope* hath a particular Contrivance a b f, of Fig. 2. deſcribed Page 3, proper to hold down the Tails of Newts and Fiſhes, and the filmy Membrane between the Toes of a Frog's hind Foot; the Circulation is beſt ſeen in the *Meſentery*, or thin tranſparent Membrane, that joins the Guts together, and this Part, by pulling out the Gut a little, may be eaſily adjuſted to the Magnifier, by Help of an Apparatus hereafter to be deſcribed, which is another Method quite new, and never before applied in ſo eaſy a Manner.

Patience and Dexterity are required to diſſect Inſects, and view their internal Structure, ſuch as *Gnats*, *Mites*, *Lice*, *Fleas*, &c. which will be eaſily done with a fine Needle and a Lancet; if they are placed in a Drop of Water, their Parts will then be ſeparated with Eaſe; and the Stomach and Bowels lie plainly (before the Microſcope) to be viewed and examined.

Bits of different colour'd Glaſs are neceſſary for this Purpoſe, to place *Objects* on, becauſe many *Objects* are much more diſtinguiſhable, when placed on one Colour, than on another. Glaſs Tubes of all Sizes, are likewiſe of Uſe, from $\frac{1}{4}$ an Inch Bore to a fine Capillary.

It is alſo neceſſary to have a few *Glaſs Tubes*, ready prepared, with Cork Stoppers, one at each End, each Cork having a Bit of a ſmall capillary Tube, run thro' its Center, as at Fig. 25. in this Manner *pregnant Inſects* may be kept alive till they lay their Eggs; and their *Worms* or *Maggots* after they are hatched, till they paſs thro' their ſeveral Changes; and in ſuch *Glaſs Tubes* it is, that Mr. *Leeuwenhoek* made his greateſt Diſcoveries: They are more particularly deſcribed in the 2d Section of the 19th Chapter, and are to be applied to the *Univerſal Microſcope*, between the Object-carrying Plate I, and Springs b.

Fig. 27. is a very ſhort cylindrical Glaſs, which may be filled with Water, or any other Liquid, in order to examine Aquaticks, which are too large for the Slider S.

Fig. 26. A rectangular Box having its two broadeſt Sides of Glaſs, is deſign'd on Purpoſe to be filled with Water, in order to apply Aquaticks to the ſolar Microſcope.

Theſe

These two last are also to be placed between the Springs b, and Object-Plate I.

Fig. 28. Is another Contrivance to place transparent *Objects* between two circular Plates of Ising-Glass, one of them being divided into Partitions, by pasting a cut Paper to it, whereon the Partitions are number'd, having different Objects placed between them, and covered with another Talc, which is held down by a Brass Ring, as in the Ivory Sliders. This is a concise Way of keeping a great Number of *Objects*, ready to shew a Friend at all Opportunities; so that any Person who is desirous to preserve a large Collection of *Objects*, may have as many of these, or of the Ivory Sliders, as he thinks proper. They are to be applied to the *Universal Microscope*, between the Object-Plate I, and Springs b; the two Brass Ribs to which the Springs are fixed, being filed into concave circular Arches for their Reception, they may be turn'd round at Pleasure, and by pushing the Object-Plate either nearer to, or farther from the Pillar E, any *Object* contain'd between them will be easily brought under the Magnifier.

There is no better Way to preserve transparent *Objects*, than placing them between two *Muscovy* Talcs in Sliders, or in the circular Talc-Plates, Fig. 28.

And the very best Way of preserving opake *Objects* for those Gentlemen who are desirous to keep a Collection of them, is to prepare small thin Slips of Ivory, or rather Holly, about an Inch long, and $\frac{1}{10}$ of an Inch wide, and some a little broader, according to the Size of the *Objects* to be put thereon. Which Slips being stain'd of several Colours, we shall obtain a Contrast to almost any Colour, and by fixing Objects upon Colours the most contrary to themselves, they will be seen to the best Advantage.

I have contrived these chiefly for my new *Universal Microscope*, to be applied between the Nippers, under the reflecting Speculum O, Fig. 1.

Wet the Slips about half their Length with strong, but very transparent Gum-Water, and upon that stick on your Objects.

I have also contrived a little Ivory Box, in Form of a Parallelopipid, to keep these Slips in. In the Sides of which there is cut small Curfs, to receive the Ends of these small Ivory Slips, that they may be placed three or four of them in a Row, and also so high above each other, as that the upper Row shall not touch the Objects in that next under it.

I have prepar'd some of these little *Cabinets* for *opake Objects*, which contain some 30, some 60, *&c.* of those Slips, which when stored with *Objects*, will be always ready for Examination, and may be carried from Place to Place, without doing the least Injury to the Objects therein contain'd.

The Reader may be supplied with these *Ivory* and *Holly Slips*, *Cabinets*, *Ivory Sliders*, *Talc Rings*, short cylindrical *Glasses*, *rectangular Boxes*, with *Glass Sides*, circular *Ising-Glass Plates*, and *Glass Tubes*, all together in one

Box,

Box, or ſeparate if he pleaſes, at my Shop, the Sign of *Tycho Brahe*'s Head, the Corner of *Racquet-Court*, in *Fleet-Street*, LONDON.

Having deſcribed the new invented *Univerſal Portable Microſcope*, together with its Application to the ſolar Apparatus; and the other Sorts which are moſt in Uſe amongſt us: By which the Reader will be able to determine how much eaſier it is in all its Applications than any, nay all of them taken together are, and have alſo ſhewn how to calculate their magnifying Powers, and how to prepare and preſerve Objects: I ſhall next proceed to ſhew what wonderful and ſurprizing Diſcoveries have been made by the Microſcope. In the Proceſs of which, I ſhall not only preſent the Reader with a Variety of Copper-Cuts, of moſt of the minute Inſects and Animalcules that have been obſerved by Mr. *Hook*, Mr. *Leeuwenhoek*, Mr. *Joblott*, myſelf, and others, but alſo ſhew how to apply either the whole, or the ſeveral Parts thereof to the Microſcope. In doing of which I have ſpared neither Coſt nor Pains to make the Work compleat.

CHAP. XI.

Of the Circulation of the Blood, and how to examine it by the Microſcope.

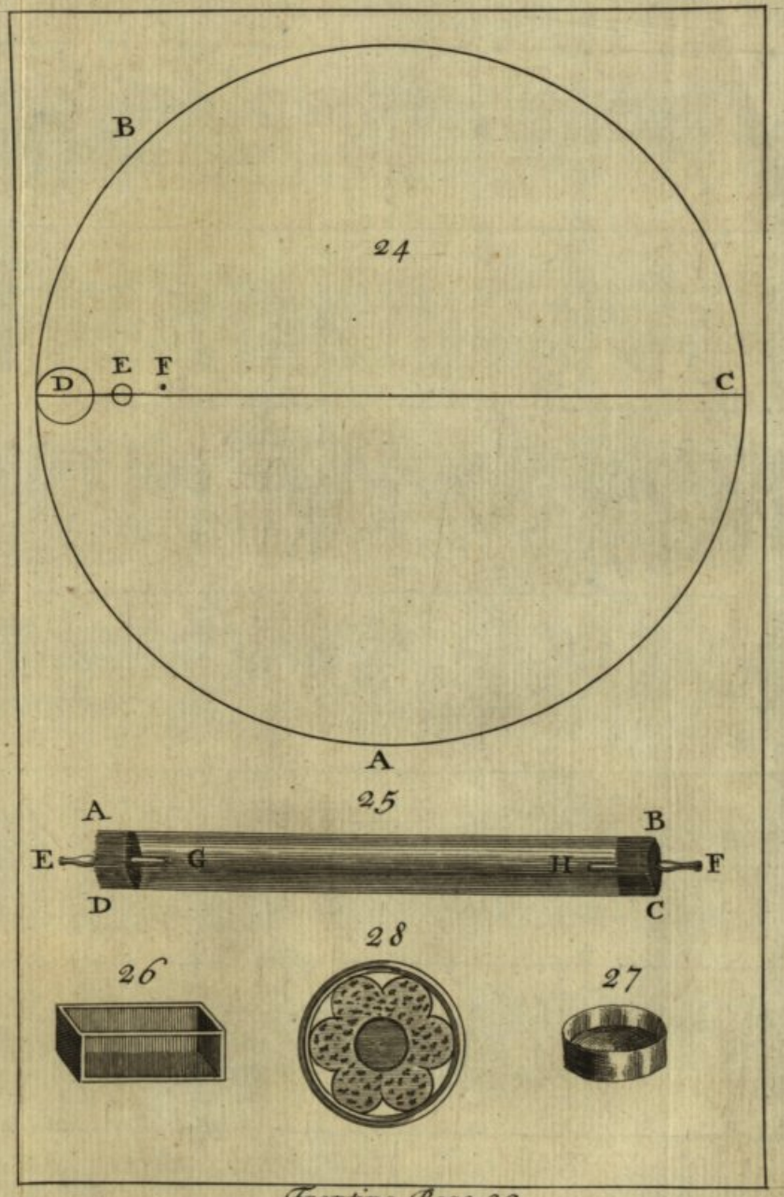
SECT. I.

THIS noble Fluid, the *Blood*, yields us the moſt ſublime Speculations imaginable, by the Aſſiſtance of the *Microſcope*. For by the Help of it, *human Blood*, and that of *Land Animals* is found to conſiſt of round red Globules, which float in a tranſparent Fluid, each of which is compos'd of ſix ſmaller, and more tranſparent ones, and each of theſe (as Mr. *Leeuwenhoek* has ſhewn in his 128th *Epiſtle to the Royal Society*) into ſix more minute and without Colour. He hath alſo ſhewn us how eaſily ſix ſoft flexible Globules, which are compreſſible into any Shape, and in continual Motion, may, by ſtriking againſt each other, compoſe one large Globule of a perfectly ſpherical Figure, one of which, and five of the ſmaller Sort, as they appear in Contact, the ſixth lying behind, is repreſented Fig. 29. which, by their mutual Attraction to, and Preſſure againſt each other, readily unite to form a perfectly round Body, as at Fig. 30. Their Attraction towards each other is ſo conſiderable, as to form a Kind of fleſhy Subſtance, when brought into Contact; and their ſpecifick * Gravity more than the Serum in which they float.

How theſe Globules, and alſo the more minute ones of which they are compoſed, are occaſionally ſeparated, in order to paſs through extremely

* *Phil. Tranſ.* No. 361.

minute



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minute Veſſels, which without ſuch a Separation, they cannot poſſibly enter, and how they re-unite again in Veſſels where they have more Room, is eaſily comprehended by a due Conſideration of the two foregoing Figures.

The Diameter of a common round Globule of *human Blood*, is equal to the $\frac{1}{1\,0\,0}$th Part of an Inch, as by the Method deſcribed, Page 27. appears.

In order to view the *Blood* with the *Microſcope*, upon the Tip of an Hair Pencil, take a ſmall Drop of *warm Blood*, immediately as it comes from the *Vein*, and ſpread it as thin as poſſible upon the Object carrying Glaſs R, Fig. 2. of the *Univerſal Microſcope*, and apply it between the Object-Plate I, and Springs, to the firſt and ſecond Magnifiers. It may alſo be extreamly well examined, if a little of it be taken up into a ſmall, but very thin capillary Tube, which being held in the Nippers m of the Apparatus V, Fig. 2. may be readily applied to the Magnifier. If you dilute a Drop of *Blood* with warm Water, and apply it either of theſe Ways to the Magnifier, ſome of the larger Globules will be ſeparated from each other, and ſeveral of them will be divided into the ſmaller ones of which they are compos'd.

By either of theſe Methods, the Globules of the *Blood* may be diſtinctly ſeen, and a little Practice will diſcover any Alteration that may happen in the Colour, Shape, or Size of them; in its ſeveral Changes between Sickneſs and Health. Mixtures of medicinal, or poiſonous Liquors, may be blended with it immediately as it comes from the Vein, and a Drop of this Mixture, if applied as before directed to the *Microſcope*, will diſcover what Alterations can be produced on the Contexture of the *Blood*. The Veſſel in which the *Blood* is received, ſhould be put into a Baſon of Water, ſomewhat hotter than the *Blood* †, to prevent its coagulating before the Mixture.

The *Circulation* of the *Blood* thro' its Veſſels, is to be ſeen in ſuch ſmall Creatures, whoſe Tranſparency permits us to look within them, or in the thinneſt Parts of larger ones; by which we are very well informed, the whole animal Syſtem being eſtabliſhed on the ſame Plan, the Circulations carried on in Veſſels of a like Form, both in the meaneſt and nobleſt living Creature, and accelerated or retarded by the ſame Cauſes.

In theſe ſmall Creatures we are not only able to ſee the general Courſe of the *Blood*, but can perfectly diſtinguiſh each Globule, and the Alteration they ſuffer in paſſing out of the larger into the more minute Veſſels, many of them being ſo ſmall, that ſingle Globules can ſcarce enter, till they are

† The exact *Blood-heat* of the Water, may be obtain'd by a Pocket *Thermometer*, made with *Quickſilver*, with which the Reader may be ſupplied at my Shop, at *Tycho Brahe's Head* in *Fleet-Street*.

compreſſed into an oval Form; and yet theſe very Veſſels are large, when compar'd with the fineſt of all, in which the Globules muſt be divided and ſubdivided into their ſmalleſt component Parts, before they can find a Paſſage.

Providence has been ſurprizingly careful in the Diſpoſition of the Veins and Arteries, for theſe laſt, which convey the *Blood* to the Extremities of the Animal, continually leſſen their Diameters in their Progreſſion, and divide into ſmaller Branches. At which Diviſion, the Globules ruſh againſt an Angle, which as it were cauſes them to recoil upon thoſe immediately behind, before they can readily ſeparate into the two ſmaller Branches C D, of the Artery A B, Fig. 31. in which the Blood flows upwards from B to A, towards the Extremity; and on the contrary in its Return back from the Extremities to the Heart, their Diameters increaſe, and thoſe ſmaller Veſſels are continually uniting into larger, as in the foregoing, Fig. 31. the Branches C and D join their Currents in the Vein E F, till at laſt all their Streams fall into one, at every ſuch Conjunction of two Branches, as at E, and their Streams violently ruſh againſt each other, by which means unnatural Coheſions are prevented.

The Microscope affords us an ample View of the Veins and Arteries, the latter of which is very diſtinguiſhable by a Protruſion of the Blood, at each Contraction of the Heart, then a Stop, and then a new Protruſion, continually ſucceeding each other, whilſt in the Veins it rolls on with inexpreſſible Rapidity.

The ingenious Mr. *Leeuwenhoek* hath told us, that with great Admiration he ſaw in the utmoſt Extremities of a very ſmall *Fiſh's Tail*, how the larger Arteries were divided into the fineſt Veſſels, * and many of the ſmall Veins, which returned from the ſaid Extremities, met together in a larger Vein; that there was ſuch an Agitation of that *Blood*, which flowed from the larger Arteries, towards the evaneſcent ones, at the Extremity of the *Tail*, and returned afterwards through many minute Veins into a larger one, as can hardly be conceived: In the larger Arteries he ſaw a continual new Protruſion of the *Blood*'s Courſe, received from the Heart; but in the ſmaller, the Motion ſeem'd equable without any ſuch repeated Propulſion; and tho' no Colour appear'd in the minute Veſſels, yet in the larger Arteries and Veins, that were near the Extremity of the Tail, the Blood was plainly red.

The exact Magnitude this *Fiſh* appear'd of to the naked Eye, as delineated by him, is repreſented in Fig. 32. Its Tail magnified, as it appear'd in the Microſcope, at Fig. 33. In which were 17 little *Bones* or *Griſtles*, that give a Stiffneſs to the *Tail*, three of them are ſhewn by the Letters A B C, on each Side of which he ſaw a very open Communication

* *Arc. Nat. Tom.* IV. *p.* 167.

of

of the Veins and Arteries, the Blood running thro' Arteries, and returning back thro' Veins, which were of the ſame Size, and evidently a Continuation of the ſame Veſſel, this was diſtinctly ſeen in 34 different Places, ſo that in the Tail of this *ſmall Fiſh* could plainly be ſeen 64 *Blood Veſſels*, 34 of them Arteries, and as many Veins, beſides the little Spaces about D and E, which were not obſerved.

This will be better underſtood by a microſcopical Repreſentation of Part of one of theſe little *Griſtles* F H G, Fig. 34. on each Side of which runs an Artery I K and M N. The Blood flowing rapidly from I and M, to K and N, their open Communication with the Veins K L, and N O, from whence it return'd to L and O, ſo that both theſe were but one continued *Blood Veſſel*; for no Veſſel can be properly called an Artery beyond the Pulſation; farther than which, and returning towards the Heart, it may be called a Vein; for Veins, as by the preſent Figure appears, are only Arteries elongated; and as they generally divide into Branches that eſcape the Sight, it is very difficult to determine where the Arteries end, or where the Veins begin. If in the Tail of this ſmall Fiſh, the whole Bulk of which was no bigger than that of Fig. 32. and conſequently under half an Inch in Length, 34 diſtinct Circulations of the Blood could be ſeen, how incredibly numerous muſt that of the Circulation be in an human Body? Nor is it to be wonder'd at, when we ſee it iſſue forth at every Prick of a Pin or Needle. In this Conſideration he alſo adds, that he is fully convinced in a Space no bigger than his fore Finger Nail, a thouſand diſtinct Circulations of the Blood are performed.

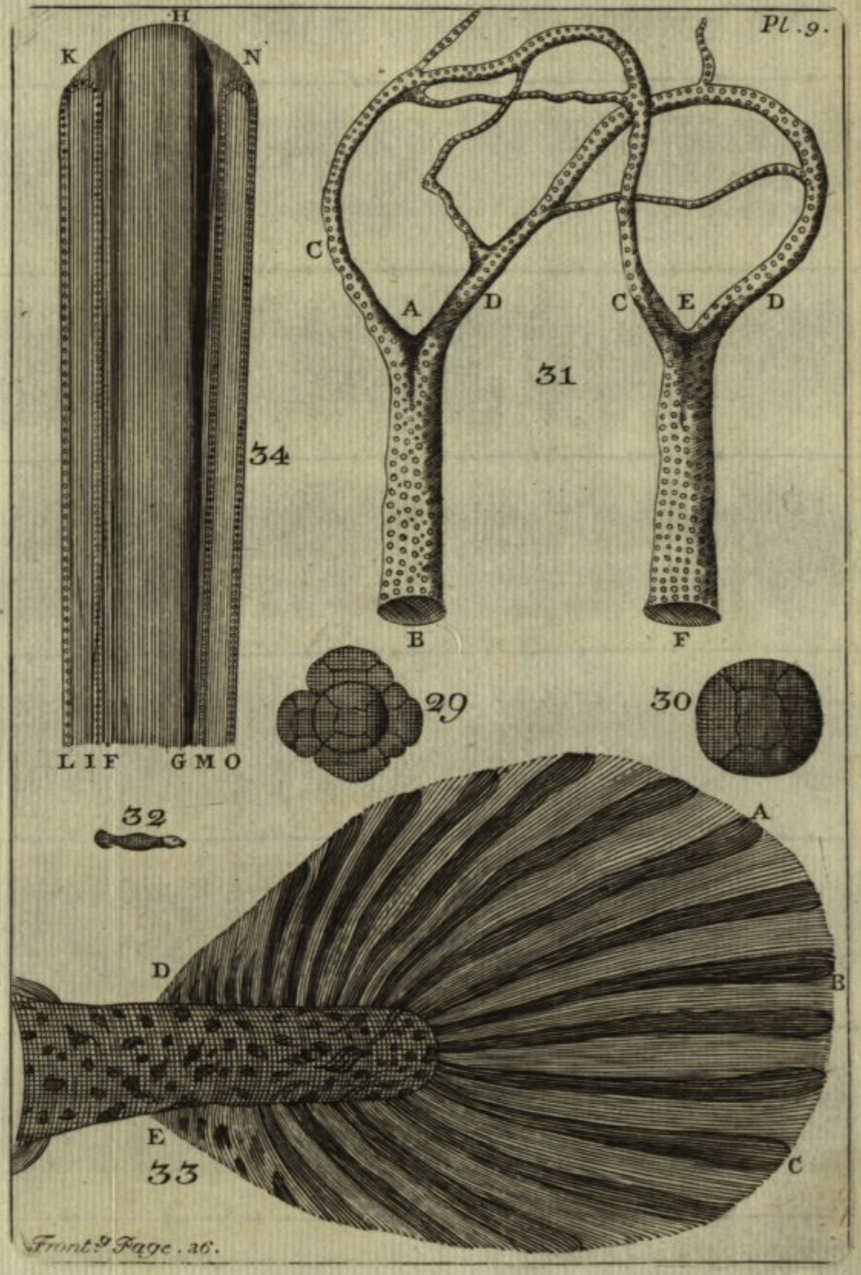
Mr. *Leeuwenhoek* obſerved the Motion of the *Blood* in a ſmall Veſſel, in the Tail of a *Tadpole*, ſomewhat wider than to admit a red Globule thereof, as A and B, Fig. 35. which Veſſel is called an Artery, through which the *Blood* coming from the Heart, in the Direction A, B, is impelled with great Swiftneſs, and divided at B into two Branches, B C and B E, which are again united at D, and continue ſo to F, where they are again divided into two other Branches F G and F I running crooked till they are again united at H, where they formed a ſomewhat larger Veſſel as H K, and became bigger at K, for which Reaſon we muſt call the *Blood Veſſels* A B C, D F G, and A B E F I, Arteries, * becauſe they convey the Blood to their greateſt Diſtance from the Heart at G and I, and the *Blood Veſſels* G H K, and I H K, Veins, becauſe they return the *Blood* to the Heart again.

In another Place he ſaw the *Blood* running in an Artery, large enough to admit about 20 red Globules † at once; this was a great Artery in Proportion to that before-mentioned, a ſmall Part of which is delineated at L M, Fig. 36. out of which proceeded a leſſer, as M O. The *Blood* in the Veſſel from L to M, had not ſo quick a Motion as it had in others,

* *Arc. Nat. Ep.* 119. † *Phil. Tranſ.* No. 260.

becauſe the *Blood* in the Veſſel at R, did in a Manner ſtagnate, inſomuch, that no ſeparated Parts could be diſtinctly ſeen, it appearing there of one uniform red Colour; yet in the Veſſel M O, the *Circulation* was as ſwift as in any other Veſſel. That the blue Spots, occaſioned by a Fall or Bruiſe, is not ſtagnated *Blood*, which perſpires before it begins to corrupt through the Skin with the Sweat, Mr. *Leeuwenhoek* was convinced of by the following Obſervation. The *Blood* at R being thus without the leaſt Motion, it was by every Pulſation of the Heart impelled upward, from N to P, and the next Moment recoiled back again, and this alternately with an undulatory Motion; as is known if never ſo much Violence be uſed in preſſing Water, yet it cannot be preſſed cloſer than it was before; ſo the *Blood* being now impelled forwards through the Heart, cannot be compreſſed into a leſs Space; this being ſo, we muſt conclude, that the Tunick of the *Blood Veſſels* between N and P, and alſo ſomewhat below N, is diſtended at every Pulſation of the Heart; and as ſoon as this uncommon Diſtention is performed, ſo ſoon alſo does the Tunick of the Veſſel contract itſelf again; whereby the *Blood* that was thus puſhed forwards is forced to run back again. After a ſhort Space of Time he ſaw the *Blood* begin to move from P to R, in ſuch a Manner as to be puſhed back again, and that during his Obſervation, the *Blood Veſſel* M O, was a little more extended; conſequently more *Blood* ran through it than when he firſt began to look upon it; the *Blood* in the Veſſel N S, wherein was little or no Motion before, now ran as ſwift as in any other Veſſel, the Veſſel P Q was ſo ſmall, that only one ſingle Globule could paſs through it at once, wherein not the leaſt Motion, at his firſt obſerving it, could be diſcovered, now began to flow; yet the Particles of *Blood*, which at firſt paſſed through it, were but few in Number, and conſequently far aſunder; henceforward all the *Blood* from P to R was put into Motion, as well by being puſhed forward, as by recoiling back again, and that at every Pulſation of the Heart; Mr. *Leeuwenhoek* ſpent about two Minutes in theſe Obſervations. From whence it plainly appears, that the ſtagnant *Blood* can not only be made to move again by the Motion of the Heart, which we call the beating of the Pulſe, but alſo that the coagulated red Globules are again diſſolved, and aſſume their firſt Figure; from which we may reaſonably conclude, that the coagulated *Blood* in any Animal occaſioned by a Blow or Bruiſe, can in a few Days be made to move again; it being taken for granted, that the Heart of a Man puſhes out the Blood 75 times in one Minute, which is 4500 in one Hour, and 108000 times in the Space of a Day and Night; and finding that in 10 Days Time the coagulated *Blood* ſeem'd to vaniſh, and alſo conſidering that in this Time the Heart performs 1080000 Pulſations, and that in each Motion, into ſeveral Veſſels together, there has been looſen'd and ſet a-going the Quantity of a Grain of Sand, how much more will be puſhed forward in the ſame Time.

Mr.


Pl. 9.
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Mr. *Leeuwenhoek* could ſee the *Blood* received from the Heart at each Impulſe, in the Veſſel above-mention'd. If we ſuppoſe that the Quantity of a cubick Inch of coagulated *Blood*, occaſioned by a Blow, is too much, and that ſeldom ſo much is coagulated at once, we may eaſily conceive, that ſuch coagulated *Blood*, by Means of ſo many Protruſions as above-mention'd, may be looſen'd, and its Motion again reſtor'd, if not in all, yet in moſt of the Veſſels.

At another Time Mr. *Leeuwenhoek* laid one of theſe *Tadpoles* upon a Piece of white Paper, a little while before he came to look upon it. A ſmall Part of the Tail was wounded by the Skin ſticking to the Paper; ſo that out of an Artery in the excoriated Part, ſo large that about four red Globules of the *Blood* might paſs through it at once, there flowed ſome *Blood* that remain'd without Motion about the wounded Part, yet that whereon his Eye was fixed, not being half an Hair's Breadth from the excoriated Artery, there proceeded a Branch of a Vein, wherein the Circulation of the *Blood* did ſtill remain, as if the Artery had not been broken, Fig. 37. T V, exhibits the Artery wounded a little above V. V X ſhews the *extravaſated Blood*. V W, the ſmall Artery wherein the *Blood* retain'd its full Courſe, altho' it was ſo near the Artery T V, out of which the *Blood* flowed; which at firſt ſeemed very ſtrange, but obſerving that the *Blood-Veſſel* V W was united at W to a large *Blood Veſſel*, that conveyed the *Blood* to the Heart, the *Blood* out of V W was continued as ſwift as if it had been impelled from T to V, in ſuch a Manner that Mr. *Leeuwenhoek* imagined, the Vein at V had not been united with T, but had lain with its Aperture at V, in the *extravaſated Blood*; ſo that the *extravaſated Blood* was only for a little ſucked up and convey'd thro' it. He then ſaw a Vein wherein the Motion of the *Blood* ſeemed very uncommon, as at Fig. 38. whereof a b repreſents an Artery, whereby the *Blood* is impelled with great Velocity from a to b, then b c, whereby the *Blood* is conveyed towards the Heart, muſt be called a Vein, cloſe by which lies another Artery d c e, wherein the *Blood* is conveyed from the Heart from d to c; now if the Vein b c be united with the Artery d e, as is ſeen at c, and the *Blood* be thus conveyed from c to e, b c ſhould be called a Vein, and the *Blood* coming to c, being there transfuſed into c e, is the arterial *Blood*, becauſe it is conveyed thither from the Heart, it being certain, that d c e is an Artery.

Amongſt others, Mr. *Leeuwenhoek* had a *Tadpole*, wherein he could perceive no Motion at all of the *Blood*, how attentively ſoever he view'd it; at firſt there appear'd no Reaſon for it, till upon examining this Animal with his naked Eye, he obſerved the fore Part of his Body was contracted, by which he imagin'd the Heart was ſo oppreſſed, that it could not force out the *Blood*, and receive it back again. Whilſt he was thus contemplating, the Animal made a very ſtrong Motion; beating its Tail about, and bending its Body, by which it got clear of the Oppreſſion it was under;

der; and on viewing it again, perceived the *Blood* to have a ſlow Motion, and Impulſe in ſeveral Veſſels, which increaſed till it at length came to its proper Motion, yet not with ſuch Velocity as it would have had, if the Heart or Body had not been oppreſſed. Mr. *Leeuwenhoek* ſays, that the Motion of the *Blood* in theſe *Tadpoles*, exceeds what he ever ſaw in any other Animal. Fig. 39. exhibits a *Tadpole* arrived to ſuch a Bigneſs, as to uſe its hinder Legs, and the fore Legs were alſo diſcernable, but yet covered with the Skin.

Mr. *Leeuwenhoek* obſerved the Circulation of the *Blood* in ſeveral *Butts*, one of which, bating the Tail, was but an Inch in Length, the greateſt Motion of the *Blood* obſervable through the Fins, was on each Side the various little ſingle Bones placed therein, where the *Blood-Veſſels* were ſo large, that 25 of thoſe Particles which conſtitute the *Blood* of a red Colour, could paſs in Breadth, but diſappear'd as they drew nigh the Extremity of the Fins, ſmall Veſſels being all along diſpers'd from the Arteries; on one Side of a little Bone, runs an Artery, and on the other a Vein, correſponding thereto; and finding it eaſy to extend the Tail, he accordingly ſtretched it in Breadth, equal to what the Fiſh gives in ſwimming, that he might the better obſerve the Motion of the *Blood* in theſe extended Veſſels, and found when the Fiſh did not move, ſome of thoſe ſmall Veſſels, which before received three Particles in Breaſt, being now ſtretched out with the Tail-fin, which they run a-croſs, did not only admit no more than one Particle, but likewiſe theſe Particles did not move ſo faſt, as when the Veſſels were not extended; and in ſome Places were at ſuch a Diſtance, that one or two more might lie in the Intervals, but could not from all this determine, that the Particles were perfectly oval *.

But to trace the Matter further, he took the *Blood* running from a live *Salmon*, † when cut into Pieces, and put it into a Glaſs Tube, no larger than a ſmall Quill, which in a ſhort Time congealed; but when it became partly fluid again, he put it into a ſmaller Glaſs Tube, and having placed it before his Eye in the *Microſcope*, the Particles being in Motion, ſome of them appear'd of a flat oval Figure, and others, which ſhewed themſelves ſideways to the Eye, ſeem'd a little thick, and thoſe whoſe Sides did not directly face the Eye, ſeem'd a little broader, without the leaſt Appearance of any globular Form. Mr. *Leeuwenhoek* alſo put ſome of the ſame *Blood* upon a very clean Glaſs, and where the Particles lay thin, he perceived them oval; nay in ſeveral Ovals he diſcovered Globules, and in ſome few ſix Globules.

Fig. 40. A B C D repreſent the oval Particles of the *Blood* of a *Salmon*, that weighed 30 Pounds; A B, the Particles that appear'd flat and broad, but did not directly face the Eye; thoſe about c were ſtreight be-

* *Arca Nat. Epiſt.* 128. † *Philoſ. Tranſ.* 263.

fore

fore the Eye, and for the moſt Part a little clear Sort of Light in the Middle, larger in ſome than others.

Mr. *Leeuwenhoek*, likewiſe, placed ſome of the *Blood* of a very ſmall *Butt* before the Microſcope, which was not mixed with any Liquor, only the Particles lay in their Serum, and are repreſented by Fig. 41.

Thoſe Particles of the *Blood*, which are diſtinguiſhed by ſhining Spots in the Middle, are delineated Fig. 42. Mr. *Leeuwenhoek* proſecuted this Enquiry yet farther, with a greater Magnifier than he had hitherto uſed, and ſo he plainly made out the oval Particles; now the greater the magnifying Power of the Glaſs, the ſwifter does the Circulation of the *Blood* appear; and having retarded this Motion, he employed two or three Seconds of Time, in obſerving the little Veins, and found, that in ſeveral ſmall Veſſels, the oval Particles were ſo broke, that he could neither ſee them, nor thoſe, of which ſix conſtituted a Particle of *Blood*, but only a ſimple Fluid of a faint Colour, running along the Veſſels; but in a great Artery at the Tail, the *Blood* mov'd ſo ſlowly, that he could eaſily diſcern the Particles were oval; and not only ſo, but he likewiſe perceived more clearly than before, the Globules that conſtituted the oval Parts, if not always, yet at leaſt for the moſt Part, as repreſented in Fig. 43.

How venous *Blood* may become arterious without being firſt in the Heart, appears by the following Experiment. Suppoſe A B, in Fig. 44. to be a Vein, in which the *Blood* view'd thro' the *Microſcope*, paſſes with great Celerity from B to A, from this Vein proceeds two ſmall Branches, C and D, which unite between E and F. Again ſuppoſe H I to be an Artery, in which the *Blood* moves upwards with equal Swiftneſs from H to I, out of H I ariſes a venous Spring, delineated in K F L; the *Blood* moving from K to F, joins the other at F; and by this Means, Part of the *Blood* coming from the Artery, is thrown into the Vein, as paſſing from F to G, and to the beſt of Mr. *Leeuwenhoeck*'s Obſervation, a Quantity of Blood, juſt equal to that carried from K F to G, moves from C E to F, and directs its Courſe upwards from F to L, ſo that whatever Quantity of arterious *Blood* paſſes thro' K F and F G, an equal Quantity of venous *Blood* returns thro' C E and F L. Though the agreeable Motion of the *Blood* was formerly apparent, yet this Experiment afforded him a very clear Perception of the above-mention'd Variety; and beſides, this Union of the *Blood-Veſſels* was not formerly diſcover'd.

Mr. *Leeuwenhoeck*, in his 112th *Epiſt.* has given us an accurate Delineation of the *Blood-Veſſels* in Part of the *Tail* of an *Eel*, whoſe whole Length did not exceed that of the Length of his little Finger. The Figure, as by him delineated, is repreſented in Fig. 45. whereof A, C, E, repreſents the Veins, and B, D, F Arteries.

The Letter D repreſents an Artery, from which a Branch G proceeds, that is divided about H, into two leſſer Branches, one of them repreſented

ed by the Letters H I K, ſo much of this ſmall Veſſel as reaches to I, is called an Artery, becauſe the *Blood* may to that Place be propelled in its Progreſſion from the Heart. The other Part I K of the ſame Branch may be called a Vein, becauſe by it the *Blood* is conveyed back again to the Heart. In the other Part of the ſame Branch H L M, the *Blood* is drove forwards till it arrives at M, where it is diſcharged into the Vein E, which in this Figure is the firſt Place that can take the Name of a Vein.

Here alſo it may be obſerved, that as the Arteries are extended in Length, they gradually leſſen. And on the contrary, the Veins increaſe in their Diameters as they approach the Heart.

Furthermore, from this ſame Artery D, another Veſſel may be ſeen branching out from N, from whence the Blood flows to O, and there diſcharges itſelf into the Vein E.

Raiſe your Eye a little higher to P, where another ſmall Artery advances from the great one D, towards Q, where it cloſes again with the Vein E.

Alſo obſerve that about the Letter R, another ſmall Veſſel leads from the ſame Artery towards S, at which Place the *Blood* that flows both from the Artery D and B, is joined, and from thence pour'd into the Vein C.

Somewhat higher, about T, advances a little *Blood-Veſſel*, which is divided into two Branches at V, ſo that from thence two diſtinct Veſſels may be ſeen to diſcharge themſelves into the Vein E, at X and h.

About the Letter Y proceeds from the ſame Artery D, another ſmall Veſſel, which at Z branches out into two more minute Veſſels; the *Blood* flowing through them toward a and b, where it is diſcharged into the Vein C.

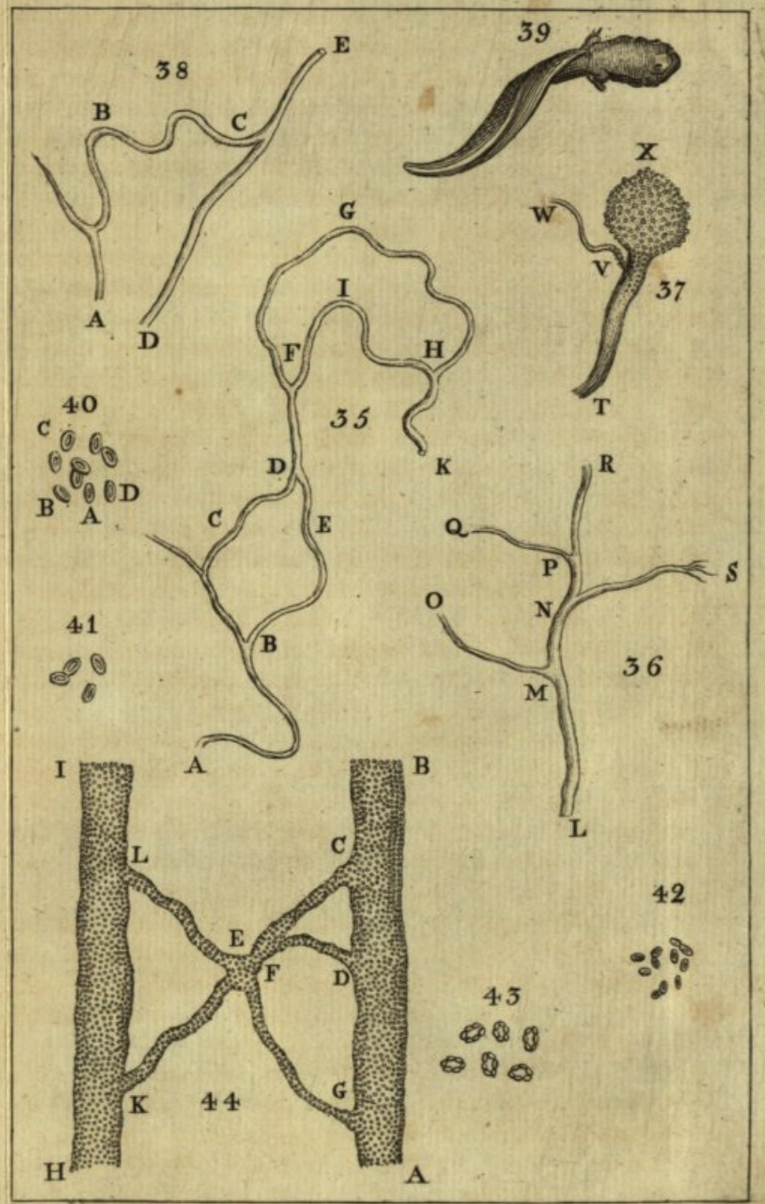
Not far from Y, about c, proceeds a ſmall Branch from the Artery D, through which the *Blood* alſo returns into the Vein C, with which it joins at d.

From the ſame Artery D riſes a minute Branch e, f, which is ſeparated into two leſſer Branches at f, ſending back the *Blood* to the Vein E, at g and h.

If the ſame Artery be examined a little higher, another Branch I k l, will be ſeen iſſuing from I, which is alſo divided at l into two others, that likewiſe diſcharge themſelves into the Vein E, at m and n, near I; at o, are alſo two other Branches, which vent their Streams at p and q, into the Vein C.

Moreover from the ſame Artery D, about r, proceeds forward a ſmall one r ſ, which is divided into finer Branches, one of which r ſ t, joins the Vein C, the other ſ, u, w, x, joins the Vein E at x.

The moſt evaneſcent Artery, flowing from the large one D, which is repreſented by the Letters r y z, unites with the Vein E at A; the ſame minute



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minute Artery, near the Letter u, is again divided into two Branches, the Part u b is diſcharged into the Vein C, at t.

An Eel of this Size may be conveniently placed before the Magnifiers in the *Univerſal Microſcope*, either in the Fiſh Pan, or in a ſmall Glaſs Tube filled with Water, and put between the Object Plate and Springs, after wiping off its Slime, which would obſcure the Glaſs, ſtop both its Ends to prevent the Water from running out; the Tail may then be viewed, and the Circulation will appear in an agreeable and pleaſant Manner, as in the foregoing Figure is deſcribed.

The Tails of any Sort of ſmall Fiſh, may be alſo readily applied to the Magnifiers in the ſame Manner. Under the Spring of the Fiſh-Pan a b f, as is before directed in Fig. 2. of Chap. 1. *Flounders*, *Eels*, and *Gudgeons* live a long Time out of Water, and are to be had at almoſt any Time in *London* alive.

Alſo the Tail * of a *Water Newt*, or a *Lizard*, if applied to the *Microſcope* in a Glaſs Tube, repreſents an agreeable Proſpect of the Circulation, through Variety of ſmall Veſſels, particularly in an exceeding ſmall one of the Water-Kind, which may ſometimes be procured ſhorter than an Inch, and ſo tranſparent, that the *Blood* may be ſeen running in all Directions, not only through the Tail, but particularly in every ſingle Toe, and thro' its Fins or pointed Branches. The *Blood* may be ſeen running through an Artery towards the Extremity, and returning through a Vein, with which its Communication is very apparent, and ſurprizingly delightful.

Mr. *Leeuwenhoek* informs us, that he has obſerved the Circulation of the *Blood*, in the fartheſt Joints of little *Crabs* † hinder Legs, with greater Rapidity than in any other Creature, and that their red Globules were twenty-five times fewer than in any other Land or Water Animal he had before examined.

Exceeding ſmall *Crabs* may be found under Brickbats and Stones, on the Shores of the River *Thames*, when the Tide is out.

The Circulation of the *Blood* may be ſeen in the Legs and Tails of *Shrimps*, if view'd in Water, wherein you have mixed a little Salt, but in theſe the *Blood* is not red.

I have frequently ſeen a Fluid flowing through the filmy Wings of *Graſshoppers*, of a greeniſh Colour.

The Motion of the *Blood* is alſo to be ſeen in the tranſparent Legs and Feet of ſmall *Spiders*, and in the Legs of very ſmall *Buggs*, and an extraordinary Vibration of the Veſſels not diſcernable in other Creatures.

You may often obſerve in viewing ſeveral of thoſe Objects, the Globules cannot paſs through the ſmaller Veſſels, otherwiſe than ſingle, and then ſqueezed into an oval Form.

* *Philoſ. Tranſ.* No. 288. † *Arc. Nat. Tom.* IV. *Ep.* 84, and 86.

If a little *Frog's Spawn*, in the Spring Time, be kept a few Days in ſome of the Ditch-Water, in which it is found, you'll have a great Number of exceeding ſmall *Tadpoles*, which at their firſt beginning to ſwim, are nearly tranſparent, place them before the Microſcope in a ſmall Tube, with a little Water, or in a cylindrical Glaſs, and you may behold the Circulation of the *Blood* in every Part of the Subject, and in a more particular Manner in the Tail, near * fifty Veſſels preſenting themſelves at once to View; and alſo the Pulſation of the Heart; but they grow ſo opake in a Day or two, that the Circulation can then be only ſeen in the Fins, and at the joining on of the Head, and in the Tail.

The Circulation of the *Blood* affords an entertaining Sight in the thin Membrane between the Toes of the hind Foot of *Frogs*, if well expanded; in the Machine a b f, of Fig. 2. Chap. 1. of the *Univerſal Microſcope*, and being ſo placed before the Magnifiers as there directed, the Arteries and Veins will be diſtinctly ſeen.

The *Blood* may be retain'd in the Lungs of *Frogs* and *Lizards*, as follows; on making an Inciſion into the Bodies of theſe Animals, their Lungs will ſtart out, and be diſtended with inſpired Air; on theſe as quick as you can, paſs a waxed Thread, and tie it firmly towards the upper Part of the Lobe, as near the Heart as poſſible; when the Lungs are dried, after being thus diſtended, they may be placed in Parts, between the Talcs of the Ivory Slider T, Fig. 2. and by this Means you may always keep by you, Objects of the Lungs of thoſe Animals, only remember to place their external ſmooth Surface towards the Magnifier. Theſe ſeveral Parts of the Lungs, are very entertaining Objects in the *Microſcope*.

But the Circulation of the *Blood* is no where ſeen with ſo much Satisfaction as in the Meſentery of a *Frog*. For which I have contrived an eaſy Method to hold the Animal during the Operation, as will be ſeen in the following

SECT. II.

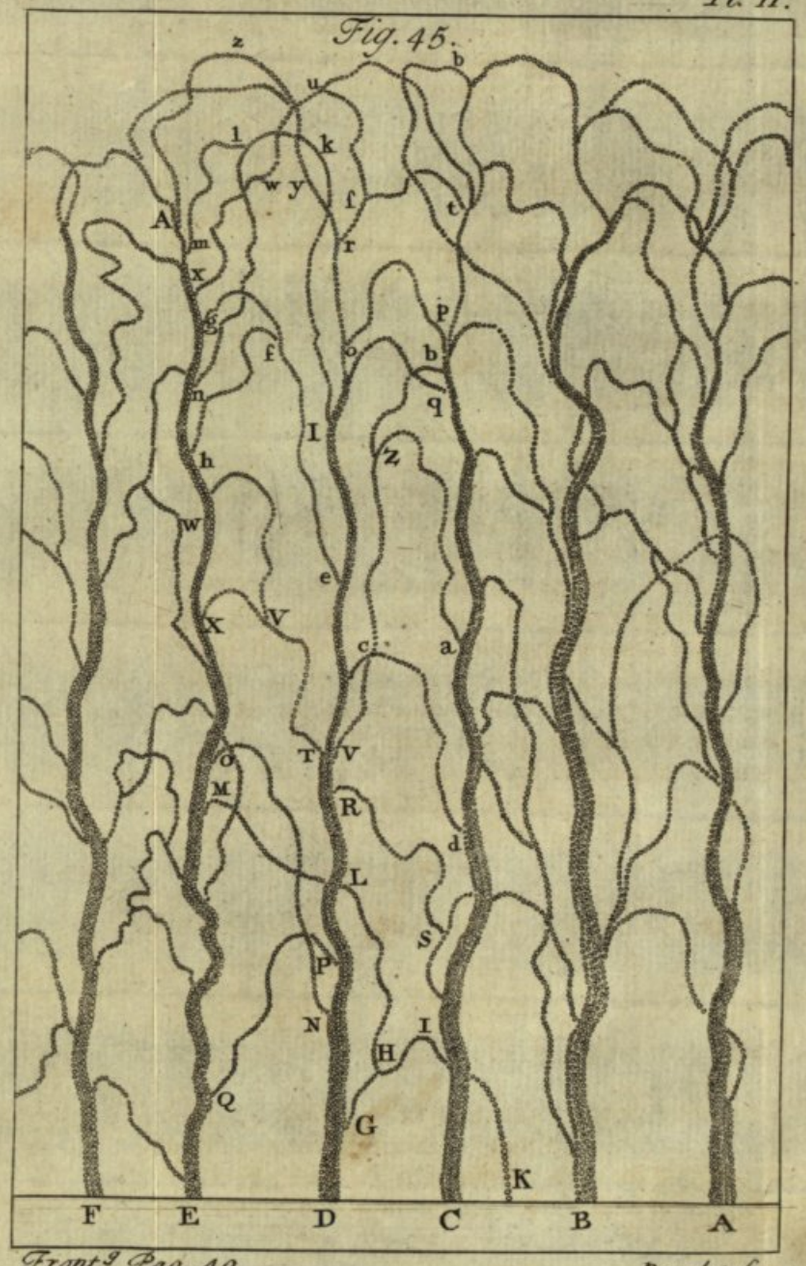
The Deſcription of a New Apparatus for confining Frogs, Mice, Bats, *or any other Creatures of the like Size, particularly adapted to the* Univerſal Microſcope, Fig. 1.

THIS Apparatus conſiſts of a ſquare Frame of Braſs A, B, C, D, Fig. 46. which may be taken to Pieces at Pleaſure. It is held together at the Corners, by the four Pillars F, F, F, F, which alſo ſupport the Frame. At the lower End of the two Pillars which ſupport the Corners C and D of the Frame, is fixed a Steel Bar G H, having one of its

* *Arcan. Nat. Epiſt.* 112.

Ends

Fig. 45.



Front.ᵍ Pag. 42.

Bowles sc.

Ends made faſt to one of the Pillars at G, and the other End ſcrewed to the oppoſite Pillar by the Nut H: On this ſquare Bar is fitted a ſliding Socket I K, with its Stem T V.

When a *Frog* is to be diſſected, tie a String to each of its four Legs; firſt having ſtrain'd Strings thro' ſome of the principal Holes of the Frame, croſſing each other, as in the Figure is repreſented by the ſmall Letters a b, c d, e f, g h, i k, l m, which form a kind of Lattice, or Couch, whereon to extend the *Frog*. Then firſt put the two Strings which are tied about his Arms, thro' two Holes, the neareſt to the Corners A, C, and there fix them with two Pegs made of Fur, as at n and o, in the Figure. The Reaſon why I direct his two fore Legs or Arms to be faſtened firſt is, becauſe you may with Eaſe hold his hind Legs in your Hand, till the fore Legs are pegg'd down faſt; whereas if you attempt to fix the hind Legs firſt, the Creature will give ſuch Springs and Starts, as will not only tire himſelf, and thereby prevent him from being able to go thro' the Operation, but even make it almoſt impoſſible for you to fix him to your Mind. Then fix his hind Legs as before directed by the Pegs p, q. If now you find him not quite faſt, you may make him ſo, by pulling out one of the Pegs at a Time, and ſtraining the String a little tighter, after which replace the Peg. The Ends of the Strings which confine his Arms and Legs, are repreſented in the Figure by the Letters r, ſ, t, v, and the *Frog* lying upon his Back.

The Object being thus extended, and faſtened on the Frame, as above directed, open the Skin of the Belly, from near the Anus to the Throat in the Direction of the dotted Line I K, by firſt juſt entering the Point of a very ſharp Penknife at I, thro' the firſt Skin only, taking Care not to touch the ſecond Skin, and let the Inciſion be no longer than the little ſtreight Stroke I w, in which thruſt the Probe or Director, Fig. 47. almoſt up to his Throat, with the Curf x y upwards, in which Curf you may run the Point of a Pair of Sciſſars, without being in any Danger of cutting any other Part of the Subject, and thereby open the upper Skin from I to K, then turn the Director ſideways from K to L, and from I to M, and give it a little Snip in that Direction, both at the Top and Bottom. Stick a Fiſh-Hook, with the Barbs filed off, into each Corner of the Skin, firſt having put the Strings N O, to which the Hooks are tied, through any two of the Holes in the Frame, as at P and Q. Then by gently pulling the Strings N O, the Skin will readily ſtretch out into the Direction of a ſquare Flap, as repreſented in the Figure by the Letters L M R S, and the three dotted Lines which ſurround them.

If now you put the Stem T V into the Hole of the Pillar E of the *Univerſal Microſcope*, you may place any Part of this Flap before the Magnifiers, either by ſlipping the ſquare Steel Bar G H backwards and forwards in its ſliding Socket I K, or elſe by pulling the ſaid Socket farther from, or

puſhing it nearer to the upright Pillar E of the *Microſcope*, Fig. 1. by which Means, you may with the greateſt Eaſe imaginable, examine all the *Blood Veſſels* in this tranſparent Flap or Piece of Skin, by ſitting at a Table before a Window, and directing the illuminating Glaſs, ſo as to fling the Rays of Light immediately under this Part of the Skin.

If the Sun ſhines, and you have the ſolar Apparatus, deſcrib'd Page 9. ſcrew'd ready in the Window Shutter, take out the illuminating Glaſs F, and in its Stead, ſcrew the Socket K, of the ſolar Apparatus, and apply the *Microſcope* and *Frog* to the ſolar Part as before ſhewn, and after having directed the Sun's Rays thro' the Tube, upon any Part of the ſkinny Flap L R S M, and placed the Screen at about four or five Foot from the Machine, ſo as to receive the Sun's Rays, and adjuſted the Object to the Focus of the Magnifier, and Diſtance of the Screen, by Help of the Screw P, as in Fig. 1.

You will have repreſented on the Screen, a moſt beautiful Picture of the Veins and Arteries in the Skin, with the *Blood* circulating thro' them; in the Arteries you may plainly perceive the *Blood* ſtopping, and as it were receding a little at each Dilatation of the Heart, and then immediately ruſhing forwards again at each Contraction; whilſt in the Veins it rolls on in a continual Current, with inexpreſſible Rapidity; and when the Arteries are very much magnified, if you remove the Screen to a conſiderable Diſtance, the alternate Expanſion and Contraction of their Sides are very viſible.

When you have conſider'd this as long as you think needful, open the Abdomen, and extend the Muſcles before the *Microſcope*, by Means of the two Fiſh-Hooks, as before in the Extenſion of the Skin, and you will with Pleaſure view their Structure, which conſiſts of Numbers of tranſparent Strings or Fibres, lying parallel to one another, and joined together by a common Membrane.

Theſe Strings or Fibres appear thro' their whole Length, to be made up of minute roundiſh Veſicles; and the *Blood Veſſels* which intermix with them, afford an agreeable Proſpect.

The next Experiment is gently to draw out a Part of the Frog's Gut, in order to apply the Meſentery to the *Microſcope*, which is a moſt beautiful and ſurprizing Phenomena, when view'd through the *Univerſal Microſcope*, as ſtanding upon a Table: But when applied to the ſolar Apparatus before deſcribed, you may view it in ſo diſtinct and fine a Manner, that no Words can deſcribe the wonderful Scene which will then be preſented to your Sight. The *Blood* flowing through numberleſs Veſſels at one and the ſame Inſtant, in ſome one Way, in others the quite contrary; ſeveral of the Veſſels may be magnified to an Inch in Diameter, and the *Blood* Globules rolling thro' them, will appear near as large as Pepper-Corns, and at the ſame Time in the minuteſt Veſſels, only ſingle Globules can find a Paſſage, and that not without putting on the Form of oblong

Sphe-

Spheriods; here alſo in the moſt inexpreſſible Manner, will be ſeen the Pulſation and Acceleration of the *Blood* in the Arteries, as before deſcribed.

As the *Animal* grows languid, and near expiring, the *Blood* in the Arteries will be ſeen to ſtop ſuddenly, and as it were ſeem to coagulate, and then run backwards for ſome Time; after which it will again recover its natural Courſe, with a great deal of Rapidity.

A due Conſideration of theſe Appearances, may poſſibly account for the Intermiſſions, Starts, and Irregularities in the Pulſe of Perſons near the Point of Death.

Fig. 48. M, L, R, S, repreſents a microſcopick Picture of a Part of the *Frog's Gut*, and *Meſentery* extended, by Means of the Fiſh Hooks R, S, M, the Ends of their Strings being pegg'd to the ſquare Frame, one of which is ſeen at p. B, I, K, C, is a Part of the Body of the Frog. And I, K, that Part where the Belly was opened. D, E, Part of the ſquare Braſs Frame. The ſhaded Part within the Gut, marked M, L, R, S, is called the Meſentery, in which is plainly ſeen the *Blood-Veſſels*. Thoſe Veſſels, which are a little darker than the reſt, are called Arteries. In every one of which I plainly ſaw a Pulſe, and the *Blood* flowing from A to R. The others are Veins, thro' which the *Blood* flowed in a conſtant Stream, in the Direction V, N.

As there are many ſmall *Fiſh*, whoſe Fins are more tranſparent than their Tails; I thought it might be acceptable in this Place, to give a Cut of the Manner how they may be faſtened upon the ſame Frame the *Frog* was, which take as follows,

Firſt cut a Piece of Leather in the Shape of Fig. 49. and tie a String to each Corner of it, as at A, B, C, D, and obſerve, that the Part G H of the Leather be no longer than from the *Fiſh's Neck* to the Part where the Tail begins to grow ſmall, and cut a Slit from A to I, and from B to K, then put the String C E through the Slit A I, and the String D F thro' the Slit B K, and put the *Fiſh* in Head foremoſt; after which draw the Strings cloſe, and apply it to the Frame, Fig. 50. fixing down the String D F to the Frame by the Peg N, and the String B M by the Peg O. The String C E may be made faſt with the Peg P, and the String A L with the Peg Q, in which Poſition the *Fiſh* cannot poſſibly get away, but on the contrary will lie exceeding quiet: Then may you ſtick a Fiſh-Hook to the thick Part of its Fin at R, and ſtretch it out by drawing the String R S gently, and then making it faſt by the Peg T.

After which place the Frame to the *Microſcope*, as above directed; and you will have a beautiful Proſpect of the Circulation, if viewed thro' the Eye-Piece N upon a Table; but much more ſo if you apply it to the ſolar Apparatus.

I hope by this Time the Reader will be enabled to fix any other Subject of the like Size to this Apparatus, in order for Diſſection, and alſo be ready

at

at applying them to the Microſcope, either to be look'd at by the Eye through the Magnifiers, or caſt upon a Screen when applied to the ſolar Apparatus. The Reader will alſo percceive that none of the modern Microſcopes, is ſo capable of having all Sorts of Subjects applied to them, as this is, and that in one Apparatus; and ſo eaſy in its Uſe, as to give Gentlemen as little Trouble as poſſible in the Application of all Sorts of Objects.

CHAP. XII.

Of Bones.

THEIR ſuperficial Part is found to conſiſt of a vaſt many ſmall Veſſels, and ſome few of a larger Size; which laſt, when they came to the Surface of the Bone, appeared to Mr. *Leeuwenhoeck* either with a Membrane, or *bony* Subſtance, perfectly tranſparent: He once diſcovered four or five Veſſels in a ſmall Piece of a Shin *Bone* of a ſufficient Size for a ſingle Filament of Silk to paſs through them, and one of them ſeemed to him to have a Valve * ſo diſpoſed as to admit nothing into it, but only to let out what was therein contained.

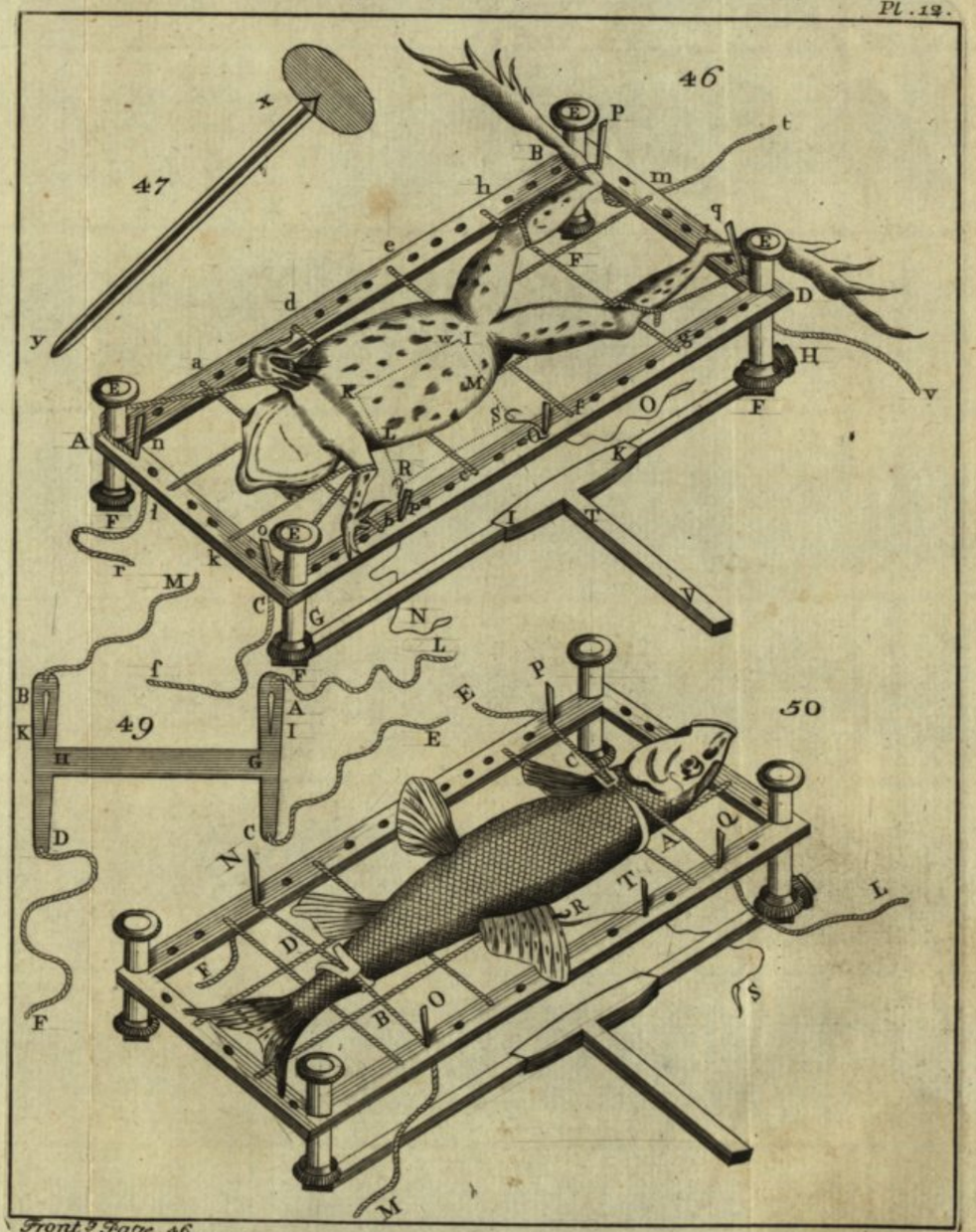
The ſpongy or cellular Subſtance on the Inſide of the *Bone*, conſiſts of long Particles cloſely united, that are made up of a vaſt many ſmall Veſſels, ſome running lengthways, others tending towards the Sides of the *Bony* Particles, ſome lying parallel, and others perpendicular to the Length of the *Bone*, theſe laſt have Veſſels proceeding from their Extremities; and others that compoſe the Cortex or ſuperficial Part of the *Bone*, proceed from their Sides, thoſe long Particles, which lie parallel to the Length of the *Bone*, emit Veſſels from their Sides, that iſſue out through the Side of the *Bone*. It is impoſſible to conceive what a prodigious Number of ſmall Veſſels compoſe the cortical Part of the *Bone*, which on the ſpongy Part in ſome Places is no thicker than a human Hair; tho', in others, three or four times that Thickneſs.

The *Perioſteum* is united to the Cortex of the *Bone*, not only to the Outſide of the Cortex, but even by entering into its very Subſtance in ſeveral Places, and is joined thereto by the Veſſels which proceed from the *Bone*.

Fig. 51. repreſents a ſmall part of the *Bone* with the Perioſteum adhering to it; ABCDEF ſhews the Bony Part, BGHIE the Perioſteum, in which all the ſmall Veſſels are repreſented by Dots. In other Places where the Thickneſs was twice as much, not only thoſe Veſſels that had been tranſverſly cut, and conſequently repreſented by ſo many Points;

* *Phil. Tranſact.* No. 366.

but



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but alſo many other Veſſels running lengthways, as in Fig. 52. L O P Q N M, and that Part repreſented by B G H I E, Fig. 51. are not entirely membraneous, but really *bony*. K L M N A repreſent the *bony* Part, in which tho' no Pores or Veſſels are here repreſented, yet it is full of Openings. Fig. 53. R S W X T V repreſents a Part of another *Bone*, S W X T the *Perioſteum*, which in this Place was no thicker than a large Hair of a Man's Beard; but in another Part of the ſame, and at a ſmall Diſtance, it was four times that Thickneſs. In another Piece of *Bone* ſo placed before the *Microſcope* as to ſhew only the *Perioſteum* and *muſcular Fibres*, which were cut tranſverſly, and appeared to be ſurrounded by Fibrils of the *Perioſteum*, as in Fig. 54. where Y Z A B is the *Perioſteum*, and Z C D A are the fleſhy *Fibres* cut tranſverſly, this was part of a Rib taken from a fat Ox.

It appears therefore from Mr. *Leeuwenhoeck*'s Obſervation on *Bones* of all Kinds, that they do conſiſt of exceeding ſmall Veſſels, ariſing from the inner hollow or ſpongy Part of the *Bone*, and paſſing thro' the ſuperficial or cortical Subſtance, enter the *Perioſteum*; and from thence are continued farther into the Body, even to the remote Parts thereof. Hence it is, that in a healthful Body there is a conſtant Supply of an oily Subſtance conveyed into the *Bones*; which again is conſtantly carried out from the *Bones* by Means of theſe Veſſels into all Parts of the Body, even to the Extremity of the Fingers. He examined a very ſmall Piece of the ſolid Part of the *Shin Bone* of an *Ox*, and found it to conſiſt of four Sorts of Tubes, perforated lengthways. The firſt Sort ſo ſmall and ſo cloſely united, as ſcarce to be diſcernable in a tranſverſe Section of it. The ſecond Sort of Tubes (ſome of which are four, ſome ſix times larger than the firſt) are alſo difficult to be diſcover'd; becauſe in cutting or ſhaving the *Bone*, although the Knife was ſharp, it deſtroyed and broke many of the tubular Parts, which ſhut up their Apertures. The third Sort greatly exceed thoſe of the ſecond, but were alſo difficult to be diſcerned, becauſe the Knife tore ſome of them in cutting; yet notwithſtanding he was perſwaded, that *Bones* are compoſed out of ſucceſſive Additions of Rings of Tubes, in the ſame Manner as Wood is. The fourth Sort are much larger than theſe, and fewer, as will appear in Fig. 62. whereof M repreſents a very ſmall Piece of a Shin *Bone*, which when viewed by the naked Eye, appeared no bigger than the Spot, Fig. M.

A B C D is the ſame Piece of *Bone* magnified, E F G is the Point of a very ſmall Needle, upon which this little Piece of *Bone* * was ſtuck for Examination before the *Microſcope*, he was not able to repreſent the firſt Sort of theſe little Tubes in the Picture, becauſe their Surface was ſo mangled in cutting, but the ſecond Sort is repreſented by the Letters H H H, the

* *Arc. Nat. Tom.* I. *p.* 200.

third

third Sort by the Letters I I I, which are ſeldom circular, but of different Shapes, like the great Veſſels in Wood. The fourth Sort are a great deal larger, as ſhewn by the Letters K K. The curved Lines L and M are little Cleſts or Cracks made by the Knife in Cutting.

To examine the *Bones*, ſhave off with a very ſharp Razor thin Pieces of them croſſways, lengthways, and obliquely, and that from the Inſide, Outſide, and Middle of the Bone: Then apply to the Microſcope ſome of theſe Shavings dry, and others moiſtened with warm Water, by which Means you may view the Veſicles in all Directions. Or put the Bones in a clear Fire till they are red hot; then carefully taking them out, you will find the bony Cells perfect and entire, and being quite empty, may be view'd with great Eaſe and Pleaſure.

They may be applied to the *Univerſal Microſcope*, Fig. 1. either upon the Glaſs R, Fig. 2. or ſtuck upon the Point of a very ſmall Needle, which Needle may be held between the Nippers m of the Apparatus V, Fig. 2. and thereby examined with Eaſe, and little Bits thereof may be preſerved between the Talcs in an Ivory Slider, or in one of the circular Talc Rings.

CHAP. XIII.

Of the Muſcular or Fleſhy Fibres of Animals.

MR. *Leeuwenhoeck* hath diſcovered each muſcular Fibre to be made up of ſmaller *Fibrils*, which, notwithſtanding their Smallneſs, he plainly diſcern'd to be vaſcular, for on cutting a-croſs their Length, the Light might be ſeen thro' their Apertures; but if he cut them ever ſo little obliquely, could ſee no Light. He alſo obſerved the Structure of the *Fibres* in the Fleſh of an *Ox*, and of a *Whale*, but plainer in that of a *Whale*; the Fibres of the other being more compact and cloſe, and found alſo that the Fibres of a *Mouſe* were of the ſame Size as * thoſe of an *Ox*, from whence he concludes, the different Size of *Animals* is entirely owing to the Number and Length of their Fibres. Theſe fleſhy Fibres appear throughout their whole Length, to be encompaſſed as it were with ſpiral Circumvolution, as is exactly repreſented in Fig. 69.

Which Diſpoſition ſeems to be wonderfully contrived for Readineſs in the Diſtenſion and Contraction of the Fibres. Two of thoſe *fleſhy Fibres* are repreſented by G H, and I K, Fig. 68.

To view the muſcular *Fibres* with the Microſcope, cut off a Piece of dried Fleſh or Fiſh, as thin as poſſible, and lay it upon the Glaſs R, of

* *Arc. Nat. Tom.* III. *p.* 108.

Fig.

Pl. 13.

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Fig. 2. and moiſten it with warm Water, which drying ſoon away, will leave the Veſſels open and diſtinguiſhable. As the Learned differ in their Opinions with Reſpect to the Figure and Structure of theſe little Veſicles, I ſhall leave it to the Curious for farther Examination.

Mr. *Leeuwenhoek* informs us, that the fleſhy Fibres in Inſects are no leſs viſible than thoſe of larger Creatures, which he found by cutting off the Legs of *Flies*, *Gnats*, *Ants*, &c. in all which he could plainly diſtinguiſh the circular Wrinkles or Circumvolutions encompaſſing the Fibres, as in Fig. 69.

Upon cutting the fleſhy *Fibres* of a *Whale*, length-wiſe, and a-croſs, † he plainly diſcovered each Particle, or fleſhy *Fibre*, to be enveloped in a fine thin Membrane. It appear'd in the Microſcope, as repreſented Fig. 55. in which the Parts lay ſo cloſe together, that their encompaſſing Membranes, repreſented by the black Lines, were but juſt diſcernable; ſome however appear'd larger than others, and theſe, † if attentively view'd, ſeem'd to be divided into a great many others, ſome alſo cut tranſverſly, and crowded ſo cloſe together, that their Figure, as well as Size, was very different. Fig. 56, repreſents a thin Slice of the Fleſh of a *Whale*, which after having been made throughly wet, and applied to the Microſcope, appear'd as in the Figure. Upon letting the Moiſture evaporate from theſe Slices, the Particles became much ſmaller, and the Membranes, with which each was encompaſſed, were very viſible. Fig. 57. repreſents a Piece of the ſame Fleſh, wherein the Particles ſeem'd to touch, but on their being dried, ſhrunk up, from the ſurrounding Membranes, whereas the Membranes themſelves could not ſhrink, becauſe they were all join'd together. All along theſe fleſhy *Fibres* § run Membranes about the Thickneſs of an Hair, and Diſtance of a Grain of Sand; from theſe larger Membranes, other Parts were ſpread, dividing each *Fibre* into a great many *Fibrils*; from whence we may ſay, that each fleſhy *Fibre*, no bigger than an Hair, is a ſmall Muſcle encompaſſed with its peculiar Coat or Membrane. Fig. 58. repreſents a ſmall Piece of theſe *Fibres* greatly magnified; on moiſtening again the *Fibres* repreſented by the two laſt Figures (that were dried and ſhrivell'd up) they became ſo diſtended, as to fill up the Spaces between the Membranes, and re-aſſume the Shape they had before they were dried. Among ſeveral little Pieces of Fleſh, moiſten'd as above, and placed before the Microſcope, there was one, whoſe Particles were not ſeparated upon drying; ſuppos'd to be owing to the ſplitting and tearing ‡ aſunder of a large Membrane, which run thro' its Middle, as repreſented in Fig. 59. by Q R S T V W, where between S T and V, the dried Particles remain unſeparated, S W ſhews the thick Membrane that divided this Piece about

† *Epiſt. Phyſ. p.* 3. § *Ibid. p.* 4. ‡ *Phil. Tranſ.* No. 39.

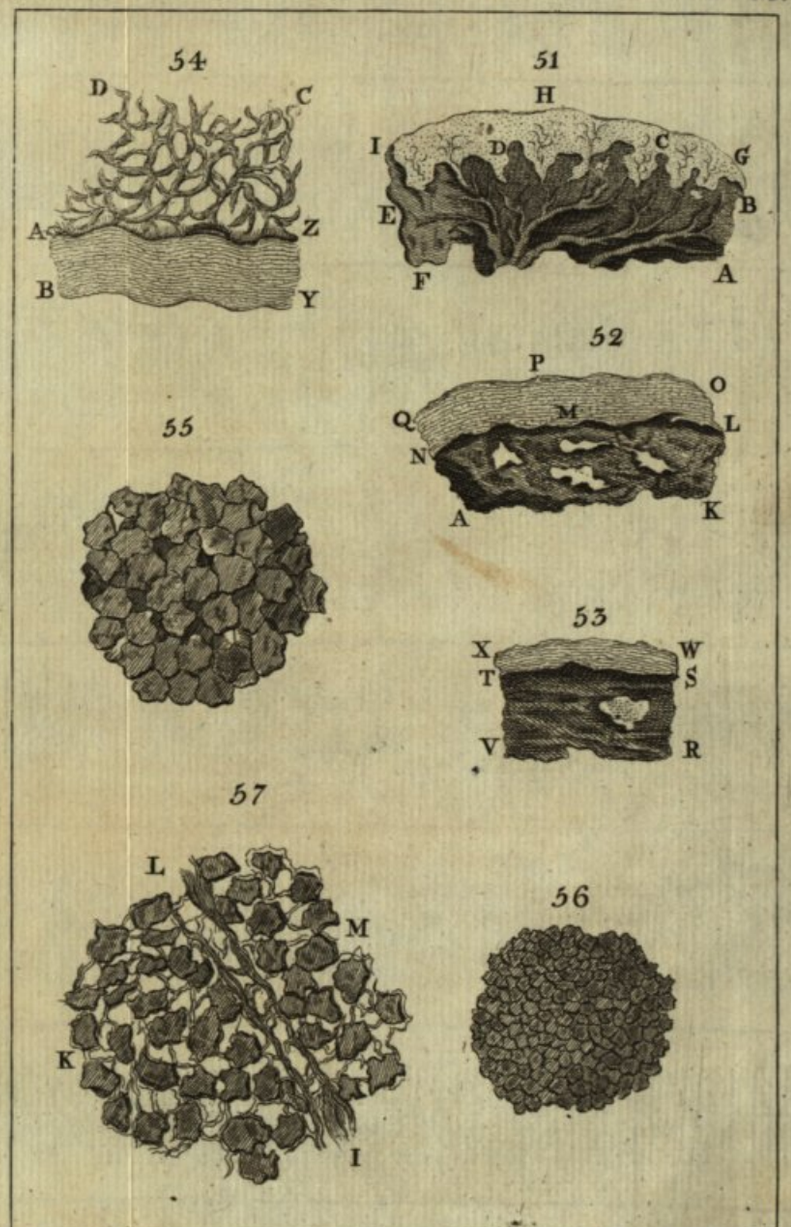
the Thickneſs of an Hair, that ſent out a Branch at T, and at W was ſplit into two. Fig. 60. repreſents a very ſmall Piece, conſiſting only of five *Fibres* cut lengthwiſe, as they appear'd thro' the Microſcope; between C and F may be ſeen the little Membranes which encompaſs the *Fibrils*, but are here torn aſunder. Fig. 61. exhibits four ſmall *Fibrils* of a Piece of Fleſh of another Whale, by which it plainly appears, that the Diameters of theſe *Fibres* are as ſmall again as thoſe in the foregoing Figure, therefore they muſt be four Times as big as theſe; as each fleſhy *Fibre* is compoſed of a great many ſmaller *Fibrils*, we may imagine each of theſe incloſed ones, to conſiſt alſo of others of the like Nature.

Mr. *Leeuwenhoek*, on viewing ſeveral ſmall *Fibres* of *Ox* Fleſh, obſerved each of its contained *Fibrils* to be encompaſſed with a thin Membrane; but could not ſhew theſe Membranes ſo diſtinctly to others in this Fleſh, as in that of a Whale; becauſe the Parts of the firſt are of a Texture much more compact and cloſe, than thoſe of the latter; for which Reaſon they do not ſhrink ſo much in drying. And is alſo of Opinion, that what he has ſaid of the Membranes encompaſſing the *Fibres* and *Fibrils* of Whale-Fleſh, will alſo hold true in other Kinds of Fleſh, even down to that of a *Rat* or *Mouſe*.

Mr. *Muys* confirms the foregoing Obſervations on the fleſhy *Fibres* of the Muſcles, being compoſed of ſmaller *Fibrils*, and computes that 500 or 600 of them may be reckoned into one fleſhy *Fibre*, whoſe Diameter is the 24th Part of an Inch, * and that each of theſe *Fibrils* are alſo made up of more than 300 tranſparent Tubuli, but ſo ſlender as not to admit a 24th Part of a ſingle Globule of *Blood*. He has ſhewn, that tho' the fleſhy *Fibres* of the Muſcles are joined to the Tendons, and tendinous Membrane of a Muſcle; yet thoſe tendinous *Fibres* are not a Continuation of the fleſhy ones, as is generally ſuppoſed. He found that upon injecting warm Water into the crural Artery of a *Lamb* of a Year old, all the fleſhy *Fibres* loſt their Redneſs and became White. He then injected a colour'd Liquor into the ſame Artery, upon which not only the ſmall Arteries appear'd replete with the tingid Liquor, but that it had alſo paſſed thro' each *Fibre*. He alſo obſerved, that ſeveral Branches of the Arteries now became viſibly ſpread round the ſmall *Fibrils*, and tingid with the ſame Liquor; and upon examining the Parts of the fleſhy *Fibres*, near the Extremity of the Arteries with a Microſcope, found the ſmall *Fibrils* filled and tingid with the ſame Liquor; and not the leaſt Appearance of the Liquor in the Interſtices between the *Fibrils*. And upon injecting another colour'd Liquor by the crural Artery, he ſaw not only the *Fibres* in ſome of the Muſcles, and moſt Part of them in others, filled with this Matter, but upon examining them in a good Microſcope, found the Fibrils, and even the leaſt

* *Phil. Tranſ.* No. 339.

Tubuli



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Tubuli that compos'd them, filled and tingid with the same, yet the small Ramifications of the Nerves appear'd perfectly white. Whence it appears, that the small Tubes which form a *Fibril*, are really hollow; and that the Extremities of the capillary Arteries open into them, and empty therein a Part of their Liquor, which is re-conveyed by the Veins into the Heart.

In the spinal Marrow of an *Ox*, Mr. *Leeuwenhoek* tells us, he saw with great Delight minute hollow Vessels of an inconconceivable Fineſs, invested with their Membranes, and extending length-wise parallel to each other, make up their Composition. He did not only discern their Cavities, which he computed to be 3 times less than their Diameters, but in some perceived the Orifices, as the Holes in a prick'd Paper are seen, when held against the Sun. This Examination requires the utmost Dexterity. For after a thin Slice of the spinal Marrrow is placed before the Microscope, in less than a Minute's Time it becomes dry, and the whole Appearance lost *.

He also examined the Brain of an *Indian Hen*, a *Sheep*, an *Ox*, a *Sparrow*, &c. and did in them distinguish Multitudes of Vessels extreamly small; and farther † observ'd, that the Vessels in the Brain of a *Sparrow* are no smaller than in an *Ox*, and from thence he argues, that there is no other real Difference between the Brain of a larger and a smaller Animal, but only a greater or a smaller Number of Vessels; and that the Globules of the Fluid passing thro' them, are in both of the same Size.

CHAP. XIV.

Of Hairs.

FROM *Malphigi*'s curious Obſervations of the *Hair*, we are informed, that they are compos'd of a Number of extreamly minute Tubes, which are mostly distinguishable near the End of the *Hairs*, in a Horse's Main and Tail, and in the Bristles of a Boar, wherein those Tubes so manifestly appear, that he could sometimes reckon above 20 of them; and in the Hedge-Hog's Prickles, he plainly saw those Tubes, together with medullary Valves and Cells.

That which this sagacious and not enough to be commended Obſerver, took Notice of in the Structure of *Hair*, and its Parity to the *Spines*, § is obſervably true in some Measure in the *Hairs* of *Cats*, *Rats*, *Mice*, and in divers other Animals, which look very prettily when viewed with a good Microscope.

Fig. 63. A, B, C, represents three cylindrical Pieces of human *Hairs*, they are transparent throughout their whole ‖ Length; and are composed of small

* *Arc. Nat. Tom.* III. *p.* 310, 355, 440. † *Ibid. Tom.* I. *Part* I. *p.* 38. § *Derham*'s *Phiſ. Theſ. p.* 220. ‖ *Hook*'s *Microgra.* 1 *Ed. p.* 158.

long tubular Fibres, encompaſſed with a Kind of Bark; from which Structure, the Ends of long Hairs when ſplit, appear like a Stick ſhrivelled with Beating, ſome of them in *Men*, *Horſes*, *Sheep*, *Hogs*, &c. having ſix or more Splinters.

Fig. 64. repreſents a cylindrical Piece of the *Hair*, or *Briſtle* of an *Hog*, which is neither perfectly round nor ſharp edged, but priſmatical, with divers Sides and roundiſh Angles.

Part of a Whiſker of a *Cat* cut tranſverſly, is repreſented by the ſhort Cylinder, Fig. 65. which ſeem'd to have a large Pith in the Middle, like that of Elder.

The *Hairs* of *Indian-Deer* appear perforated from Side to Side. The long *Hairs* of *Horſes*, as at D E F, Fig. 66. ſeem cylindrical, and ſomewhat pithy.

The *Hair* of a *Mouſe* ſeems to be one ſingle tranſparent *Tube*, with a *Pith*, made up of a fibrous Subſtance, running in dark Lines, in ſome *Hairs* tranſverſly, in others ſpirally, theſe darker medullary * Parts are no other than ſmall Fibres convolved round; and lying cloſer together than other Parts of the *Hair*; they run from the Bottom to the Top of the *Hair*, and it is apprehended that they run round in a Screw-like Faſhion. A B, Fig. 67. repreſents that Part of the *Hair* which grew near the Skin, the middle Part of the ſame *Hair* is ſhewn at C D, and the Point of it at E F.

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 Genius, but of different Species.

Hairs have each a round bulbous Root, which lies pretty deep in the Skin, being planted in the pyramidal Papillæ, and, by this imbibe their proper Food from the adjacent Humours, and as hinted above, their Extremities ſplit or divide in two or three Branches, eſpecially when kept dry, and left to grow too long; ſo that what to the naked Eye appears only a ſingle *Hair*, to the Microſcope ſeems a Bruſh.

CHAP. XV.

Of the Scales in Human Skin.

THE *Cuticula*, ſcarf *Skin*, or outward Covering of the Body, is remarkable for its *Scales* and *Pores*.

The *Scales* grow upon our Bodies, juſt as the *Scales* grow upon the ex-

* *Arc. Nat. Tom.* III. *p.* 47.

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