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BRITANNICA

MICROSCOPE

LONDON
1797

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THE THIRD EDITION, IN EIGHTEEN VOLUMES, GREATLY IMPROVED.

ILLUSTRATED WITH FIVE HUNDRED AND FORTY-TWO COPPERPLATES.

VOL. XI.

INDOCTI DISCANT, ET AMENT MEMINISSE PERITI.

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Mickle. Spencer," 4to; and in 1769 he publiſhed, "A Letter to Mr Harwood, wherein ſome of his evaſive Gloſſes, falſe Tranſlations, and blundering Criticiſms, in ſupport of the Arian Hereſy, contained in his Literal Tranſlation of the New Teſtament, are pointed out and confuted," 8vo: and next year he publiſhed "Mary Queen of Scots, an Elegy;" "Hengiſt and Mary, a Ballad;" and "Knowledge, an Ode;" in Pearch's Collection of Poems. In 1770 he publiſhed "Voltaire in the Shades, or Dialogues on the Deiſtical Controverſy," 8vo. The Elegy on Mary had been ſubmitted to the judgment of Lord Lyttelton, who declined to criticiſe it, not for its deficiency in poetical merit, but from thinking differently from the author concerning that unfortunate princeſs.

About this time Mr Mickle was a frequent writer in the Whitehall Evening Poſt; but a more important work now engaged his atention. When no more than 17 years of age he had read Caſtara's tranſlation of the Luſiad of Camoens into French, and then projected the deſign of giving an Engliſh tranſlation of it. From this, however, he was prevented by various avocations till the year 1771, when he publiſhed the firſt book as a ſpecimen: and having prepared himſelf by acquiring ſome knowledge of the Portugueſe language, he determined to apply himſelf entirely to this work. With this view he quitted his reſidence at Oxford, and went to a farm-houſe at Foreſt-hill, where he purſued his deſign with unremitting aſſiduity till the year 1775, when the work was entirely finiſhed.

During the time that Mr Mickle was engaged in this work, he ſubſiſted entirely by his employment as corrector of the preſs; and on his quitting that employment he had only the ſubſcriptions he received for his tranſlation to ſupport him. Notwithſtanding theſe difficulties, he adhered ſteadily to the plan he had laid down, and completed it in about five years.

When his work was finiſhed, Mr Mickle applied to a perſon of great rank, with whom his family had been connected, for permiſſion to dedicate it to him. Permiſſion was granted, and his patron honoured him with a very polite letter; but after receiving a copy, for which an extraordinary price was paid for the binding, he did not think proper to take any notice of the author. At laſt a gentleman of high rank in the political world, a firm friend to the author, and who afterwards took him under his protection, waited on the patron, and heard him declare that he had not read the work, but that it had been repreſented not to have the merit it was at firſt ſaid to poſſeſs. The applauſe with which the work was received, however, ſoon baniſhed from the author's mind thoſe diſagreeable ſenſations which had been occaſioned by the contemptuous neglect of his patron, as well as ſome ſevere criticiſms which had been circulated concerning it. A ſecond edition was prepared in 1778, with a plate prefixed to it, executed by the celebrated artiſt Mortimer; on whom Mr Mickle wrote an epitaph in 1779. This year alſo he publiſhed a pamplet, intitled, "A Candid Examination of the Reaſons for depriving the Eaſt India Company of its Charter, contained in The Hiſtory and Management of the Eaſt India Company from its Commencement to the Preſent Time; together with ſome Strictures on the Self-Contradictions and Hiſtorical Errors of Dr Adam Smith, in his Reaſons for the Abolition of the ſaid Company," 4to. About this time ſome of his friends thought of recommending him to the king as deſerving of a penſion; but this ſcheme was never put in execution. Dr Lowth, biſhop of London, would have put him into orders, and provided for him in the church; but this was not agreeable to our author's diſpoſition. While he was meditating a publication of all his poems, in which he would moſt probably have found his account, he was appointed ſecretary to Commodore Johnſtone, who had lately obtained the command of the Romney man of war. In November 1779 he arrived at Liſbon, and was named by his patron joint agent for the prizes which were taken. In this capital and its neighbourhood he reſided more than ſix months, being every where received with every mark of politeneſs and attention; and during this period he compoſed his poem called "Almada Hill," which in 1781 was publiſhed in quarto. He collected alſo many particulars concerning the manners of the Portugueſe, which he intended alſo to have publiſhed. During his ſtay at Liſbon the royal academy was opened; and Mr Mickle, who was preſent at the ceremony of its commencement, had the honour to be admitted a member under the preſidency of Don John of Braganza duke of Laſoens. His preſence being thought neceſſary in England to attend to the proceedings of the courts of law reſpecting the condemnation of ſome of the prizes, he did not accompany the commodore in his laſt expedition, nor did he go any more to ſea. In 1782 he publiſhed "The Prophecy of Queen Emma, an ancient Ballad lately diſcovered, written by Johannes Turgottus, prior of Durham, in the reign of William Rufus; to which is added by the Editor, an Account of the Diſcovery, and Hints towards a Vindication of the Authenticity, of the Poems of Oſſian and Rowley," 8vo.

Mickle || Microcoſmic.

In June this year Mr Mickle married Miſs Tomkins, daughter of the perſon with whom he reſided at Foreſt-hill, while engaged in tranſlating the Luſiad. Having received ſome fortune with this lady, as well as made ſome money himſelf when in the ſervice of Commodore Johnſtone, he now enjoyed a comfortable independence. Having fixed his reſidence at Wheatley in Oxfordſhire, he devoted his time to the reviſion of his poetical works, which he propoſed to publiſh by ſubſcription; but the plan has not yet been carried into execution. The laſt ſeven years of his life were employed in writing for the European Magazine. The Fragments of Leo, and ſome of the moſt approved reviews of books, in that performance, were of his production. He died after a ſhort illneſs on the 25th of October 1788 at Wheatley, leaving one ſon behind him. His poetry poſſeſſes much beauty, variety, harmony of numbers, and vigour of imagination: his life was without reproach; his foibles were few and in offenſive; his virtues many; and his genius very conſiderable.

MICROCOSM, a Greek term ſignifying the *little world*; uſed by ſome for *man*, as being ſuppoſed an epitome of the univerſe or great world.

MICROCOSMIC ACID. See PHOSPHORUS (*Acid of*).

MICRO-

Micrography, Micrometer.

MICROGRAPHY, the deſcription of objects too minute to be viewed without the aſſiſtance of a microſcope. See *Microscopic Objects.*

MICROMETER, an inſtrument, by the help of which the apparent magnitudes of objects viewed thro' teleſcopes or microſcopes are meaſured with great exactneſs.

I. The firſt TELESCOPIC micrometers were only mechanical contrivances for meaſuring the image of an object in the focus of the object-glaſs. Before theſe contrivances were thought of, aſtronomers were accuſtomed to meaſure the field of view in each of their teleſcopes, by obſerving how much of the moon they could ſee through it, the ſemidiameter being reckoned at 15 or 16 minutes; and other diſtances were eſtimated by the eye, comparing them with the field of view. Mr Gaſcoigne, an Engliſh gentleman, however, fell upon a much more exact method, and had a Treatiſe on Optics prepared for the preſs; but he was killed during the civil wars in the ſervice of Charles I. and his manuſcript was never found. His inſtrument, however, fell into the hands of Mr R Townly, who ſays, that by the help of it he could mark above 40,000 diviſions in a foot.

Mr Gaſcoigne's inſtrument being ſhown to Dr Hooke, he gave a drawing and deſcription of it, and propoſed ſeveral improvements in it, which may be ſeen in Phil. Tranſ. abr. Vol. I. p 217. Mr Gaſcoigne divided the image of an object, in the focus of the object-glaſs, by the approach of two pieces of metal ground to a very fine edge, in the place of which Dr Hooke would ſubſtitute two fine hairs ſtretched parallel to one another. Two other methods of Dr Hooke's, different from this, are deſcribed in his Poſthumous Works, p. 497, 498. An account of ſeveral curious obſervations that Mr Gaſcoigne made by the help of his micrometer, particularly in the menſuration of the diameters of the moon and other planets, may be ſeen in the Phil. Tranſ. Vol. XLVIII. p. 190.

Mr Huygens, as appears by his Syſtem of Saturn, publiſhed in 1659, uſed to meaſure the apparent diameters of the planets, or any ſmall angles, by firſt meaſuring the quantity of the field of view in his teleſcope; which, he ſays, is beſt done by obſerving the time which a ſtar takes up in paſſing over it, and then preparing two or three long and ſlender braſs plates, of various breadths, the ſides of which were very ſtraight, and converging to a ſmall angle. In making uſe of theſe pieces of braſs, he made them ſlide in two ſlits, that were made in the ſides of the tube, oppoſite to the place of the image, and obſerved in what place it juſt covered the diameter of any planet, or any ſmall diſtance that he wanted to meaſure. It was obſerved, however, by Sir Iſaac Newton, that the diameters of planets, meaſured in this manner, will be larger than they ſhould be, as all lucid objects appear to be when they are viewed upon dark ones.

In the Ephemerides of the Marquis of Malvaſia, publiſhed in 1662, it appears that he had a method of meaſuring ſmall diſtances between fixed ſtars and the diameters of the planets, and alſo of taking accurate draughts of the ſpots of the moon; and this was by a net of ſilver wire, fixed in the common focus of the object and eye-glaſs. He alſo contrived to make one of two ſtars to paſs along the threads of this net, by turning it, or the teleſcope, as much as was neceſſary for that purpoſe; and he counted, by a pendulum-clock, beating ſeconds, the time that elapſed in its paſſage from one wire to another, which gave him the number of the minutes and ſeconds of a degree contained between the intervals of the wires of his net, with reſpect to the focal length of his teleſcope. Micrometer.

In 1666, Meſſrs Azout and Picard publiſhed a deſcription of a micrometer, which was nearly the ſame with that of the Marquis of Malvaſia, excepting the method of dividing it, which they performed with more exactneſs by a ſcrew. In ſome caſes they uſed threads of ſilk, as being finer than ſilver wires. Dechales alſo recommends a micrometer conſiſting of fine wires, or ſilken threads, the diſtances of which were exactly known, diſpoſed in the form of a net, as peculiarly convenient for taking a map of the moon.

M. de la Hire ſays, that there is no method more ſimple or commodious for obſerving the digits of an eclipſe than a net in the focus of the teleſcope. Theſe, he ſays, were generally made of ſilken threads; and that for this particular purpoſe fix concentric circles had alſo been made uſe of, drawn upon oiled paper; but he adviſes to draw the circles on very thin pieces of glaſs with the point of a diamond. He alſo gives ſeveral particular directions to aſſiſt perſons in the uſe of them. In another memoir he ſhows a method of making uſe of the ſame net for all eclipſes, by uſing a teleſcope with two object-glaſſes, and placing them at different diſtances from one another.

Different Conſtructions of Micrometers. The firſt we ſhall deſcribe is that by Mr Huygens. Let ABCD be a ſection of the teleſcope at the principal focus of the object-glaſs, or where the wires are ſituated, which are placed in a ſhort tube containing the eye-glaſs, and may be turned into any poſition by turning that tube; *mn* is a fine wire extended over its centre; *vw*, *xy*, are two ſtraight plates whoſe edges are parallel and well defined, and perpendicular to *mn*; *vw* is fixed, and *xy* moves parallel to it by means of a ſcrew, which carries two indexes over a graduated plate, to ſhow the number of revolutions and parts of a revolution which it makes. Now to meaſure any angle, we muſt firſt aſcertain the number of revolutions and parts of a revolution correſponding to ſome known angle, which may be thus done: 1ſt, Bring the inner edges of the plates exactly to coincide, and ſet each index to 0; turn the ſcrew, and ſeparate the plates to any diſtance; and obſerve the time a ſtar *m* is in paſſing along the wire *mn* from one plate to the other: for that time, turned into minutes and ſeconds of a degree, will be the angle anſwering to the number of revolutions, or the angle correſponding to the diſtance. Thus, if d = cof. of the ſtar's declination, we have $15'd$, the angle correſponding to this diſtance; and hence, by proportion, we find the angle anſwering to any other. 2*dly*, Set up an object of a known diameter, or two objects at a given diſtance, and turn the ſcrew till the edges of the plates become tangents to the object, or till their opening juſt takes in the diſtance of the two objects upon the wire *mn*; then from the diameter, or diſtance of the two objects from each other, and their diſtance from the glaſs, calculate the angle, and obſerve the number of revolutions and parts correſponding. 3*dly*, Take the diameter of the ſun on any day, by making the edges of the plates tangents to the oppoſite limbs, and find, from Plate CCXCV. fig. 1.

MICROMETER.

Plate CCXCV.

Fig. 1.

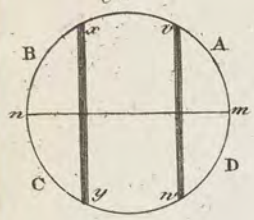


Fig. 3.

Fig. 8.

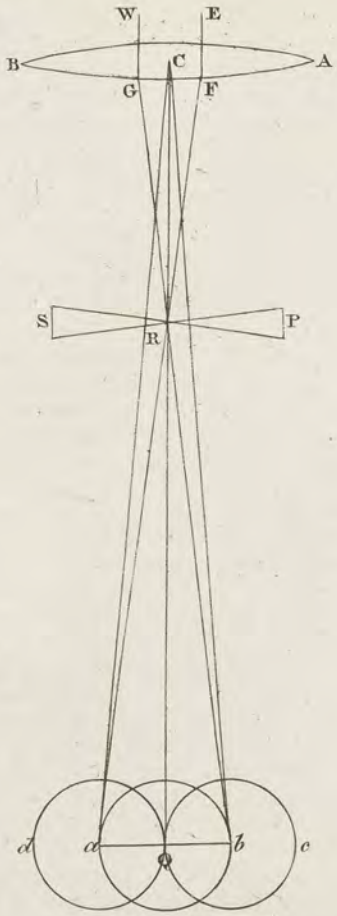
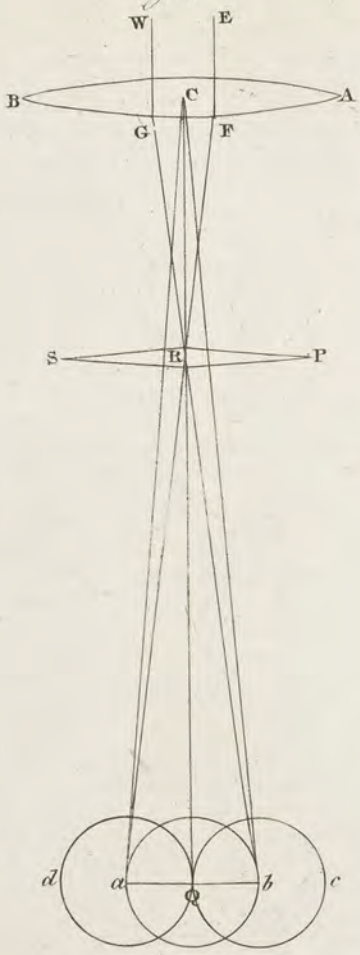


Fig. 9.



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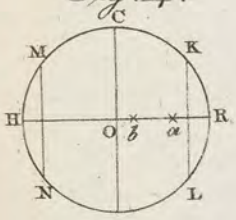


Fig. 5.

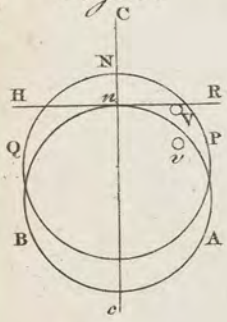


Fig. 6.

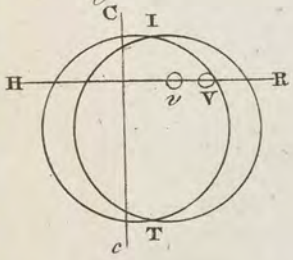


Fig. 10.

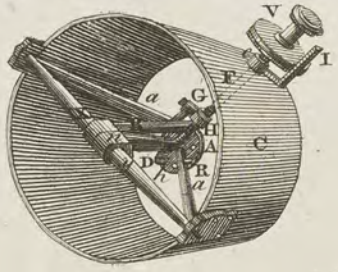


Fig. 2.

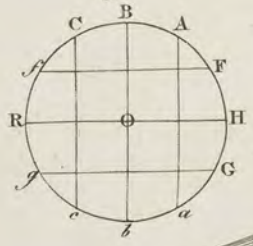


Fig. 7.

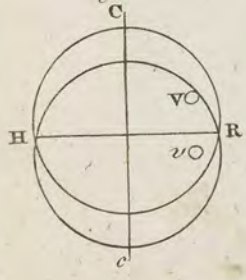


Fig. 11.

A. Bell Brin. Mal. Sculptor fecit.

Micrometer.

from the nautical almanac, what is his diameter on that day. Here it will be beſt to take the upper and lower limbs of the ſun when on the meridian, as he has then no motion perpendicular to the horizon. If the edges do not coincide when the indexes ſtand at o, we muſt allow for the error. Inſtead of making a proportion, it is better to have a table calculated to ſhow the angle correſponding to every revolution and parts of a revolution. But the obſerver muſt remember, that when the micrometer is fixed to teleſcopes of different focal lengths, a new table muſt be made. The whole ſyſtem of wires is turned about in its own plane, by turning the eye-tube round with a hand, and by that means the wire *mn* can be thrown into any poſition, and conſequently angles in any poſition may be meaſured. Dr Bradley added a ſmall motion by a rack and pinion to ſet the wires more accurately in any poſition.

Inſtead of two plates, two wires were afterwards put; and Sir Iſaac Newton obſerved, that the diameters of the planets meaſured by the plates were ſomewhat bigger than they ought, as appeared by comparing Mr Huygens's meaſures with others taken with the wires; and alſo by comparing the diameter of mercury obſerved in and out of the ſun's diſk, the latter being the greateſt. Dark objects on bright ones appear leſs, and light objects on dark ones appear greater, than if they were equally bright; owing, perhaps, to the brighter image on the retina diffuſing itſelf into the darker: and the bright image of the planet being intercepted by the plates, the faint diffuſed light becomes more ſenſible, and is miſtaken for the edge of the planet.

But the micrometer, as now contrived, is of uſe, not only to find the angular diſtance of bodies in the field of view at the ſame time, but alſo of thoſe which, when the teleſcope is fixed, paſs through the field of view ſucceſſively; by which means we can find the difference of their right aſcenſions and declinations.

Fig. 2. Let A *a*, B *b*, C *c*, be three parallel and equidiſtant wires, the middle one biſecting the field of view; H O R a fixed wire perpendicular to them paſſing through the centre of the field; and F *f*, G *g*, two wires parallel to it, each moveable by a micrometer ſcrew, as before, ſo that they can be brought up to H O R, or a little beyond. Then to find the angular diſtance of two objects, bring them very near to B *b*, and in a line parallel to it, by turning about the wires, and bring one upon HOR, and by the micrometer ſcrew make F *f* or *G g* paſs through the other; then turn the ſcrew till that wire coincides with H O R, and the arc which the index has paſſed over ſhows their angular diſtance. If the objects be further remote than you can carry the diſtance of one of the wires F *f*, G *g*, from H O R, then bring one object to F *f* and the other to G *g*; and turn each micrometer ſcrew till they meet, and the ſum of the arcs paſſed over by each index gives their angular diſtance. If the objects be two ſtars, and one of them be made to run along H O R, or either of the moveable wires as occaſion may require, the motion of the other will be parallel to theſe wires, and their difference of declinations may be obſerved with great exactneſs; but in taking any other diſtances, the motion of the ſtars being oblique to them, it is not quite ſo eaſy to get them parallel to B *b*; becauſe if one ſtar be brought near, and the eye be applied to the other to adjuſt the wires to it, the former ſtar will have gotten a little away from the wire. Dr Bradley, in his account of the uſe of this micrometer, publiſhed by Dr Maſkeleyne in the Philoſophical Tranſactions for 1772, thinks the beſt way is to move the eye backwards and forwards as quick as poſſible; but it ſeems to me to be beſt to fix the eye at ſome point between, by which means it takes in both at once ſufficiently well defined to compare them with B *b*. In finding the difference of declinations, if both bodies do not come into the field of view at the ſame time, make one run along the wire H O R, as before, and fix the teleſcope and wait till the other comes in, and then adjuſt one of the moveable wires to it, and bring it up to H O R, and the index gives the difference of their declinations. The difference of time between the paſſage of the ſtar at either of the croſs moveable wires, and the tranſit of the other ſtar over the croſs fixed wire (which repreſents a meridian), turned into degrees and minutes, will give the difference of right aſcenſion. The ſtar has been here ſuppoſed to be biſected by the wire; but if the wire be a tangent to it, allowance muſt be made for the breadth of the wire, provided the adjuſtment be made for the coincidence of the wires. In obſerving the diameters of the ſun, moon, or planets, it may perhaps be moſt convenient to make uſe of the outer edges of the wires, becauſe they appear moſt diſtinct when quite within the limb: but if there ſhould be any ſenſible inflection of the rays of light in paſſing by the wires, it will be beſt avoided by uſing the inner edge of one wire and the outward edge of the other; for by that means the inflection at both limbs will be the ſame way, and therefore there will be no alteration of the relative poſition of the rays paſſing by each wire. And it will be convenient in the micrometer to note at what diviſion the index ſtands when the moveable wire coincides with H O R; for then you need not bring the wire when a ſtar is upon it up to H O R, only reckon from the diviſion at which the index then ſtands to the above diviſion.

With a micrometer therefore thus adapted to a teleſcope, Mr Servington Savery of Exeter propoſed a new way of meaſuring the difference between the greateſt and leaſt apparent diameters of the ſun, although the whole of the ſun was not viſible in the field of view at once. The method we ſhall briefly deſcribe. Place two object-glaſſes inſtead of one, ſo as to form two images whoſe limbs ſhall be at a ſmall diſtance from each other; or inſtead of two perfect lenſes, he propoſed to cut a ſingle lens into four parts of equal breadths by parallel lines, and to place the two ſegments with their ſtraight ſides againſt each other, or the two middle fruſtrums with their oppoſite edges together; in either caſe, the two parts which before had a common centre and axis, have now their centres and axes ſeparated, and conſequently two images will be formed as before by two perfect lenſes. Another method in reflectors was to cut the large concave reflector through the centre, and by a contrivance to turn up the outer edges whilſt the ſtraight ones remained

Micrometer.

mained fixed; by which means the axis of the two parts became inclined, and formed two images. Two images being formed in this manner, he propoſed to meaſure the diſtance between the limbs when the diameters of the ſun were the greateſt and leaſt, the difference of which would be the difference of the diameters required. Thus far we are indebted to Mr Savery for the idea of forming two images; and the admirable uſes to which it was afterwards applied, we ſhall next proceed to deſcribe.

The divided object-glaſs micrometer, as now made, was contrived by the late Mr John Dollond, and by him adapted to the object-end of a reflecting teleſcope, and has been ſince by the preſent Mr P. Dollond his ſon applied with equal advantage to the end of an achromatic teleſcope. The principle is this: The object-glaſs is divided into two ſegments in a line drawn through the centre; each ſegment is fixed in a ſeparate frame of braſs, which is moveable, ſo that the centres of the two ſegments may be brought together by a handle for that purpoſe, and thereby form one image of an object; but when ſeparated they will form two images, lying in a line paſſing through the centre of each ſegment; and conſequently the motion of each image will be parallel to that line, which can be thrown into any poſition by the contrivance of another handle to turn the glaſs about in its own plane. The braſs-work carries a vernier to meaſure the diſtance of the centres of the two ſegments. Now let E and H be the centres of the two ſegments, F their principal focus, and P Q two diſtant objects in FE, FH, produced, or the oppoſite limbs of the ſame object PBQD; then the images of P and Q, formed by each ſegment, or the images of the oppoſite limbs of the object PBQD, coincide at F: hence two images $m \times F$, $n \times F$ of that object are formed, whoſe limbs are in contact; therefore the angular diſtance of the points P and Q is the ſame as the angle which the diſtance EH ſubtends at F, which, as the angles ſuppoſed to be meaſured are very ſmall, will vary as EH extremely nearly; and conſequently if the angle corresponding to one interval of the centres of the ſegments be known, the angle corresponding to any other will be found by proportion. Now to find the interval for ſome one angle,

Fig. 3.

take the horizontal diameter of the ſun on any day, by ſeparating the images till the contrary limbs coincide, and read off by the vernier the interval of their centres, and look into the nautical almanac for the diameter of the ſun on that day, and you have the corresponding angle. Or if greater exactneſs be required than from taking the angle in proportion to the diſtances of their centres, we may proceed thus:—Draw FG perpendicular to EH, which therefore biſects it; then one half EH, or EG, is the tangent of half the angle EFH; hence, half the diſtance of their centres: tangent of half the angle corresponding to that diſtance :: half any other diſtance of the centres: tangent of half the corresponding angle (A).

Micrometer.

Hence the method of meaſuring ſmall angles is manifeſt; for we conſider P, Q, either as two objects whoſe images are brought together by ſeparating the two ſegments, or as the oppoſite limbs of one object PBQA, whoſe images, formed by the two ſegments E, H, touch at F: in the former caſe, EH gives the angular diſtance of the two objects; and in the latter, it gives the angle under which the diameter of the object appears. Hence, to find the angular diſtance of two objects, ſeparate the ſegments till the two images which approach (B) each other coincide; and to find the diameter of an object, ſeparate the ſegments till the contrary limbs of the images touch each other, and read off the diſtance of the centres of the ſegment from the vernier (C), and find the angle as directed in the laſt article. From hence appears one great ſuperiority in this above the wire micrometer; as, with this, any diameter of an object may be meaſured with the ſame eaſe and accuracy; whereas with that we cannot with accuracy meaſure any diameter, except that which is at right angles to its apparent motion.

But, beſides theſe two uſes to which the inſtrument ſeems ſo well adapted, Dr Maſkelyne has ſhown, in the Philoſophical Tranſactions for the year 1771, how it may be applied to find the difference of right aſcenſions and declinations. For this purpoſe, two wires at right angles to each other, biſecting the field of view, muſt be placed in the principal focus of the eye-glaſs, and moveable about in their own plane.—

Let

(A) If the object be not a diſtant one, let f be the principal focus; then $Ff : FG :: FG : FK$ (FG being produced to meet a line joining the apparent places of the two objects P, Q), $\therefore$ dividendo, $fG : FG :: GK : FK$, and alternando, $fG : GK :: FG : FK ::$ (by ſimilar triangles) $EH : PQ$, hence $\frac{EH}{fG} = \frac{PQ}{GK}$, therefore the angle ſubtended by EH at f = the angle ſubtended by PQ at G; and conſequently, as fG is conſtant, the angle meaſured at G is, in this caſe alſo, in proportion to EH. The inſtrument is not adapted to meaſure the angular diſtance of bodies, one of which is near and the other at a diſtance, becauſe their images would not be formed together.

(B) Beſides theſe two images, there will be two others receding from each other, for each ſegment gives an image of each object.

(C) To determine whether there be any error of adjuſtment of the micrometer ſcale, meaſure the diameter of any ſmall well defined object, as Jupiter's equatorial diameter, or the longeſt axis of Saturn's ring, both ways, that is, with o on the vernier to the right and left of o on the ſcale, and half the difference is the error required; which muſt be added to or ſubtracted from all obſervations, according as the diameter meaſured with o on the vernier, when advanced on the ſcale, is leſs or greater than the diameter meaſured the other way. And it is alſo evident, that half the ſum of the diameters thus meaſured gives the true diameter of the object.

Micrometer.

Let HCR*c* be the field of view, HR and C*c* the two wires; turn the wires till the weſternmoſt ſtar (which is the beſt, having further to move) run along ROH; then ſeparate the two ſegments and turn about the micrometer till the two images of the ſame ſtar lie in the wire C*c*; and then, partly by ſeparating the ſegments, and partly by raiſing or depreſſing the teleſcope, bring the two innermoſt images of the two ſtars to appear and run along ROH, as *a*, *b*, and the vernier will give the difference of their declinations; becauſe, as the two images of one of the ſtars coincided with C*c*, the image of each ſtar was brought perpendicularly upon HR, or to HR in their proper meridian. And, for the ſame reaſon, the difference of their times of paſſing the wire CO*c* will give their difference of right aſcenſions. Theſe operations will be facilitated, if the teleſcope be mounted on a polar axis. If two other wires KL, MN, parallel to C*c*, be placed near H and R, the obſervation may be made on two ſtars whoſe difference of meridians is nearly equal to HR the diameter of the field of view, by bringing the two images of one of the ſtars to coincide with one of theſe wires. If two ſtars be obſerved whoſe difference of declinations is well ſettled, the ſcale of the micrometer will be known.

Fig. 4.

It has hitherto been ſuppoſed, that the images of the two ſtars can be both brought into the field of view at once upon the wire HOR: but if they cannot, ſet the micrometer to the difference of their declinations as nearly as you can, and make the image which comes firſt run along the wire HOR, by elevating or depreſſing the teleſcope; and when the other ſtar comes in, if it do not alſo run along HOR, alter the micrometer till it does, and half the ſum of the numbers ſhown by the micrometer at the two ſeparate obſervations of the two ſtars on the wire HOR will be the difference of their declinations. That this ſhould be true, it is manifeſtly neceſſary that the two ſegments ſhould recede equally in oppoſite directions; and this is effected by Mr Dollond in his new improvement of the object-glaſs micrometer.

The difference of right aſcenſions and declinations of Venus or Mercury in the ſun's diſk and the ſun's limb may be thus found. Turn the wires ſo that the north limb *n* of the ſun's image AB, or the north limb of the image V of the planet, may run along the wire RH, which therefore will then be parallel to the equator, and conſequently C*c* a ſecondary to it; then ſeparate the ſegments, and turn about the micrometer till the two images V*v* of the planet paſs C*c* at the ſame time, and then by ſeparating the ſegments, bring the north limb of the northernmoſt image V of the planet to touch HR, at the time the northenmoſt limb *n* of the ſouthernmoſt image AB of the ſun touches it, and the micrometer ſhows the difference of declinations of the northernmoſt limbs of the planet and ſun, for the reaſon formerly given †, we having brought the northernmoſt limbs of the two innermoſt images V and AB to HR, theſe two being manifeſtly interior to *v* and the northernmoſt limb N of the image PQ. In the ſame manner we take the difference of declinations of their ſouthernmoſt limbs; and half the difference of the two meaſures, (taking immediately one after another) is equal to the difference of the declinations of their centres, without any regard to the ſun's or planet's diameters, or error of adjuſtment of the micrometer; for as it affects both equally, the difference is the ſame as if there were no error: and the difference of the times of the tranſits of the eaſtern or weſtern limbs of the ſun and planet over C*c* gives the difference of their right aſcenſions.

Fig. 5.

† See the preceding page col 2. par. 2.

Micrometer.

Inſtead of the difference of right aſcenſions, the diſtance of the planet from the ſun's limb, in lines parallel to the equator, may be more accurately obſerved thus: Separate the ſegments, and turn about the wires and micrometer, ſo as to make both images V, *v*, run along HR, or ſo that the two interſections I, T, of the ſun's image may paſs C*c* at the ſame time. Then bring the planet's and ſun's limbs into contact, as at V, and do the ſame for the other limb of the ſun, and half the difference gives the diſtance of the centre of the planet from the middle of the chord on the ſun's diſk parallel to the equator, or the difference of the right aſcenſions of their centres, allowing for the motion of the planet in the interval of the obſervations, without any regard to the error of adjuſtment, for the ſame reaſon as before. For if you take any point in the chord of a circle, half the difference of the two ſegments is manifeſtly the diſtance of the point from the middle of the chord; and as the planet runs along HR, the chord is parallel to the equator.

Fig. 6.

In like manner, the diſtances of their limbs may be meaſured in lines perpendicular to the equator, by bringing the micrometer into the poſition already deſcribed*, and inſtead of bringing V to HR, ſeparate the ſegments till the northernmoſt limbs coincide as at V; and in the ſame manner make their ſouthernmoſt images to coincide, and half the difference of the two meaſures, allowing for the planet's motion, gives the difference of the declinations of their centres.

Fig. 7.

* See the preceding column, par. 3.

Hence the true place of a planet in the ſun's diſk may at any time of its tranſit be found; and conſequently the neareſt approach to the centre and the time of ecliptic conjunction may be deduced, although the middle ſhould not be obſerved.

But however valuable the object-glaſs micrometer undoubtedly is, difficulties ſometimes have been found in its uſe, owing to the alteration of the focus of the eye, which will cauſe it to give different meaſures of the ſame angle at different times. For inſtance, in meaſuring the ſun's diameter, the axis of the pencil coming through the two ſegments from the contrary limbs of the ſun, as PF, QF, fig. 3. croſſing one another in the focus F under an angle equal to the ſun's ſemidiameter, the union of the limbs cannot appear perfect, unleſs the eye be diſpoſed to ſee objects diſtinctly at the place where the images are formed; for if the eye be diſpoſed to ſee objects nearer to or further off than that place, in the latter caſe the limbs will appear ſeparated, and in the former they will appear to lap over (D). This imperfection led Dr Maſkelyne

(D) For if the eye can ſee diſtinctly an image at F, the pencils of rays, of which PF, QF are the two axes, diverging from F, are each brought to a focus on the retina at the ſame point; and therefore the two limbs appear

Micrometer. Maſkelyne to inquire, whether ſome method might not be found of producing two diſtinct images of the ſun, or any other object, by bringing the axis of each pencil to coincide, or very nearly ſo, before the formation of the images, by which means the limbs when brought together would not be liable to appear ſeparated from any alteration of the eye; and this he found would be effected by the refraction of two priſms, placed either without or within the teleſcope; and on this principle, placing the priſms within, he conſtructed a new micrometer, and had one executed by Mr Dollond, which upon trial anſwered as he expected. The conſtruction is as follows.

Fig. 8, 9. Let AB be the object-glaſs; *ab* the image, ſuppoſe of the ſun, which would have been formed in the principal focus Q; but let the priſms PR, SR be placed to intercept the rays, and let EF, WG, be two rays proceeding from the eaſtern and weſtern limbs of the ſun, converging, after refraction at the lens, to *a* and *b*; and ſuppoſe the refraction of the priſms to be ſuch, that in fig. 8. the ray EFR, after refraction at R by the priſm PR, may proceed in the direction RQ; and as all the rays which were proceeding to *a* ſuffer the ſame refraction at the priſm, they will all be refracted to Q; and therefore, inſtead of an image *ab*, which would have been formed by the lens alone, an image Q*c* is formed by thoſe rays which fall on the priſm PR; and for the ſame reaſon, the rays falling on the priſm SR will form an image Q*d*: and in fig. 9. the image of the point *b* is brought to Q, by the priſm PR, and conſequently an image Q*d* is formed by thoſe rays which fall on PR: and for the ſame reaſon, an image Q*c* is formed by the rays falling on SR. Now in both caſes, as the rays EFR, WGR, coming from the two oppoſite limbs of the ſun, and forming the point of contact of the two limbs, proceed in the ſame direction RQ, they muſt thus accompany each other through the eye-glaſs and alſo through the eye, whatever refractive power it has, and therefore to every eye the images muſt appear to touch. Now the angle *a*R*b* is twice the refraction of the priſm, and the angle *a*C*b* is the diameter of the ſun; and as theſe angles are very ſmall, and have the ſame ſubtenſe *ab*, we have the angle *a*R*b* : angle *a*C*b* : : CQ : RQ.—Now as CQ is conſtant, and alſo the angle *a*R*b*, being twice the refraction of the priſm, the angle *a*C*b* varies as RQ. Hence the extent of the ſcale for meaſuring angles becomes the focal length of the object glaſs, and the angle meaſured is in proportion to the diſtance of the priſms from the principal focus of the object glaſs; and the micrometer can meaſure all angles (very ſmall ones excepted, for the reaſon afterwards given*) which do not exceed the ſum of the refractions of the priſms; for the angle *a*C*b*, the diameter of the object to be meaſured, is always *leſs* than the angle *a*R*b*, the ſum of the refractions of the priſms, except when the priſms touch the object glaſs, and then they become *equal*. The ſcale can never be out of adjuſtment, as the point o, where the meaſurement begins, anſwers to the focus of the object glaſs, which is a fixed point for all diſtant objects, and we have only to find the value of the ſcale anſwering to ſome known angle: for inſtance, bring the two limbs of the ſun's images into contact, and meaſure the diſtance of the priſms from the focus, and look in the nautical almanac for the ſun's diameter, and you get the value of the ſcale. Micrometer.

In fig. 8. the limb Q, of the image Q*c*, is illuminated by the rays falling on the object glaſs between A and F, and of the image Q*d* by thoſe falling between B and G; but in fig. 9. the ſame limbs are illuminated by the rays falling between B and F, A and G reſpectively, and therefore will be more illuminated than in the other caſe; but the difference is not conſiderable in achromatic teleſcopes, on account of the great aperture of the object-glaſs compared with the diſtance FG.

It might be convenient to have two ſets of priſms, one for meaſuring angles not exceeding 36′, and therefore fit for meaſuring the diameters of the ſun and moon, and the lucid parts and diſtances of the cuſps in their eclipſes; and another for meaſuring angles not much greater than 1′, for the conveniency of meaſuring the diameters of the planets. For as QC : QR : : ſum of the refractions of the priſms : angle *a*C*b*, the apparent diameter of the object, it is evident that if you diminiſh the third term, you muſt increaſe the ſecond in the ſame ratio, in order to meaſure the ſame angle; and thus by diminiſhing the refractive angle of the priſms, you throw them further from Q, and conſequently avoid the inconvenience of bringing them near to Q, for the reaſon in the next paragraph; and at the ſame time you will increaſe the illumination in a ſmall degree. The priſms muſt be achromatic, each compoſed of two priſms of flint and crown glaſs, placed with their refracting angles contrariways, otherwiſe the images will be coloured.

In the conſtruction here deſcribed, the angle meaſured becomes evaneſcent when the priſms come to the principal focus of the object glaſs, and therefore o on the ſcale then begins: but if the priſms be placed in the principal focus they can have no effect, becauſe the pencil of rays at the junction of the priſms would then vaniſh, and therefore it is not practicable to bring the two images together to get o on the ſcale. Dr Maſkelyne, therefore, thought of placing another pair of priſms within, to refract the rays *before* they came to the other priſms, by which means the two images would be formed into one before they came to the principal focus, and therefore o on the ſcale could be determined. But to avoid the error ariſing from the multiplication of mediums, he, inſtead of adding another pair of priſms, divided the object glaſs through its centre, and ſliding the ſegments a little it ſeparated the images, and then by the priſms he could form one image very diſtinctly, and conſequently could determine o on the ſcale; for by ſeparating the two ſegments you form two images, and you will ſeparate the two pencils ſo that you may move up the two priſms, and the two pencils will fall on each reſpectively, and the two images may be formed into one. In the inſtrument which Dr Maſkelyne had made, o on the ſcale was choſen to be about $\frac{1}{7}$ of the focal length of the object-glaſs,

*Next col. Par. laſt.

appear to coincide: but if we increaſe the refractive power of the eye, then each pencil is brought to a focus, and they croſs each other before the rays come to the retina, conſequently the two limbs on the retina will lap over; and if we diminiſh the refractive power of the eye, then each pencil being brought to a focus beyond the retina, and not croſſing till after they have paſſed it, the two limbs on the retina muſt be ſeparated.

Micrometer. glaſs, and each priſm refracted 27′. By this means all angles are meaſured down to 0.

In the Philoſophical Tranſactions for 1779, Mr Ramſden has deſcribed two new micrometers, which he contrived with a view of remedying the defects of the object-glaſs micrometer.

1. One of theſe is a *catoptric* micrometer, which, beſide the advantage it derives from the principle of reflection, of not being diſturbed by the heterogeneity of light, avoids every defect of other micrometers, and can have no aberration, nor any defect ariſing from the imperfection of materials or of execution; as the extreme ſimplicity of its conſtruction requires no additional mirrors or glaſſes to thoſe required for the teleſcope; and the ſeparation of the image being effected by the inclination of the two ſpecula, and not depending on the focus of any lens or mirror, any alteration in the eye of an obſerver cannot affect the angle meaſured. It has peculiar to itſelf the advantages of an adjuſtment, to make the images coincide in a direction perpendicular to that of their motion; and alſo of meaſuring the diameter of a planet on both ſides of the zero, which will appear no inconſiderable advantage to obſervers who know how much eaſier it is to aſcertain the contact of the external edges of two images than their perfect coincidence.

Fig. 10. A repreſents the ſmall ſpeculum divided into two equal parts; one of which is fixed on the end of the arm B; the other end of the arm is fixed on a ſteel axis X, which croſſes the end of the teleſcope C. The other half of the mirror A is fixed on the arm D, which arm at the other end terminates in a ſocket *y*, that turns on the axis X; both arms are prevented from bending by the braces *a a*. G repreſents a double ſcrew, having one part *e* cut into double the number of threads in an inch to that of the part *g*: the part *e* having 100 threads in one inch, and the part *g* 50 only. The ſcrew *e* works in a nut F in the ſide of the teleſcope, while the part *g* turns in a nut H, which is attached to the arm B; the ends of the arms B and D, to which the mirrors are fixed, are ſeparated from each other by the point of the double ſcrew preſſing againſt the ſtud *h*, fixed to the arm D, and turning in the nut H on the arm B. The two arms B and D are preſſed againſt the direction of the double ſcrew *eg* by a ſpiral ſpring within the part *n*, by which means all ſhake or play in the nut H, on which the meaſure depends, is entirely prevented.

From the difference of the threads on the ſcrew at *e* and *g*, it is evident, that the progreſſive motion of the ſcrew through the nut will be half the diſtance of the ſeparation of the two halves of the mirror; and conſequently the half mirrors will be moved equally in contrary directions from the axis of the teleſcope C.

The wheel V fixed on the end of the double ſcrew has its circumference divided into 100 equal parts, and numbered at every fifth diviſion with 5, 10, &c. to 100, and the index I ſhows the motion of the ſcrew with the wheel round its axis, while the number of revolutions of the ſcrew is ſhown by the diviſions on the ſame index. The ſteel ſcrew at R may be turned by the key S, and ſerves to incline the ſmall mirror at right angles to the direction of its motion. By turning the finger-head T (fig. 11.), the eye-tube P is brought nearer or farther from the ſmall mirror, to adjuſt the teleſcope to diſtinct viſion; and the teleſcope itſelf hath a motion round it axis for the conveniency of meaſuring the diameter of a planet in any direction. The inclination of the diameter meaſured with the horizon is ſhown in degrees and minutes by a level and vernier on a graduated circle, at the breech of the teleſcope. Micrometer.

"It is neceſſary to obſerve (ſays Mr Ramſden), that, beſides the table for reducing the revolutions and parts of the ſcrew to minutes, ſeconds, &c. it may require a table for correcting a very ſmall error which ariſes from the excentric motion of the half-mirrors. By this motion their centres of curvature will (when the angle to be meaſured is large) approach a little towards the large mirror: the equation for this purpoſe in ſmall angles is inſenſible; but when angles to be meaſured exceed ten minutes, it ſhould not be neglected. Or, the angle meaſured may be corrected by diminiſhing it in the proportion the verſed ſine of the angle meaſured, ſuppoſing the eccentricity radius, bears to the focal length of the ſmall mirror."

Mr Ramſden preferred Caſſegrain's conſtruction of the reflecting teleſcope to either the Gregorian or Newtonian; becauſe in the former, errors cauſed by one ſpeculum are diminiſhed by thoſe in the other. From a property of the reflecting teleſcope (which, he obſerves, has not been attended to), that the apertures of the two ſpecula are to each other very nearly in the proportion of their focal lengths, it follows, that their aberrations will be to each other in the ſame proportion; and theſe aberrations are in the ſame direction, if the two ſpecula are both concave; or in contrary directions, if one ſpeculum is concave and the other convex. In the Gregorian conſtruction, both ſpecula being concave, the aberration at the ſecond image will be the ſum of the aberrations of the two mirrors; but in the Caſſegrain conſtruction, one mirror being concave and the other convex, the aberration at the ſecond image will be the difference between their aberrations. By aſſuming ſuch proportions for the *foci* of the ſpecula as are generally uſed in the reflecting teleſcope, which is about as 1 to 4, the aberration in the Caſſegrain conſtruction will be to that in the Gregorian as 3 to 5.

2. The other is a *dioptric* micrometer, or one ſuited to the principle of refraction. This micrometer is applied to the erect eye-tube of a refracting teleſcope, and is placed in the conjugate focus of the firſt eye-glaſs: in which poſition, the image being conſiderably magnified before it comes to the micrometer, any imperfection in its glaſs will be magnified only by the remaining eye-glaſſes, which in any teleſcope ſeldom exceeds five or ſix times. By this poſition alſo the ſize of the micrometer glaſs will not be the $\frac{1}{100}$ part of the area which would be required if it was placed in the object-glaſs; and, notwithſtanding this great diſproportion of ſize, which is of great moment to the practical optician, the ſame extent of ſcale is preſerved, and the images are uniformly bright in every part of the field of the teleſcope.

Fig. 12. repreſents the glaſſes of a refracting teleſcope; *xy*, the principal pencil of rays from the object-glaſs O; *t t* and *u u*, the axis of two oblique pencils, *a*, the firſt eye-glaſs; *m*, its conjugate focus, or the Plate CCXCVI.

Micrometer.

place of the micrometer; *b* the second eye-glaſs; *c* the third; and *d* the fourth, or that which is neareſt the eye. Let *p* be the diameter of the object-glaſs, *e* the diameter of a pencil at *m*, and *f* the diameter of the pencil at the eye; it is evident, that the axis of the pencils from every part of the image will croſs each other at the point *m*; and *e*, the width of the micrometer-glaſs, is to *p* the diameter of the object-glaſs as *m a* is to *g o*, which is the proportion of the magnifying power at the point *m*; and the error cauſed by an imperfection in the micrometer-glaſs placed at *m* will be to the error, had the micrometer been at O, as *m* is to *p*.

Fig. 13. repreſents the micrometer; A, a convex or concave lens divided into two equal parts by a plane acroſs its centre; one of theſe ſemi-lenſes is fixed in a frame B, and the other in the frame E; which two frames ſlide on a plate H, and are preſſed againſt it by thin plates *a a*: the frames B and E are moved in contrary directions by turning the button D; L is a ſcale of equal parts on the frame B; it is numbered from each end towards the middle with 10, 20, &c. There are two verniers on the frame E, one at M and the other at N, for the convenience of meaſuring the diameter of a planet, &c. on both ſides the zero. The firſt diviſion on both theſe verniers coincides at the ſame time with the two zeros on the ſcale L; and, if the frame is moved towards the right, the relative motion of the two frames is ſhown on the ſcale L by the vernier M; but if the frame B be moved towards the left, the relative motion is ſhown by the vernier N.—This micrometer has a motion round the axis of viſion, for the convenience of meaſuring the diameter of a planet, &c. in any direction, by turning an endleſs ſcrew F; and the inclination of the diameter meaſured with the horizon is ſhown on the circle *g* by a vernier on the plate V. The teleſcope may be adjuſted to diſtinct viſion by means of an adjuſting ſcrew, which moves the whole eye-tube with the micrometer nearer or farther from the object-glaſs, as teleſcopes are generally made; or the ſame effect may be produced in a better manner, without moving the micrometer, by ſliding the part of the eye tube *m* on the part *n*, by help of a ſcrew or pinion. The micrometer is made to take off occaſionally from the eye tube, that the teleſcope may be uſed without it.

Still, however, micrometers remained in ſeveral reſpects imperfect. In particular, the imperfections of the parallel-wire micrometer in taking the diſtance of very cloſe double ſtars, are the following.

When two ſtars are taken between the parallels, the diameters muſt be included. Mr Herſchel informs us, he has in vain attempted to find lines ſufficiently thin to extend them acroſs the centres of the ſtars ſo that their thickneſs might be neglected. The ſingle threads of the ſilk-worm, with ſuch lenſes as he uſes, are ſo much magnified that their diameter is more than that of many of the ſtars. Beſides, if they were much leſs than they are, the power of deflection of light would make the attempt to meaſure the diſtance of the centres this way fruitleſs: for he has always found the light of the ſtars to play upon thoſe lines and ſeparate their apparent diameters into two parts. Now ſince the ſpurious diameters of the ſtars thus included, as Mr. Herſchel aſſures us, are continually changing according to the ſtate of the air, and the length of time we look at them, we are, in ſome reſpect, left at an uncertainty, and our meaſures taken at different times and with different degrees of attention, will vary on that account. Nor can we come at the true diſtance of the centres of any two ſtars, one from another, unleſs we could tell what to allow for the ſemidiameters of the ſtars themſelves; for different ſtars have different apparent diameters, which, with a power of 227, may differ from each other as far as two ſeconds.

Micrometer.

The next imperfection is that which ariſes from a deflection of light upon the wires when they approach very near to each other; for if this be owing to a power of repulſion lodged at the ſurface, it is eaſy to underſtand, that ſuch powers muſt interfere with each other, and give the meaſures larger in proportion than they would have been if the repulſive power of one wire had not been oppoſed by a contrary power of the other wire.

Another very conſiderable imperfection of theſe micrometers is a continual uncertainty of the real zero. Mr Herſchel has found, that the leaſt alteration in the ſituation and quantity of light will affect the zero, and that a change in the poſition of the wires, when the light and other circumſtances remain unaltered, will alſo produce a difference. To obviate this difficulty, whenever he took a meaſure that required the utmoſt accuracy, his zero was always taken immediately after, while the apparatus remained in the ſame ſituation it was in when the meaſure was taken; but this enhances the difficulty, becauſe it introduces an additional obſervation.

The next imperfection, which is none of the ſmalleſt, is that every micrometer that has hitherto been in uſe requires either a ſcrew, or a divided bar and pinion, to meaſure the diſtance of the wires or divided image. Thoſe who are acquainted with works of this kind are but too ſenſible how difficult it is to have ſcrews that ſhall be perfectly equal in every thread or revolution of each thread; or pinions and bars that ſhall be ſo evenly divided as perfectly to be depended upon in every leaf and tooth to perhaps the two, three, or four thouſandth part of an inch: and yet, on account of the ſmall ſcale of thoſe micrometers, theſe quantities are of the greateſt conſequence; an error of a ſingle thouſandth part inducing in moſt inſtruments a miſtake of ſeveral ſeconds.

The laſt and greateſt imperfection of all is, that theſe wire micrometers require a pretty ſtrong light in the field of view; and when Mr Herſchel had double ſtars to meaſure, one of which was very obſcure, he was obliged to be content with leſs light than is neceſſary to make the wires perfectly diſtinct; and ſeveral ſtars on this account could not be meaſured at all, though otherwiſe not too cloſe for the micrometer.

Mr Herſchel, therefore, having long had much occaſion for micrometers that would meaſure exceeding ſmall diſtances exactly, was led to bend his attention to the improvement of theſe inſtruments; and the reſult of his endeavours has been a very ingenious inſtrument called a *lamp-micrometer*, which is not only free from the imperfections above ſpecified, but alſo poſſeſſes the advantages of a very large ſcale. This inſtrument is deſcribed in the Philoſophical Tranſactions for 1782; and the conſtruction of it is as follows:

ABGCFE

Fig. 12.

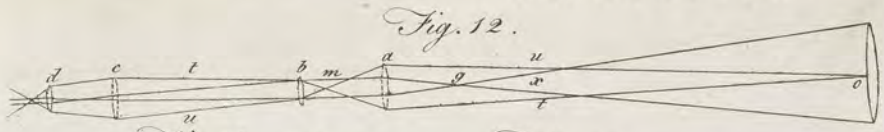


Fig. 13.

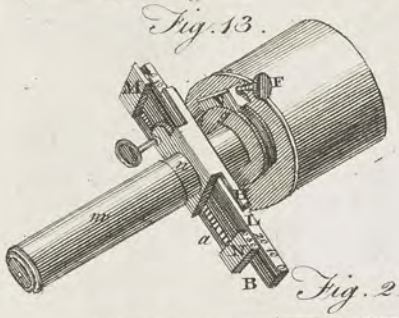


Fig. 23.

Fig. 15.

Fig. 22.

Fig. 25.

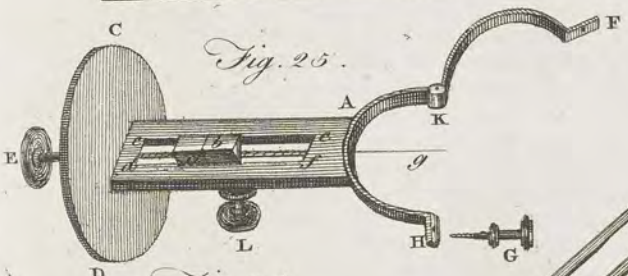


Fig. 24.

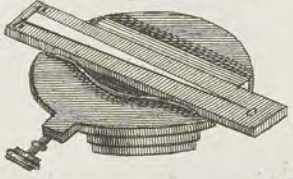


Fig. 20.

Fig. 14.

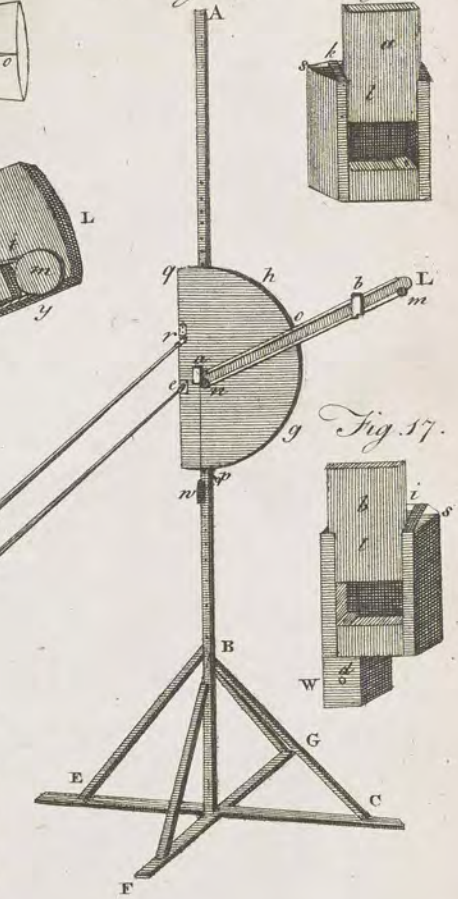


Fig. 16.

Fig. 17.

Fig. 18.

Fig. 19.

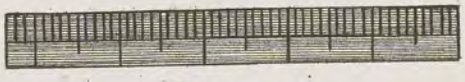
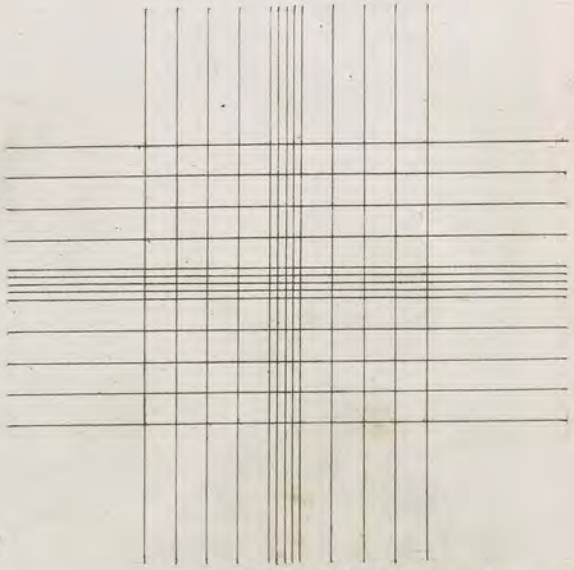


Fig. 26.



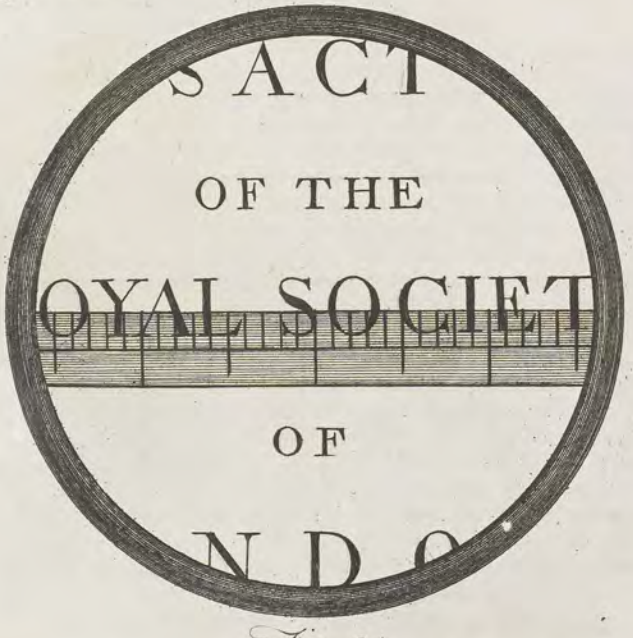
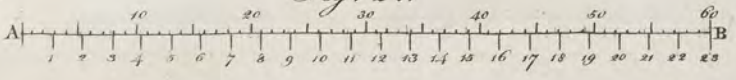


Fig. 21.



J. Bell Prin. Wal. Sculptor. fecit.

Micrometer.

ABGCFE (fig. 14.) is a ſtand nine feet high, upon which a ſemicircular board *qhogp* is moveable upwards or downwards, in the manner of ſome fire-ſcreens, as occaſion may require, and is held in its ſituation by a peg *p* put into any one of the holes of the upright piece AB. This board is a ſegment of a circle of fourteen inches radius, and is about three inches broader than a ſemicircle, to give room for the handles *r*D, *e*P, to work. The uſe of this board is to carry an arm L, thirty inches long, which is made to move upon a pivot at the centre of the circle, by means of a ſtring, which paſſes in a groove upon the edge of the ſemicircle *pgohq*; the ſtring is faſtened to a hook at *o* (not expreſſed in the figure, being at the back of the arm L), and paſſing along the groove from *oh* to *q* is turned over a pulley at *q*, and goes down to a ſmall barrel *e*, within the plane of the circular board, where a double-jointed handle *e*P commands its motion. By this contrivance, we ſee, the arm L may be lifted up to any altitude from the horizontal poſition to the perpendicular, or be ſuffered to deſcend by its own weight below the horizontal to the reverſe perpendicular ſituation. The weight of the handle P is ſufficient to keep the arm in any given poſition; but if the motion ſhould be too eaſy, a friction ſpring applied to the barrel will moderate it at pleaſure.

In front of the arm L a ſmall ſlider, about three inches long, is moveable in a rabbet from the end L towards the centre backwards and forwards. A ſtring is faſtened to the left ſide of the little ſlider, and goes towards L, where it paſſes round a pulley at *m*, and returns under the arm from *m*, *n*, towards the centre, where it is led in a groove on the edge of the arm, which is of a circular form, upwards to a barrel (raiſed above the plane of the circular board) at *r*, to which the handle *r*D is faſtened. A ſecond ſtring is faſtened to the ſlider, at the right ſide, and goes towards the centre, where it paſſes over a pulley *n*; and the weight *w*, which is ſuſpended by the end of this ſtring, returns the ſlider towards the centre, when a contrary turn of the handle permits it to act.

By *a* and *b* are repreſented two ſmall lamps, two inches high, 1½ in breadth by 1¼ in depth. The ſides, back, and top, are made ſo as to permit no light to be ſeen, and the front conſiſts of a thin braſs ſliding door. The flame in the lamp *a* is placed three-tenths of an inch from the left ſide, three-tenths from the front, and half an inch from the bottom. In the lamp *b* it is placed at the ſame height and diſtance, meaſuring from the right ſide. The wick of the flame conſiſts only of a ſingle very thin lamp cotton-thread; for the ſmalleſt flame being ſufficient, it is eaſier to keep it burning in ſo confined a place. In the top of each lamp muſt be a little ſlit lengthways, and alſo a ſmall opening in one ſide near the upper part, to permit air enough to circulate to feed the flame. To prevent every reflection of light, the ſide opening of the lamp *a* ſhould be to the right, and that of the lamp *b* to the left. In the ſliding door of each lamp is made a ſmall hole with the point of a very fine needle juſt oppoſite the place where the wicks are burning, ſo that when the ſliders are ſhut down, and every thing dark, nothing ſhall be ſeen but two fine lucid points of the ſize of two ſtars of the third or fourth magnitude. The lamp *a* is placed ſo that its lucid point may be in the centre of the circular board where it remains fixed. The lamp *b* is hung to the little ſlider which moves in the rabbet of the arm, ſo that its lucid point, in an horizontal poſition of the arm, may be on a level with the lucid point in the centre. The moveable lamp is ſuſpended upon a piece of braſs faſtened to the ſlider by a pin exactly behind the flame, upon which it moves as a pivot. The lamp is balanced at the bottom by a leaden weight, ſo as always to remain upright, when the arm is either lifted above or depreſſed below the horizontal poſition. The double-jointed handles *r*D, *e*P, conſiſt of light deal rods, ten feet long, and the loweſt of them may have diviſions, marked upon it near the end P, expreſſing exactly the diſtance from the central lucid point in feet, inches, and tenths.

Micrometer.

From this conſtruction we ſee, that a perſon at a diſtance of ten feet may govern the two lucid points, ſo as to bring them into any required poſition ſouth or north preceding or following from 0 to 90° by uſing the handle P, and alſo to any diſtance from ſix-tenths of an inch to five or ſix and twenty inches by means of the handle D. If any reflection or appearance of light ſhould be left from the top or ſides of the lamps, a temporary ſcreen, conſiſting of a long piece of paſte-board, or a wire frame covered with black cloth, of the length of the whole arm, and of any required breadth, with a ſlit of half an inch broad in the middle, may be affixed to the arm by four bent wires projecting an inch or two before the lamps, ſituated ſo that the moveable lucid point may paſs along the opening left for that purpoſe.

Fig. 15. repreſents part of the arm L, half the real ſize; S the ſlider; *m* the pulley, over which the cord *xtyz* is returned towards the centre; *v* the other cord going to the pulley *n* of fig. 14. R the braſs piece moveable upon the pin *c*, to keep the lamp upright. At R is a wire rivetted to the braſs piece, upon which is held the lamp by a nut and ſcrew. Fig. 16. 17. repreſent the lamps *a*, *b*, with the ſliding doors open, to ſhow the ſituation of the wicks. W is the leaden weight with a hole *d* in it, through which the wire R of fig. 15. is to be paſſed when the lamp is to be faſtened to the ſlider S. Fig. 18. repreſents the lamp *a* with the ſliding door ſhut; *l* the lucid point; and *ik* the openings at the top, and *s* at the ſides, for the admiſſion of air.

"Every ingenious artiſt (ſays Mr Herſchel) will ſoon perceive, that the motions of this micrometer are capable of great improvement by the application of wheels and pinions, and other well known mechanical reſources; but as the principal object is only to be able to adjuſt the two lucid points to the required poſition and diſtance, and to keep them there for a few minutes, while the obſerver goes to meaſure their diſtance, it will not be neceſſary to ſay more upon the ſubject.

"I am now to ſhow the application of this inſtrument. It is well known to opticians and others who have been in the habit of uſing optical inſtruments, that we can with one eye look into a microſcope or teleſcope, and ſee an object much magnified, while the naked eye may ſee a ſcale upon which the magnified picture is thrown. In this manner I have generally determined the power of my teleſcopes; and any one who has acquired a facility of taking ſuch obſervations

will

Micrometer.

will very seldom mistake so much as one in fifty in determining the power of an instrument, and that degree of exactness is fully sufficient for the purpose.

"The Newtonian form is admirably adapted to the use of this micrometer; for the observer stands always erect, and looks in a horizontal direction, notwithstanding the telescope should be elevated to the zenith. Besides, his face being turned away from the object to which his telescope is directed, this micrometer may be placed very conveniently without causing the least obstruction to the view: therefore, when I use this instrument, I put it at ten feet distance from the left eye, in a line perpendicular to the tube of the telescope, and raise the moveable board to such a height that the lucid point of the central lamp may be upon a level with the eye. The handles, lifted up, are passed through two loops fastened to the tube, just by the observer, so as to be ready for his use. I should observe, that the end of the tube is cut away, so as to leave the left eye entirely free to see the whole micrometer.

"Having now directed the telescope to a double star, I view it with the right eye, and at the same time with the left see it projected upon the micrometer: then, by the handle P, which commands the position of the arm, I raise or depress it so as to bring the two lucid points to a similar situation with the two stars; and, by the handle D, I approach or remove the moveable lucid point to the same distance of the two stars, so that the two lucid points may be exactly covered by or coincide with the stars. A little practice in this business soon makes it easy, especially to one who has already been used to look with both eyes open.

"What remains to be done is very simple. With a proper rule, divided into inches and fortieth parts, I take the distance of the lucid points, which may be done to the greatest nicety, because, as I observed before, the little holes are made with the point of a very fine needle. The measure thus obtained is the tangent of the magnified angle under which the stars are seen to a radius of ten feet; therefore, the angle being found and divided by the power of the telescope gives the real angular distance of the centres of a double star.

"For instance, September 25, 1781, I measured α Herculis with this instrument. Having caused the two lucid points to coincide exactly with the stars centre upon centre, I found the radius or distance of the central lamp from the eye 10 feet 4.15 inches; the tangent or distance of the two lucid points 50.6 fortieth parts of an inch; this gives the magnified angle 35′, and dividing by the power 460, which I used, we obtain 4″ 34‴ for the distance of the centres of the two stars. The scale of the micrometer at this very convenient distance, with the power of 460 (which my telescope bears so well upon the fixed stars that for near a twelvemonth past I have hardly used any other), is above a quarter of an inch to a second; and by putting on my power of 932, which in very fine evenings is extremely distinct, I obtain a scale of more than half an inch to a second, without increasing the distance of the micrometer; whereas the most perfect of my former micrometers, with the same instrument, had a scale of less than the two thousandth part of an inch to a second.

"The measures of this micrometer are not confined to double stars only, but may be applied to any other objects that require the utmost accuracy, such as the diameters of the planets or their satellites, the mountains of the moon, the diameters of the fixed stars, &c. Micrometer.

"For instance, October 22. 1781, I measured the apparent diameter of α Lyræ; and judging it of the greatest importance to increase my scale as much as convenient, I placed the micrometer at the greatest convenient distance, and (with some trouble, for want of longer handles, which might easily be added) took the diameter of this star by removing the two lucid points to such a distance as just to enclose the apparent diameter. When I measured my radius, it was found to be twenty-two feet six inches. The distance of the two lucid points was *about* three inches, for I will not pretend to *extreme* nicety in this observation, on account of the very great power I used, which was 6450. From these measures we have the magnified angle 38′ 10″: this divided by the power gives 0″.355 for the apparent diameter of α Lyræ. The scale of the micrometer, on this occasion, was no less than 8.443 inches to a second, as will be found by multiplying the natural tangent of a second with the power and radius in inches.

"November 28. 1781, I measured the diameter of the new star; but the air was not very favourable, for this singular star was not so distinct with 227 that evening as it generally is with 460: therefore, without laying much stress upon the exactness of the observation, I shall only report it to exemplify the use of the micrometer. My radius was 35 feet 11 inches. The diameter of the star, by the distance of the lucid points, was 2.4 inches, and the power I used 227: hence the magnified angle is found 19′, and the real diameter of the star 5″.022. The scale of this measure .474 millesimals of an inch, or almost half an inch to a second."

In the Philosophical Transactions for 1791, a very simple micrometer for measuring small angles with the telescope is described by Mr Cavallo; who introduces his description with the following observations upon the different sorts of telescopical micrometers in use. "These instruments may be divided into two classes; namely, those which have not, and those which have, some movement amongst their parts. The micrometers of the former sort consist mostly of fine wires or hairs, variously disposed, and situated within the telescope, just where the image of the object is formed. In order to determine an angle with those micrometers, a good deal of calculation is generally required. The micrometers of the other sort, of which there is a great variety, some being made with moveable parallel wires, others with prisms, others again with a combination of lenses, and so on, are more or less subject to several inconveniencies, the principal of which are the following. 1. Their motions generally depend upon the action of a screw; and of course the imperfections of its threads, and the greater or less quantity of lost motion, which is observable in moving a screw, especially when small, occasion a considerable error in the mensuration of angles. 2. Their complication and bulk renders them difficultly applicable to a variety of telescopes, especially to the pocket ones. 3. They do not measure the angle without some loss of time, which is necessary to turn the

Micrometer. screw, or to move ſome other mechaniſm. 4. and laſtly, They are conſiderably expenſive, ſo that ſome of them coſt even more than a tolerably good teleſcope."

After having had long in view (our author informs us) the conſtruction of a micrometer which might be in part at leaſt, if not entirely, free from all thoſe objections; he, after various attempts, at laſt ſucceeded with a ſimple contrivance, which, after repeated trials, has been found to anſwer the deſired end, not only from his own experience, but from that alſo of ſeveral friends, to whom it has been communicated.

This micrometer, in ſhort, conſiſts of a thin and narrow ſlip of mother-of-pearl finely divided, and ſituated in the focus of the eye-glaſs of a teleſcope, juſt where the image of the object is formed. It is immaterial whether the teleſcope be a refractor or a reflector, provided the eye-glaſs be a convex lens, and not a concave one as in the Galilean conſtruction.

The ſimpleſt way of fixing it is to ſtick it upon the diaphragm which generally ſtands within the tube and in the focus of the eye-glaſs. When thus fixed, if you look through the eye-glaſs, the diviſions of the micrometrical ſcale will appear very diſtinct, unleſs the diaphragm is not exactly in the focus; in which caſe, the micrometrical ſcale muſt be placed exactly in the focus of the eye-glaſs, either by puſhing the diaphragm backwards or forwards, when that is practicable; or elſe the ſcale may be eaſily removed from one or the other ſurface of the diaphragm by the interpoſition of a circular piece of paper or card, or by a bit of wax. This conſtruction is fully ſufficient, when the teleſcope is always to be uſed by the ſame perſon; but when different perſons are to uſe it, then the diaphragm which ſupports the micrometer muſt be conſtructed ſo as to be eaſily moved backwards or forwards, though that motion needs not be greater than about a tenth or an eighth of an inch. This is neceſſary, becauſe the diſtance of the focus of the ſame lens appears different to the eyes of different perſons; and, therefore, whoever is going to uſe the teleſcope for the menſuration of any angle, muſt firſt of all unſcrew the tube which contains the eye-glaſs and micrometer from the reſt of the teleſcope, and, looking through the eye-glaſs, muſt place the micrometer where the diviſions of it may appear quite diſtinct to his eye.

In caſe that any perſon ſhould not like to ſee always the micrometer in the field of the teleſcope, then the micrometrical ſcale, inſtead of being fixed to the diaphragm, may be fitted to a circular perforated plate of braſs, wood, or even paper, which may be occaſionally placed upon the ſaid diaphragm.

Mr Cavallo has made ſeveral experiments to determine the moſt uſeful ſubſtance for this micrometer.—Glaſs, which he had ſucceſsfully applied for a ſimilar purpoſe to the compound microſcope, ſeemed at firſt to be the moſt promiſing; but it was at laſt rejected after ſeveral trials: for the diviſions upon it generally are either too fine to be perceived, or too rough; and though with proper care and attention the diviſions may be proportioned to the ſight, yet the thickneſs of the glaſs itſelf obſtructs in ſome meaſure the diſtinct view of the object. Ivory, horn, and wood, were found uſeleſs for the conſtruction of this micrometer, on account of their bending, ſwelling, and contracting very eaſily; whereas mother-of-pearl is a very ſteady ſubſtance, the diviſions upon it may be marked very eaſily, and when it is made as thin as common writing paper it has a very uſeful degree of tranſparency. Micrometer.

Fig. 19. exhibits this micrometer ſcale, but ſhows it four times larger than the real ſize of one, which he has adapted to a three-feet achromatic teleſcope that magnifies about 84 times. It is ſomething leſs than the 24th part of an inch broad; its thickneſs is equal to that of common writing-paper; and the length of it is determined by the aperture of the diaphragm, which limits the field of the teleſcope. The diviſions upon it are the 200ths of an inch, which reach from one edge of the ſcale to about the middle of it, excepting every fifth and tenth diviſion, which are longer. The divided edge of it paſſes through the centre of the field of view, though this is not a neceſſary precaution in the conſtruction of this micrometer. Two diviſions of the above deſcribed ſcale in my teleſcope are very nearly equal to one minute; and as a quarter of one of thoſe diviſions may be very well diſtinguiſhed by eſtimation, therefore an angle of one eighth part of a minute, or of $7''\frac{1}{2}$, may be meaſured with it.

When a teleſcope magniſies more, the diviſions of the micrometer muſt be more minute; and Mr Cavallo finds, that when the focus of the eye-glaſs of the teleſcope is ſhorter than half an inch, the micrometer may be divided with the 500ths of an inch; by means of which, and the teleſcope magnifying about 200 times, one may eaſily and accurately meaſure an angle ſmaller than half a ſecond. On the other hand, when the teleſcope does not magnify above 30 times, the diviſions need not be ſo minute: for inſtance, in one of Dollond's pocket teleſcopes, which when drawn out for uſe is about 14 inches long, a micrometer with the hundredths of an inch is quite ſufficient, and one of its diviſions is equal to little leſs than three minutes, ſo that an angle of a minute may be meaſured by it.

"In looking through a teleſcope furniſhed with ſuch a micrometer (ſays our author), the field of view appears divided by the micrometer ſcale, the breadth of which occupies about one-ſeventh part of the aperture; and as the ſcale is ſemitranſparent, that part of the object which happens to be behind it may be diſcerned ſufficiently well to aſcertain the diviſion, and even the quarter of a diviſion, with which its borders coincide. Fig. 20. ſhows the appearance of the field of my teleſcope with the micrometer, when directed to the title page of the Philoſophical Tranſactions, wherein one may obſerve that the thickneſs of the letter C is equal to three-fourths of a diviſion, the diameter of the O is equal to three diviſions, and ſo on.

"At firſt view, one is apt to imagine, that it is difficult to count the diviſions which may happen to cover or to meaſure an object; but upon trial it will be found, that this is readily performed; and even people who have never been uſed to obſerve with the teleſcope,

Micrometer.

ſcope, ſoon learn to meaſure very quickly and accurately with this micrometer; for ſince every fifth and tenth diviſion is longer than the reſt, one ſoon acquires the habit of ſaying, five, ten, fifteen; and then, by adding the other diviſions leſs than five, completes the reckoning. Even with a teleſcope which has no ſtand, if the object end of it be reſted againſt a ſteady place, and the other end be held by the hand near the eye of the obſerver, an object may be meaſured with accuracy ſufficient for ſeveral purpoſes, as for the eſtimation of ſmall diſtances, for determining the height of a houſe, &c.

"After having conſtructed and adapted this micrometer to the teleſcope, it is then neceſſary to aſcertain the value of the diviſions. It is hardly neceſſary to mention in this place, that though thoſe diviſions meaſure the chords of the angles, and not the angles or arches themſelves, and the chords are not as the arches, yet it has been ſhown by all the trigonometrical writers, that in ſmall angles the chords, arches, ſines, and tangents, follow the ſame proportion ſo very nearly, that the very minute difference may be ſafely neglected: ſo that if one diviſion of this micrometer is equal to one minute, we may ſafely conclude, that two diviſions are equal to two minutes, three diviſions to three minutes, and ſo on. There are various methods of aſcertaining the value of the diviſions of ſuch a micrometer, they being the very ſame that are uſed for aſcertaining the value of the diviſions in other micrometers. Such are, the paſſage of an equatorial ſtar over a certain number of diviſions in a certain time; or the meaſuring of the diameter of the ſun, by computation from the focal diſtance of the object and other lenſes of the teleſcope; the laſt of which, however, is ſubject to ſeveral inaccuracies; but as they are well known to aſtronomical perſons, and have been deſcribed in many books, they need not be farther noticed here. However, for the ſake of workmen and other perſons not converſant in aſtronomy, I ſhall deſcribe an eaſy and accurate method of aſcertaining the value of the diviſions of the micrometer.

"Mark upon a wall or other place the length of ſix inches, which may be done by making two dots or lines ſix inches aſunder, or by fixing a ſix-inch ruler upon a ſtand; then place the teleſcope before it ſo that the ruler or ſix-inch length may be at right angles with the direction of the teleſcope, and juſt 57 feet $3\frac{1}{2}$ inches diſtant from the object-glaſs of the teleſcope: this done, look through the teleſcope at the ruler or other extenſion of ſix inches, and obſerve how many diviſions of the micrometer are equal to it, and that ſame number of diviſions is equal to half a degree, or 30′; and this is all that needs be done for the required determination; the reaſon of which is, becauſe an extenſion of ſix inches ſubtends an angle of 30′ at the diſtance of 57 feet $3\frac{1}{2}$ inches, as may be eaſily calculated by the rules of plane trigonometry.

"In one of Dollond's 14-inch pocket teleſcopes, if the diviſions of the micrometer be the hundredths of an inch, $11\frac{1}{2}$ of thoſe diviſions will be found equal to 30′, or 23 to a degree. When this value has been once aſcertained, any other angle meaſured by any other number of diviſions is determined by the rule of three. Thus, ſuppoſe that the diameter of the ſun ſeen through the ſame teleſcope, be found equal to 12 diviſions, ſay as $11\frac{1}{2}$ diviſions are to 30 minutes, ſo are 12 diviſions to $\left(\frac{12 \times 30'}{11.5}\right)$ 31′.3, which is the required diameter of the ſun. Micrometer.

"Notwithſtanding the facility of this calculation, a ſcale may be made anſwering to the diviſions of a micrometer, which will ſhow the angle correſponding to any number of diviſions to mere inſpection. Thus, for the above-mentioned ſmall teleſcope, the ſcale is repreſented in fig. 21. AB is a line drawn at pleaſure; it is then divided into 23 equal parts, and thoſe diviſions which repreſent the diviſions of the micrometer that are equal to one degree, are marked on one ſide of it. The line then is divided again into 60 equal parts, which are marked on the other ſide of it; and theſe diviſions repreſent the minutes which correſpond to the diviſions of the micrometer: thus the figure ſhows, that ſix diviſions of the micrometer are equal to $15\frac{1}{2}$ minutes, $11\frac{1}{2}$ diviſions are nearly equal to 29 minutes, &c. What has been ſaid of minutes may be ſaid of ſeconds alſo, when the ſcale is to be applied to a large teleſcope.

"Thus far this micrometer and its general uſe have been ſufficiently deſcribed; and mathematical perſons may eaſily apply it to the various purpoſes to which micrometers have been found ſubſervient. But as the ſimplicity, cheapneſs, and at the ſame time the accuracy of this contrivance, may render the uſe of it much more general than that of any other micrometer; and I may venture to ſay, that it will be found very uſeful in the army, and amongſt ſea-faring people, for the determination of diſtances, heights, &c.; I ſhall therefore join ſome practical rules to render this micrometer uſeful to perſons unacquainted with trigonometry and the uſe of logarithms.

"Problem I. The angle, not exceeding one degree, which is ſubtended by an extenſion of one foot, being given, to find its diſtance from the place of obſervation. *N. B.* This extenſion of one foot, or any other which may be mentioned hereafter, muſt be perpendicular to the direction of the teleſcope through which it is obſerved. The diſtances are reckoned from the object-glaſs of the teleſcope; and the anſwers obtained by the rules of this problem, though not exactly true, are however ſo little different from the truth, that the difference ſeldom amounts to more than two or three inches, which may be ſafely neglected.

"Rule 1. If the angle be expreſſed in minutes, ſay, as the given angle is to 60, ſo is 687.55 to a fourth proportional, which gives the anſwer in inches. —2. If the angle be expreſſed in ſeconds, ſay, as the given angle is to 3600, ſo is 687.55 to a fourth proportional, which expreſſes the anſwer in inches. —3. If the angle be expreſſed in minutes and ſeconds, turn it all into ſeconds, and proceed as above.

"Example. At what diſtance is a globe of one foot in diameter when it ſubtends an angle of two ſeconds?

$$2 : 3600 :: 687{,}55 : \frac{3600 \times 687.55}{2} = 1237590$$

inches, or $10313\frac{2}{3}$ feet, which is the anſwer required.

Micrometer

" This calculation may be ſhortened; for ſince two of the three proportionals are fixed, their product in the firſt caſe is 41253, and in the other two caſes is 2475180; ſo that in the firſt caſe, viz. when the angle is expreſſed in minutes, you need only divide 41253 by the given angle; and in the other two caſes, viz. when the angle is expreſſed in ſeconds, divide 2475180 by the given angle, and the quotient in either caſe is the anſwer in inches.

" Problem II. The angle, not exceeding one degree, which is ſubtended by any known extenſion, being given, to find its diſtance from the place of obſervation.

" Rule. Proceed as if the extenſion were of one foot by Problem I. and call the anſwer B; then, if the extenſion in queſtion be expreſſed in inches, ſay, as 12 inches are to that extenſion, ſo is B to a fourth proportional, which is the anſwer in inches; but if the extenſion in queſtion be expreſſed in feet, then you need only multiply it by B, and the product is the anſwer in inches.

" Example. At what diſtance is a man ſix feet high, when he appears to ſubtend an angle of 30″.

" By problem I. if the man were one foot high, the diſtance would be 82506 inches; but as he is ſix feet high, therefore multiply 82506 by 6, and the product gives the required diſtance, which is 495036 inches, or 41253 feet.

" For greater conveniency, eſpecially in travelling, or in ſuch circumſtances in which one has not the opportunity of making even the eaſy calculations required in thoſe problems, I have calculated the following two tables; the firſt of which ſhows the diſtance anſwering to any angle from one minute to one degree, which is ſubtended by an extenſion of one foot; and the ſecond table ſhows the diſtance anſwering to any angle from one minute to one degree, which is ſubtended by a man, the height of which has been called an extenſion of ſix feet; becauſe, at a mean, ſuch is the height of a man when dreſſed with hat and ſhoes on. Theſe tables may be tranſcribed on a card, and may be had always ready with a pocket teleſcope furniſhed with a micrometer. Their uſe is evidently to aſcertain diſtances without any calculation; and they are calculated only to minutes, becauſe with a pocket teleſcope and micrometer it is not poſſible to meaſure an angle more accurately than to a minute.

" Thus, if one wants to meaſure the extenſion of a ſtreet, let a foot ruler be placed at the end of the ſtreet; meaſure the angular appearance of it, which ſuppoſe to be 36′, and in the table you will have the required diſtance againſt 36′, which is 95½ feet. Thus alſo a man who appears to be 49′ high, is at the diſtance of 421 feet.

Angles ſubtended by an extenſion of one foot at different diſtances.

Angles.	Diſtances in feet.	Angles.	Diſtances in feet.
Min. 1	3437,7	Min. 31	110,9
2	1718,9	32	107,4
3	1145,9	33	104,2
4	859,4	34	101,1
5	687,5	35	98,2
6	572,9	36	95,5
7	491,1	37	92,9
8	429,7	38	90,4
9	382,0	39	88,1
10	343,7	40	85,9
11	312,5	41	83,8
12	286,5	42	81,8
13	264,4	43	79,9
14	245,5	44	78,1
15	229,2	45	76,4
16	214,8	46	74,7
17	202,2	47	73,1
18	191,0	48	71,6
19	180,9	49	70,1
20	171,8	50	68,7
21	162,7	51	67,4
22	156,2	52	66,1
23	149,4	53	64,8
24	143,2	54	63,6
25	137,5	55	62,5
26	132,2	56	61,4
27	127,3	57	60,3
28	122,7	58	59,2
29	118,5	59	58,2
30	114,6	60	57,3

Angles ſubtended by an extenſion of ſix feet at different diſtances.

Angles.	Diſtances in feet.	Angles.	Diſtances in feet.
Min. 1	20626,8	Min. 31	665,4
2	10313.	32	644,5
3	6875,4	33	625.
4	5156,5	34	606,6
5	4125,2	35	589,3
6	3437,7	36	572,9
7	2946,6	37	557,5
8	2578,2	38	542,8
9	2291,8	39	528,9
10	2062,6	40	515,6
11	1875,2	41	503,1
12	1718,8	42	491,1
13	1586,7	43	479,7
14	1473,3	44	468,8
15	1375.	45	458,4
16	1298,1	46	448,4
17	1213,3	47	438,9
18	1145,9	48	429,7
19	1085,6	49	421.
20	1031,4	50	412,5
21	982,2	51	404,4
22	937,6	52	396,7
23	896,8	53	389,2
24	859,4	54	381,9
25	825.	55	375.
26	793,3	56	368,3
27	763,9	57	361,9
28	736,6	58	355,6
29	711,3	59	349,6
30	687,5	60	343,7

Micrometer.

II. The Micrometer has not only been applied to teleſcopes, and employed for aſtronomical purpoſes; but there have alſo been various contrivances for adapting it to MICROSCOPICAL obſervations. Mr Leeuwenhoek's method of eſtimating the ſize of ſmall objects was by comparing them with grains of ſand, of which 100 in a line took up an inch. Theſe grains he laid upon the ſame plate with his objects, and viewed them at the ſame time. Dr Jurin's method was ſimilar to this; for he found the diameter of a piece of fine ſilver wire, by wrapping it as cloſe as he could about a pin, and obſerving how many rings made an inch; and he uſed this wire in the ſame manner as Leeuwenhoek uſed his ſand. Dr Hooke uſed to look upon the magnified object with one eye, while at the ſame time he viewed other objects placed at the ſame diſtance with the other eye. In this manner he was able, by the help of a ruler, divided into inches and ſmall parts, and laid on the pedeſtal of the microſcope, to caſt as it were the magnified appearance of the object upon the ruler, and thus exactly to meaſure the diameter which it appeared to have through the glaſs; which being compared with the diameter as it appeared to the naked eye, eaſily ſhowed the degree in which it was magnified. A little practice, ſays Mr Baker, will render this method exceedingly eaſy and pleaſant.

Mr Martin in his Optics recommended ſuch a micrometer for a microſcope as had been applied to teleſcopes: for he adviſes to draw a number of parallel lines on a piece of glaſs, with the fine point of a diamond, at the diſtance of one-fortieth of an inch from one another, and to place it in the focus of the eye-glaſs. By this method, Dr Smith contrived to take the exact draught of objects viewed by a double microſcope; for he adviſes to get a lattice, made with ſmall ſilver wires or ſquares, drawn upon a plain glaſs by the ſtrokes of a diamond, and to put it into the place of the image, formed by the object-glaſs: then by transferring the parts of the object, ſeen in the ſquares of the glaſs or lattice upon ſimilar correſponding ſquares drawn on paper, the picture may be exactly taken. Mr Martin alſo introduced into compound microſcopes another micrometer, conſiſting of a ſcrew. See both theſe methods deſcribed in his *Optics*, p. 277.

The mode of actual admeaſurement (Mr Adams obſerves*) is without doubt the moſt ſimple that can be uſed; as by it we comprehend, in a manner, at one glance, the different effects of combined glaſſes; and as it ſaves the trouble, and avoids the obſcurity, of the uſual modes of calculation: but many perſons find it exceedingly difficult to adopt this method, becauſe they have not been accuſtomed to obſerve with both eyes at once. To obviate this inconvenience, the late Mr Adams contrived an inſtrument called the *Needle-Micrometer*, which was firſt deſcribed in his *Micrographia Illuſtrata*; and of which, as now conſtructed, we have the following deſcription by his ſon Mr George Adams in the ingenious Eſſays above quoted.

* *Microſcopical Eſſays*, P. 59.

This micrometer conſiſts of a ſcrew, which has 50 threads to an inch; this ſcrew carries an index, which points to the diviſions on a circular plate, which is fixed at right angles to the axis of the ſcrew. The revolutions of the ſcrew are counted on a ſcale, which is an inch divided into 50 parts; the index to theſe diviſions is a flower-de-luce marked upon the ſlider, which carries the needle point acroſs the field of the microſcope. Every revolution of the micrometer ſcrew meaſures $\frac{1}{50}$th part of an inch, which is again ſubdivided by means of the diviſions on the circular plate, as this is divided into 20 equal parts, over which the index paſſes at every revolution of the ſcrew; by which means we obtain with eaſe the meaſure of 1000th part of an inch: for 50, the number of threads on the ſcrew in one inch, being multiplied by 20, the diviſions on the circular plate are equal to 1000; ſo that each diviſion on the circular plate ſhows that the needle has either advanced or receded 1000th part of an inch.

Micrometer.

To place this micrometer on the body of the microſcope, open the circular part FKH, fig. 25. by taking out the ſcrew G, throw back the ſemicircle FK, which moves upon a joint at K; then turn the ſliding tube of the body of the microſcope, ſo that the ſmall holes which are in both tubes may exactly coincide, and let the needle *g* of the micrometer have a free paſſage through them; after this, ſcrew it faſt upon the body by the ſcrew G. The needle will now traverſe the field of the microſcope, and meaſure the length and breadth of the image of any object that is applied to it. But further aſſiſtance muſt be had, in order to meaſure the object itſelf, which is a ſubject of real importance; for though we have aſcertained the power of the microſcope, and know that it is ſo many thouſand times, yet this will be of little aſſiſtance towards aſcertaining an accurate idea of its real ſize; for our ideas of bulk being formed by the compariſon of one object with another, we can only judge of that of any particular body, by comparing it with another whoſe ſize is known: the ſame thing is neceſſary, in order to form an eſtimate by the microſcope; therefore, to aſcertain the real meaſure of the object, we muſt make the point of the needle paſs over the image of a known part of an inch placed on the ſtage, and write down the revolutions made by the ſcrew, while the needle paſſed over the image of this known meaſure; by which means we aſcertain the number of revolutions on the ſcrew, which are adequate to a real and known meaſure on the ſtage. As it requires an attentive eye to watch the motion of the needle point as it paſſes over the image of a known part of an inch on the ſtage, we ought not to truſt to one ſingle meaſurement of the image, but ought to repeat it at leaſt ſix times; then add the ſix meaſures thus obtained together, and divide their ſum by ſix, or the number of trials; the quotient will be the mean of all the trials. This reſult is to be placed in a column of a table next to that which contains the number of the magnifiers.

Plate CCXCVI.

By the aſſiſtance of the ſectoral ſcale, we obtain with eaſe a ſmall part of an inch. This ſcale is ſhown at fig. 22, 23, 24, in which the two lines *ca*, *cb*, with the ſide *ab*, form an iſoſceles triangle; each of the ſides is two inches long, and the baſe ſtill only of one-tenth of an inch. The longer ſides may be of any given length, and the baſe ſtill only of one-tenth of an inch. The longer lines may be conſidered as the line of lines upon a ſector opened to one-tenth of an inch. Hence whatever number of equal parts *ca*, *cb* are divided into, their tranſverſe meaſure will be ſuch a part of one-tenth as is expreſſed by their diviſions. Thus if it be divided into ten equal parts, this will divide

the

Micrometer. the inch into 100 equal parts; the firſt diviſion next *c* will be equal to 100th part of an inch, becauſe it is the tenth part of one-tenth of an inch. If theſe lines are divided into twenty equal parts, the inch will be by that means divided into 200 equal parts. Laſtly, if *ab*, *ca*, are made three inches long, and divided into 100 equal parts, we obtain with eaſe the 1000th part. The ſcale is repreſented as ſolid at fig. 23. but as perforated at fig. 22. and 24. ſo that the light paſſes thro' the aperture, when the ſectoral part is placed on the ſtage.

To uſe this ſcale, firſt fix the micrometer, fig. 25. to the body of the microſcope; then fit the ſectoral ſcale, fig. 24. in the ſtage, and adjuſt the microſcope to its proper focus or diſtance from the ſcale, which is to be moved till the baſe appears in the middle of the field of view; then bring the needle point *g*, fig. 25. (by turning the ſcrew L) to touch one of the lines *ca*, exactly at the point anſwering to 20 on the ſectoral ſcale. The index *a* of the micrometer is to be ſet to the firſt diviſion, and that on the dial plate to 20, which is both the beginning and end of its diviſions; we are then prepared to find the magnifying power of every magnifier in the compound microſcope which we are uſing.

Example. Every thing being prepared agreeable to the foregoing directions, ſuppoſe you are deſirous of aſcertaining the magnifying power of the lens marked N° 4. turn the micrometer ſcrew until the point of the needle has paſſed over the magnified image of the tenth part of one inch; then the diviſion, where the two indices remain, will ſhow how many revolutions, and parts of a revolution, the ſcrew has made, while the needle point traverſed the magnified image of the one-tenth of an inch; ſuppoſe the reſult to be 26 revolutions of the ſcrew, and 14 parts of another revolution, this is equal to 26 multiplied by 20, added to 14; that is, 534,000 parts of an inch.—The 26 diviſions found on the ſtraight ſcale of the micrometer, while the point of the needle paſſed over the magnified image of one-tenth part of an inch, were multiplied by 20, becauſe the circular plate CD, fig. 25. is divided into 20 equal parts; this produced 520; then adding the 14 parts of the next revolution, we obtain the 534,000 parts of an inch, or five-tenths and 3400 parts of another tenth, which is the meaſure of the magnified image of one-tenth of an inch, at the aperture of the eye-glaſſes or at their foci. Now if we ſuppoſe the focus of the two eye-glaſſes to be one inch, the double thereof is two inches; or if we reckon in the 1000th part of an inch, we have 2000 parts for the diſtance of the eye from the needle point of the micrometer. Again, if we take the diſtance of the image from the object at the ſtage at 6 inches, or 6000, and add thereto 2000, double the diſtance of the focus of the eye-glaſs, we ſhall have 8000 parts of an inch for the diſtance of the eye from the object; and as the glaſſes double the image, we muſt double the number 534 found upon the micrometer, which then makes 1068: then, by the following analogy, we ſhall obtain the number of times the microſcope magnifies the diameter of the object; ſay, as 240, the diſtance of the eye from the image of the object, is to 800, the diſtance of the eye from the object; ſo is 1068, double the meaſure found on the micrometer, to 3563, or the number of times the microſcope magnifies the diameter of the object. By working in this manner, the magnifying power of each lens uſed with the compound microſcope may be eaſily found, though the reſult will be different in different compound microſcopes, varying according to the combination of the lenſes, their diſtance from the object and one another, &c. Micrometer.

Having diſcovered the magnifying power of the microſcope, with the different object-lenſes that are uſed therewith, our next ſubject is to find out the real ſize of the objects themſelves, and their different parts: this is eaſily effected, by finding how many revolutions of the micrometer-ſcrew anſwer to a known meaſure on the ſectoral ſcale or other object placed on the ſtage; from the number thus found, a table ſhould be conſtructed, expreſſing the value of the different revolutions of the micrometer with that object lens, by which the primary number was obtained. Similar tables muſt be conſtructed for each object lens. By a ſet of tables of this kind, the obſerver may readily find the meaſure of any object he is examining; for he has only to make the needle point traverſe over this object, and obſerve the number of revolutions the ſcrew has made in its paſſage, and then look into his table for the real meaſure which correſponds to this number of revolutions, which is the meaſure required.

Mr Coventry of Southwark has favoured us with the deſcription of a micrometer of his own invention; the ſcale of which, for minuteneſs, ſurpaſſes every inſtrument of the kind of which we have any knowledge, and of which, indeed, we could ſcarcely have formed a conception, had he not indulged us with ſeveral of theſe inſtruments, graduated as underneath.

The micrometer is compoſed of glaſs, ivory, ſilver, &c. on which are drawn parallel lines from the 10th to the 10,000th part of an inch. But an inſtrument thus divided, he obſerves, is more for curioſity than uſe: but one of thoſe which Mr Coventry has ſent us is divided into ſquares, ſo ſmall that ſixteen million of them are contained on the ſurface of one ſquare inch, each ſquare appearing under the microſcope true and diſtinct; and though ſo ſmall, it is a fact, that animalcula are found which may be contained in one of theſe ſquares.

The uſe of micrometers, when applied to microſcopes, is to meaſure the natural ſize of the object, and how much that object is magnified. To aſcertain the real ſize of an object in the ſingle microſcope, nothing more is required than to lay it on the micrometer, and adjuſt it to the focus of the magnifier, noticing how many diviſions of the micrometer it covers. Suppoſe the parallel lines of the micrometer to be the 1000th of an inch, and the object covers two diviſions; its real ſize is 500ths of an inch; if five, 200ths, and ſo on.

But to find how much the object is magnified, is not mathematically determined ſo eaſily by the ſingle as by the compound microſcope: but the following ſimple method (ſays Mr Coventry) I have generally adopted, and think it tolerably accurate. Adjuſt a micrometer under the microſcope *o*, ſay the 100th of an inch of diviſions, with a ſmall object on it; if ſquare, the better: notice how many diviſions one ſide of the object covers, ſuppoſe 10: then cut a piece

Micrometer. of white paper ſomething larger than the magnified appearance of the object: then fix one eye on the object through the microſcope, and the other at the ſame time on the paper, lowering it down till the object and the paper appear level and diſtinct: then cut the paper till it appear exactly the ſize of the magnified object; the paper being then meaſured, ſuppoſe an inch ſquare: Now, as the object under the magnifier, which appeared to be one inch ſquare, was in reality only ten hundredths, or the tenth of an inch, the experiment proves that it is magnified ten times in length, one hundred times in ſuperfices, and one thouſand times in cube, which is the magnifying power of the glaſs; and, in the ſame manner, a table may be made of the power of all the other glaſſes.

In uſing the compound microſcope, the real ſize of the object is found by the ſame method as in the ſingle: but to demonſtrate the magnifying power of each glaſs to greater certainty, adopt the following method.—Lay a two-feet rule on the ſtage, and a micrometer level with its ſurface (an inch ſuppoſe, divided into 100 parts): with one eye ſee how many of thoſe parts are contained in the field of the microſcope, (ſuppoſe 50); and with the other, at the ſame time, look for the circle of light in the field of the microſcope, which with a little practice will ſoon appear diſtinct; mark how much of the rule is interſected by the circle of light, which will be half the diameter of the field. Suppoſe eight inches; conſequently the whole diameter will be ſixteen. Now, as the real ſize of the field, by the micrometers, appeared to be only 50 hundredths, or half an inch, and as half an inch is only one 32d part of 16 inches, it ſhows the magnifying power of the glaſs to be 32^{2} times in length, 1024 ſuperfices, and 32,768 cube (E).

Another way of finding the magnifying power of compound microſcopes, is by uſing two micrometers of the ſame diviſions; one adjuſted under the magnifier, the other fixed in the body of the microſcope in the focus of the eye-glaſs. Notice how many diviſions of the micrometer in the body are ſeen in one diviſion of the micrometer under the magnifier, which again muſt be multiplied by the power of the eye-glaſs. Micrometer. Example: Ten diviſions of the micrometer in the body are contained in one diviſion under the magnifier; ſo far the power is increaſed ten times: now, if the eye-glaſs be one inch focus, ſuch glaſs will of itſelf magnify about eight times in length, which, with the ten times magnified before, will be eight times ten, or 80 times in length, 6400 ſuperficies, and 512,000 cube.

"If (ſays Mr Coventry) theſe micrometers are employed in the ſolar microſcope, they divide the object into ſquares on the ſcreen in ſuch a manner as to render it extremely eaſy to make a drawing of it. And (ſays he) I apprehend they may be employed to great advantage with ſuch a microſcope as Mr Adams's Lucernal; becauſe this inſtrument may be uſed either by day or night, or in any place, and gives the actual magnifying power without calculation."

The caſe with which we have been favoured by Mr Coventry contains ſix micrometers, two on ivory and four on glaſs. One of thoſe on ivory is an inch divided into one hundred parts, every fifth line longer than the intermediate one, and every tenth longer ſtill, for the greater eaſe in counting the diviſions under the microſcope, and is generally uſed in meaſuring the magnifying power of microſcopes. The other ivory one is divided into ſquares of the 50th and 100th of an inch and is commonly employed in meaſuring opaque objects.

Thoſe made of glaſs are for tranſparent objects, which, when laid on them, ſhow their natural ſize.—That marked on the braſs 100, are ſquares divided to the 100th of an inch: that marked 5000 are parallel lines forming nine diviſions, each diviſion the 1000th of an inch; the middle diviſion is again divided into 5, making diviſions to the 5000th of an inch. That marked 10,000 is divided in the ſame manner, with the middle diviſion divided into 10, making the 10,000th of an inch. Example:

The glaſs micrometer without any mark is alſo divided, the outſide lines into 100th, the next into 100th, and the inſide lines into the 4000th of an inch: theſe are again croſſed with an equal number of lines in the ſame manner, making ſquares of the 100th, 1000th, and 4000th of an inch, thus demonſtrating each other's ſize. The middle ſquare of the 1000th of an inch (ſee fig. 26.) is divided into ſixteen ſquares; now

(E) It will be neceſſary, for great accuracy, as well as for comparative obſervations, that the two-feet rule ſhould always be placed at a certain diſtance from the eye: eight inches would, in general, be a proper diſtance.

MICROSCOPE.

Plate CCXCVII.

Fig. 1.

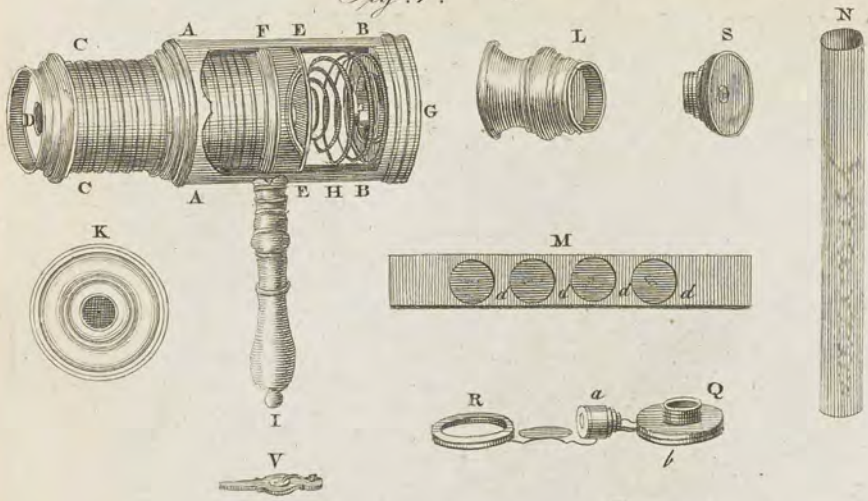


Fig. 2.

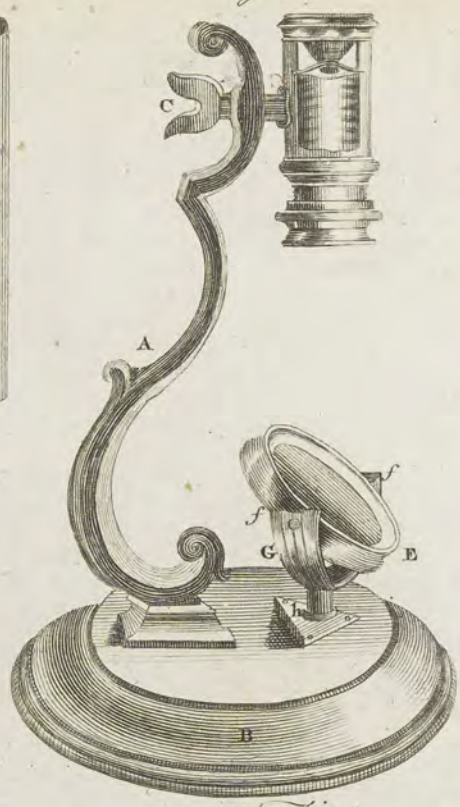


Fig. 7.

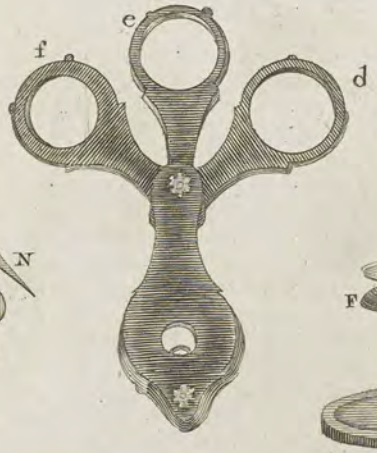


Fig. 3.

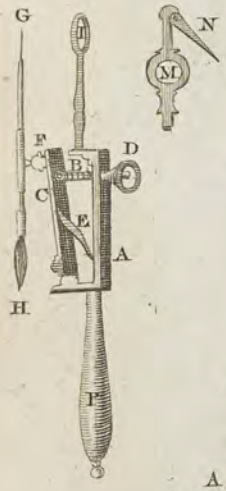


Fig. 4.

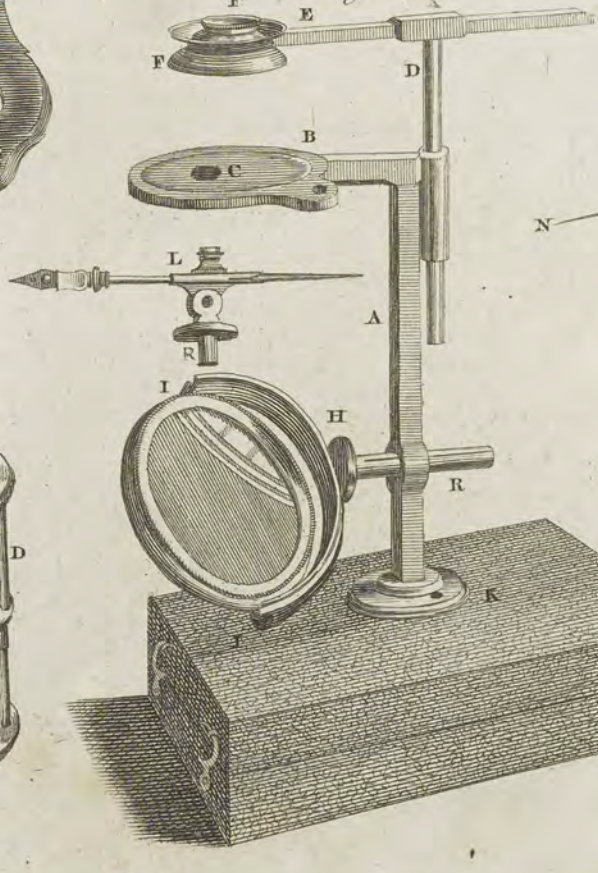


Fig. 5.

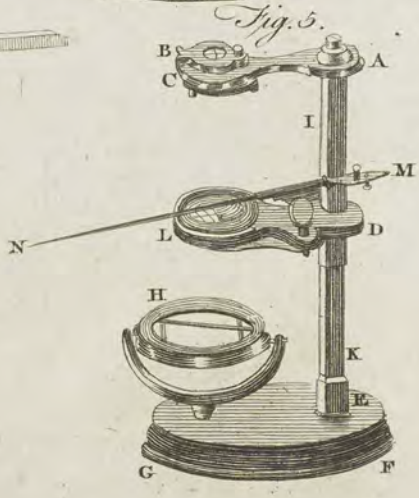
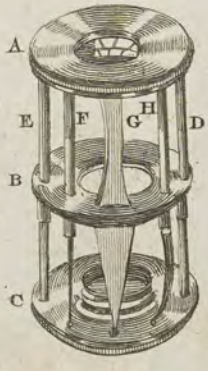
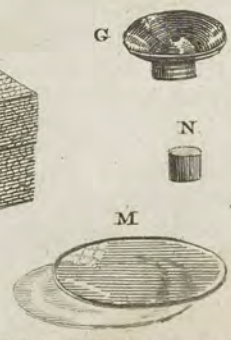


Fig. 6.





A. Bell. Prin. Wal. Sculptor fecit.

Micropus, Microſcope

now as 1000 ſquares in the length of an inch, multiplied by 1000, gives one million in an inch ſurface; by the ſame rule, one of thoſe ſquares divided into 16 muſt be the ſixteen millionth part of an inch ſurface See fig. 26. which is a diminiſhed view of the apparent ſurface exhibited under the magnifier n° 1 of Wilſon's microſcope. In viewing the ſmalleſt lines, Mr Coventry uſes n° 2. or 3.; and they are all better ſeen, he ſays, by candle than by day-light.

MICROPUS, BASTARD CUDWEED: A genus of the polygamia neceſſaria order, belonging to the ſyngeneſia claſs of plants; and in the natural method ranking under the 49th order, *Compoſitæ*. The receptacle is paleaceous; there is no pappus; the calyx is calyculated; there is no radius of the corolla. The female florets are wrapped in the ſcales of the calyx. There are two ſpecies, the ſupinus and erectus; but only the former is ever cultivated in gardens. It is an annual plant, growing naturally in Portugal, in places near the ſea. The root ſends out ſeveral trailing ſtalks, about ſix or eight inches long, which are garniſhed with ſmall, oval, ſilvery leaves, whoſe baſes embrace the ſtalks. The flowers come out in cluſters from the wings of the ſtalks, and are very ſmall, and of a white colour. It flowers in June and July; and is frequently preſerved in gardens on account of the beauty of its ſilvery leaves. It is eaſily propagated by ſeed ſown in autumn, and requires no other culture but to be kept free from weeds.

MICROSCOPE, an optical inſtrument, conſiſting of lenſes, or mirrors, by means of which ſmall objects appear larger than they do to the naked eye. *Single* microſcopes conſiſt of a ſingle lens or mirror; or if more lenſes or mirrors be made uſe of, they only ſerve to throw light upon the object, but do not contribute to enlarge the image of it. *Double* or *compound* microſcopes are thoſe in which the image of an object is compoſed by means of more lenſes or mirrors than one.

For the principles on which the conſtruction of microſcopes depends, ſee OPTICS. In the preſent article, it is intended to deſcribe the finiſhed inſtrument, with all its varied apparatus, according to the lateſt improvements; and to illuſtrate by proper details its uſes and importance.

I. *Of* SINGLE *Microſcopes.*

THE famous microſcopes made uſe of by Mr Leewenhoeck, were all, as Mr Baker aſſures us, of the ſingle kind, and the conſtruction of them was the moſt ſimple poſſible; each conſiſting only of a ſingle lens ſet between two plates of ſilver, perforated with a ſmall hole, with a moveable pin before it to place the object on and adjuſt it to the eye of the beholder. He informs us alſo, that *lenſes* only, and not *globules*, were uſed in every one of theſe microſcopes.

Plate CCXCVII. fig. 1.

1. The ſingle microſcope now moſt generally known and uſed is that called *Wilſon's Pocket Microſcope*. The body is made of braſs, ivory, or ſilver, and is repreſented by AA, BB. CC is a long fine-threaded male ſcrew that turns into the body of the microſcope; D a convex glaſs at the end of the ſcrew. Two concave round pieces of thin braſs, with holes of different diameters in the middle of them, are placed to cover the abovementioned glaſs, and thereby diminiſh the aperture when the greateſt magnifiers are employed. EE, three thin plates of braſs within the body of the microſcope; one of which is bent ſemicircularly in the middle, ſo as to form an arched cavity for the reception of a tube of glaſs, the uſe of the other two being to receive and hold the ſliders between them. F, a piece of wood or ivory, arched in the manner of the ſemicircular plate, and cemented to it. G, the other end of the body of the microſcope, where a hollow female ſcrew is adapted to receive the different magnifiers. H, is a ſpiral ſpring of ſteel, between the end G and the plates of braſs, intended to keep the plates in a right poſition and counteract the long ſcrew CC. I, is a ſmall turned handle, for the better holding of the inſtrument, to ſcrew on or off at pleaſure. Microſcope

To this microſcope belong ſix or ſeven magnifying glaſſes: ſix of them are ſet in ſilver, braſs, or ivory, as in the figure K; and marked 1, 2, 3, 4, 5, 6, the loweſt numbers being the greateſt magnifiers. L is the ſeventh magnifier, ſet in the manner of a little barrel, to be held in the hand for the viewing of any larger object. M, is a flat ſlip of ivory, called a *ſlider*, with four round holes through it, wherein to place objects between two pieces of glaſs or Muſcovy talc, as they appear at *d d d d*. Six ſuch 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 collection, may have as many as he deſires. The braſs ſlider is to confine any ſmall object, that it may be viewed without cruſhing or deſtroying it. N, is a tube of glaſs contrived to confine living objects, ſuch as frogs, fiſhes, &c. in order to diſcover the circulation of the blood. All theſe are contained in a little neat box of fiſh-ſkin or mahogany, very convenient for carrying in the pocket.

When an object is to be viewed, thruſt the ivory ſlider, in which the ſaid object is placed, between the two flat braſs plates EE: obſerving always to put that ſide of the ſlider where the braſs rings are fartheſt from the eye. Then ſcrew on 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 CC, till your object be brought to ſuit your eye; which will be known by its appearing perfectly diſtinct and clear. It is moſt proper to look at it firſt through a magnifier that can ſhow the whole at once, and afterwards to inſpect the ſeveral parts more particularly with one of the greateſt magnifiers; for thus you will gain a true idea of the whole, and of all its parts. And though the greateſt magnifiers can ſhow 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 which contains the object, the eye will gradually examine it all over.

As objects muſt be brought very near the glaſſes when the greateſt magnifiers are made uſe of, be careful not to ſcratch them by rubbing the ſlider againſt them as you move it in or out. A few turns of the ſcrew CC will eaſily prevent this miſchief, by giving them room enough. You may change the objects in your ſliders for any others you think proper, by taking out the braſs rings with the point of a penknife; the talcs will then fall out, if you but turn the ſliders;

Microſcope

and after putting what you pleaſe between them, by replacing the braſs rings you will faſten them as they were before. It is proper to have ſome ſliders furniſhed with talcs, but without any object between them, to be always in readineſs for the examination of fluids, ſalts, ſands, powders, the farina of flowers, or any other caſual objects of ſuch ſort as need only be applied to the outſide of the talc.

The circulation of the blood may be eaſieſt ſeen in the tails or fins of fiſhes, in the fine membranes between a frog's toes, or beſt of all in the tail of a water-newt. If your object be a ſmall fiſh, place it within the tube N, and ſpread its tail or fin along the ſide thereof: if a frog, chooſe ſuch an one as can but juſt be got into your tube; and, with a pen, or ſmall ſtick, expand the tranſparent membrane between the toes of the frog's hind foot as much as you can. When your object is ſo adjuſted that no part of it can intercept the light from the place you intend to view, unſcrew the long ſcrew CC, and thruſt your tube into the arched cavity, quite through the body of the microſcope; then ſcrew it to the true focal diſtance, and you will ſee the blood paſſing along its veſſels with a rapid motion, and in a moſt ſurpriſing manner.

The third or fourth magnifiers may be uſed for frogs or fiſhes: but for the tails of water-newts, the fifth or ſixth will do; becauſe the globules of their blood are twice as large as thoſe of frogs or fiſh. The firſt or ſecond magnifier cannot well be employed for this purpoſe; becauſe the thickneſs of the tube in which the object lies, will ſcarce admit its being brought ſo near as the focal diſtance of the magnifier.

An apparatus for the purpoſe of viewing opaque objects generally accompanies this microſcope; and which conſiſts of the following parts. A braſs arm QR, which is ſcrewed at Q, upon the body of the microſcope at G. Into the round hole R, any of the magnifiers ſuitable to the object to be viewed are to be ſcrewed; and under it, in the ſame ring, the concave poliſhed ſilver ſpeculum S. Through a ſmall aperture in the body of the microſcope under the braſs plates EE, is to ſlide the long wire with the forceps T: This wire is pointed at one of its ends; and ſo, that either the points or forceps may be uſed for the objects as may be neceſſary. It is eaſy to conceive, therefore, that the arm at R, which turns by a twofold joint at *a* and *b*, may be brought with its magnifier over the object, the light reflected upon it by the application of the ſpeculum, and the true focus obtained by turning of the male ſcrew CC as before directed.—As objects are ſometimes not well fixed for view, either by the forceps or point, the ſmall piece ſhown at N is added, and in ſuch caſes anſwers better: it ſcrews over the point of T; it contains a ſmall round piece of ivory, blackened on one ſide, and left white upon the other as a contraſt to coloured objects, and by a ſmall piece of watch-ſpring faſtens down the objects upon the ivory.

2. *Single Microſcope by reflection.* In fig. 2. A is a ſcroll of braſs fixed upright upon a round wooden baſe B, or mahogany drawer or caſe, ſo as to ſtand perfectly firm and ſteady. C is a braſs ſcrew, that paſſes through a hole in the upper limb of the ſcroll into the ſide of the microſcope D, and ſcrews it faſt to the ſaid ſcroll. E is a concave ſpeculum ſet in a box of braſs, which hangs in the arch G by two ſmall ſcrews *f f*, that ſcrew into the oppoſite ſides thereof. At the bottom of this arch is a pin of the ſame metal, exactly fitted to a hole *h* in the wooden pedeſtal, made for the reception of the pin. As the arch turns on this pin, and the ſpeculum turns on the end of the arch, it may, by this twofold motion, be eaſily adjuſted in ſuch a manner as to reflect the light of the ſun, of the ſky, or of a candle, directly upwards through the microſcope that is fixed perpendicularly over it; and by ſo doing may be made to anſwer many purpoſes of the large double reflecting microſcope. The body of the microſcope may alſo be fixed horizontally, and objects viewed in that poſition by any light you chooſe; which is an advantage the common double reflecting microſcope has not. It may alſo be rendered further uſeful by means of a ſlip of glaſs; one end of which being thruſt through between the plates where the ſliders go, and the other extending to ſome diſtance, ſuch objects may be placed thereon as cannot be applied in the ſliders: and then, having a limb of braſs that may faſten to the body of the microſcope, and extend over the projecting glaſs a hollow ring wherein to ſcrew the magnifiers, all ſorts of ſubjects may be examined with great convenience, if a hole be made in the pedeſtal, to place the ſpeculum exactly underneath, and thereby throw up the rays of light. The pocket-microſcope, thus mounted, ſays Mr Baker, "is as eaſy and pleaſant in its uſe; as fit for the moſt curious examination of the animalcules and ſalts in fluids, of the farinæ in vegetables, and of the circulation in ſmall animals; in ſhort, is as likely to make conſiderable diſcoveries in objects that have ſome degree of tranſparency, as any microſcope I have ever ſeen or heard of."

The braſs ſcroll A is now generally made to unſcrew into three parts, and pack with the microſcope and apparatus into the drawer of a mahogany pocket-caſe, upon the lid of which the ſcroll is made to fix when in uſe.

The opaque apparatus alſo, as above deſcribed, is applicable this way by reflection. It only conſiſts in turning the arm R (fig. 1.), with the magnifier over the concave ſpeculum below (fig. 2), or to receive the light as reflected obliquely from it: the ſilver ſpeculum ſcrewed into R will then reflect the light, which it receives from the glaſs ſpeculum, ſtrongly upon the object that is applied upon the wire T underneath.

This microſcope, however, is not upon the moſt convenient conſtruction, in compariſon with others now made: it has been eſteemed for many years paſt from its popular name, and recommendation by its makers. Its portability is certainly a great advantage in its favour; but in moſt reſpects it is ſuperſeded by the microſcopes hereafter deſcribed.

3. *Microſcope for Opaque Objects, called the Single Opaque Microſcope.* Fig. 3. This microſcope remedies the inconvenience of having the dark ſide of an object next the eye, which formerly was an unſurmountable objection to the making obſervations on opaque objects with any conſiderable degree of exactneſs or ſatisfaction: for, in all other contrivances commonly known, the nearneſs of the inſtrument to the object (when glaſſes that magnify much are uſed) unavoidably overſhadows it ſo much, that its appearance is rendered obſcure and indiſtinct. And, notwithſtanding ways have

Microſcope have been tried to point light upon an object, from the ſun or a candle, by a convex glaſs placed on the ſide thereof, the rays from either can be thrown upon it in ſuch an acute angle only, that they ſerve to give a confuſed glare, but are inſufficient to afford a clear and perfect view of the object. But this microſcope, by means of a concave ſpeculum of ſilver highly poliſhed, in whoſe centre a magnifying lens is placed, ſuch a ſtrong and direct light is reflected upon the object, that it may be examined with all imaginable eaſe and pleaſure. The ſeveral parts of this inſtrument, made either of braſs or ſilver, are as follow.

Through the firſt ſide A, paſſes a fine ſcrew B, the other end of which is faſtened to the moveable ſide C. D is a nut applied to this ſcrew, by the turning of which the two ſides A and C are gradually brought together. E is a ſpring of ſteel that ſeparates the two ſides when the nut is unſcrewed. F is a piece of braſs, turning round in a ſocket, whence proceeds a ſmall ſpring tube moving upon a rivet; through which tube there runs a ſteel wire, one end whereof terminates in a ſharp point G, and the other with a pair of pliers H faſtened to it. The point and plyers are to thruſt into, or take up and hold, any inſect or object; and either of them may be turned upwards, as beſt ſuits the purpoſe. I is a ring of braſs, with a female ſcrew within it, mounted on an upright piece of the ſame metal; which turns round on a rivet, that it may be ſet at a due diſtance when the leaſt magnifiers are employed. This ring receives the ſcrews of all the magnifiers. K is a concave ſpeculum of ſilver, poliſhed as bright as poſſible; in the centre of which is placed a double convex lens, 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, to ſcrew into it at pleaſure. There are four of theſe concave ſpecula of different depths, adapted to four glaſſes of different magnifying powers, to be uſed as the objects to be examined may require. The greateſt magnifiers have the leaſt apertures. M, is a round object-plate, one ſide of which is white and the other black: The intention of this is to render objects the more viſible, by placing them, if black, on the white ſide, or, if white, on the black ſide. A ſteel ſpring N turns down on each ſide to make any object faſt; and iſſuing from the object-plate is a hollow pipe to ſcrew it on the needle's point G. O, is a ſmall box of braſs, with a glaſs on each ſide, contrived to confine any living object, in order to examine it: this alſo has a pipe to ſcrew upon the end of the needle G. P, is a turned handle of wood, to ſcrew into the inſtrument when it is made uſe of. Q, a pair of braſs pliers to take up any object, or manage it with conveniency. R, is a ſoft hair-bruſh for cleaning the glaſſes, &c. S, is a ſmall ivory box for tales, to be placed, when wanted, in the ſmall braſs-box O.

When you would view any object with this microſcope, ſcrew the ſpeculum, with the magnifier you think proper to uſe, into the braſs ring I. Place your object, either on the needle G in the pliers H, on the object-plate M, or in the hollow braſs box O, as may be moſt convenient: 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 removed farther from it, till you find the true focal diſtance, and the light be ſeen ſtrongly reflected from the ſpeculum upon the object, by which means it will be ſhown in a manner ſurpriſingly diſtinct and clear; and for this purpoſe the light of the ſky or of a candle will anſwer very well. Tranſparent objects may alſo be viewed by this microſcope; only obſerving, that when ſuch come under examination, it will not always be proper to throw on them the light reflected from the ſpeculum; for the light tranſmitted through them, meeting the reflected light, may together produce too great a glare. A little practice, however, will ſhow how to regulate both lights in a proper manner. Microſcope

4. *Ellis's ſingle and Aquatic Microſcope.* Fig. 4. repreſents a very convenient and uſeful microſcope, contrived by Mr John Ellis, author of An Eſſay upon Corallines, &c. To practical botaniſts, obſervers of animalcula, &c. it poſſeſſes many advantages above thoſe juſt deſcribed. It is portable, ſimple in its conſtruction, expeditious, and commodious in uſe. K, repreſents the box containing the whole apparatus: it is generally made of fiſh-ſkin; and on the top there is a female ſcrew, for receiving the ſcrew that is at the bottom of the pillar A: this is a pillar of braſs, and is ſcrewed on the top of the box. D, is a braſs pin which fits into the pillar; on the top of this pin is a hollow ſocket to receive the arm which carries the magnifiers; the pin is to be moved up and down, in order to adjuſt the lenſes to their focal or proper diſtance from the object. [N. B. In the repreſentations of this microſcope, the pin D is delineated as paſſing through a ſocket at one ſide of the pillar A; whereas it is uſual at preſent to make it paſs down a hole bored through the middle of the pillar.] E, the bar which carries the magnifying lens; it fits into the ſocket X, which is at the top of the pin or pillar D. This arm may be moved backwards and forwards in the ſocket X, and ſideways by the pin D; ſo that the magnifier, which is ſcrewed into the ring at the end E of this bar, may be eaſily made to traverſe over any part of the object that lies on the ſtage or plate B. FF is a poliſhed ſilver ſpeculum, with a magnifying lens placed at the centre thereof, which is perforated for this purpoſe. The ſilver ſpeculum ſcrews into the arm E, as at F. G, another ſpeculum, with its lens, which is of a different magnifying power from the former. H, the ſemicircle which ſupports the mirror I; the pin R, affixed to the ſemicircle H, paſſes thro' the hole which is towards the bottom of the pillar A. B, the ſtage, or the plane, on which the objects are to be placed; it fits into the ſmall dove-tailed arm which is at the upper end of the pillar DA. C, a plane glaſs, with a ſmall piece of black ſilk ſtuck on it; this glaſs is to lay in a groove made in the ſtage B. M, a hollow glaſs to be laid occaſionally on the ſtage inſtead of the plane glaſs C. L, a pair of nippers. Theſe are fixed to the ſtage by the pin at bottom; the ſteel wire of theſe nippers ſlides backwards and forwards in the ſocket, and this ſocket is moveable upwards and downwards by means of the joint, ſo that the poſition of the object may be varied at pleaſure. The object may be fixed in the nippers, ſtuck on the point, or affixed, by a little gum-water, &c. to the

Microſcope

ivory cylinder N, which occaſionally ſcrews to the point of the nippers.

To *uſe* this microſcope: Take all the parts of the apparatus out of the box; then begin by ſcrewing the pillar A to the cover thereof; paſs the pin R of the ſemicircle which carries the mirror thro' the hole that is near the bottom of the pillar A; puſh the ſtage into the dove-tail at B, ſlide the pin into the pillar (ſee the N. B. above); then paſs the bar E through the ſocket which is at the top of the pin D, and ſcrew one of the magnifying lenſes into the ring at F. The microſcope is now ready for uſe: and though the enumeration of the articles may lead the reader to imagine the inſtrument to be of a complex nature, we can ſafely affirm that he will find it otherwiſe. The inſtrument has this peculiar advantage, that it is difficult to put any of the pieces in a place which is appropriated to another. Let the object be now placed either on the ſtage or in the nippers L, and in ſuch manner that it may be as nearly as poſſible over the centre of the ſtage: bring the ſpeculum F over the part you mean to obſerve; then throw as much light on the ſpeculum as you can, by means of the mirror I, and the double motion of which it is capable; the light received on the ſpeculum is reflected by it on the object. The diſtance of the lens F from the object is regulated by moving the pin D up and down, until a diſtinct view of it is obtained. The beſt rule is, to place the lens beyond its focal diſtance from the object, and then gradually to ſlide it down till the object appears ſharp and well defined. The adjuſtment of the lenſes to their focus, and the diſtribution of the light on the object, are what require the moſt attention: on the firſt the diſtinctneſs of the viſion depends; the pleaſure ariſing from a clear view of the parts under obſervation is due to the modification of the light. No preciſe rule can be given for attaining accurately theſe points; it is from practice alone that ready habits of obtaining theſe neceſſary properties can be acquired, and with the aſſiſtance of this no difficulty will be found.

5. A very ſimple and convenient microſcope for botanical and other purpoſes, though inferior in many reſpects to that of Mr Ellis, was contrived by the late ingenious Mr Benjamin Martin, and is repreſented at fig. 5. where AB repreſents a ſmall arm ſupporting two or more magnifiers, one fixed to the upper part as at B, the other to the lower part of the arm at C; theſe may be uſed ſeparately or combined together. The arm AB is ſupported by the ſquare pillar IK, the lower end of which fits into the ſocket E of the foot FG; the ſtage DL is made to ſlide up and down the ſquare pillar; H, a concave mirror for reflecting light on the object.—To *uſe* this microſcope, place the object on the ſtage, reflect the light on it from the concave mirror, and regulate it to the focus, by moving the ſtage nearer to or farther from the lens at B. The ivory ſliders paſs through the ſtage; other objects may be fixed in the nippers MN, and then brought under the eye-glaſſes; or they may be laid on one of the glaſſes which fit the ſtage. The apparatus to this inſtrument conſiſts of three ivory ſliders; a pair of nippers; a pair of forceps; a flat glaſs and a concave ditto, both fitted to the ſtage.

The two laſt microſcopes are frequently fitted up with a toothed rack and pinion, for the more ready adjuſtment of the glaſſes to their proper focus. Microſcope

6. *Withering's portable Botanic Microſcope.* Fig. 6. repreſents a ſmall botanical microſcope contrived by Dr Withering, and deſcribed by him in his *Botanical Arrangements*. It conſiſts of three braſs plates, A, B, C, which are parallel to each other; the wires D and E are rivetted into the upper and lower plates, which are by this means united to each other; the middle plate or ſtage is moveable on the aforeſaid wires by two little ſockets which are fixed to it. The two upper plates each contain a magnifying lens, but of different powers; one of theſe confines and keeps in their places the fine point F, the forceps G, and the ſmall knife H.—To *uſe* this inſtrument, unſcrew the upper lens, and take out the point, the knife, and the forceps; then ſcrew the lens on again, place the object on the ſtage, and then move it up or down till you have gained a diſtinct view of the object, as one lens is made of a ſhorter focus than the other; and ſpare lenſes of a ſtill deeper focus may be had if required. This little microſcope is the moſt portable of any. Its principal merit is its ſimplicity.

7. *Botanical Lenſes or Magnifiers.* The haſte with which botaniſts, &c. have frequently occaſion to view objects, renders an extempore pocket-glaſs indiſpenſably neceſſary. The moſt convenient of any yet conſtructed, appears to be that contrived, in regard to the form of the mounting, by the late Mr Benjamin Martin; and is what he called a *Hand Megalaſcope*, becauſe it is well adapted for viewing all the larger ſort of ſmall objects univerſally, and by only three lenſes it has ſeven different magnifying powers.

Fig. 7. repreſents the caſe with the three frames and lenſes, which are uſually of 1, 1½, and 2 inches focus: they all turn over each other, and ſhut into the caſe, and are turned out at pleaſure.

The three lenſes ſingly, afford three magnifying powers; and by combining two and two, we make three more: for *d* with *e* makes one, *d* with *f* another, and *e* with *f* a third; which, with the three ſingly, make ſix; and laſtly, all three combined together make another; ſo that upon the whole, there are ſeven powers of magnifying with theſe glaſſes only.

When the three lenſes are combined, it is better to turn them in, and look through them by the ſmall apertures in the ſides of the caſe. The eye in this caſe is excluded from extra light; the aberration of the ſuperfluous rays through the glaſſes is cut off; and the eye coincides more exactly with the common axes of the lenſes.

A very uſeful and eaſy kind of microſcope (deſcribed by Joblot, and which has been long in uſe), adapted chiefly for viewing, and confining at the ſame time, any living inſects, ſmall animals, &c. is ſhown at fig. 8. where A repreſents a glaſs tube, about 1¾ inches diameter, and 2 inches high. B, a caſe of braſs or wood, containing a ſliding tube, with two or three magnifying glaſſes that may be uſed either ſeparately or combined. In the inſide, at the bottom, is a piece of ivory, black and white on oppoſite ſides, that is occaſionally removed, and admits a point to be ſcrewed into the centre. The cap unſcrews at D, to admit the placing of the object: the proper diſtance of the glaſſes from Plate CCXCVIII

MICROSCOPE.

Fig. 8.

Fig. 9.

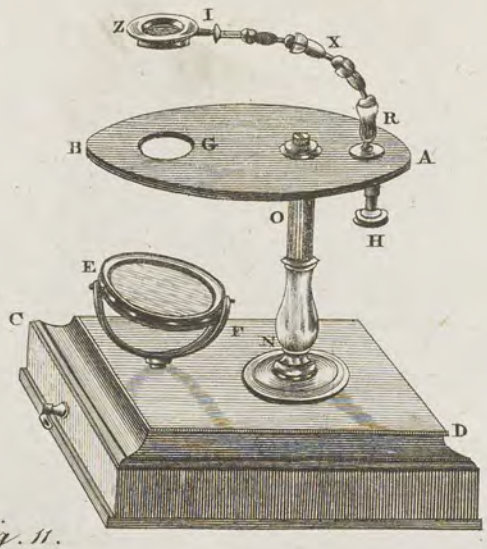


Fig. 10

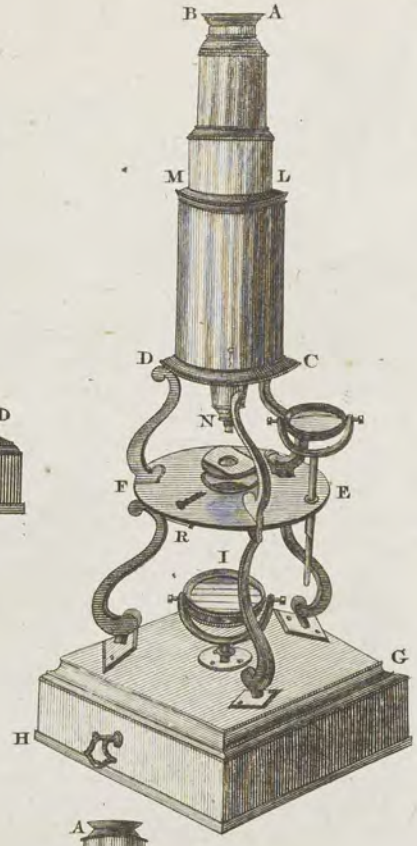


Fig. 11.

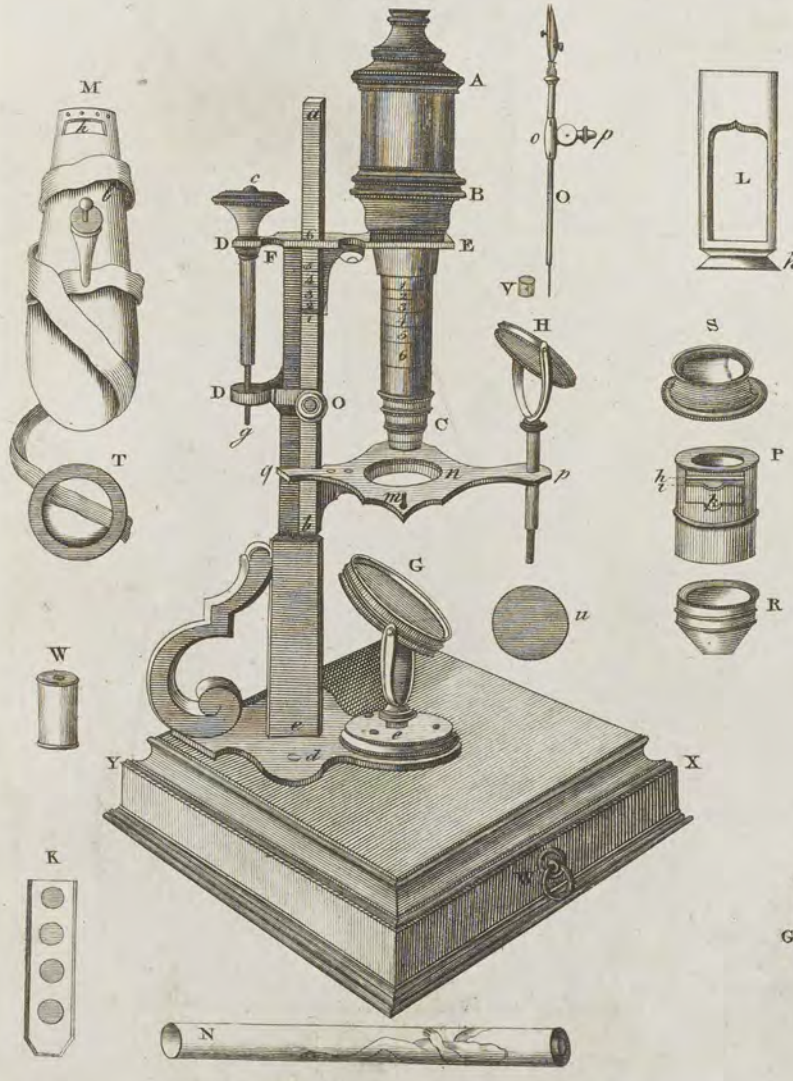
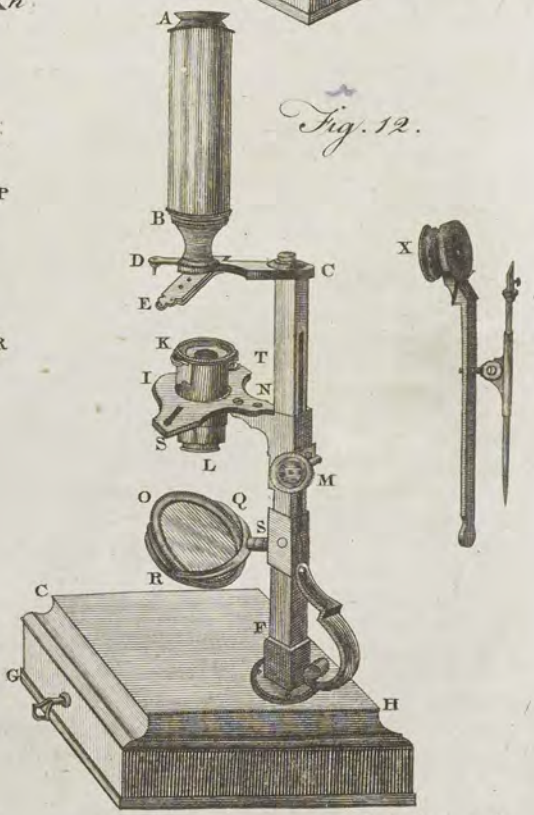


Fig. 12.



A. Bell Prin. Wal. Sculptor fecit.

Microſcope from the object is regulated by pulling up or down the braſs tube E at top containing the eye-glaſſes.

This microſcope is particularly uſeful for exhibiting the well-known curious *curculio imperialis*, vulgarly called the *diamond beetle*, to the greateſt advantage; for which, as well as for other objects, a glaſs bottom, and a poliſhed reflector at the top, are often applied, to condenſe the light upon the object. In this caſe, the ſtand and braſs-bottom F, as ſhown in the figure, are taken away by unſcrewing.

9. *Mr Lyonet's Single Anatomical Diſſecting Microſcope.* Fig. 9. repreſents a curious and extremely uſeful microſcope, invented by that gentleman for the purpoſe of minute diſſections, and microſcopic preparations. This inſtrument muſt be truly uſeful to amateurs of the minutiæ of inſects, &c. being the beſt adapted of any for the purpoſes of diſſection. With this inſtrument Mr Lyonet made his very curious microſcopical diſſection of the *chenille de ſaule*, as related in his *Traitè Anatomique de la chenille qui ronge le bois de ſaule*, 4to.

AB is the anatomical table, which is ſupported by a pillar NO; this is ſcrewed on the foot CD. The table AB is prevented from turning round by means of two ſteady pins. In this table or board there is a hole G, which is exactly over the centre of the mirror EF, that is to reflect the light on the object; the hole G is deſigned to receive a flat or concave glaſs, on which the objects for examination are to be placed.

RXZ is an arm formed of ſeveral balls and ſockets, by which means it may be moved in every poſſible ſituation; it is fixed to the board by means of the ſcrew H. The laſt arm IZ has a female ſcrew, into which a magnifier may be ſcrewed as at Z. By means of the ſcrew H, a ſmall motion may be occaſionally given to the arm IZ, for adjuſting the lens with accuracy to its focal diſtance from the object.

Another chain of balls is ſometimes uſed, carrying a lens to throw light upon the object; the mirror is likewiſe ſo mounted, as to be taken from its place at K, and fitted on a clamp, by which it may be fixed to any part of the table AB.

To uſe the Diſſecting Table:—Let the operator ſit with his left ſide near a light window; the inſtrument being placed on a firm table, the ſide DH towards the ſtomach, the obſervations ſhould be made with the left eye. In diſſecting, the two elbows are to be ſupported by the table on which the inſtrument reſts, the hands reſting againſt the board AB; and in order to give it greater ſtability (as a ſmall ſhake, though imperceptible to the naked eye, is very viſible in the microſcope), the diſſecting inſtruments are to be held one in each hand, between the thumb and two forefingers.

II. *Of* Double *Microſcopes, commonly called* Compound *Microſcopes.*

Double microſcopes are ſo called, from being a combination of two or more lenſes.

The particular and chief advantages which the compound microſcopes have over the ſingle, are, that the objects are repreſented under a larger field of view, and with a greater amplification of reflected light.

1. *Culpeper's Microſcope.* The compound microſcope, originally contrived by Mr Culpeper, is repreſented at fig. 10. It conſiſts of a large external braſs body A, Microſcope B, C, D, ſupported upon three ſcrolls, which are fixed to the ſtage EF; the ſtage is ſupported by three larger ſcrolls, that are ſcrewed to the mahogany pedeſtal GH. There is a drawer in the pedeſtal, which holds the apparatus. The concave mirror *I* is fitted to a ſocket in the centre of the pedeſtal. The lower part LMCD of the body forms an exterior tube, into which the upper part of the body ABLM ſlides, and may be moved up or down, ſo as to bring the magnifiers, which are ſcrewed on at N, nearer to or farther from the object.

To *uſe* this microſcope: Screw one of the buttons, which contains a magnifying lens, to the end N of the body; place the ſlider, with the objects, between the plates of the ſlider-holder. Then, to attain diſtinct viſion, and a pleaſing view of the object, adjuſt the body to the focus of the lens you are uſing, by moving the upper part gently up and down, and regulate the light by the concave mirror.

For opaque objects, two additional pieces muſt be uſed. The firſt is a cylindrical tube of braſs (repreſented at L, fig. 11.), which fits on the cylindrical part at N of the body. The ſecond piece is the concave ſpeculum *b*; this is to be ſcrewed to the lower end of the aforeſaid tube: the upper edge of this tube ſhould be made to coincide with the line which has the ſame number affixed to it as to the magnifier you are uſing; *ex. gr.* if you are making uſe of the magnifier marked 5, ſlide the tube to the circular line on the tube N that is marked alſo with N°5. The ſlider-holder ſhould be removed when you are going to view opaque objects, and a plane glaſs ſhould be placed on the ſtage in its ſtead to receive the object; or it may be placed in the nippers, the pin of which fits into the hole in the ſtage.

The apparatus belonging to this microſcope conſiſts of the following particulars; *viz.* Five magnifiers, each fitted in a braſs button; one of theſe is ſeen at N, fig. 10. Six ivory ſliders, five of them with objects. A braſs tube, to hold the concave ſpeculum. The concave ſpeculum in a braſs box. A fiſh pan. A ſet of glaſs tubes. A flat glaſs fitted to the ſtage. A concave glaſs fitted to the ſtage. A pair of forceps. A ſteel wire, with a pair of nippers at one end and a point at the other. A ſmall ivory cylinder, to fit on the pointed end of the aforeſaid nippers. A convex lens, moveable in a braſs ſemicircle; this is affixed to a long braſs pin, which fits into a hole on the ſtage.

The conſtruction of the foregoing microſcope is very ſimple, and it is eaſy in uſe; but the advantages of the ſtage and mirror are too much confined for an extenſive application and management of all kinds of objects. Its greateſt recommendation is its cheapneſs; and to thoſe who are deſirous of having a compound microſcope at a low price, it may be acceptable.

2. *Cuff's Microſcope.* The improved microſcope next in order is that of Mr Cuff. Beſides remedying the diſadvantages above mentioned, it contains the addition of an adjuſting ſcrew, which is a conſiderable improvement, and highly neceſſary to the examination of objects under the beſt defined appearance from the glaſſes. It is repreſented at fig. 11. with the apparatus that uſually accompanies it. A, B, C, ſhows the body of this microſcope; which contains an eye-glaſs at A, a broad lens at B, and

Microſcope

a magnifier which is ſcrewed on at C. The body is ſupported by the arm D E, from which it may be removed at pleaſure. The arm D E is fixed on the ſliding-bar F, and may be raiſed or depreſſed to any height within its limits. The main pillar *a b* is fixed in the box *b e;* and by means of the braſs foot *d* is ſcrewed to the mahogany pedeſtal X Y, in which is a drawer containing all the apparatus. O, is a milled-headed ſcrew, to tighten the bar F when the adjuſting ſcrew *c g* is uſed. *p q* Is the ſtage, or plate, which carries the objects; it has a hole at the centre *n*. G a concave mirror, that may be turned in any direction, to reflect the light of a candle, or the ſky, upon the object.

To *uſe* this microſcope: Screw the magnifier you intend to uſe to the end C of the body, place the ſlider-holder P in the hole *n*, and the ſlider with the object between the plates of the ſlider-holder; ſet the upper edge of the bar D E to coincide with the diviſions which correſpond to the magnifier you have in uſe, and pinch it by the milled nut; now reflect a proper quantity of light upon the object, by means of the concave mirror G, and regulate the body exactly to the eye and the focus of the glaſſes by the adjuſting ſcrew *c g*.

To view *opaque* objects, take away the ſlider-holder P, and place the object on a flat glaſs under the centre of the body, or on one end of the jointed nippers *o p*. Then ſcrew the ſilver concave ſpeculum *b* to the end of the cylinder L, and ſlide this cylinder on the lower part of the body, ſo that the upper edge thereof may coincide with the line which has the ſame mark with the magnifier that is then uſed; reflect the light from the concave mirror G to the ſilver ſpeculum, from which it will again be reflected on the object. The glaſſes are to be adjuſted to their focal diſtance as before directed.

The *apparatus* conſiſts of a convex lens H, to collect the rays of light from the ſun or a candle, and condenſe them on the object. L a cylindrical tube, open at each ſide, with a concave ſpeculum ſcrewed to the lower end *b*. P the ſlider-holder: this conſiſts of a cylindrical tube, in which an inner tube is forced upwards by a ſpiral ſpring; it is uſed to receive an ivory ſlider K, which is to be ſlid between the plates *b* and *i*. The cylinder P fits the hole *n* in the ſtage; and the hollow part at *k* is deſigned to receive a glaſs tube. R is a braſs cone, to be put under the bottom of the cylinder P, to intercept occaſionally ſome of the rays of light. S a box containing a concave and a flat glaſs, between which a ſmall living inſect may be confined: it is to be placed over the hole *n*. T a flat glaſs, to lay any occaſional object upon; there is alſo a concave one for fluids. O is a long ſteel wire, with a ſmall pair of pliers at one end, and a point at the other, deſigned to ſtick or hold objects; it ſlips backwards and forwards in the ſhort tube *o;* the pin *p* fits into the hole of the ſtage. W a little round ivory box, to hold a ſupply of talc and rings for the ſliders. V a ſmall ivory cylinder, that fits on the pointed end of the ſteel wire: it is deſigned for opaque objects. Light-coloured ones are to be ſtuck upon the dark ſide, and *vice verſa*. M a fiſh-pan, whereon to faſten a ſmall fiſh, to view the circulation of the blood: the tail is to be ſpread acroſs the oblong hole *k* at the ſmall end, and tied faſt, by means of a rib-band fixed thereto; the knob *l* is to be ſhoved through the ſlit made in the ſtage, that the tail may be brought under the magnifier. Microſcope

3. This microſcope has received ſeveral material improvements from Mr Martin, Mr Adams, &c. By an alteration, or rather an enlargement, of the body of the tube which contains the eye-glaſſes, and alſo of the eye-glaſſes themſelves, the field of view is made much larger, the mirror below for reflecting light is made to move upon the ſame bar with the ſtage; by which means the diſtance of it from the ſtage may be very eaſily and ſuitably varied. A condenſing glaſs is applied under the ſtage in the ſlider-holder, in order to modify and increaſe the light that is reflected by the mirrors below from the light of a candle or lamp. It is furniſhed alſo with two mirrors in one frame, one concave and the other plane, of glaſs ſilvered; and by ſimply unſcrewing the body, the inſtrument, when deſired, may be converted into a ſingle microſcope. Fig. 12. is a repreſentation of the inſtrument thus improved; and the following is the deſcription of it, as given by Mr Adams in his Eſſays.

A B repreſents the body of the microſcope, containing a double eye-glaſs and a body-glaſs: it is here ſhown as ſcrewed to the arm C D, from whence it may be occaſionally removed, either for the convenience of packing, or when the inſtrument is to be uſed as a ſingle microſcope.

The eye glaſſes and the body glaſſes are contained in a tube which fits into the exterior tube A B; by pulling out a little this tube when the microſcope is in uſe, the magnifying power of each lens is increaſed.

The body A B of the microſcope is ſupported by the arm C D; this arm is fixed to the main pillar C F, which is ſcrewed firmly to the mahogany pedeſtal G H; there is a drawer to this pedeſtal, which holds the apparatus.

N I S, The plate or ſtage which carries the ſlider-holder K L: this ſtage is moved up or down the pillar C F, by turning the milled nut M; this nut is fixed to a pinion, that works in a toothed rack cut on one ſide of the pillar. By means of this pinion, the ſtage may be gradually raiſed or depreſſed, and the object adjuſted to the focus of the different lenſes.

K L is a ſlider-holder, which fits into a hole that is in the middle of the ſtage N I S; it is uſed to confine and guide either the motion of the ſliders which contain the objects, or the glaſs tubes that are deſigned to confine ſmall fiſhes for viewing the circulation of the blood. The ſliders are to be paſſed between the two upper plates, the tubes through the bent plates.

L is a braſs tube, to the upper part of which is fixed the condenſing lens before ſpoken of; it fits into the under part of the ſlider-holder K L, and may be ſet at different diſtances from the object, according to its diſtance from the mirror or the candle.

O is the frame which holds the two reflecting mirrors, one of which is plane, the other concave. Theſe mirrors may be moved in various directions, in order to reflect the light properly, by means of the pivots on which they move, in the ſemicircle Q S R, and the motion of the ſemicircle itſelf on the pin S: the concave mirror generally anſwers beſt in the day-time; the plane mirror combines better with the condenſing

Microſcope

lens, and a lamp or candle. At D there is a ſocket for receiving the pin of the arm Q (fig. 31.), to which the concave ſpeculum, for reflecting light on opaque objects, is fixed. At S is a hole and ſlit for receiving either the nippers L (fig. 31. Pl. ccci.) or the fiſh-pan I; when theſe are uſed, the ſlider-holder muſt be removed. T, a hole to receive the pin of the convex lens M, fig. 31.

To *uſe* this microſcope: Take it out of the box. Screw the body into the round end of the upper part of the arm C D. Place the braſs ſliders, which contain the magnifiers, into the dove-tailed ſlit which is on the under ſide of the aforeſaid arm, as ſeen at E, and ſlide it forwards until the magnifier you mean to uſe is under the centre of the body: oppoſite to each magnifier in this ſlit there is a notch, and in the dove-tailed part of the arm C D there is a ſpring, which falls into the above-mentioned notch, and thus makes each magnifier coincide with the centre of the body. Paſs the ivory ſlider you intend to uſe between the upper plates of the ſlider-holder KL, and then reflect as ſtrong a light as you can on the object by means of one of the mirrors; after this, adjuſt the object to the focus of the magnifier and your eye, by turning the milled ſcrew M, the motion of which raiſes and depreſſes the ſtage N I S. The degree of light neceſſary for each object, and the accuracy required in the adjuſtment of the lenſes to their proper focal diſtance from the object will be eaſily attained by a little practice.

When *opaque* objects are to be examined, remove the ſlider-holder, and place the object on a flat glaſs, or fix it to the nippers L, the pin of theſe fit into the hole on the ſtage; ſcrew the concave ſpeculum R into the arm Q (fig. 31.), and then paſs the pin of this arm through the ſocket D, fig. 12. the light is now to be reflected from the concave mirror to the ſilver ſpeculum, and from this down on the object. No exact rule can be given for reflecting the light on the object; we muſt therefore refer the reader to the mother of all aptneſs, practice. The ſpeculum muſt be moved lower or higher, to ſuit the focus of the different magnifiers and the nature of the object.

The foregoing directions apply equally to the uſing of this inſtrument as a *ſingle microſcope;* with this difference only, that the body AB is then removed, and the eye is applied to the upper ſurface of the arm CD, exactly over the magnifiers.

This microſcope is ſometimes made with the following *alterations*, which are ſuppoſed to make it ſtill more convenient and uſeful. The arm CD that carries the body and magnifiers is made both to turn on a pin, and to ſlide backwards and forwards in a ſocket at C; ſo that, inſtead of moving the objects below on the ſtage, and diſturbing them, the magnifiers are more conveniently brought over any part of the objects as deſired. The condenſing glaſs is made larger, and ſlides upon the ſquare bar CF quite diſtinct from the ſtage, like the mirrors below; and it is thereby made uſeful for any other objects that may be applied on glaſſes fitted to the ſtage, as well as thoſe put into the ſlider-holder K. It is thereby not confined to this ſtage alone, as in the preceding. When the body AB is taken away, the arm CD may be ſlipt away from its bar, with the magnifiers, and the forceps, wire, and joint, applied to it; and it thereby ſerves the purpoſe of a ſmall hand ſingle or opaque microſcope, for any object occaſionally applied to this wire. The magnifiers in the ſlider E are mounted in a wheel caſe, which perhaps prevents its being in the way ſo much as the long ſlider E before deſcribed.—This contrivance is repreſented at X, fig. 12.

Microſcope

4. *Martin's New Univerſal Compound Microſcope.*—This inſtrument was originally conſtructed by the late Mr B. Martin, and intended to compriſe all the uſes and advantages of the ſingle, compound, opaque, and aquatic microſcopes. The following is a deſcription of it as now made, with a few alterations, chiefly ſuggeſted (we are told) by Mr Jones of Holborn.

Plate CCXCIX.

Fig. 13. is a repreſentation of the inſtrument placed up for uſe. A, B, C, D, is the body of the microſcope: which conſiſts of four parts, viz. AB the eye-piece, or that containing the eye-glaſſes, and is ſcrewed into C, which is a moveable or ſliding tube on the top; this inner tube contains the body-glaſs ſcrewed into its lower part. D is the exterior tube or caſe, in which the other ſlides up and down in an eaſy and ſteady manner. This motion of the tube C is uſeful to increaſe or decreaſe the magnifying power of the body-glaſs when thought neceſſary, as before mentioned. E is a pipe or ſnout ſcrewed on to the body of the microſcope D, and at its lower part, over the ſeveral magnifying lenſes hereafter deſcribed. FGHI is the ſquare ſtem of the microſcope, upon which the ſtage R moves in an horizontal poſition, upwards or downward, by means of the fine rackwork of teeth and pinion. KL is a ſtrong ſolid joint and pillar, by which the poſition of the inſtrument is readily altered from a vertical one to an oblique or to a perfectly horizontal one, as may be required: it is thus well adapted to the eaſe of the obſerver either ſitting or ſtanding; and as it is very often convenient to view objects by direct unreflected light, when the ſquare ſtem FI is placed in an horizontal poſition for this purpoſe, the mirror T is then to be taken off in order to prevent the obſtruction of the rays. M is a circular piece of braſs, ſerving as a baſe to the pillar. NOP, the tripod or foot by which the whole body of the microſcope is ſteadily ſupported; it folds up when packed into the caſe. W is a braſs frame, that contains the condenſing lens, and acts in conjunction with the large concave and plane mirrors below at T; the reflected rays from which, either of the common light or of that of a candle or lamp, it agreeably modifies, and makes ſteady in the field of view.

The particulars of the apparatus to this microſcope are as follow: Q is a circular braſs box, containing ſix magnifiers or object lenſes, numbered 1, 2, 3, 4, 5, 6; the digits of which appear ſeverally through a ſmall round hole in the upper plate of it. To the upper ſide is fixed a ſmall circle of braſs, by which it is connected with, and ſcrewed into, the round end of the arm *abcd;* which is a long piece of braſs, and moves through either by teeth or pinion, or not, as may be deſired, in *ef;* which is a ſocket on the upper part of the pillar, and admits, with a motion both eaſy and ſteady, the braſs arm. R is a fixed ſtage, upon which the objects to be viewed are to be placed: it is firmly faſtened to the ſquare pillar, which is moved by the rackwork. In the middle is a large circular hole, for

Microſcope

receiving concave glaſſes, with fluids, &c. it has alſo a ſliding ſpring-frame to faſten down ſlips of glaſs or other things: at *a b c* are three ſmall ſockets or holes, intended to receive ſeveral parts of the apparatus. S is the refractor, or illuminating lens, for converging the ſun's rays upon opaque objects laid upon the ſtage R. To this purpoſe it moves on a ſemicircle upon a long ſhank *g*, in a ſpring ſocket *h*, in the arm *i*; this arm moving every way by a ſtout pin *k* in the ſocket *a* of the ſtage. In this manner it is eaſily adjuſted to any poſition of the ſun, candle, &c.—T, the reflecting-glaſs frame, containing a concave and plane ſpeculum, which is moved upon the ſquare pillar by the hand. The uſe of it is to illuminate all tranſparent objects that are applied to the ſtage above.

Fig. 14. n° 1. is an auxiliary moveable ſtage; which by means of a pin *k* is placed in the hole *a* of the ſtage R, and can be moved in an horizontal direction over the whole field of the ſtage. In this ſtage, there are three circular holes with ſhouldered bottoms; a large one in the middle, and on each ſide a ſmall one, for the reception of the three following neceſſary articles: n° 2. a watch-glaſs to be placed in the large hole, to hold fluids containing animalcules, &c.; a circular piece of ivory, n° 3. one ſide of which is black, the other white, to ſupport opaque objects of different contraſted colours; and circular plane and concave glaſſes, n° 4. for extemporaneous tranſparent objects.—The ſame uſe is made of the other ſmall hole as of the large one, only in a leſſer degree, to receive ſmall concave glaſſes, plates, &c.

* Or that adjoining to n° 8. (the n° having been omitted by the engraver).

N° 5.* is the ſilvered ſpeculum, called a *Liberkhun*, which makes the ſingle opaque microſcope, by being ſcrewed to the ſlider *a b c d* (fig. 13.) in room of the box of lenſes Q, and the body AE above it. The chief uſe of this is to view very ſmall objects ſtrongly illuminated near the compounded focus of the mirror T (fig. 13.) N° 6. is the forceps or pliers, for holding ſuch kind of objects, and by which they can be applied very readily to the focus of the lens in the liberkhun. They have a motion all ways by means of the ſpring ſocket *a*, the joint *b*, and the ſhank *c*: they are placed in the ſocket *c* of the fixed ſtage R (fig. 13.) N° 7. is a ſmall piece of ivory, to be placed upon the pointed end of the pliers: it is black upon one ſide, and white upon the other, to receive opaque objects.

N° 8. is a liberkhun of a larger ſize than that firſt mentioned, with a hole in its centre: this is ſcrewed into n° 9. the hole *a* of a braſs ring, faſtened to a long wire *b*; which moves up and down in the ſpring ſocket *b* of the ſtage R, in which it alſo moves ſideways; and thus, with the body AE above, forms an *aquatic compound microſcope* for ſhowing all ſorts of objects in water and other fluids placed under it in the watch-glaſs n° 2. on the ſtage.

N° 11. is a cone, with a proper aperture *a* to exclude ſuperfluous light, that would diſturb a critical obſervation of a curious object; it is placed on the under ſide of the fixed ſtage R.

N° 12. is what is uſually called a bug-box, conſiſting of a concave glaſs with a plane one ſcrewed over it; by means of which a bug, louſe, flea, &c. may be ſecured and viewed alive. It is to be placed on either of the ſtages R (fig. 13.), or n° 1 (fig. 14.) Microſcope

N° 13. is the fiſh-pan. In the long concave body *a b*, a fiſh may be ſo confined by the ribband *c*, that the tranſparent tail may be in part over the ſlit or hole at *a*. In this ſtate, it is placed on the ſtage R, with the pin *d* in the hole *c* of the ſtage, and moves freely and horizontally for viewing the circulation of the blood, &c.

N° 14. is the ſlider-holder that is placed on the ſtage R: it receives the ſliders and tubes when filled with tranſparent objects, to be viewed either by the compound or ſingle microſcope.

N° 15. repreſents the ivory ſlider, to hold the objects between the talcs as uſual.

N° 16. is a uſeful auxiliary ſlider framed in braſs. In this ſlider ſmall concave glaſſes are cemented; and a ſlip of plane glaſs ſlides over them; by which any ſmall living object, as mites, &c. may be confined without injury, and deliberately viewed.

N° 17. repreſents a ſet of glaſs tubes, three in number, one within another; they are uſeful for ſmall tadpoles, water-newts, eels, &c. when the circulation of the blood is to be viewed. There is a ſmall hole at one end of each tube, that ſerves to admit the air; for when they are filled with water, the other end is ſtopped with a cork.

N° 18. is a ſmall ivory box, containing ſpare talcs and wires, to ſupply the ſliders with occaſionally.

N° 19. a braſs cell or button, containing a very ſmall lens, properly ſet between two ſmall plates of braſs, that it may be brought very near to the object when viewed therewith as a ſingle microſcope. This magnifier is ſcrewed into the ſame hole as the wheel of ſix magnifiers Q are (fig. 13).

N° 20. is a lens, adapted to view and examine objects, by magnifying them ſufficiently, ſo as to be able to apply them to the microſcope for inſpection: on this account it is called the *explorator*.

The preceding are the chief articles of the apparatus; which, on account of their being ſomewhat different from what is applied to other microſcopes, we have been thus particular in deſcribing. In uſing the microſcope, and while viewing objects by either the ſingle or compound inſtrument, the focal diſtances of the magnifiers are made perfectly exact by turning of the pinion at the nut *w*, in one way or the other, very eaſily in the teeth of the rack-work at X (fig. 13).

It is neceſſary that the centres of the object lenſes or magnifiers, the ſtage, and the mirrors at bottom, ſhould all be in a right line in the axis of the microſcope, when opaque objects are to be viewed, that are placed upon the ivory piece n° 7, or the forceps n° 6. and all other ſuch ſort of objects which are placed in the centre of the ſtage R, or ſlider-holder n° 14: But when aquatic or living objects, which require a great ſpace to move in, are to be viewed, then the horizontal motion at *e f* (fig. 13.) is made uſe of, and the view may be extended laterally over the whole of the diameter of the object or field of view; and by putting the arm *a b c d* forward or backward in its ſocket *e f*, the view is extended in the contrary direction equally well; and in this manner the whole

of

MICROSCOPE.

Fig. 13.

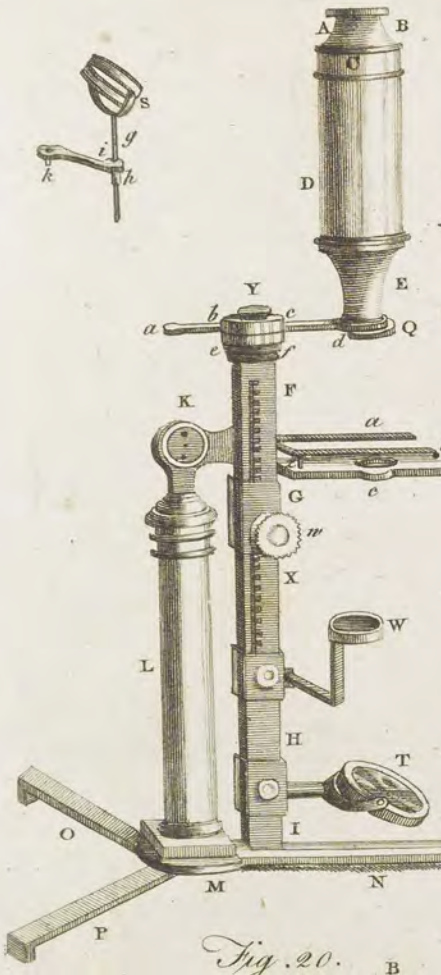
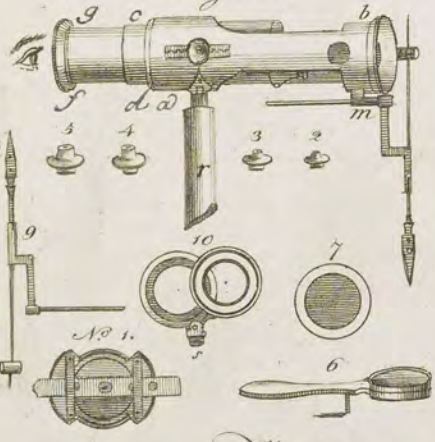


Fig. 14.

Fig. 17.

Fig. 16.



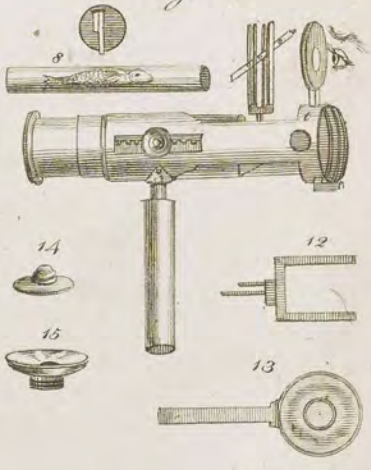
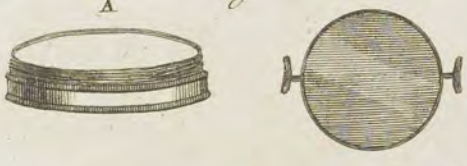
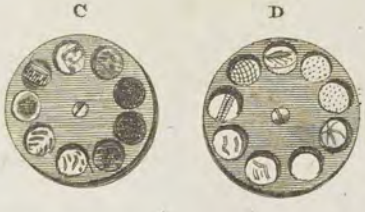


Fig. 19.

Fig. 15.

Fig. 20.





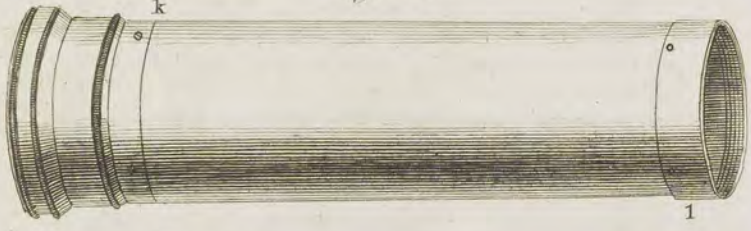
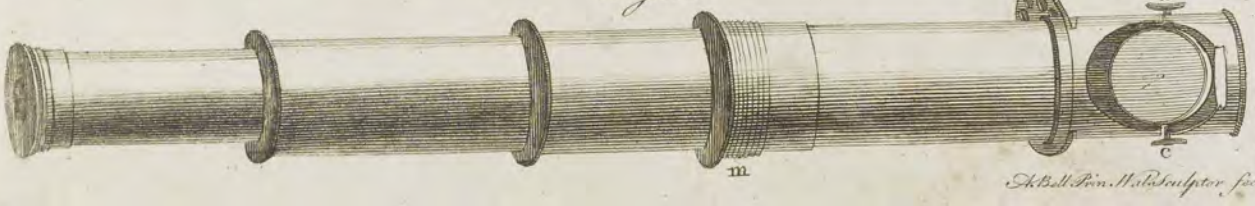


Fig. 18.



Sk. Bell. Pein. Wale. sculptor. fecit.

Microſcope

of the objects may be viewed without the leaſt diſturbance.

As the braſs arm *abcd* may be brought to the height of three or four inches above the ſtage R; ſo, by means of the rack-work motion of the ſtage, a lens of a greater focal diſtance than the greateſt in the wheel Q may be occaſionally applied in place of the wheel, and thereby the larger kind of objects be viewed; the inſtrument becoming, in this caſe, what is called a *megalaſcope*.

In viewing moving living objects, or even fixed ones, when nice motions are requiſite, a rack-work and pinion is often applied to the arm *abcd*: the arm is cut out with teeth; and the pinion, as ſhown at Y, is applied to work it. This acts but in one direction; and, in order to produce an equally neceſſary motion perpendicular to this, rack-work and pinion is applied tangent-wiſe to the ſtage, which is then jointed.

What has been related above reſpects the conſtruction of thoſe denominated *parlour* microſcopes, in contradiſtinction to thoſe which are portable: their dimenſions, however, have been conſiderably reduced by opticians, in order to render them fit for the pocket; and as they are for the moſt part conſtructed on nearly the ſame principles as thoſe which have been already deſcribed, what has been ſaid will ſufficiently inſtruct our readers in uſing any pocket microſcope whatever. Only it may be obſerved, that in thoſe reduced inſtruments, both the field of view and the magnifying power are proportionably diminiſhed.

We ſhall conclude the account of this ſort of microſcope with deſcriptions of a very portable pocket apparatus of microſcopic inſtruments, and of a new microſcopic pocket-teleſcope, both invented by the late Mr B. Martin, and ſince made by moſt inſtrument-makers in London.

The former is repreſented at fig. 15. It conſiſts of two parts, viz. the body *ab*, and the pedeſtal *ik*, which is joined by a ſcrew at the part between *b* and *i*. It conſiſts of three cyliadric tubes, viz. (1.) the exterior tube, or caſe *ab*; (2.) a middle tube *cb*; and (3.) the interior tube *fg*.—The middle tube *cd* is the adjuſter; and is connected with the outer tube by the rack-work of teeth and pinion, as ſhown at *e*: by which means it is moved up and down at pleaſure through the ſmalleſt ſpace, and carries with it the internal tube *fg*. The interior tube *fg* receives on its lower part at *b* the ſeveral capſules or boxes 2, 3, 4, 5, (fig. 16.) which contain the object lenſes or magnifiers.

The method of *uſing* this compound microſcope in the perpendicular poſition, is as follows. The ſtage n° 1. is put within the exterior tube at *b*. Under the ſprings are applied the four ivory ſliders, which contain a variety of tranſparent objects; then move the interior tube *fg* up and down with the hand, till you diſcern the object in the ſlider, and there let it reſt. After this, turn the pinion at *e* very tenderly one way or the other, till you obtain a perfect view of the tranſparent objects properly illuminated, from a mirror contained in the pedeſtal or ſtand *ik*, ſuſpended upon, and moveable about, the points of two ſcrews *(ll)*. N° 6. (fig. 16.) repreſents a moveable ſtage, which is placed in the ſpring ſocket *m*. It contains a concave glaſs, for the reception of animalcules in fluids; and has the advantage of bringing any part into view by moving the handle at *n*. If living and moving objects are required to be ſhown, they muſt be confined in the concave, by putting a glaſs cover, n° 7. upon the ſtage; and then a ſmall ſpider, a louſe, flea, bug, &c. may be ſeen, and the motion or circulation of the blood, &c. obſerved with ſurpriſing diſtinctneſs. Microſcope

To view the circulation of the blood in the moſt eminent degree, it muſt be done by placing ſmall frogs, tadpoles, water-newts, fiſhes, &c. in a tube as repreſented n° 8. (fig. 17.); which tube is placed in the holes *o* in the oppoſite ſides of the caſe *ab*, fig. 15. in the lower part.—N° 9. (fig. 16.) is a pair of pincers or pliers *d*, for holding any object; the other end of the ſteel wire is pointed to receive a piece of ivory *b*, with one end black, and the other white, on which you ſtick objects of different hue: this alſo, when uſed, is placed in the ſpring ſocket *m*.

To uſe this inſtrument as a compound opaque, you ſcrew off the body part *ab*, and ſcrew to it the handle *r* (fig. 16.); by this means you may hold the microſcope in a horizontal poſition, as ſhown in the figure. The ſilver diſh or ſpeculum (which is contained in the bottom or baſe *k*, fig. 15), is then ſcrewed on at *b*. N° 9. is placed in the ſpring-ſocket *m*, and adjuſted backward and forward in *m*, till the reflected light from the ſpeculum falls in a proper manner on the opaque object. Either of the 4 magnifiers, 2, 3, 4, 5, may be uſed, and brought to a proper focus, as before deſcribed, by the tooth and pinion *e* (fig. 15.) If you take off the opaque apparatus, and apply the ſtage n° 1. (fig. 16.) with an ivory ſlider, and at the end *b* ſcrew in either of the two lenſes, n° 10. (which are diſtinguiſhed by the name of illuminators), the microſcope being held up to the light (and properly adjuſted), the whole field of view will be ſtrongly illuminated, and preſent a moſt pleaſing appearance of any tranſparent object. Theſe two convex lenſes are of different focuſes, and are to be uſed ſingly or together; n° 2. being the greateſt magnifier, will require the object to be ſtrongly illuminated, and of courſe both the lenſes muſt be uſed together. By candle-light, this method of viewing tranſparent objects will prove very entertaining; by ſcrewing the handle *r* into the part *s* of n° 10. it becomes a delightful hand megalaſcope for viewing flowers, foſſils, ſhells, &c.; and each lens, as before mentioned, having a different focus, produces two magnifying powers uſed ſingly, and when combined a third.

The manner of uſing this inſtrument as a ſingle microſcope (like Wilſon's) is repreſented in fig. 17. where the button or magnifier at each is to be ſcrewed off, and the circular piece n° 11. is ſcrewed in its place. This piece has a ſpring ſocket made to receive the ſlider holder n° 12. N° 13. is a circular piece of braſs, with a long ſhank and ſpring, and is introduced through the outſide tube *ab* at *t*. N° 2, 3, 4, 5, are ſcrewed occaſionally in the centre of this piece, and uſed as ſingle lenſes with ivory ſliders, &c. N° 14. contains a lens of a great magnifying power, for viewing very minute objects: to render this inſtrument the moſt complete ſingle opaque microſcope, you have only to ſcrew into n° 13. the ſilver ſpeculum

Microſcope n° 15, which has a ſmall lens ſet in its centre. The ſlider-holder n° 12 is taken out of n° 11, and the pincers or nippers *d b*, being detached from the other part of n° 9. are paſſed through the long ſpring ſocket n° 11. and ready to receive any opaque body in the pincers or on the black and white piece of ivory To the large ſcrew of n° 13. are applied the two lenſes n° 10. which make it the completeſt megalaſcope that can be deſired.

The handle *r* contains the four ivory ſliders with objects.

The ſhagreeen caſe which contains this univerſal microſcope and its apparatus, is ſix inches long, three inches wide, two inches deep, and weighs together 16 ounces. "Thus (ſays Mr Martin) ſo ſmall, ſo light, ſo portable, and yet ſo univerſally complete, is this pocket microſcopic apparatus, that you find nothing material in the large three-pillared microſcope, the opaque microſcope, Wilſon's ſingle microſcope, and the aquatic microſcope, all together, which you have not in this; beſide ſome very conſiderable advantages in regard to the field of view, &c. which they have not (A)."

This inventive artiſt having contrived a conſtruction of the compound microſcope ſo ſmall as to admit of being packed in a common walking cane, thought next of introducing the ſame inſtrument into the inſide of what he called his *Pocket Three-braſs drawer Achromatic Teleſcope*. The ſame eye-glaſſes that ſerve the purpoſe of a teleſcope, anſwer as the compound magnifier, for viewing tranſparent and opaque objects in a microſcope.

Fig. 18, 19, 20. repreſent the teleſcope ſeparated by unſcrewing it at *m*, in order that the whole of the neceſſary parts in uſe may be exhibited. Fig. 19. repreſents the exterior tube, which is of mahogany, and its rims of braſs. It is detached from the reſt of the teleſcope, as not making any part of the microſcope. The braſs cover *k l*, that ſhuts up the object-glaſs of the teleſcope, is alſo the box which contains the two-wheel object-frames, and a ſmall plain reflecting mirror.

In fig. 20. A is the cover taken off, by unſcrewing the top part: The mirror B is taken out; and alſo, by unſcrewing the bottom part, the two circular wheels, with the objects ſhown in C and D.

Fig. 18. is a repreſentation of the three internal braſs ſliding tubes of the teleſcope, which form the microſcopic part. The tubes are to be drawn out as ſhown in this figure; then, at the lower end of the large tube in the inſide, is to be pulled out a ſhort tube *be*, that ſerves as a kind of ſtage to hold the wheels with objects, and ſupport the reflecting mirror. This tube is to be partly drawn out, and turned ſo that the circular hole that is pierced in it may coincide with a ſimilar hole that is cut in the exterior tube. This tube is repreſented as drawn out in the figure; and the mirror B placed therein, and the wheel with tranſparent objects. C (fig. 20.) repreſents the wheel with tranſparent objects, and D the wheel with opaque objects. They are both made of ivory; and turn round upon a centre braſs pin ſlit upon the top, which fits upon the edge of the tube; which tube is then to be puſhed up into the teleſcope tube, ſo that its lower end may reſt upon the upper edge of the wheel according to its view at *a* fig. 18. Microſcope

In viewing the objects, the ſecond braſs tube of the teleſcope muſt be puſhed down, till its milled edge at top falls upon that of the exterior tube; taking care that the circular hole is duly placed to the exterior one. Theſe circular holes are not ſeen in fig. 18. being ſuppoſed in the oppoſite ſide, where the wheel is fixed. The adjuſtment for the focus is now only neceſſary; which is obtained by puſhing downwards or upwards the proper tube, till the object appear quite diſtinct. In viewing tranſparent objects, the inſtrument may be uſed in two poſitions; one vertical, when the light is to be reflected upon the object by the mirror; the other, by looking up directly againſt the light of a candle, common light, &c.; in which caſe the mirror muſt be taken away. In viewing opaque objects, the mirror is not uſed: but as much common light as poſſible muſt be admitted through the circular holes in the ſides of the tubes.

There is a ſpare hole in the tranſparent wheel, and alſo one in the opaque, to receive any occaſional object that is to be viewed. Any ſort of object whatſoever may be viewed, by only puſhing up the microſcope tube into its exterior, and bringing the firſt eye-tube to its focal diſtance from the object.

The braſs tubes are ſo contrived, that they ſtop when drawn out to the full length: ſo that by applying one hand to the outſide tube, and the other to the end of the ſmalleſt tube, the teleſcope at one pull may be drawn out; then any of the tubes (that next to the eye is beſt) may be puſhed in gradually, till the moſt diſtinct view of the object be obtained.

The tubes all ſlide through ſhort braſs ſpring tubes, any of which may be unſcrewed from the ends of the ſliding tubes by means of the milled edges which project above the tubes, taken from each other, and the ſprings ſet clear if required.

III. *Of* Solar *Microſcopes.*

Plate CCC.

This inſtrument, in its principle, is compoſed of a tube, a looking-glaſs or mirror, a convex lens, and Wilſon's ſingle microſcope before deſcribed. The ſun's rays being reflected through the tube by means of the mirror upon the object, the image or picture of the object is thrown diſtinctly and beautifully upon a ſcreen of white paper or a white linen ſheet, placed at

(A) Notwithſtanding the properties that have been aſcribed to the above inſtrument, and the praiſes beſtowed upon it by ſome, which induced us to admit ſo minute a deſcription; we muſt appriſe our readers, that it has been omitted in Mr Adams's enumeration: and upon inquiry we learn, that it has fallen into neglect among the moſt judicious opticians, being found too imperfect to ſerve the purpoſes of ſcience, and too complicated for the uſe of perſons who ſeek only entertainment.

Microſcope at a proper diſtance to receive the ſame; and may be magnified to a ſize not to be conceived by thoſe who have not ſeen it: for the farther the ſcreen is removed, the larger will the object appear; inſomuch, that a louſe may thus be magnified to the length of five or ſix feet, or even a great deal more; though it is more diſtinct when not enlarged to above half that ſize

The different forms in which the Solar Microſcope is conſtructed, are as follow.

I. The old conſtruction is repreſented in fig. 21. A is a ſquare wodden frame, through which paſs two long ſcrews aſſiſted by a couple of nuts 1, 1. By theſe it is faſtened firmly to a window ſhutter, wherein a hole is made for its reception; the two nuts being let into the ſhutter, and made faſt thereto. A circular hole is made in the middle of this frame to receive the piece of wood B, of a circular figure; whoſe edge, that projects a little beyond the frame, compoſes a ſhallow groove 2, wherein runs a catgut 3; which, by twiſting round, and then croſſing over a braſs pulley 4, (the handle whereof 5, paſſes through the frame), affords an eaſy motion for turning round the circular piece of wood B, with all the parts affixed to it. C is a braſs tube, which, ſcrewing into the middle of the circular piece of wood, becomes a caſe for the uncovered braſs tube D to be drawn backwards or forwards in. E is a ſmaller tube, of about one inch in length, cemented to the end of the larger tube D. F is another braſs tube, made to ſlide over the above deſcribed tube E; and to the end of this the microſcope muſt be ſcrewed, when we come to uſe it. 5. a convex lens, whoſe focus is about 12 inches, deſigned to collect the ſun's rays, and throw them more ſtrongly upon the object. G is a looking-glaſs of an oblong figure, ſet in a wooden frame, faſtened by hinges in the circular piece of wood B, and turning about therewith by means of the abovementioned cat-gut. H is a jointed wire, partly braſs and partly iron; the braſs part whereof 6, which is flat, being faſtened to the mirror, and the iron part 7, which is round, paſſing through the wooden frame, enable the obſerver, by putting it backwards or forwards, to elevate or depreſs the mirror according to the ſun's altitude. There is a braſs ring at the end of the jointed wire 8, whereby to manage it with the greater eaſe. The extremities of the cat-gut are faſtened to a braſs pin, by turning of which it may be braced up, if at any time it becomes too ſlack.

When this microſcope is employed, the room muſt be rendered as dark as poſſible; for on the darkneſs of the room, and the brightneſs of the ſunſhine, depend the ſharpneſs and perfection of your image. Then putting the looking-glaſs G through the hole in your window-ſhutter, faſten the ſquare frame A to the ſhutter by its two ſcrews and nuts 1, 1. This done, adjuſt your looking-glaſs to the elevation and ſituation of the ſun, by means of the jointed wire H, together with the cat-gut and pulley, 3, 4. For the firſt of theſe raiſing or lowering the glaſs, and the other inclining it to either ſide, there reſults a twofold motion, which may eaſily be ſo managed as to bring the glaſs to a right poſition, that is, to make it reflect the ſun's rays directly through the lens 5, upon the paper ſcreen, and form thereon a ſpot of light exactly round. But though the obtaining a perfect circular ſpot of light upon the ſcreen before you apply the microſcope, is a certain proof that your mirror is adjuſted right, that proof muſt not always be expected: for the ſun is ſo low in winter, that if it ſhine in a direct line againſt the window, it cannot then afford a ſpot of light exactly round; but if it be on either ſide, a round ſpot may be obtained, even in December. As ſoon as this appears, ſcrew the tube C into the braſs collar provided for it in the middle of your wood-work, taking care not to alter your looking-glaſs: then ſcrewing the magnifier you chooſe to employ to the end of your microſcope in the uſual manner, take away the lens at the other end thereof, and place a ſlider, containing the objects to be examined, between the thin braſs plates, as in the other ways of uſing the microſcope. Microſcope

Things being thus prepared, ſcrew the body of the microſcope over the ſmall end E of the braſs tube F; which ſlip over the ſmall end E of the tube D, and pull out the ſaid tube D leſs or more as your object is capable of enduring the ſun's heat. Dead objects may be brought within about an inch of the focus of the convex lens 5; but the diſtance muſt be ſhortened for living creatures, or they will ſoon be killed.

If the light fall not exactly right, you may eaſily, by a gentle motion of the jointed wire and pulley, direct it through the axis of the microſcopic lens. The ſhort tube F, to which the microſcope is ſcrewed, renders it eaſy, by ſliding it backwards or forwards on the other tube E, to bring the objects to their focal diſtance; which will be known by the ſharpneſs and clearneſs of their appearance: they may alſo be turned round by the ſame means without being in the leaſt diſordered.

The magnifiers moſt uſeful in the ſolar microſcope are in general, the fourth, fifth, or ſixth. The ſcreen on which the repreſentations of the objects are thrown, is uſually compoſed of a ſheet of the largeſt elephant paper, ſtrained on a frame which ſlides up or down, or turns about at pleaſure on a round wooden pillar, after the manner of ſome fire-ſcreens. Larger ſcreens may alſo be made of ſeveral ſheets of the ſame paper paſted together on cloth, and let down from the ceiling with a roller like a large map.

"This microſcope (ſays Mr Baker) is the moſt entertaining of any; and perhaps the moſt capable of making diſcoveries in objects that are not too opaque: as it ſhows them much larger than can be done any other way. There are alſo ſeveral conveniences attending it, which no other microſcope can have: for the weakeſt eyes may uſe it without the leaſt ſtraining or fatigue: numbers of people together may view any object at the ſame time; and by pointing to the particular parts thereof, and diſcourſing on what lies before them, may be able better to underſtand one another, and more likely to find out the truth, than in other microſcopes, where they muſt peep one after another, and perhaps ſee the object neither in the ſame light nor in the ſame poſition. Thoſe alſo, who have no ſkill in drawing, may, by this contrivance, eaſily ſketch out the exact figure of any object they have a mind to preſerve a picture of; ſince they need only faſten a paper on the ſcreen, and trace

Microſcope

it out thereon either with a pen or pencil, as it appears before them. It is worth the while of thoſe who are deſirous of taking many draughts in this way, to get a frame, wherein a ſheet of paper may be put in or taken out at pleaſure; for if the paper be ſingle, the image of an object will be ſeen almoſt as plainly on the back as on the fore-ſide; and, by ſtanding behind the ſcreen, the ſhade of the hand will not obſtruct the light in drawing, as it muſt in ſome degree when one ſtands before it." This conſtruction, however, has now become rather obſolete, and is ſuperſeded by the following.

II. *The improved Solar Microſcope, as uſed with the improved ſingle Microſcope, with teeth and pinion.* Fig. 22. repreſents the whole form of the *ſingle microſcope*; the parts of which are as follows: ABCD the external tube; GHIK the internal moveable one; QM part of another tube within the laſt, at one end of which is fixed a plate of braſs hollowed in the middle, for receiving the glaſs tubes: there is alſo a moveable flat plate, between which, and the fixed end of the ſecond tube, the ivory ſliders are to be placed. L, a part of the microſcope, containing a wire ſpiral ſpring, keeping the tube QM with its plates firm againſt the fixed part IK of the ſecond tube.

EF is the ſmall rack-work of teeth and pinion, by which the tube IG is moved gradually to or from the end AB, for adjuſting the objects exactly to the focus of different lengths. NO is a braſs ſlider, with ſix magnifiers; any one of which may eaſily be placed before the object. It is known when either of the glaſſes is in the centre of the eye-hole, by a ſmall ſpring falling into a notch in the ſide of the ſlider, made againſt each of the glaſſes. Thoſe parts of the apparatus, fig. 14. (Pl. ccxcix.) marked n° 15, 16, 17, 18, 19, 20, 21. and 22. are made uſe of here to this microſcope. GH is a braſs cell, which holds an illuminating glaſs for converging the ſun's beams or the light of a candle ſtrongly upon the objects. The aperture of the glaſs is made greater or leſs, by two circular pieces of braſs, with holes of different ſizes, that are ſcrewed ſeparately over the ſaid lens. But at times, objects appear beſt when the microſcope is held up to the common light only, without this glaſs. It is alſo taken away when the microſcope is applied to the apparatus now to be deſcribed.

Fig. 23. repreſents the apparatus, with the ſingle microſcope ſcrewed to it, which conſtitutes the *Solar Microſcope*. AB is the inner moveable tube, to which the ſingle microſcope is ſcrewed. CD, is the external tube, containing a condenſing convex glaſs at the end D, and is ſcrewed into the plate EF, which is cut with teeth at its circumference, and moved by the pinion I, that is fixed with the plate GH. This plate is ſcrewed faſt againſt the window-ſhutter, or board fitted to a convenient window of a darkened room, when the inſtrument is uſed. KL is a long frame, fixed to the circular plate EF; containing a looking-glaſs or mirror for reflecting the ſolar rays through the lens in the body of the tube D. O is a braſs milled head, faſtened to a worm or endleſs ſcrew; which on the outſide turns a ſmall wheel, by which the reflecting mirror M is moved upwards or downwards.

In *uſing* this microſcope, the ſquare frame GH is firſt to be ſcrewed to the window-ſhutter, and the

Microſcope

room well darkened: which is beſt done by cutting a round hole of the ſize of the moveable plate EF, that carries the reflector, in the window-ſhutter or board; and, by means of two braſs nuts *a a*, let into the ſhutter to receive the ſcrews PP, when placed through the holes in the ſquare frame GH, at the two holes QQ; which will firmly faſten the microſcope to the ſhutter, and is eaſily taken away by only unſcrewing the ſcrews PP.

The white paper ſcreen, or white cloth, to receive the images, is to be placed ſeveral feet diſtant from the window: which will make the repreſentations the larger in proportion to the diſtance. The uſual diſtances are from 6 to 16 feet.

The frame KL, with its mirror M, is to be moved by turning the pinion I, one way or the other, till the beams of the ſun's light come through the hole into the room: then, by turning of the worm at O, the mirror muſt be raiſed or depreſſed till the rays become perfectly horizontal, and go ſtraight acroſs the room to the ſcreen. The tube CD, with its lens at D, is now to be ſcrewed into the hole of the circular plate EF: by this glaſs the rays will be converged to a focus; and from thence proceed diverging to the ſcreen, and there make a large circle of light. The ſingle microſcope, fig. 22. is to be ſcrewed on to the end AB (fig. 23.) of the inner tube; and the ſlider NO, with either of the lenſes marked 1, 2, 3, 4, 5, or 6, in the centre of the hole at the end AB. This will occaſion a circle of light upon the ſcreen much larger than before. The ſlider or glaſs-tube, with the objects to be viewed, is to be placed between the plates at IK againſt the ſmall magnifier, and moved at pleaſure. By ſhifting the tube AB in or out, you may place the object in ſuch a part of the condenſed rays as ſhall be ſufficient to illuminate it, and not ſcorch or burn it; which will generally require the glaſs to be about one inch diſtant from the focus. It now remains only to adjuſt the object, or to bring it ſo near to the magnifier that its image formed upon the ſcreen ſhall be the moſt diſtinct or perfect: and it is effected by gently turning the pinion F, fig. 22, a ſmall matter one way or the other. If the object be rather large in ſize, the leaſt magnifiers are generally uſed, and *vice verſa*.

N° 1. is the greateſt magnifier, and n° 6. the leaſt, in the braſs ſlider NO. But, if deſired, ſingle lenſes of greater magnifying powers are made: and they are applied, by being ſcrewed to the end A B, fig. 22. and the braſs ſlider N O is then taken away.

The ſame object may be variouſly magnified, by the lenſes ſeverally applied to it; and the degree of magnifying power is eaſily known by this rule: *As the diſtance of the object is to that of its image from the magnifier; ſo is the length or breadth of the object to that of the image.*

Inſtead of the braſs ſliders with the lenſes NO, there is ſometimes ſcrewed a lens of a large ſize, and longer focal diſtance: the inſtrument is then converted into a *megalaſcope*; and is adapted for viewing the larger kind of objects contained in large ſliders, ſuch as is repreſented at R. And, in the ſame manner, ſmall objects of entertainment, painted upon glaſs like the ſliders of a magic lanthorn, are much magnified, and repreſented upon the ſame ſcreen.

The ſolar microſcopes juſt deſcribed are capable, only

Fig. 25.

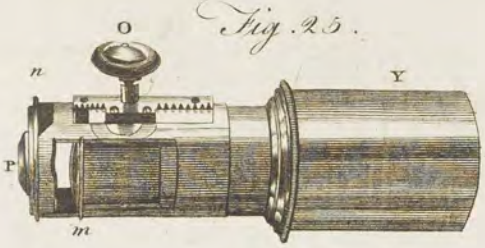


Fig. 21.

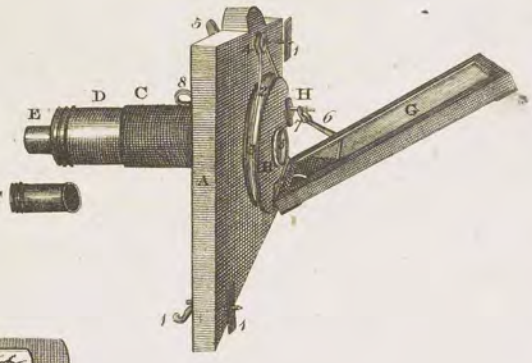


Fig. 23.

Fig. 22.

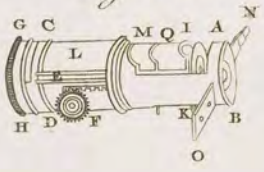
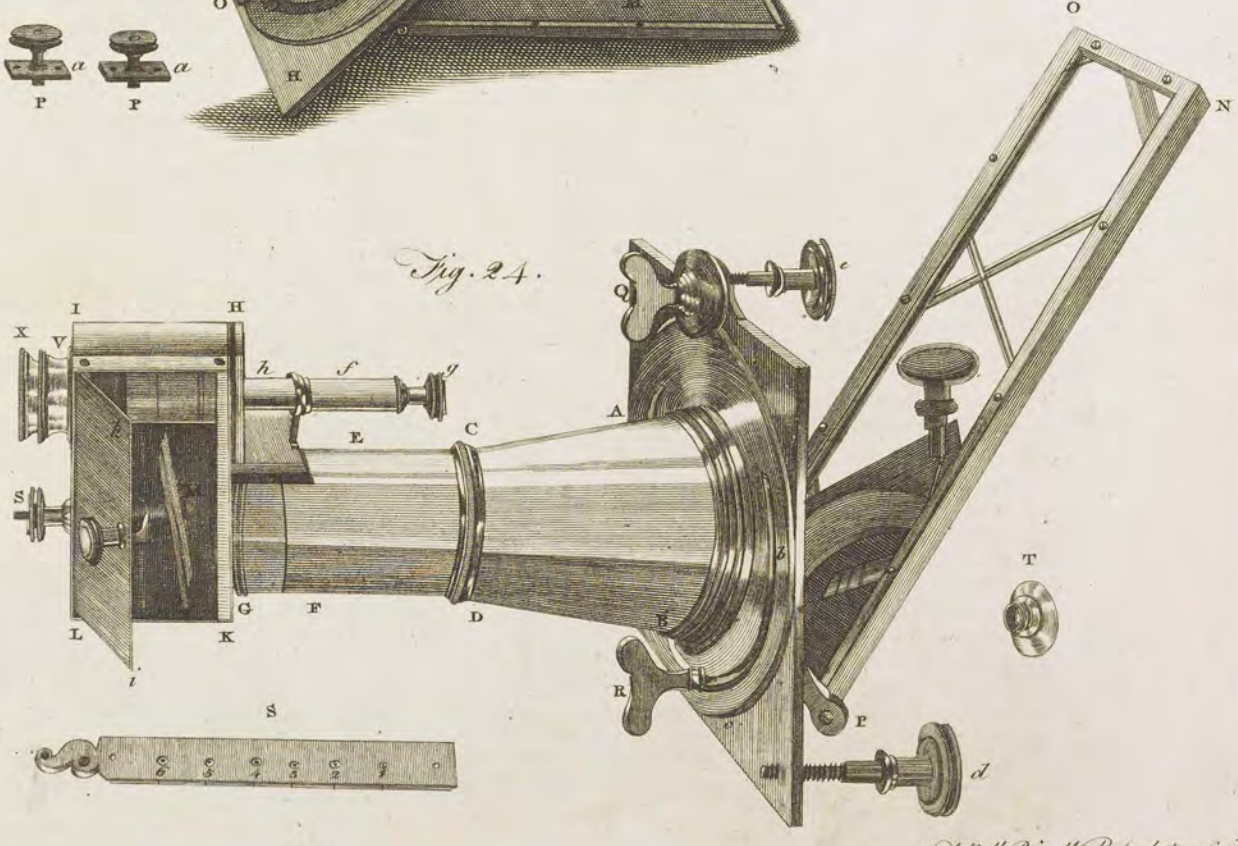


Fig. 24.



A. Bell Prin. Wal. Sculptor fecit.

Microſcope

ly of magnifying tranſparent objects; for which purpoſe the laſt inſtrument is extremely well adapted. But as opaque objects form the moſt conſiderable part of the curious collections in the works of art as well as nature, a ſolar microſcope for this purpoſe was a long time wanted.—For ſeveral years previous to 1774, the late Mr Martin made ſeveral eſſays towards the conſtruction of ſuch an inſtrument; and at laſt completed one about the time juſt mentioned, which he named,

III. *The Opaque Solar Microſcope.* With this inſtrument (to uſe his own words) all *opaque* objects, whether of the animal, vegetable, or mineral kingdom, may be exhibited in great perfection, in all their native beauty: the lights and ſhades, the prominences and cavities, and all the varieties of different hues, tints, and colours; heightened by reflection of the ſolar rays condenſed upon them."—*Tranſparent objects* are alſo ſhown with greater perfection than by the common ſolar microſcope.

Fig. 24. repreſents the ſolar opaque microſcope, mounted for exhibiting opaque objects.

Fig. 25. is the ſingle tooth-and-pinion microſcope, as before, which is uſed for ſhowing tranſparent objects; the cylindrical tube Y thereof being made to fit into the tube FE of the ſolar microſcope.

ABCDEF, (fig. 24.) repreſents the body of the ſolar microſcope; one part thereof, ABCD, is conical; the other, CDEF, is cylindrical. The cylindrical part receives the tube G of the opaque box, or the tube Y of the ſingle microſcope. At the large end AB of the conical part, there is a lens to receive the rays from the mirror, and refract them towards the box HIKL. NOP is a braſs frame; which is fixed to the moveable circular plate *abc*: in this frame there is a plane mirror, to reflect the ſolar rays on the aforementioned lens. This mirror may be moved into the moſt convenient poſition for reflecting the light, by means of the nuts Q and R. By the nut Q it may be moved from eaſt to weſt; and it may be elevated or depreſſed by the nut R. *d e*, Two ſcrews to faſten the microſcope to a window-ſhutter. The box for opaque objects is repreſented at HIKL: it contains a plane mirror M, for reflecting the light which it receives from the large lens to the object, and thereby illuminating it; S is a ſcrew to adjuſt this mirror, or place it at a proper angle for reflecting the light. VX, two tubes of braſs, one ſliding within the other, the exterior one in the box HIKL; theſe carry the magnifying lenſes: the interior tube is ſometimes taken out, and the exterior one is then uſed by itſelf. Part of this tube may be ſeen in the plate within the box HIKL. At H there is a braſs plate, the back part of which is fixed to the hollow tube *h*, in which there is a ſpiral wire, which keeps the plate always bearing againſt the ſide H of the braſs box HIKL. The ſliders, with the opaque objects, paſs between this plate and the ſide of the box; to put them there, the plate is to be drawn back by means of the nut *g*: *ik* is a door to one ſide of the opaque box. The foregoing pieces conſtitute the ſeveral parts neceſſary for viewing opaque objects. We ſhall now proceed to deſcribe the ſingle microſcope, which is uſed for tranſparent objects: but in order to examine theſe, the box HIKL muſt be firſt removed, and in its place we muſt inſert the tube Y of the ſingle microſcope that we are now going to deſcribe. Microſcope

Fig. 25. repreſents a large tooth-and-pinion microſcope: at *m*, within the body of this microſcope, are two thin plates, that are to be ſeparated, in order to let the ivory ſliders paſs between them; they are preſſed together by a ſpiral ſpring, which bears up the under plate, and forces it againſt the upper one.

The ſlider S (under fig. 24.), which contains the magnifiers, fits into the hole *n*; and any of the magnifiers may be placed before the object, by moving the aforeſaid ſlider: when the magnifier is at the centre of the hole P, a ſmall ſpring falls into one of the notches which is on the ſide of the ſlider.

Under the plate *m* are placed two lenſes, for enlarging the field of view on the ſcreen: the ſmaller of the two is fixed in a piece of braſs, and is neareſt the plate *m*; this is to be taken out when the magnifiers, N° 4, 5, or 6, are uſed, or when the megalaſcope lens T (fig. 24.) is uſed; but is to be replaced for N° 1, 2, 3.

This microſcope is adjuſted to the focus by turning the milled nut O.

To *uſe* the ſolar microſcope:—Make a round hole in the window-ſhutter, a little larger than the circle *abc*; paſs the mirror ONP through this hole, and apply the ſquare plate to the ſhutter; then mark with a pencil the places which correſpond to the two holes through which the ſcrew is to paſs; take away the microſcope, and bore two holes at the marked places, ſufficiently large to let the milled ſcrews *de* paſs through them.

The ſcrews are to paſs from the outſide of the ſhutter, to go through it; and being then ſcrewed into their reſpective holes in the ſquare plate, they will, when ſcrewed home, hold it faſt againſt the inſide of the ſhutter, and thus ſupport the microſcope.

Screw the conical tube ABCD to the circle *abc*, and then ſlide the tube G of the opaque box into the cylindrical part CD EF of the body, if opaque objects are to be examined; but if they be tranſparent objects you mean to ſhow, then place the tube Y within the tube CDEF.

The room is to be darkened as much as poſſible, that no light may enter but what paſſes through the body of the microſcope; for, on this circumſtance, together with the brightneſs of the ſun ſhine, the perfection and diſtinctneſs of the image in a great meaſure depend.

When the microſcope is to be uſed for opaque objects, 1. Adjuſt the mirror NOP, ſo as to receive the ſolar rays, by means of the two finger ſcrews or nuts, Q R; the firſt, Q, turns the mirror to the right or left; the ſecond, R, raiſes or depreſſes it: this you are to do till you have reflected the ſun's light through the lens at AB ſtrongly upon a ſcreen of white paper placed at ſome diſtance from the window, and formed thereon a round ſpot of light. An unexperienced obſerver will find it more convenient to obtain the light by forming this ſpot before he puts on either the opaque box or the tooth-and-pinion microſcope.

Now put in the *opaque* box, and place the object between the plates at H; open the door *ik*, and adjuſt the mirror M till you have illuminated the object ſtrongly. If you cannot effect this by the ſcrew S,

Microſcope

you muſt move the ſcrews Q, R, in order to get the light reflected ſtrongly from the mirror NOP, or the mirror M, without which the latter cannot illuminate the object.

The object being ſtrongly illuminated, ſhut the door *ik*, and a diſtinct view of the object will ſoon be obtained on your ſcreen, by adjuſting the tubes VX, which is effected by moving them backwards or forwards.

A round ſpot of light cannot always be procured in northern latitudes, the altitude of the ſun being often too low; neither can it be obtained when the ſun is directly perpendicular to the front of the room.

As the ſun is continually changing its place, it will be neceſſary, in order to keep his rays full upon the object, to keep them continually directed thro' the axis of the inſtrument, by the two ſcrews Q and R.

To view *tranſparent* objects, remove the opaque box, and inſert the tube Y, fig. 25. in its place; put the ſlider S into its place at *n*, and the ſlider with the objects between the plates at *m*; then adjuſt the mirror NOP, as before directed by the ſcrews Q, R, ſo that the light may paſs through the object; regulate the focus of the magnifier by the ſcrew O. The moſt pleaſing magnifiers in uſe are the fourth and fifth.

The ſize of the object may be increaſed or diminiſhed, by altering the diſtance of the ſcreen from the microſcope: five or ſix feet is a convenient diſtance.

To examine tranſparent objects of a larger ſize, or to render the inſtrument what is uſually called a *megalaſcope*, take out the ſlider S from its place at *n*, and ſcrew the button T (fig. 24.) into the hole at P, fig. 25. and remove the glaſs which is under the plate at *m*, and regulate the light and focus agreeable to the foregoing directions.

N. B. At the end of the tube G there is a lens for increaſing the denſity of the rays, for the purpoſe of burning or melting any combuſtible or fuſible ſubſtance: this lens muſt be removed in moſt caſes, leſt the objects ſhould be burnt. The intenſity of the light is alſo varied by moving this tube backwards or forwards.

Apparatus of the Opaque Solar Microſcope.—The large ſquare plate and mirror; the body of the microſcope; the opaque box and its tube; the tooth-and-pinion microſcope; the ſlider with the magnifiers; the megalaſcope magnifier; the two ſcrews *d* and *e*; ſome ivory ſliders; ſome ſliders with opaque objects; a braſs frame, witha bottom of ſoft deal to ſtick any object on; a braſs cylinder K (fig. 31.), for confining opaque objects.

IV. *The* Camera Obscura, *or* Lucernal, *Microſcope.*

—The great facility with which objects can be repreſented on paper or a rough glaſs in the camera obſcura, and copies drawn from them by any perſon though unſkilled in drawing, evidently ſuggeſted the application of the microſcope to this inſtrument. The greateſt number of experiments that appear to have been made with this view, were by the late Mr Martin and Mr Adams; the former of whom frequently applied the microſcope to the portable camera, and with much effect and entertainment. But theſe inſtruments being found to anſwer only with the aſſiſtance of the ſun, Mr Adams directed his experiments to the conſtruction of an inſtrument of more extended utility, which could be equally employed in the day-time and by night. He accordingly ſucceeded ſo far as to produce, by *candle-light*, the images of objects refracted from a ſingle magnifier upon one or two large convex lenſes (of about five inches or upwards in diameter), at the end of a pyramidal ſhaped box, in a very pleaſing and magnified appearance, ſo as to give opaque objects as well as tranſparent ones the utmoſt diſtinctneſs of repreſentation: but ſtill the light of a candle or lamp was found generally inſufficient to throw the requiſite degree of illumination upon the objects. The invention of what is called *Argand's lamp*, within theſe few years offered a complete remedy for this defect, by the intenſity and ſteadineſs of its light. This did not eſcape the preſent Mr Adams (ſon of the former), who immediately applied it; and who had likewiſe ſo altered and improved his father's inſtrument, both in conſtruction and form, as to render it altogether a different one, and far more perfect and uſeful.

Microſcope

The advantages and properties of this excellently conceived inſtrument are numerous and important. "As the far greater part of the objects which ſurround us are opaque (ſays our author), and very few are ſufficiently tranſparent to be examined by the common microſcopes, an inſtrument that could be readily applied to the examination of opaque objects has always been a deſideratum. Even in the examination of tranſparent objects, many of the fine and more curious portions are loſt, and drowned, as it were, in the light which muſt be tranſmitted through them; while different parts of the ſame object appear only as dark lines or ſpots, becauſe they are ſo opaque as not to permit any light to paſs through them. Theſe difficulties, as well as many more, are obviated in the lucernal microſcope; by which opaque objects of various ſizes may be ſeen with eaſe and diſtinctneſs: the beautiful colours with which moſt of them are adorned, are rendered more brilliant, without changing in the leaſt the real tint of the colour; and the concave and convex parts retain alſo their proper form.—The facility with which all opaque objects are applied to this inſtrument, is another conſiderable advantage, and almoſt peculiar to itſelf; as the texture and configuration of the more tender parts are often hurt by previous preparation, every object may be examined by this inſtrument, firſt as opaque, and afterwards (if the texture will admit of it) as tranſparent.—The lucernal microſcope does not in the leaſt fatigue that eye; the object appears like nature itſelf, giving eaſe to the ſight and pleaſure to the mind: there is alſo, in the uſe of this inſtrument, no occaſion to ſhut the eye which is not directed to the object. A further advantage peculiar to this microſcope is, that by it the outlines of every object may be taken, even by thoſe who are not accuſtomed to draw; while thoſe who can draw well will receive great aſſiſtance, and execute their work with more accuracy and in leſs time than they would otherwiſe have been able to have performed it. Tranſparent objects as well as opaque may be copied in the ſame manner. The inſtrument may be uſed at any time of the day, but the beſt effect is by night; in which reſpect it has a ſuperiority over the ſolar microſcope, as that inſtrument can only be uſed when the ſun ſhines.

Microſcope

Tranſparent objects may be examined with the lucernal microſcope in three or four different modes, from a blaze of light almoſt too great for the eye to bear, to that which is perfectly eaſy to it: And by the addition of a tin lanthorn to the apparatus, may be thrown on a ſcreen, and exhibited at one view to a large company, as by the ſolar mircoſcope.

We ſhall now proceed to the deſcription of the inſtrument and apparatus as given by Mr Adams.

Fig. 26. repreſents the improved *Lucernal Microſcope*, mounted to view opaque objects. ABCD is a large mahogany pyramidal box, which forms the body of the microſcope; it is ſupported firmly on the braſs pillar FG, by means of the ſocket H and the curved piece IK.

LMN is a guide for the eye, in order to direct it in the axis of the lenſes; it conſiſts of two braſs tubes, one ſliding within the other, and a vertical flat piece, at the top of which is the hole for the eye. The outer tube is ſeen at MN, the vertical piece is repreſented at LM. The inner tube may be pulled out, or puſhed in, to adjuſt it to the focus of the glaſſes. The vertical piece may be raiſed or depreſſed, that the hole, through which the object is to be viewed, may coincide with the centre of the field of view; it is fixed by a milled ſcrew at M, which could not be ſhown in this figure.

At N is a dove-tailed piece of braſs, made to receive the dove-tail at the end of the tubes MN, by which it is affixed to the wooden box ABCDE. The tubes MN may be removed from this box occaſionally, for the convenience of packing it up in a leſs compaſs.

OP, a ſmall tube which carries the magnifiers.

O, one of the magnifiers; it is ſcrewed into the end of a tube, which ſlides within the tube P; the tube P may be unſcrewed occaſionally from the wooden body.

QRSTVX, a long ſquarebar, which paſſes through the ſockets YZ, and carrries the ſtage or frame that holds the objects; this bar may be moved backward or forward, in order to adjuſt it to the focus by means of the pinion which is at *a*.

b, A handle furniſhed with an univerſal joint, for more conveniently turning the pinion. When the handle is removed, the nut (fig. 27.) may be uſed in its ſtead.

de, A braſs bar, to ſupport the curved piece KI, and keep the body AB firm and ſteady.

fghi, The ſtage for opaque objects: it fits upon the bar QRST by means of the ſocket *hi*, and is brought nearer to or removed farther from the magnifying lens by turning the pinion *a*: the objects are placed in the front ſide of the ſtage (which cannot be ſeen in this figure) between four ſmall braſs plates; the edges of two of theſe are ſeen at *kl*. The two upper pieces of braſs are moveable; they are fixed to a plate, which is acted on by a ſpiral ſpring, that preſſes them down, and confines the ſlider with the objects: this plate, and the two upper pieces of braſs, are lifted up by the ſmall nut *m*.

At the lower part of the ſtage, there is a ſemicircular lump of glaſs *n*, which is deſigned to receive the light from the lamp, fig. 29. and to collect and throw it on the concave mirror *o*, whence it is to be reflected on the object.

Microſcope

The upper part *fgrs* (fig. 26.) of the opaque ſtage takes out, that the ſtage for tranſparent objects may be inſerted in its place.

Fig. 28. repreſents the ſtage for tranſparent objects; the two legs 5 and 6 fit into the top of the under part *rshi* of the ſtage for opaque objects; 7 is the part which confines or holds the ſliders, and through which they are to be moved; 9 and 10 a braſs tube, which contains the lenſes for condenſing the light, and throwing it upon the object; there is a ſecond tube within that, marked 9 and 10, which may be placed at different diſtances from the object by the pin 11.

When this ſtage is uſed as a ſingle microſcope, without any reference to the lucernal, the magnifiers, or object lenſes, are to be ſcrewed into the hole 12, and to be adjuſted to a proper focus by the nut 13.

N. B. At the end AB (fig 26.) of the wooden body there is a ſlider, which is repreſented as partly drawn out at A: when quite taken out, three grooves will be perceived; one of which contains a board that forms the end of the box; the next contains a frame with a greyed glaſs; and the third, or that fartheſt from the end AB, two large convex lenſes.

Fig. 29. repreſents one of Argand's lamps, which are the moſt ſuitable for microſcopic purpoſes, on account of the clearneſs, the intenſity, and the ſteadineſs of the light. The following account of the method of managing them, with other obſervations, is copied from an account given by Mr Parker with thoſe he ſells.

The principle on which the lamp acts, conſiſts in diſpoſing the wick in thin parts, ſo that the air may come into contact with all the burning fuel; by which means, together with an increaſe of the current of air occaſioned by rarefaction in the glaſs tube, the whole of the fuel is converted into flame.

The wicks are circular; and, the more readily to regulate the quantity of light, are fixed on a braſs collar, with a wire handle, by means of which they are raiſed or depreſſed at pleaſure.

To fix the wick on, a wooden mandril is contrived, which is tapered at one end, and has a groove turned at the other.

The wick has a ſelvage at one end, which is to be put foremoſt on the mandril, and moved up to the groove; then putting the groove into the collar of the wick-holder, the wick is eaſily puſhed forward upon it.

The wick-holder and wick being put quite down in their place, the ſpare part of the wick ſhould, while dry, be ſet a-light, and ſuffered to burn to the edge of the tubes; this will leave it more even than by cutting, and, being black by burning, will be much eaſier lighted: for this reaſon, the black ſhould never be quite cut off.

The lamp ſhould be filled an hour or two before it is wanted, that the cotton may imbibe the oil and draw the better.

The lamps which have a reſervoir and valve, need no other direction for filling than to do it with a proper trimming pot, carefully obſerving when they are full; then pulling up the valve by the point, the reſervoir, being turned with the other hand, may be replaced without ſpilling a drop.

Thoſe lamps which fill in the front like a bird-fountain, muſt be reclined on the back to fill; and this

Microſcope

ſhould be done gently, that the oil in the burner may return into the body when ſo placed and filled: if, by being too full, any oil appears above the guard, only move the lamp a little, and the oil will diſappear; the lamp may then be placed erect, and the oil will flow to its proper level.

The oil muſt be of the ſpermaceti kind, commonly called chamber-oil, which may generally be diſtinguiſhed by its paleneſs, tranſparency, and inoffenſive ſcent: all thoſe oils which are of a red and brown colour, and of an offenſive ſcent, ſhould be carefully avoided, as their glutinous parts clog the lamp, and the impurities in ſuch oil, not being inflammable, will accumulate and remain in the form of a cruſt on the wick. Seal oil is nearly as pale and ſweet as chamber oil; but being of a heavy ſluggiſh quality, is not proper for lamps with fine wicks.

Whenever bad oil has been uſed, on changing it, the wick muſt alſo be changed; becauſe, after having imbibed the coarſe particles in its capillary tubes, it will not draw up the fine oil.

To obtain the greateſt degree of light, the wick ſhould be trimmed exactly even, the flame will then be completely equal.

There will be a great advantage in keeping the lamp clean, eſpecially the burner and air-tubes; the neglect of cleanlineſs in lamps is too common: a candleſtick is generally cleaned every time it is uſed, ſo ſhould a lamp; and if a candleſtick is not to be objected to becauſe it does not give light after the candle is exhauſted, ſo a lamp ſhould not be thought ill of, if it does not give light when it wants oil or cotton; but this laſt has often happened, becauſe the deficiency is leſs viſible.

The glaſs tubes are beſt cleaned with a piece of waſh leather.

If a fountain-lamp is left partly filled with oil, it may be liable to overflow; this happens by the contraction of the air when cold, and its expanſion by the warmth of a room, the rays of the ſun, or the heat of the lamp when re-lighted: this accident may be effectually prevented by keeping the reſervoir filled, the oil not being ſubject to expanſion like air. On this account, thoſe with a common reſervoir are beſt adapted for microſcopic purpoſes.

To examine Opaque Objects with the Lucernal Microſcope. To render the uſe of this inſtrument eaſy, it is uſually packed with as many of the parts together as poſſible: it occupies on this account rather more room, but is much leſs embarraſſing to the obſerver, who has only three parts to put on after it is taken out of its box, namely, the guide for the eye, the ſtage, and the tube with its magnifier.

But to be more particular: Take out the wooden ſlider A (fig. 26.), then lift out the cover and the grey glaſs from their reſpective grooves under the ſlider A.

Put the end N of the guide for the eye LMM into its place, ſo that it may ſtand in the poſition which is repreſented in this figure.

Place the ſocket which is at the bottom of the opaque ſtage, on the bar Q X T, ſo that the concave mirror *o* may be next the end DE of the wooden body.

Screw the tubes PO into the end DE. The magnifier you intend to uſe is to be ſcrewed on the end O of theſe tubes. Microſcope

The handle *Gb*, or the milled nut fig. 27. muſt be placed on the ſquare end of the pinion *a*.

Place the lamp lighted before the glaſs lump *n*, and the object you intend to examine between the ſpring-plates of the ſtage; and the inſtrument is ready for uſe.

In all microſcopes there are two circumſtances which muſt be particularly attended to: firſt, the modification of the light, or the proper quantity to illuminate the object; ſecondly, the adjuſtment of the inſtrument to the focus of the glaſſes and eye of the obſerver. In the uſe of the lucernal microſcope there is a third circumſtance, which is, the regulation of the guide for the eye.

1. To throw the light upon the object. The flame of the lamp is to be placed rather below the centre of the glaſs lump *n*, and as near it as poſſible; the concave mirror *o* muſt be ſo inclined and turned as to receive the light from the glaſs lump, and reflect it thence upon the object; the beſt ſituation of the concave mirror and the flame of the lamp depends on a combination of circumſtances, which a little practice will diſcover.

2. To regulate the guide for the eye, or to place the centre of the eye-piece L ſo that it may coincide with the focal point of the lenſes and the axis of viſion: Lengthen and ſhorten the tubes MN, by drawing out or puſhing in the inner tube, and raiſing or depreſſing the eye-piece ML, till you find the large lens (which is placed at the end AB of the wooden body) filled by an uniform field of light, without any priſmatic colours round the edge; for till this piece is properly fixed, the circle of light will be very ſmall, and only occupy a part of the lens: the eye muſt be kept at the centre of the eye-piece L, during the whole of the operation; which may be rendered ſomewhat eaſier to the obſerver, on the firſt uſe of the inſtrument, if he hold a piece of white paper parallel to the large lens, removing it from or bringing it nearer to them till he find the place where a lucid circle, which he will perceive on the paper, is brighteſt and moſt diſtinct; then he is to fix the centre of the eye-piece to coincide with that ſpot; after which a very ſmall adjuſtment will ſet it perfectly right.

3. To adjuſt the lenſes to their focal diſtance. This is effected by turning the pinion *a*, the eye being at the ſame time at the eye-piece L. The grey glaſs is often placed before the large lenſes, while regulating the guide for the eye, and adjuſting for the focal diſtance.

If the obſerver, in the proceſs of his examination of an object, advance rapidly from a ſhallow to a deep magnifier, he will ſave himſelf ſome labour by pulling out the internal tube at O.

The upper part *f g r s* of the ſtage is to be raiſed or lowered occaſionally, in order to make the centre of the object coincide with the centre of the lens at O.

To delineate objects, the grey glaſs muſt be placed before the large lenſes; the picture of the object will be formed on this glaſs, and the outline may be accurately taken by going over the picture with a pencil.

The

p. 724

MICROSCOPE.

Plate CCCI.

Fig. 26.

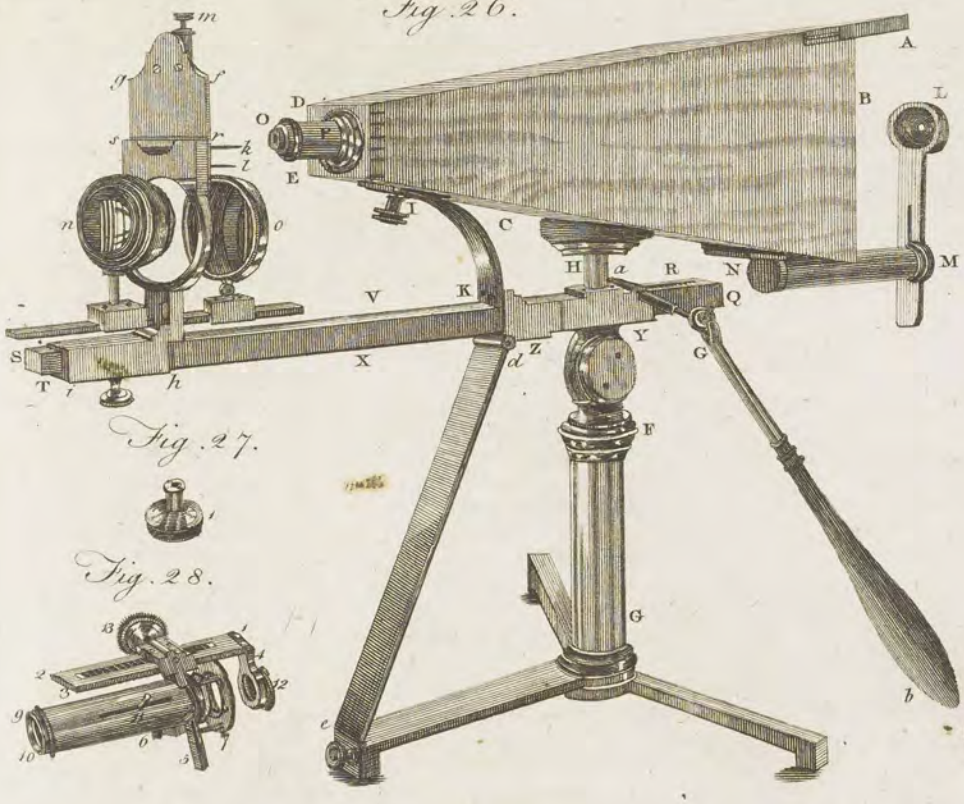


Fig. 27.

Fig. 28.

Fig. 29.

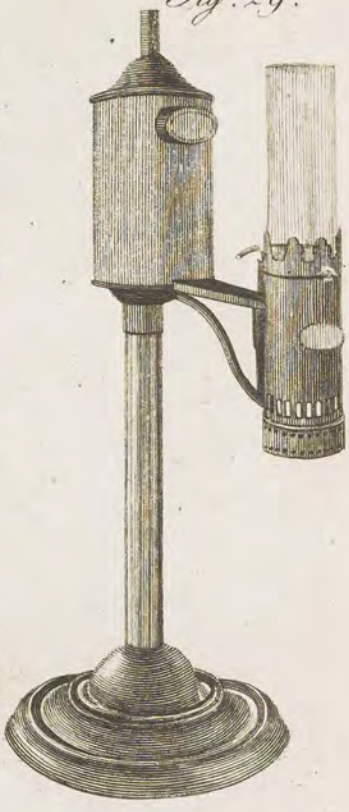


Fig. 30.

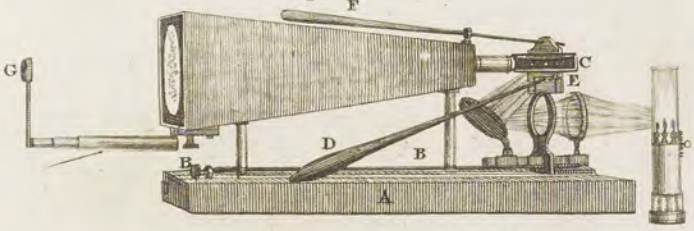
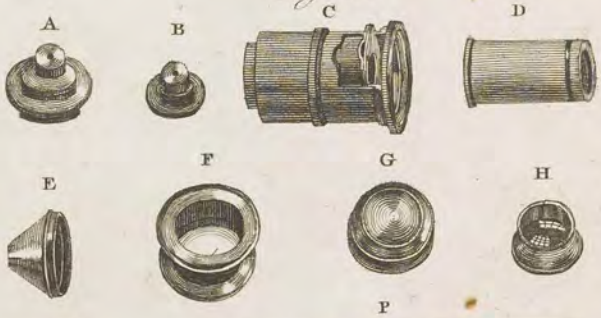
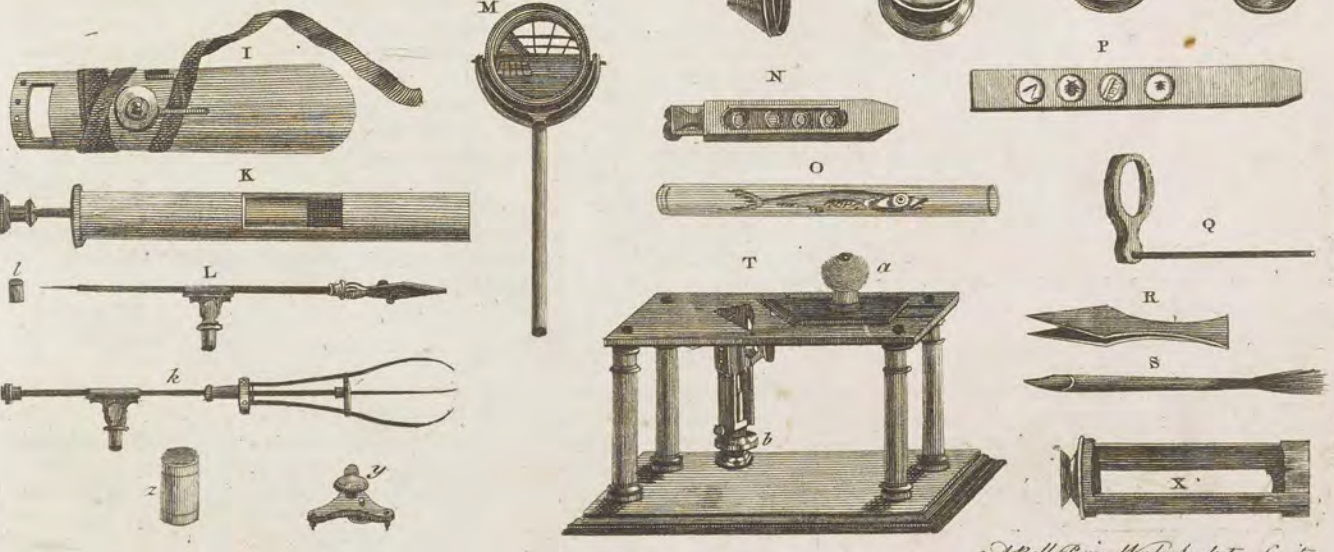


Fig. 31.





A Bell Prin. Wal. Sculptor fecit.

Microſcope

The opaque part may be uſed in the day-time without a lamp, provided the large lenſes at AB are ſcreened from the light.

To uſe the Lucernal Microſcope in the examination of Tranſparent Objects. The inſtrument is to remain as before: the upper part *f g s* of the opaque ſtage muſt be removed, and the ſtage for tranſparent objects, repreſented at fig. 28. put in its place; the end 9 10 to be next the lamp.

Place the greyed glaſs in its groove at the end AB, and the objects in the ſlider-holder at the front of the ſtage; then tranſmit as ſtrong a light as you are able on the object, which you will eaſily do by raiſing or lowering the lamp.

The object will be beautifully depicted on the grey glaſs: it muſt be regulated to the focus of the magnifier, by turning the pinion *a*.

The object may be viewed either with or without the guide for the eye. A ſingle obſerver will ſee an object to the greateſt advantage by uſing this guide, which is to be adjuſted as we have deſcribed above. If two or three wiſh to examine the object at the ſame time, the guide for the eye muſt be laid aſide.

Take the large lens out of the groove, and receive the image on the grey glaſs; in this caſe, the guide for the eye is of no uſe: if the grey glaſs be taken away, the image of the object may be received on a paper ſcreen.

Take out the grey glaſs, replace the large lenſes, and uſe the guide for the eye; attend to the foregoing directions, and adjuſt the object to its proper focus. You will then ſee the object in a blaze of light almoſt too great for the eye, a circumſtance that will be found very uſeful in the examination of particular objects. The edges of the object in this mode will be ſomewhat coloured: but as it is only uſed in this full light for occaſional purpoſes, it has been thought better to leave this ſmall imperfection, than, by remedying it, to ſacrifice greater advantages; the more ſo, as this fault is eaſily corrected, and a new and intereſting view of the object is obtained, by turning the inſtrument out of the direct rays of light, and permitting them to paſs through only in an oblique direction, by which the upper ſurface is in ſome degree illuminated, and the object is ſeen partly as opaque, partly as tranſparent. It has been already obſerved, that the tranſparent objects might be placed between the ſlider-holders of the ſtage for opaque objects, and then be examined as if opaque.

Some tranſparent objects appear to the greateſt advantage when the lens at 9 10 is taken away; as, by giving too great a quantity of light, it renders the edges leſs ſharp.

The variety of views which may be taken of every object by means of the improved lucernal microſcope, will be found to be of great uſe to an accurate obſerver: it will give him an opportunity of correcting or confirming his diſcoveries, and inveſtigating thoſe parts in one mode which are inviſible in another. Microſcope

To throw the image of tranſparent objects on a ſcreen, as in the ſolar microſcope. It has been long a microſcopical deſideratum, to have an inſtrument by which the image of tranſparent objects might be thrown on a ſcreen, as in the common ſolar microſcope: and this not only becauſe the ſun is ſo uncertain in this climate, and the uſe of the ſolar microſcope requires confinement in the fineſt part of the day, when time ſeldom hangs heavy on the mind; but as it alſo affords an increaſe of pleaſure, by diſplaying its wonders to ſeveral perſons at the ſame inſtant, without the leaſt fatigue to the eye.

This purpoſe is now effectually anſwered, by affixing the tranſparent ſtage of the lucernal to a lanthorn, with one of Argand's lamps.—The lamp is placed within the lanthorn, and the end 9 10 of the tranſparent ſtage is ſcrewed into a female ſcrew, which is rivetted in the ſliding part of the front of the lanthorn; the magnifying lenſes are to be ſcrewed into the hole repreſented at 12, and they are adjuſted by turning the milled nut. The quantity of light is to be regulated by raiſing and lowering the ſliding-plate or the lamp.

Apparatus which uſually accompanies the improved Lucernal Microſcope. The ſtage for opaque objects, with its ſemicircular lump of glaſs, and concave mirror. The ſtage for tranſparent objects, which fits on the upper part of the foregoing ſtage. The ſliding tube, to which the magnifiers are to be affixed: one end of theſe is to be ſcrewed on the end D of the wooden body; the magnifier in uſe is to be ſcrewed to the other end of the inner tube. Eight magnifying lenſes: theſe are ſo conſtructed, that they may be combined together, and thus produce a very great variety of magnifying powers. A fiſh-pan, ſuch as is repreſented at I. A ſteel wire L, with a pair of nippers at one end, and a ſmall cylinder of ivory *l* at the other. A ſlider of braſs N, containing a flat glaſs ſlider, and a braſs ſlider into which are fitted ſome ſmall concave glaſſes. A pair of forceps. Six large and ſix ſmall ivory ſliders, with tranſparent objects. Fourteen wooden ſliders, with four opaque objects in each ſlider; and two ſpare ſliders. Some capillary tubes for viewing ſmall animalcula.

Ingenious men ſeldom content themſelves with an inſtrument under one form; hence ſuch a variety of microſcopes, hence many alterations in the Lucernal Microſcope. Mr Adams himſelf, we underſtand, has fitted up this laſt in a great many different ways; and it is reaſonable to think that no perſon is more likely to give it every improvement of which is is ſuſceptible. Of the alterations by other hands we ſhall only particulariſe one, made by Mr Jones of Holborn (B), whoſe deſcription is as follows:

A, repreſents a portion of the top of the mahogany box

(B) We truſt the reader will never conſider any paragraph wherein the name of an inſtrument-maker or other artiſt is inſerted, as a recommendation of thoſe artiſts by the editors of this work. In the courſe of a pretty extenſive correſpondence, they have been favoured with very liberal communications from various artiſts, for which they are greatly indebted to them: the inſerting their names in this work is therefore to be conſidered as a grateful acknowledgment from the editors for favours conferred on them,—not as a teſtimonial

Microſcope box in which it packs, to preſerve it ſteady; it ſlides in a dove-tail groove withinſide, a ſimilar groove to which is cut in the top of the box A; ſo that when the inſtrument is to be uſed, it is ſlipt out of the box withinſide, and then ſlipt into the groove at top ready for uſe, almoſt inſtantly, as ſhown in the figure. The adjuſtment of the objects is at the ſtage E; for the right focal diſtance is readily and conveniently made by turning the long ſcrew-rod B B, which goes thro' the two pillars ſupporting the box, and works in the baſe of the braſs ſtage E; which baſe is alſo dove-tailed, ſo as to have a regular and ſteady motion in another braſs baſis that ſupports it. In this inſtrument, therefore, the pyramidical box does not move; but the ſtage part only, which, from its ſmall weight, moves in the moſt agreeable and ſteady manner. While obſerving the image of the object upon the glaſs through the ſight-hole at G, the object may be moved or changed by only turning the rack-work and pinion applied to the ſtage, by means of the handle D, for that purpoſe. By this contrivance you have no occaſion to change your poſition during the view of the objects upon one of the ſliders. This motion changes the objects horizontally only; and as they are generally placed exactly in one line, it anſwers all the purpoſes for which this motion is intended very well. But it may ſometimes happen that the obſerver would wiſh to alter the vertical poſition of the object; to perform which there is another plane rod at F, that acts ſimply as a lever for this purpoſe, and moves the ſliding part of the ſtage E vertically either upwards or downwards.

Thus, without altering his poſition, the obſerver may inveſtigate all parts of the objects in the moſt ſatisfactory manner. Rack-work and pinion might be applied to the ſtage for the vertical motion alſo; but as it would materially enhance the expence, it is ſeldom applied. The braſs work at the handle of D contains a Hooke's univerſal joint.

The brilliancy of the images of the objects ſhown upon the large lenſes at the end of the box, being very frequently ſo great as to dazzle the eyes, Mr Jones applies a ſlight tinge of blue, green, and other coloured glaſs, to the ſight-hole at G, which ſoftens this glare, and caſts an agreeable hue upon the objects.

Deſcription of thoſe Parts of a Microſcopical Apparatus, common to moſt Inſtruments, which are delineated at fig. 31.

A and B repreſent the braſs cells which contain the magnifiers belonging to the different kinds of compound microſcopes. The magnifiers are ſometimes contained in a ſlider like that which is delineated at S (fig. 24). The lenſes of A and B are confined by a ſmall cap; on unſcrewing this, the ſmall lens may be taken out and cleaned. The magnifiers A of the lucernal microſcope are ſo contrived, that any two of them may be ſcrewed together, by which means a conſiderable variety of magnifying power is obtained.

To get at the lenſes in the ſlider S (fig. 24.), take out the two ſcrews which hold on the cover.

C, repreſents the general form of the ſlider-holder. Microſcope
It conſiſts of a cylindrical tube, in which an inner tube is forced up by a ſpring. It is uſed to receive the ivory or any other ſlider, in which the tranſparent objects are placed; theſe are to be ſlid between the two upper plates: the hollow part in one of the plates is deſigned for the glaſs tubes.

D, the condenſing lens and its tube, which fits into the ſlider-holder C, and may be moved up and down in it. When this piece is puſhed up as far as it will go, it condenſes the light of a candle, which is reflected on it by the plain mirror of the compound microſcope, and ſpreads it uniformly over the object; in this caſe it is beſt adapted to the ſhalloweſt magnifiers. If the deeper lenſes are uſed, it ſhould be drawn down, or rather removed further from the object, that it may concentrate the light in a ſmall compaſs, and thus render it more denſe. The condenſing lens is ſometimes fitted up differently; but the principle being the ſame, it will be eaſy to apply it to uſe notwithſtanding ſome variations in the mechaniſm.

E, a braſs cone. It fixes under the ſlider-holder, and is uſed to leſſen occaſionally the quantity of light which comes from the mirror to any object.

F, a box with two flat glaſſes, which may be placed at different diſtances from each other in order to confine a ſmall living inſect.

G, a ſmall braſs box to hold the ſilver ſpeculum H.

H, a ſmall ſilver concave ſpeculum, deſigned to reflect the light from the mirror on opaque objects; it ſhould only be uſed with the ſhallow magnifiers. It is applied in different ways to the compound microſcope; ſometimes to a tube ſimilar to that repreſented at X, which ſlides on the lower part of the body; ſometimes it is ſcrewed into the ring of the piece Q; the pin of this generally fits into one of the holes in the ſtage. When this ſpeculum is uſed, the ſlider-holder ſhould be removed.

I, a fiſh-pan, whereon a ſmall fiſh may be faſtened, in order to view the circulation of the blood: its tail is to be ſpread acroſs the oblong hole at the ſmalleſt end, and tied faſt by means of the ribbon fixed thereto, by ſhoving the knob which is on the back of it through the ſlit made in the ſtage; the tail of the fiſh may be brought under the lens which is in uſe.

K, a cylindrical piece, intended for the ſolar opaque microſcope: by pulling back the ſpiral ſpring, ſmaller or larger objects may be confined in it.

k, A pair of triangular nippers for taking hold of and confining a large object.

L, a long ſteel wire, with a ſmall pair of pliers at one end and a ſteel point at the other: the wire ſlips backwards or forwards in a ſpring tube, which is affixed to a joint, at the bottom of which is a pin to fit one of the holes in the ſtage; this piece is uſed to confine ſmall objects.

l, A ſmall ivory cylinder that fits on the pointed end of the ſteel wire L; it is deſigned to receive opaque objects. Light-coloured ones are to be ſtuck on the dark ſide, and *vice verſa*.

M, a convex lens, which fits to the ſtage by means of

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nial of their opinion of the abilities of an individual, or as deſigned to inſinuate any preference over others in the ſame line, where ſuch preference has not been already beſtowed by the public.

Microſcope of the long pin adhering to it. This piece is deſigned to collect the light from the ſun or a candle, and to throw them on any object placed on the ſtage; but it is very little uſed at preſent.

N, a braſs ſlider, into which is fitted a flat piece of glaſs, and a braſs ſlider containing four ſmall glaſſes, one or two of them concave, the others flat; it is deſigned to confine ſmall living objects, and when uſed is to be placed between the two upper plates of the ſlider-holder.

O, a glaſs tube to receive a ſmall fiſh, &c.

P, repreſents one of the ivory ſliders, wherein objects are placed between two pieces of talc, and confined by a braſs ring.

Q, a piece to hold the ſpeculum H: this piece is generally fitted to the microſcope repreſented at fig. 12.

R, a pair of forceps, to take up any occaſional object.

S, a camel's hair pencil to bruſh the duſt off the glaſſes; the upper part of the quill is ſcooped out, to take up a drop of any fluid, and place it on either of the glaſſes for examination.

T, an inſtrument for cutting thin tranſverſe ſections of wood. It conſiſts of a wooden baſe, which ſupports four braſs pillars; on the top of the pillars is placed a flat piece of braſs, near the middle of which there is a triangular hole.

A ſharp knife, which moves in a diagonal direction, is fixed on the upper ſide of the afore-mentioned plate, and in ſuch a manner that the edge always coincides with the ſurface thereof.

The knife is moved backwards and forwards by means of the handle *a*. The piece of wood is placed in the triangular trough which is under the braſs plate, and is to be kept ſteady therein by a milled ſcrew which is fitted to the trough; the wood is to be preſſed forward for cutting by the micrometer ſcrew *b*.

The pieces of wood ſhould be applied to this inſtrument immediately on being taken out of the ground, or elſe they ſhould be ſoaked for ſome time in water, to ſoften them ſo that they may not hurt the edge of the knife.

When the edge of the knife is brought in contact with the piece of wood, a ſmall quantity of ſpirits of wine ſhould be poured on the ſurface of the wood, to prevent its curling up; it will alſo make it adhere to the knife, from which it may be removed by preſſing a piece of blotting paper on it.

y, An appendage to the cutting engine, which is to be uſed inſtead of the micrometer ſcrew, being preferred to it by ſome. It is placed over the triangular hole, and kept flat down upon the ſurface of the braſs plate, while the piece of wood is preſſed againſt a circular piece of braſs which is on the under ſide of it. This circular piece of braſs is fixed to a ſcrew, by which its diſtance from the flat plate on which the knife moves may be regulated.

z, An ivory box, containing at one end ſpare talc for the ivory ſliders, and at the other ſpare rings for preſſing the talcs together and confining them to the ſlider.

After what has been related of Microſcopes, they cannot be ſaid to be complete without the valuable addition of a *micrometer*; for the uſe and advantages of which, ſee the article Micrometer. Microſcope

Having preſented our readers with deſcriptions of the various miſcroſcopes generally uſed, we think it our duty to point out to them thoſe which we conceive to be beſt calculated to anſwer the purpoſes of ſcience. The firſt which preſents itſelf to our mind is that of *Ellis*: It is better adapted, than any other portable microſcope, to the purpoſe of general obſervation; ſimple in its conſtruction, and general in its application. To thoſe who prefer a double microſcope, we ſhould recommend that figured in Plate CCXCVIII. (12.) If opaque objects, as inſects, &c. be ſubjects of inveſtigation, the *Lucernal Microſcope* claims the preference: but if amuſement alone guides the choice, the *Solar Microſcope* muſt be fixed upon.

We ſhall now proceed to explain ſome neceſſary particulars reſpecting the method of uſing microſcopes; after which, we ſhall ſubjoin an enumeration of the principal objects diſcovered or elucidated by their means. On this ſubject Mr Adams, in his *Eſſay on the Microſcope*, has been very copious; with a view, as he informs us, to remove the common complaint made by Mr Baker, "that many of thoſe who purchaſe microſcopes are ſo little acquainted with their general and extenſive uſefulneſs, and ſo much at a loſs for objects to examine by them, that after diverting their friends ſome few times with what they find in the ſliders which generally accompany the inſtrument, or perhaps with two or three common objects, the microſcope is laid aſide as of little further value; whereas no inſtrument has yet appeared in the world capable of affording ſo conſtant, various, and ſatisfactory an entertainment to the mind."

I. In uſing the microſcope, there are three things neceſſary to be conſidered. (1.) The preparation and adjuſtment of the inſtrument itſelf. (2.) The proper quantity of light, and the beſt method of adapting it to the object. (3.) The method of preparing the objects, ſo that their texture may be properly underſtood.

1. With regard to the microſcope itſelf, the firſt thing neceſſary to be examined is, whether the glaſſes be clean or not: if they are not ſo, they muſt be wiped with a piece of ſoft leather, taking care not to ſoil them afterwards with the fingers; and, in replacing them, care muſt be taken not to place them in an oblique ſituation. We muſt likewiſe be careful not to let the breath fall upon the glaſſes, nor to hold that part of the body of the inſtrument where the glaſſes are placed with a warm hand; becauſe thus the moiſture expelled by the heat from the metal will condenſe upon the glaſs, and prevent the object from being diſtinctly ſeen. The object ſhould be brought as near the centre of the field of view as poſſible; for there only it will be exhibited in the greateſt perfection. The eye ſhould be moved up and down from the eye-glaſs of a compound microſcope, till the ſituation is found where the largeſt field and moſt diſtinct view of the object are to be had: but every perſon ought to adjuſt the microſcope to his own eye, and not to depend upon the ſituation it was placed in by another. A ſmall magnifying power ſhould

always

Microſcope always be begun with; by which means the obſerver will beſt obtain an exact idea of the ſituation and connection of the whole; and will of conſequence be leſs liable to form any erroneous opinion when the parts are viewed ſeparately by a lens of greater power. Objects ſhould alſo be examined firſt in their moſt natural poſition: for if this be not attended to, we ſhall be apt to form very inadequate ideas of the ſtructure of the whole, as well as of the connection and uſe of the parts. A living animal ought to be as little hurt or diſcompoſed as poſſible.

From viewing an object properly, we may acquire a knowledge of its nature: but this cannot be done without an extenſive knowledge of the ſubject, much patience, and many experiments; as in a great number of caſes the images will reſemble each other, though derived from very different ſubſtances. Mr Baker therefore adviſes us not to form an opinion too ſuddenly after viewing a microſcopical object; nor to draw our inferences till after repeated experiments and examinations of the object in many different lights and poſitions; to paſs no judgment upon things extended by force, or contracted by dryneſs, or in any manner out of a natural ſtate, without making ſuitable allowances. The true colour of objects cannot be properly determined by very great magnifiers; for as the pores and interſtices of an object are enlarged according to the magnifying power of the glaſſes made uſe of, the component particles of its ſubſtance will appear ſeparated many thouſand times farther aſunder than they do to the naked eye: hence the reflection of the light from theſe particles will be very different, and exhibit different colours. It is likewiſe ſomewhat difficult to obſerve opaque objects; and as the apertures of the larger magnifiers are but ſmall, they are not proper for the purpoſe. If an object be ſo very opaque, that no light will paſs through it, as much as poſſible muſt be thrown upon the upper ſurface of it. Some conſideration is likewiſe neceſſary in forming a judgment of the motion of living creatures, or even of fluids, when ſeen through the microſcope; for as the moving body, and the ſpace wherein it moves, are magnified, the motion will alſo be increaſed.

2. On the management of the light depends in a great meaſure the diſtinctneſs of the viſion: and as, in order to have this in the greateſt perfection, we muſt adapt the quantity of light to the nature of the object and the focus of the magnifier, it is therefore neceſſary to view it in various degrees of light. In ſome objects, it is difficult to diſtinguiſh between a prominence and a depreſſion, a ſhadow or a black ſtain; or between a reflection of light and whiteneſs, which is particularly obſervable in the eye of the libella and other flies: all of theſe appearing very different in one poſition from what they do in another. The brightneſs of an object likewiſe depends on the quantity of light, the diſtinctneſs of viſion, and on regulating the quantity to the object; for ſome will be in a manner loſt in a quantity of light ſcarce ſufficient to render another viſible.

There are various ways in which a ſtrong light may be thrown upon objects; as by means of the ſun and a convex lens. For this purpoſe, the microſcope is to be placed about three feet from a ſouthern window; then take a deep convex lens, mounted on a ſemicircle and ſtand, ſo that its poſition may eaſily be varied: place this lens between the object and the window, ſo that it may collect a conſiderable number of ſolar rays, and refract them on the object or the mirror of the microſcope. If the light thus collected from the ſun be too powerful, it may be leſſened by placing a piece of oiled paper, or a piece of glaſs lightly greyed, between the object and lens. Thus a proper degree of light may be obtained, and diffuſed equally all over the ſurface of an object: a circumſtance which ought to be particularly attended to; for if the light be thrown irregularly upon it, no diſtinct view can be obtained. If we mean to make uſe of the ſolar light, it will be found convenient to darken the room, and to reflect the rays of the ſun on the abovementioned lens by means of the mirror of a ſolar microſcope fixed to the window-ſhutter; for thus the obſerver will be enabled to preſerve the light on his object, notwithſtanding the motion of the ſun. But by reaſon of this motion, and the variable ſtate of the atmoſphere, ſolar obſervations are rendered both tedious and inconvenient: whence it will be proper for the obſerver to be furniſhed with a large tin lanthorn, formed ſomething like the common magic lanthorn, capable of containing one of Argand's lamps. This, however, ought not to be of the fountain kind, leſt the rarefaction of the air in the lanthorn ſhould force the oil over. There ought to be an aperture in the front of the lanthorn, which may be moved up and down, and be capable of holding a lens; by which means a pleaſant and uniform as well as ſtrong light may eaſily be procured. The lamp ſhould likewiſe move on a rod, ſo that it may be eaſily raiſed or depreſſed. This lanthorn may likewiſe be uſed for many other purpoſes; as viewing of pictures, exhibiting microſcopic objects on a ſcreen, &c. A weak light, however, is beſt for viewing many tranſparent objects: among which we may reckon the prepared eyes of flies, as well as the animalcules in fluids. The quantity of light from a lamp or candle may be leſſened by removing the microſcope to a greater diſtance from them, or by diminiſhing the ſtrength of the light which falls upon the objects. This may very conveniently be done by pieces of black paper with circular apertures of different ſizes, and placing a larger or ſmaller one upon the reflecting mirror, as occaſion may require. There is an oblique ſituation of the mirrors, which makes likewiſe an oblique reflection of the light eaſily diſcovered by practice, (but for which no general rule can be given in theory); and which will exhibit an object more diſtinctly than any other poſition, ſhowing the ſurface, as well as thoſe parts through which the light is tranſmitted. The light of a lamp or candle is generally better for viewing microſcopic objects than day-light; it being more eaſy to modify the former than the latter, and to throw it upon the objects with different degrees of denſity.

Microſcope

3. With regard to the preparation of objects, Swammerdam has, in that particular, excelled almoſt all other inveſtigators who either preceded or have ſucceeded him. He was ſo aſſiduous and indefatigable, that neither difficulty nor diſappointment could make the leaſt impreſſion upon him; and he never abandoned the purſuit of any object until he had ob-

Microſcope

tained a ſatisfactory idea of it. Unhappily, however, the methods he made uſe of in preparing his objects for the microſcope are now entirely unknown. Dr Boerhaave examined with the ſtricteſt attention all the letters and manuſcripts of Swammerdam which he could find; but his reſearches were far from being ſucceſsful. The following particulars, however, have thus come to the knowledge of the public.

For diſſecting of *ſmall inſects*, Swammerdam had a braſs table made by S. Muſchenbroek, to which were affixed two braſs arms moveable at pleaſure to any part of it. The upper part of theſe vertical arms was conſtructed in ſuch a manner as to have a ſlow vertical motion; by which means the operator could readily alter their height as he ſaw convenient. One of theſe arms was to hold the minute objects, and the other to apply the microſcope.

The lenſes of Swammerdam's microſcopes were of various ſizes as well as foci: but all of them the beſt that could be procured, both for the tranſparency of the glaſs and the fineneſs of the workmanſhip. His obſervations were always begun with the ſmalleſt magnifiers, from which he proceeded to the greateſt; but in the uſe of them, he was ſo exceedingly dexterous, that he made every obſervation ſubſervient to that which ſucceeded it, and all of them to the confirmation of each other, and to the completing of the deſcription. His chief art ſeems to have been in conſtructing ſciſſars of an exquiſite fineneſs, and making them very ſharp. Thus he was enabled to cut very minute objects to much more advantage than could be done by knives and lancets; for theſe, though ever ſo ſharp and fine, are apt to diſorder delicate ſubſtances by diſplacing ſome of the filaments, and drawing them after them as they paſs through the bodies; but the ſciſſars cut them all equally. The knives, lancets, and ſtyles he made uſe of in his diſſections, were ſo fine that he could not ſee to ſharpen them without the aſſiſtance of a magnifying glaſs; but with theſe he could diſſect the inteſtines of bees with the ſame accuracy that the beſt anatomiſts can do thoſe of large animals. He made uſe alſo of very ſmall glaſs tubes no thicker than a briſtle, and drawn to a very fine point at one end, but thicker at the other. Theſe were for the purpoſe of blowing up, and thus rendering viſible the ſmalleſt veſſels which could be diſcovered by the microſcope; to trace their courſes and communications, or ſometimes to inject them with coloured liquors.

Swammerdam ſometimes made uſe of ſpirit of wine, water, or oil of turpentine, for ſuffocating the inſects he wiſhed to examine; and would preſerve them for a time in theſe liquids. Thus he kept the parts from putrefying, and gave them beſides ſuch additional ſtrength and firmneſs, as rendered the diſſections much more eaſy than they would otherwiſe have been. Having then divided the body tranſverſely with the ſciſſars, and made what obſervations he could without farther diſſection, he proceeded to extract the inteſtines carefully with very fine inſtruments, to waſh away the fat in the like careful manner; and thus to put the parts into ſuch a ſtate as would beſt expoſe them to view; but theſe operations are beſt performed while the inſects are in their nympha ſtate.

Sometimes the delicate viſcera of the inſects, after having been ſuffocated as abovementioned, were put into water; after which, having ſhaken them gently, he procured an opportunity of examining them, eſpecially the air veſſels, which laſt he could thus ſeparate entire from all the other parts, to the admiration of all who beheld them; as theſe veſſels cannot be diſtinctly ſeen in any other manner, or indeed in any way whatever, without injuring them. Frequently alſo he injected water with a ſyringe to cleanſe the parts thoroughly, after which he blew them up with air and dried them; thus rendering them durable, and fit for examination at a proper opportunity. Sometimes he made very important diſcoveries, by examining inſects which he had preſerved for ſeveral years in balſam. Other inſects he punctured with a very fine needle; and after ſqueezing out all their moiſture through the holes made in this manner, he filled them with air, by means of very ſlender glaſs tubes; then dried them in the ſhade; and laſtly anointed them with oil of ſpike in which a little roſin had been diſſolved; and by which means they, for a long time, retained their proper forms. He was likewiſe in poſſeſſion of a ſingular ſecret, by which he could preſerve the limbs of inſects as limber and perſpicuous as ever they had been. He uſed to make a ſmall puncture or inciſion in the tails of worms; and after having with great caution ſqueezed out all the humours, as well as great part of the viſcera, he injected them with wax in ſuch a manner as to give them the appearance of living creatures in perfect health. He found that the fat of all inſects was entirely diſſolvable in oil of turpentine; by which means he was enabled plainly to diſcern the viſcera; though, after this diſſolution, it was neceſſary to cleanſe and waſh them frequently in clean water. In this manner he would frequently have ſpent whole days in the preparation of a ſingle caterpillar, and cleanſing it from its fat, in order to diſcover the true ſituation of the inſect's heart. He had a ſingular dexterity in ſtripping off the ſkins of caterpillars that were on the point of ſpinning their cones. This was done by letting them drop by their threads into ſcalding water, and then ſuddenly withdrawing them. Thus the epidermis peeled off very eaſily; and, when this was done, he put them into diſtilled vinegar and ſpirit of wine mixed together in equal proportions; which, by giving a due degree of firmneſs to the parts, gave him an opportunity of ſeparating them with very little trouble from the exuviæ, without any danger to the internal parts. Thus the nymph could be ſhown to be wrapped up in the caterpillar and the butterfly in the nymph; and there is little doubt that thoſe who look into the works of Swammerdam, will be amply recompenſed, whether they conſider the unexampled labour or the piety of the author.

M. Lyonet, a late eminent naturaliſt, uſually drowned the inſects he deſigned to examine; by which means he was enabled to preſerve both the ſoftneſs and tranſparency of the parts. According to him, the inſect, if very ſmall, *viz.* one tenth of an inch, or little more, in length, ſhould be diſſected on a glaſs ſomewhat concave. If it ſhould be ſuſpected that the inſect will putrefy by keeping for a few days, ſpirit of wine diluted with water muſt be ſubſtituted inſtead of pure water. The inſect muſt be ſuffered to dry; after which it may

Microſcope be faſtened by a piece of ſoft wax, and again covered with water.—Larger objects ſhould be placed in a trough of thin wood; and for this purpoſe the bottom of a common chip box will anſwer very well; only ſurrounding the edge of it with ſoft wax, to keep in the water or other fluid employed in preſerving the inſect. The body is then to be opened; and if the parts are ſoft like thoſe of a caterpillar, they ſhould be turned back, and fixed to the trough by ſmall pins, which ought to be ſet by a ſmall pair of nippers. At the ſame time, the ſkin being ſtretched by another pair of finer forceps, the inſect muſt be put into water, and diſſected therein, occaſionally covering it with ſpirit of wine. Thus the ſubject will be preſerved in perfection, ſo that its parts may be gradually unfolded, no other change being perceived than that the ſoft elaſtic parts become ſtiff and opaque, while ſome others loſe their colour.

The following inſtruments were made uſe of by M. Lyonet in his diſſection of the *Chenille de Saul*. A pair of ſciſſars as ſmall as could be made, with long and fine arms: A pair of forceps, with their ends ſo nicely adjuſted, that they could eaſily lay hold of a ſpider's thread, or a grain of ſand: Two fine ſteel needles fixed in wooden handles, about two inches and three quarters in length; which were the moſt generally uſeful inſtruments he employed.

Dr Hooke, who likewiſe made many microſcopic obſervations, takes notice, that the common ant or piſmire is much more troubleſome to draw than other inſects, as it is extremely difficult to get the body in a quiet natural poſture. If its feet be fettered with wax or glue, while the animal remains alive, it ſo twiſts its body, that there is no poſſibility of gaining a proper view of it; and if it be killed before any obſervation is made, the ſhape is often ſpoiled before it can be examined. The bodies of many minute inſects, when their life is deſtroyed, inſtantly ſhrivel up; and this is obſervable even in plants as well as inſects, the ſurface of theſe ſmall bodies being affected by the leaſt change of air; which is particularly the caſe with the ant. If this creature, however, be dropped into rectified ſpirit of wine, it will inſtantly be killed; and when it is taken out, the ſpirit of wine evaporates, leaving the animal dry, and in its natural poſture, or at leaſt in ſuch a ſtate that it may eaſily be placed in whatever poſture we pleaſe.

Parts of Inſects. The *wings*, in many inſects, are ſo tranſparent, that they require no previous preparation: but ſome of thoſe that are folded up under *elytra* or caſes, require a conſiderable ſhare of dexterity to unfold them; for theſe wings are naturally endowed with ſuch a ſpring, that they immediately fold themſelves again, unleſs care be taken to prevent them. The wing of the earwig, when expanded, is of a tolerable ſize, yet is folded up under a caſe not one eighth part of its bulk; and the texture of this wing renders it difficult to be unfolded. This is done with the leaſt trouble immediately after the inſect is killed. Holding then the creature by the thorax, between the finger and thumb, with a blunt-pointed pin endeavour gently to open it, by ſpreading it over the fore-finger, and at the ſame time gradually ſliding the thumb over it. When the wing is ſufficiently expanded, ſeparate it from the inſect by a ſharp knife or a pair of ſciſſars. The wing ſhould be preſſed for ſome time between the thumb and finger before it be removed; it ſhould then be placed between two pieces of paper, and again preſſed for at leaſt an hour; after which time, as there will be no danger of its folding up any more, it may be put between the talcs, and applied to the microſcope. Similar care is requiſite in diſplaying the wings of the notonecta and other water-inſects, as well as moſt kinds of grylli. Microſcope

The minute *ſcales* or *feathers*, which cover the wings of moths or butterflies, afford very beautiful objects for the microſcope. Thoſe from one part of the wing frequently differ in ſhape from ſuch as are taken from other parts; and near the thorax, ſhoulder, and on the fringes of the wings, we generally meet with hair inſtead of ſcales. The whole may be bruſhed off the wing, upon a piece of paper, by means of a camel's-hair pencil; after which the hairs can be ſeparated with the aſſiſtance of a common magnifying glaſs.

It is likewiſe a matter of conſiderable difficulty to diſſect properly the *proboſcis* of inſects, ſuch as the gnat, tabanus, &c. and the experiment muſt be repeated a great number of times before the ſtructure and ſituation of the parts can be thoroughly inveſtigated, as the obſerver will frequently diſcover in one what he could not in another. The *collector of the bee*, which forms a very curious object, ought to be firſt carefully waſhed in ſpirit of turpentine; by which means it will be freed from the unctuous matter adhering to it: when dry, it is again to be waſhed with a camel's-hair pencil to diſengage and bring forward the ſmall hairs which form part of this microſcopic beauty. The beſt method of managing the *ſtings* of inſects, which are in danger of being broken by reaſon of their hardneſs, is to ſoak the caſe and the reſt of the apparatus for ſome time in ſpirit of wine or turpentine; then lay them on a piece of paper, and with a blunt knife draw out the ſting, holding the ſheath with the nail of the finger or any blunt inſtrument; but great care is neceſſary to preſerve the *feelers*, which when cleaned add much to the beauty of the object. The *beard* of the lepas antifera is to be ſoaked in clean ſoft water, frequently bruſhing it while wet with a camel's-hair pencil: after it is dried, the bruſhing muſt be repeated with a dry pencil to diſengage and ſeparate the hairs, which are apt to adhere together.

To view to advantage the *fat*, *brains*, and other ſimilar ſubſtances, Dr Hooke adviſes to render the ſurface ſmooth, by preſſing it between two plates of thin glaſs, by which means the matter will be rendered much thinner and more tranſparent: without this precaution, it appears confuſed, by reaſon of the parts lying too thick upon one another. For *muſcular fibres*, take a piece of the fleſh, thin and dry; moiſten it with warm water, and after this is evaporated the veſſels will appear more plain and diſtinct; and by repeated macerations they appear ſtill more ſo. The *exuviæ* of inſects afford a pleaſing object, and require but little preparation. If bent or curled up, they will become ſo relaxed by being kept a few hours in a moiſt atmoſphere, that you may eaſily extend them to their natural poſitions; or the ſteam of warm water will anſwer the purpoſe very well.

The *eyes* of inſects in general form very curious

Microſcope

and beautiful objects. Thoſe of the libellula and other flies, as well as of the lobſter, &c. muſt firſt be cleaned from the blood, &c. after which they ſhould be ſoaked in water for ſome days: one or two ſkins are then to be ſeparated from the eye, which would be otherwiſe too opaque and confuſed; but ſome care is requiſite in this operation; for if the ſkin be rendered too thin, it is impoſſible to form a proper idea of the organization of the part. In ſome ſubſtances, however, the organization is ſuch, that by altering the texture of the part, we deſtroy the objects which we wiſh to obſerve. Of this ſort are the nerves, tendons, muſcular fibres, many of which are viewed to moſt advantage when floating in ſome tranſparent fluid. Thus very few of the muſcular fibres can be diſcovered when we attempt to view them in the open air, though great numbers may be ſeen if they be placed in water or oil. By viewing the thread of a ligament in this manner, we find it compoſed of a vaſt number of ſmooth round threads lying cloſe together. Elaſtic objects ſhould be pulled or ſtretched out while they are under the microſcope, that the texture and nature of thoſe parts, the figure of which is altered by being thus pulled out, may be more fully diſcovered.

Other objects. To examine *bones* by the microſcope, they ſhould firſt be viewed as opaque objects; but afterwards, by procuring thin ſlices of them, they may be viewed as tranſparent. The ſections ſhould be cut in all directions, and be well waſhed and cleaned; and in ſome caſes maceration will be uſeful, or the bones may be heated red hot in a clear fire, and then taken out; by which means the bony cells will appear more conſpicuous. The *pores of the ſkin* may be examined by cutting off a thin ſlice off the upper ſkin with a razor, and then a ſecond from the ſame place; applying the latter to the microſcope. The lizard, guana, &c. have two ſkins, one very tranſparent, the other thicker and more opaque; and, ſeparating theſe two, you obtain very beautiful objects.

To view the *ſcales of fiſh* to advantage, they ought to be ſoaked in water for a few days, and then carefully rubbed to clean them from the ſkin and dirt which may adhere to them. The ſcales of the eel are a great curioſity; and the more ſo, as this creature was not known to have any ſcales till they were diſcovered by the microſcope. The method of diſcovering them is this. Take a piece of the ſkin of an eel from off its ſide, and ſpread it while moiſt on a piece of glaſs, that it may dry very ſmooth: when thus dried, the ſurface will appear all over dimpled or pitted by the ſcales, which lie under a ſort of cuticle or thin ſkin; which may be raiſed with the ſharp point of a penknife, together with the ſcales, which will then eaſily ſlip out; and thus we may procure as many as we pleaſe.

The *leaves* of many *trees*, as well as of ſome plants, when diſſected, form a very agreeable object. In order to diſſect them, take a few of the moſt perfect leaves you can find, and place them in a pan with clean water. Let them remain there three weeks, or a month, without changing the water; then take them up; and if they feel very ſoft, and almoſt rotten, they are ſufficiently ſoaked. They muſt then be laid on a flat board, and holding them by the ſtalk, draw the edge of a knife over the upper ſide of the leaf, which will take off moſt of the ſkin. Then turn the leaf, and do the ſame with the under ſide; and when the ſkin is taken off on both ſides, waſh out the pulpy matter, and the fibres will be exhibited in a very beautiful manner. The leaf may be ſlit into two parts, by ſplitting the ſtalk; and the ſkins peeled from the fibres will alſo make a good object. This operation is beſt performed in the autumn: the fibres of the leaves are much ſtronger at that ſeaſon, and leſs liable to be broken.—The internal ſtructure of ſhells may be obſerved by grinding them down on a hone: and all ores and minerals ſhould be carefully waſhed and bruſhed with a ſmall bruſh to remove any ſordes that may adhere to them.

Microſcope

To view the *circulation of the blood*, we muſt obſerve living animals of the moſt tranſparent kind.—A ſmall eel is ſometimes uſed for this purpoſe; in which caſe it muſt be cleanſed from the ſlime naturally adhering to it; after which it may be put into a tube filled with water, where it can be viewed in a ſatisfactory manner. The tail of any other ſmall fiſh may be viewed in the ſame manner, or put upon a ſlip of flat glaſs, and thus laid before the microſcope. By filling the tube with water when an eel is made uſe of, we prevent in a great meaſure the ſlimineſs of the animal from ſoiling the glaſs.

The particles of the blood form a very curious object, and have been carefully viewed by different philoſophers; who, nevertheleſs, differ from one another very much in their accounts of them. The beſt method of viewing theſe is to take a ſmall drop of blood when warm, and ſpread it as thin as poſſible upon a flat piece of glaſs. By diluting it a little with warm water, ſome of the large globules will be ſeparated from the ſmaller, and many of them ſubdivided; or a ſmall drop of blood may be put into a capillary glaſs-tube, and then placed before the microſcope. Mr Baker adviſes warm milk as proper to be mixed with the blood; but Mr Hewſon, who is accounted the moſt accurate obſerver, diluted the blood with that fluid which undoubtedly is more natural to it, *viz.* its own ſerum: by this method he could preſerve the ſmall particles entire, and view them diſtinctly; and thus he found that they were not globular, as had been imagined by other anatomiſts, but flat. Having ſhaken a piece of the craſſamentum of the blood in ſerum till the latter became a little coloured, he ſpread it with a ſoft hair pencil on a piece of thin glaſs, which he placed under the microſcope, in ſuch a manner as not to be quite horizontal, but rather higher at one end than the other. Thus the ſerum flows from the higher to the lower part; and, as it flows, ſome of the particles will be found to ſwim on their flat ſides, and will appear to have a dark ſpot in the middle; while others will turn over from one ſide to the other as they roll down the glaſs. Many cruel experiments have been tried in order to obſerve the circulation of the blood in living creatures, and an apparatus has been invented for viewing the circulation in the meſentery of a frog; but as this can anſwer no uſeful purpoſe, and will never be put in practice by perſons of humanity, we forbear to mention it.

Microſcope

II. Beſides the objects for the microſcope already mentioned, there are innumerable others, ſome hardly viſible, and others totally inviſible, to the naked eye; and which therefore, in a more peculiar ſenſe, are denominated,

Microſcopic animals. They are the animalcules or moving bodies in water, in which certain ſubſtances have been infuſed; and of which there are a great many different kinds. Theſe animalcula are ſometimes found in water which we would call *pure*, did not the microſcopes diſcover its minute inhabitants; but not equally in all kinds of water, or even in all parts of the ſame kind of it. The ſurfaces of infuſions are generally covered with a ſcum which is eaſily broken, but acquires thickneſs by ſtanding. In this ſcum the greateſt number of animalcules are uſually found. Sometimes it is neceſſary to dilute the infuſions; but this ought always to be done with water, not only diſtilled, but viewed through a microſcope, leſt it ſhould alſo have animalcules in it, and thus prove a ſource of deception. It is, however, moſt proper to obſerve thoſe minute objects after the water is a little evaporated; the attention being leſs diverted by a few objects than when they appear in great numbers. One or two of the animalcules may be ſeparated from the reſt by placing a ſmall drop of water on the glaſs near that of the infuſion; join them together by making a ſmall connection between them with a pin; and as ſoon as you perceive that an animalcule has entered the clear drop, cut off the connection again.

Eels in paſte are obtained by boiling a little flour and water into the conſiſtence of book-binders paſte; then expoſing it to the air in an open veſſel, and beating it frequently together to keep the ſurface from growing mouldy or hard. In a few days it will be found peopled with myriads of little animals viſible to the naked eye, which are the eels in queſtion. They may be preſerved for a whole year by keeping the paſte moiſtened with water; and while this is done, the motion of the animals will keep the ſurface from growing mouldy. Mr Baker directs a drop or two of vinegar to be put into the paſte now and then. When they are applied to the microſcope, the paſte muſt be diluted in a piece of water for them to ſwim in.

Numberleſs animalcules are obſerved by the microſcope in infuſions of pepper. To make an infuſion for this purpoſe, bruiſe as much common black pepper as will cover the bottom of an open jar, and lay it thereon about half an inch thick: pour as much ſoft water into the veſſel as will riſe about an inch above the pepper. Shake the whole well together: after which they muſt not be ſtirred, but be left expoſed to the air for a few days; in which time a thin pellicle will be formed on the ſurface, in which innumerable animals are to be obſerved by the microſcope.

The microſcopic animals are ſo different from thoſe of the larger kinds, that ſcarce any ſort of analogy ſeems to exiſt between them; and one would almoſt be tempted to think that they lived in conſequence of laws directly oppoſite to thoſe which preſerve ourſelves and other viſible animals in exiſtence. They have been ſyſtematically arranged by O. F. Muller; though it is by no means probable that all the different claſſes have yet been diſcovered. Such as have been obſerved, however, are by this author divided in the following manner. Microſcope

I. *Such as have no external organs.*

1. Monas: Punctiforma. A mere point.
2. Proteus: Mutabilis. Mutable.
3. Volvox: Sphæricum. Spherical.
4. Enchelis: Cylindracea. Cylindrical.
5. Vibrio: Elongatum. Long.

* Membranaceous.

6. Cyclidium: Ovale. Oval.
7. Paramecium: Oblongum. Oblong.
8. Kolpoda: Sinuatum. Sinuous.
9. Gonium: Angulatum. With angles.
10. Burſaria. Hollow like a purſe.

II. *Thoſe that have external organs.*

* Naked, or not incloſed in a ſhell.

1. Cercaria: Caudatum. With a tail.
2. Trichoda: Crinitum. Hairy.
3. Kerona: Corniculatum. With horns.
4. Himantopus: Cirratum. Cirrated.
5. Leucophra: Ciliatum undique. Every part ciliated.
6. Vorticella: Ciliatum apice. The apex ciliated.

* Covered with a ſhell.

7. Brachionus: Ciliatum apice. The apex ciliated.

I. *Monas.*

This is by our author defined to be "an inviſible (to the naked eye), pellucid, ſimple, punctiform worm;" but of which, ſmall as it is, there are ſeveral ſpecies.

1. The *monas termo* or *geletinoſa*, is a ſmall jelly-like point, which can be but imperfectly ſeen by the ſingle microſcope, and not at all by the compound one. In a full light they totally diſappear, by reaſon of their tranſparency. Some infuſions are ſo full of them that ſcarce the leaſt empty ſpace can be perceived; the water itſelf appearing compoſed of innumerable globular points, in which a motion may be perceived ſomewhat ſimilar to that which is obſerved when the ſun's rays ſhine on the water; the whole multitude of animals appearing in commotion like a hive of bees. This animal is very common in ditch-water, and in almoſt all infuſions either of animal or vegetable ſubſtances.

2. *Monas atomus* or *albida*; white monas with a variable point. This appears like a white point, which thro' a high magnifier apppears ſomewhat egg-ſhaped. The ſmaller end is generally marked with a black point, the ſituation of which is variable; ſometimes it appears on the large end, and ſometimes there are two black ſpots in the middle. This ſpecies was found in ſea-water, which had been kept through the whole winter, but was not very fetid. No other kind of animalcule was found in it.

3. *Monas punctum* or *nigra*, black monas. This was found in a fetid infuſion of pears, and appears in form of a very minute, opaque, and black point, moving with a ſlow and wavering motion.

4. *Monas ocellus*, tranſparent like talc, with a point in the middle. This is found in ditches covered with con-

Microſcope

ferva, and ſometimes with the cyclidium milium; the margin of it is black, with a black point in the middle.

5. *Monas lens* or *hyalina;* of a talcy appearance. This is found in all kinds of water; ſometimes even in that which is pure, but always in the ſummer-time in ditch-water. It is found alſo in all infuſions of animal or vegetable ſubſtances, whether in freſh or ſalt water; myriads being contained in a ſingle drop. It is found likewiſe in the filth of the teeth. It is nearly of a round figure; and ſo tranſparent, that it is impoſſible to diſcover the leaſt veſtige of inteſtines. They generally appear in cluſters, but ſometimes ſingly. Contrary to what happens to other animalcules, they appear to cover the edges of the drop when evaporating, and where they inſtantly die. A few dark ſhades, probably occaſioned by the wrinkling of the body, are perceived when the water is nearly evaporated. The motions of this animalcule are generally very quick; and two united together, may ſometimes be ſeen ſwimming among the reſt; which is thought to be a ſingle one generating another by diviſion, as is related under the article ANIMALCULE. Theſe and the animalcules of the firſt ſpecies are ſo numerous, that they exceed all calculation even in a very ſmall ſpace.

6. *Monas mica*, marked with a circle. This is found in the pureſt waters, and may be diſcovered with the third lens of the ſingle microſcope when the magnifying power is increaſed. It appears like a ſmall lucid point; but can aſſume an oval or ſpherical ſhape at pleaſure: ſometimes the appearance of two kidneys may be perceived in its body, and there is commonly the figure of an ellipſe in it; the ſituation of which is moveable, ſometimes appearing in the middle and ſometimes approaching to either extremity. It ſeems encompaſſed with a beautiful halo, which is thought to be occaſioned by the vibration of fine inviſible hairs. It has a variety of motions, and often turns round for a long time in the ſame place.

7. The *tranquilla*, or egg-ſhaped tranſparent monas with a black margin, is found in urine which has been kept for ſome time. Urine in this ſtate acquires a ſcum in which the animalcules reſide; but though kept for ſeveral months, no other ſpecies was found in it. A drop of urine is uſually fatal to other animalcules, though this ſpecies is to be met with in no other ſubſtance. It is generally fixed to one point, but has a kind of vacillatory motion. Frequently theſe creatures are ſurrounded with a halo. Sometimes they are quadrangular, and at other times ſpherical; the black margin is not always to be found; and ſometimes there is even an appearance of a tail.

8. The *lamellula*, or flat tranſparent monas, is moſt uſually found in ſalt-water; is of a whitiſh colour and tranſparent, more than twice as long as it is broad, with a dark margin, having a vacillatory motion, and frequently appearing as double.

9. The *pulviſculus* or *monas* with a green margin. Theſe are generally found in marſhy grounds in the month of March. They appear like ſmall ſpherical grains of a green colour on the circumference, having ſometimes a green bent line paſſing through the middle. They appear ſometimes in cluſters, from three to ſeven or more in number, having a wavering kind of motion.

10. The *uva*, or tranſparent gregarious mona, is found in a variety of infuſions, and is of that kind which multiplies by dividing itſelf. They appear in cluſters of four, five, or ſometimes many more; the corpuſcles being of various ſizes, according to the number collected into one group. The ſmaller particles, when ſeparated from the larger, move about with incredible ſwiftneſs. A ſingle corpuſcle ſeparated from the heap, and put by itſelf into a glaſs, ſoon increaſed in ſize till it nearly attained the bulk of the parent group. The ſurface then aſſumed a wrinkled appearance, and gradually became like the former, ſeparating again into ſmall particles, which likewiſe increaſed in bulk as before.

Microſcope

II. *The Proteus.*

An inviſible, very ſimple, pellucid worm, of a variable form.

1. The *diffluens*, branching itſelf out in a variety of directions. It is very rare, and only met with in fens; appearing like a grey mucous maſs, filled with a number of black globules, and continually changing its figure, puſhing out branches of different lengths and breadths. The internal globules divide immediately, and paſs into the new formed parts; always following the various changes of the animalcule; which changes ſeem to proceed entirely from the internal mechaniſm of its body, without the aid of any external power.

2. The *tenax*, running out into a fine point. This is a pellucid gelatinous body, ſtored with black molecules, and likewiſe changing its figure, but in a more regular order than the former. It firſt extends itſelf in a ſtraight line, the lower part terminating in a bright acute point. It appears to have no inteſtines; and when the globules are all collected in the upper part, it next draws the pointed end up toward the middle of the body, which aſſumes a round form. It goes through a number of different ſhapes, part of which are deſcribed under the article ANIMALCULE. It is found in ſome kinds of river-water, and appears confined almoſt entirely to one place, only bending ſidewiſe.

III. *Volvox.*

An inviſible, very ſimple, pellucid, ſpherical worm.

1. The *punctum*; of a black colour, with a lucid point. This is a ſmall globule, with one hemiſphere opaque and black, the other having a cryſtalline appearance; and a vehement motion is obſerved in the black part. It moves as on an axis, frequently paſſing thro' the drop in this manner. Many are often ſeen joined together in their paſſage through the water; ſometimes moving as in a little whirlpool, and then ſeparating. They are found in great numbers on the ſurface of fetid ſea-water.

2. The *granulum* is of a ſpherical figure and green colour, the circumference being bright and tranſparent. It is found in marſhy places about the month of June, and moves but ſlowly. It ſeems to have a green opaque nucleus.

3. The *globulus*, with the hinder part ſomewhat obſcure, ſometimes verges a little towards the oval in its ſhape, having a ſlow fluttering kind of motion, but

more

Microſcope more quick when diſturbed. The inteſtines are but juſt viſible. It is found in moſt vegetable infuſions, and is ten times larger than the mona lens.

4. The *pilula*, ſmall and round, with green inteſtines. This is found in water where the lemna minor grows, in the month of December, and has a kind of rotatory motion, ſometimes ſlow and at others quick. The inteſtines are placed near the middle, apparently edged with yellow. There is a ſmall inciſion on one of the edges of the ſphere, which may poſſibly be the mouth of the creature. The whole animal appears encompaſſed with an halo.

5. The *grandinella*, with immoveable inteſtines, is much ſmaller than the laſt, and marked with ſeveral circular lines. The inteſtines are immoveable, and no motion is perceived among the interior molecules. Sometimes it moves about in a ſtraight line, at others irregularly, and ſometimes keeps in the ſame ſpot, with a tremulous motion.

6. The *ſocialis*, with cryſtalline molecules placed at equal diſtances from one another. This is found in water where the chara vulgaris has been kept; and has its molecules diſpoſed in a ſphere, filling up the whole body of the animalcule; but whether they be covered by a common membrane or united by a ſtalk (as in the *verticella ſocialis* to be afterwards deſcribed) is not known. When very much magnified, ſome black points may be ſeen in the cryſtalline molecules. Its motion is ſometimes rotatory and ſometimes not.

7. The *ſphericula*, with round molecules, appears to conſiſt of pellucid homogeneous points of different ſizes. It moves ſlowly from right to left and back again, about a quarter of a circle each time.

8. The *lunula*, with lunular molecules, is a ſmall roundiſh tranſparent body, conſiſting of an innumerable multitude of homogeneous molecules of the ſhape of a creſcent, without any common margin. It moves continually in a twofold manner, *viz.* of the molecules among one another, and the whole maſs turning ſlowly round. It is found in marſhy places in the beginning of ſpring.

9. The *globator*, or ſpherical membranaceous volvox, is found in great numbers in the infuſions of hemp and tremella, and in ſtagnant waters in ſpring and ſummer; it was firſt obſerved and depicted by Leewenhoeck, but the deſcriptions of it given by authors differ conſiderably from each other. The following is that of Mr Baker. "There is no appearance of either head, tail, or fins. It moves in every direction, backwards, forwards, up or down, rolling over and over like a bowl, ſpinning horizontally like a top, or gliding along ſmoothly without turning itſelf at all; ſometimes its motions are very ſlow, at other times very ſwift; and when it pleaſes it can turn round as upon an axis very nimble, without moving out of its place. The body is tranſparent, except where the circular ſpots are placed, which are probably its young. The ſurface of the body in ſome is as if all dotted over with little points, and in others as if granulated like ſhagreen. In general it appears as if ſet round with ſhort moveable hairs." Another author informs us, that "they are at firſt very ſmall, but grow ſo large that they can be diſcerned with the naked eye: they are of a yelloviſh green colour, globular figure, and in ſubſtance membranaceous and tranſparent; and in the midſt of this ſubſtance ſeveral ſmall globes may be perceived. Each of theſe are ſmaller animalcula, which have alſo the diaphanous membrane, and contain within themſelves ſtill ſmaller generations, which may be diſtinguiſhed by means of very powerful glaſſes. The larger globules may be ſeen to eſcape from the parent, and then increaſe in ſize." Microſcope

This little animal appears like a tranſparent globule of a greeniſh colour, the fœtus being compoſed of ſmaller greeniſh globules. In proportion to its age it becomes whiter and brighter, and moves ſlowly round its axis; but to the microſcope its ſurface appears as if granulated, the roundeſt molecules fixed in the centre being largeſt in thoſe that are young. The exterior molecules may be wiped off, leaving the membrane naked. When the young ones are of a proper ſize, the membrane opens, and they paſs through the fiſſure; after which the mother melts away. Sometimes they change their ſpherical figure, and become flat in ſeveral places. They contain from 8 to between 30 and 40 globules within the membrane.

10. The *morum*, with ſpherical green globules in the centre. This is found amongſt the lemna in the months of October and December, and has a ſlow rotatory motion. The globules ſeldom move, though a ſlow quivering motion may ſometimes be perceived among them in the centre.

11. The *alva*, compoſed of green globules not incloſed in any membrane, is found in the month of Auguſt in water where the lemma polyrrhiza grows. —It conſiſts of a congeries of greeniſh-coloured globules, apparently of an equal ſize, with a bright ſpot in the middle; the whole maſs is ſometimes of a ſpherical form, ſometimes oval, without any common membrane: a kind of halo may be perceived round it, and the maſs generally moves from right to left, but ſcarce any motion can be perceived among the globules themſelves. Theſe maſſes contain from four to fifty globules, of which a ſolitary one may ſometimes be ſeen. Sometimes alſo two maſſes of globules have been perceived joined together.

12. The *vegetans*, terminating in a little bunch of globules. This is found in river-water in the month of November. It conſiſts of a number of floccoſe opaque branches inviſible to the naked eye; and at the apex of theſe is a ſmall congeries of very minute oval pellucid corpuſcles. Muller, who diſcovered this, ſuppoſed it at firſt to be a ſpecies of microſcopic and river ſertularia: but he afterwards found the bunches quitting the branches, and ſwimming about in the water with a proper ſpontaneous motion; many of the old branches being deſerted, and the younger ones furniſhed with them.

IV. *Enchelis*:

A ſimple, inviſible, cylindric worm.

1. The *viridis*, or green enchelis, has an obtuſe tail, the forepart terminating in an acute truncated angle; the inteſtines are obſcure and indiſtinct. It continually varies its motion, turning from right to left.

2. The *punctifera*, having the fore part obtuſe, the hinder part pointed. It is opaque, and of a green colour, with a ſmall pellucid ſpot in the fore part, in which two black points may be ſeen; and a kind of double

Microſcope double band croſſes the middle of the body. The hinder part is pellucid and pointed, with an inciſion, ſuppoſed to be the mouth, at the apex of the fore-part. It is found in marſhes.

3. The *deſes*, or gelatinous enchelis, is found, though rarely, in an infuſion of lemnæ, and moves very ſlowly. The body is round, of a very dark-green, the fore-part bluntly rounded off, and the hinder part ſomewhat tapering, but finiſhed with a round end: near the extremities there is a degree of tranſparency.

4. The *ſimilis*, with moveable inteſtines, is found in water that has been kept for ſeveral months: it is of an egg-ſhape, and generally moves very quick, either to the right or left. It is ſuppoſed to be furniſhed with hairs, becauſe when moving quickly the margin appears ſtriated. The body is opaque with a pellucid margin, and filled with moveable ſpherules.

5. The *ſerotina*, with immoveable inteſtines, is of an oval figure, partly cylindrical, the fore-part ſmaller than the hind, with a black margin, full of gray veſicular molecules: it moves very ſlowly.

6. The *nebuloſa*, with viſible moveable inteſtines, is found in the ſame water with the cyclidium glaucoma, but is much more ſcarce. The body is egg-ſhaped, the fore-part narrow, and frequently filled with opaque confuſed inteſtines: when moving, it elevates the fore-part of the body. It is about three times as large as the cyclidium glaucoma.

7. The *ſeminulum* is found in water that has been kept for ſome days, and moves by aſcending and deſcending altenately. It is of a cylindrical figure, twice as long as broad, the inteſtines in the fore-part tranſparent, but opaque in the hinder part. Sometimes it is obſerved ſwimming about with the extremities joined together.

8. The *intermedia*, with a blackiſh margin, is one of the ſmalleſt animalcules: it has a tranſparent body, without any viſible inteſtines. The fore and hind parts are of an equal ſize, and the edge is of a deeper colour than the reſt. Some have a point in the middle, others a line paſſing through it.

9. The *ovulum*, is tranſparent, round, and egg-ſhaped. A very ſtrong magnifier diſcovers ſome long foldings on the ſurface, with a few bright molecules here and there.

10. The *pirum*, with the hinder part tranſparent, has the fore-part protuberant and filled with molecules. The hinder part is ſmaller and empty, with moveable molecular inteſtines. Its motion is rapid, paſſing backwards and forwards through the diameter of the drop. When at reſt, it appears to have a little ſwelling on the middle of the body.

11. The *tremula* was found in an infuſion with the paramæcia aurelia, and many other animalcules. It is among the leaſt of theſe minute creatures, and is of a cylindrical figure and gelatinous texture. Its extremity appears pointed, and has a tremulous motion, ſo as to induce a ſuſpicion that the creature has a tail. Two of theſe creatures may at times be ſeen to adhere together.

12. The *conſtricta*, with a ſtricture in the middle, is found in ſalt-water, and is of a very ſmall ſize, having the middle drawn in as if tied with a ſtring. It is of an oval ſhape.

13. The *elliptica*, with a congeries of green inteſtines, is found among the green matter on the ſides of veſſels Microſcope in which water has been kept for ſome time. It is of a roundiſh ſhape, and tranſparent; the fore-part obtuſe, the hinder part rather ſharp, and marked with green ſpots. They are generated in ſuch numbers, that myriads may ſometimes be found in one drop.

14. The *fuſus*, with both ends truncated, was found in water called pure, and had a languid motion. The body is round and tranſparent, with the fore and hind parts ſomewhat ſmaller then the reſt. In the inſide is a long and ſomewhat winding inteſtine, with a bright ſky-coloured fluid, and ſome black molecules tranſverſely ſituated.

15. The *fritillus*, with the fore-part truncated, is found in an infuſion of graſs and hay, and runs backward and forward through the drop with a wavering motion. It is one of the moſt tranſparent animalcules, and has the fore-part obtuſely convex.

16. The *caudata*, with a kind of tail, is but ſeldom met with. The body is grey and tranſparent, with globular molecules divided from each other, and diſperſed thro' the whole; the fore-part is thick and obtuſe, the hind part cryſtalline and ſmall, the end truncated.

17. The *epiſtomium*, with the fore-part ſlender and roundiſh, is among the ſmaller animalcula; the body cylindrical and bright, the hind part obtuſe, the fore-part ſmaller, and terminating in a globule, with now and then a black line down the middle.

18. The *gemmata* is found in ditch-water where the lemna thrives. It has a cylindrical body, the upper part running out into a tranſparent neck, with a double ſeries of globules running down the body. It moves ſlowly, and generally in a ſtraight line.

19. The *retrograda* moves commonly ſideways, and ſometimes in a retrograde manner. It has a gelatinous tranſparent body, thicker in the middle than at the ends, without any thing that can be called inteſtines, except a pellucid globule diſcoverable near the hinder part.

20. The *feſtinans*, with obtuſe ends, is found in ſea-water, and has a quick vacillatory motion from one ſide to the other. The body is round, with the fore-part tranſparent. More than half the length of it is without any viſible inteſtines; but the lower end is filled with minute veſicular and tranſparent globules; a large globular veſicle is alſo obſerved in the fore-part.

21. The *farcimen* was found by Joblot in an infuſion of blue bottles, moving very ſlowly in an undulatory manner. The body is cylindrical, about four times as long as broad, truncated at both ends, the inteſtines opaque, and not to be diſtinguiſhed from one another. It forms itſelf into the ſhape of the letter *S*, by turning the two extremities contrariwiſe.

22. The *index* is found in water with the lemna minor; the body opaque, of a grey colour, and long conical ſhape: the lower end is obtuſe, one ſide projecting like a finger from the edge, with two very ſmall projections from the lower end. It has the power of retracting theſe projections, and making both ends appear obtuſe.

23. The *truncus*, with a kind of head, is the largeſt of this kind of animalcules. The body is grey, long, and mucous; the fore-part globular, the hinder part obtuſe; but it can alter its ſhape conſiderably. Sometimes there is an appearance of three teeth proceeding

from

Microſcope

from one of the ſides. Globules of different ſizes may be obſerved within the body. The creature rolls ſlowly about from right to left.

24. The *larva* is long, round, and filled with molecules. The fore-part is obtuſe and tranſparent, with a kind of neck or ſmall contraction formed near this end: the lower part is pointed; and about the middle of the body are two ſmall pointed projections like nipples, one on each ſide.

25. The *ſpatula*, with the fore-part tranſparent, and of the ſhape of a ſpatula. It is perfectly cylindrical, cryſtalline, and marked with fine longitudinal furrows; having generally two tranſparent globules, one below the middle, the other near the extremity. It moves in a wavering kind of manner, retaining its general form, but moving the ſpatula in various ways. Muller informs us, that he ſaw it once draw the ſpatula within the body, and keep it there for two hours.

26. The *pupula*, with the fore-part papillary, is found in dunghill water in November and December: it has a rotatory motion on a longitudinal axis, and moves in an oblique direction through the water. Both ends are obtuſe; and the hinder part is marked with a tranſparent circle, or circular aperture.

27. The *pupa*, with a ſmall nipple proceeding from the apex, has a very ſlow motion, and reſembles the former, only that it wants the tranſparent circle, and is much larger. It is all opaque but the fore-end, and filled with obſcure points.

V. *Vibrio*:

A very ſimple, inviſible, round, and rather long worm.

1. The *lineola* is found in moſt vegetable infuſions in ſuch numbers, that it ſeems to fill up almoſt the whole of their ſubſtance. It is ſo ſmall, that with the beſt magnifiers we can diſcern little more than an obſcure tremulous motion among them. It is more ſlender than the monas terma.

2. The *rugula* is like a bent line; and ſometimes draws itſelf up in an undulated ſhape, at others moves without bending the body at all.

3. The *bacillus*, equally truncated at both ends, is found in an infuſion of hay; but Muller mentions the following remarkable fact, *viz.* that having made two infuſions of hay in the ſame water, he put the hay whole in the one, but cut it in pieces in the other: he found in the former none of the vibrio bacillus, but many of the monas lens and kolpoda cucullus; in the latter were many of the vibrio, but few of the other.—This is from ſix to ten times longer than the monas lens, but much more ſlender.

4. The *undula*, is a round, gelatinous, little, undulating line. This is the animal which Leewenhoeck ſays is leſs than the tail of one of the ſeminal animalcules. It never appears ſtraight; but when at reſt it reſembles the letter V, and when in motion the letter M. It commonly reſts on the top of the water: ſometimes it fixes itſelf by one extremity, and whirls round.

5. The *ſerpens*, with obtuſe windings or flexures, is found in river-water, but ſeldom. It is ſlender, and gelatinous, reſembling a ſerpentine line, with an inteſtine down the middle.

6. The *ſpirillum* is exceedingly minute, and twiſted in the form of a ſpiral, which ſeems to be its natural ſhape, as it never untwiſts itſelf, but moves forward in a ſtraight line, vibrating the hind and fore parts. It was found in 1782 in an infuſion of the ſonchus arvenſis. Microſcope

7. The *vermiculus* has a milky appearance, with an obtuſe apex, and a languid undulatory motion, like that of the common worm. It is found in marſhy water in November, but ſeldom. It is thought to be the animal mentioned by Leewenhoeck as found in the dung of the frog and ſpawn of the male libellula.

8. The *inteſtinum* is found in marſhy waters, and has a ſlow progreſſive motion. It is milk-coloured, with two obtuſe ends, and four or five ſpherical eggs are perceivable at the hinder extremity.

9. The *bipunctatus* is found in fetid ſalt-water, and moves ſlowly; for the moſt part in a ſtraight line. The body is pellucid, and of a talc-like appearance; both ends are truncated, and in the middle one or two pellucid globules placed lengthwiſe.

10. The *tripunctatus* is alſo tranſparent and talcy, with both ends tapering. It has three pellucid globules, the middle one of which is largeſt, the ſpace between them being generally filled with a green matter. It moves in a ſtraight line, backwards and forwards.

11. The *paxilifer*, or ſtraw-like vibrio, conſiſts of a tranſparent membrane, with yellow inteſtines, and two or three viſible points. They are found in parcels together from ſeven to forty in number, and ranged in a variety of forms. When at reſt, they generally aſſume a quadrangular figure; and are thought to have ſome affinity to the *hair-like animal* deſcribed by Mr Baker, and of which an account is given under the article ANIMALCULE, n° 3.

12. The *lunula*, or bow-ſhaped vibrio, reſembles the moon at its firſt quarter; it is of a green colour, and has from ſeven to ten globules diſpoſed in a longitudinal direction.

13. The *verminus* is found in great plenty in ſalt-water kept for ſome days till it becomes fetid. It moves quickly, and with an undulatory motion, backwards and forwards. It is a long tranſparent membrane, with the hind part broader than the fore one. Theſe animalcula ſeem to be joined together in a very ſingular manner.

14. The *mallæus* is found in great plenty in ſpring-water, and is alternately at reſt and in motion every moment; in the former caſe reſembling the letter T, and in the latter V. It is a white pellucid animalcule, with a globule affixed to the baſe.

15. The *acus* is in the ſhape of a ſewing needle; the neck round and partly tranſparent, and marked in the middle with a red point; the tail reſembling a fine briſtle.

16. The *ſagitta*, with a ſetaceous tail, has a long and flexible body; broadeſt about the middle, and filled there alſo with grey molecules; the fore-part being drawn out into a thin and tranſparent neck, and the upper end thick and black. It is found in ſalt-water, and ſeems to move by contracting and extending its neck.

17. The *gordius*, with a tail terminated by a ſmall tubercle, was found in an infuſion made with ſalt water. Its fore part throughout about one ſixth of its length is tranſparent, and furniſhed with an alimentary tube of a ſky colour; the lower part being

Microſcope

ing bright and pointed, and the middle full of ſmall globules.

18. The *ſerpentulus*, ſomewhat pointed at both ends. This is found in the infuſions of vegetables which have been kept for ſome weeks. Its body is of a whitiſh colour, frequently convoluted, and drawn into different figures. The tail is furniſhed with a long row of very minute points.

19. The *coluber* is found in river water; the tail is extremely ſmall, and bent ſo as to form a conſiderable angle with the body; the mouth, œſophagus, the molecules in the inteſtines, and the twiſtings of them, are eaſily diſcerned.

20. The *anguillula* is divided into four varieties: 1. The vinegar eel; 2. That in paſte; 3. That of freſh water; and, 4. That of ſalt. The two firſt are treated of under the article ANIMALCULE; the third is exceedingly tranſparent, with a few tranſverſe lines upon the body, but without any appearance of inteſtines. Sometimes it has a long row of little globules, and is frequently furniſhed with two ſmall oval ones: the tail terminates in a point. It has been found in the ſediment formed by vegetables on the ſides of veſſels in which water had been kept for a long time. The fourth variety appears, when preſſed between two glaſs plates, to be little more than two cryſtalline ſkins with a kind of inteſtines of a clay colour. The younger ones are furniſhed with pellucid molecules.

21. The *linter*, or ventricoſe oval vibrio, with a ſhort neck, is found among the *lemnæ*, but not very frequently. It is among the larger kinds of animalcules, egg-ſhaped, pellucid, inflated, and ſomewhat depreſſed at top; having a moveable cryſtalline neck, and the belly filled with pellucid molecules.

22. The *utriculus* reſembles a bottle; the belly is full of molecular inteſtines, the neck bright and clear, the top truncated, and ſome have a pellucid point at the bottom of the belly. It has a conſtant and violent vacillatory motion, the neck moving very quickly from ſide to ſide.

23. The *faſciola* is found in water juſt freed from the froſt, and not often in any other fluid. It is pellucid, with inteſtines like points in the middle. There is likewiſe an alimentary canal gradually diminiſhing in ſize. Its motion is very quick.

24. The *colymbus* is larger than many of the other ſpecies of vibrio, and reſembles a bird in ſhape. The neck, which is a little bent, is round, ſhorter than the trunk, of an equal ſize throughout, and of a bright appearance, with the apex obtuſe. The trunk is thick, ſomewhat triangular, full of yellow molecules; the fore-part broad, the hinder part acute, the motion ſlow.

25. The *ſtrictus* has a linear body, being a bright membranaceous thread; the hinder part ſomewhat thicker, round, and filled with molecules, excepting at the end, where there is a ſmall empty pellucid ſpace. It can draw in the ſlender filiform part at pleaſure.

26. The *anas*, with both ends attenuated, and the neck longer than the tail, is found in ſalt water; tho' a kind is likewiſe found in freſh water with a neck longer than the other. The trunk of this animalcule is oblong, opaque, and filled with molecules; the fore and hind parts are drawn out into a pellucid talcy membrane, which the creature can retract at pleaſure.

27. The *cygnus* is a very pellucid line, crooked at top, ſwelling in the middle, and ſharp at the end; the middle full of dark coloured molecules and pellucid inteſtines. It is very ſmall, and moves more ſlowly than any of thoſe that move and advance their necks. Microſcope

28. The *anſer* is found in water where duckweed grows. The trunk is elliptic, round, and without any inequality on the ſides. It is full of molecules: the hind part ſharp and bright; the fore part produced into a bending neck, longer than the body; the apex whole and even, with blue canals paſſing between the marginal edges, occupying the whole length of the neck; and in one of them a violent deſcent of water to the beginning of the trunk is obſervable. It moves the body ſlow, but the neck more briſkly.

29. The *olor* is found in water that has been kept for a long time, and is full of vegetable green matter. The body is elliptical and ventricoſe, the hind part ſomewhat ſharp, and ſometimes filled with darkiſh molecules. The neck is three or four times longer than the body; of an equal ſize throughout, and is moved very quickly; but the motion of the body itſelf is ſlow.

30. The *falx*, with a crooked neck, and obtuſe hinder part, is pellucid and elliptical; the fore part leſſening into a little, round, bright neck, nearly as long as the trunk. The latter is ſomewhat gibbous, and filled with very ſmall molecules; and there are two ſmall bright globules, one within the hind extremity, and the other in the middle of the body. The neck of this animalcule is immoveable; whence it moves ſomething like a ſcythe.

31. The *intermedius* appears to be an intermediate ſpecies betwixt the falx and the faſciola. It ſeems to be a thin membrane conſtantly folded. The whole has a cryſtalline talcy appearance; the middle filled with grey particles of different ſizes. It has all round a diſtinct bright margin.

VI. *Cyclidium.*

A ſimple, inviſible, flat, pellucid, orbicular or oval worm.

1. The *bulla*, or orbicular bright cyclidium. This is found occaſionally in an infuſion of hay. It is very pellucid and white, but the edges ſomewhat darker than the reſt. It moves ſlowly, and in a ſemicircular direction.

2. The *millium* is very pellucid, and ſplendid like cryſtal; and of an elliptical figure, with a line through the whole length of it. The motion is ſwift, interrupted, and fluttering.

3. The *fluitans* is one of the ſmalleſt animalcula; the body ſomewhat of an oval ſhape, with two ſmall blue ſpaces at the ſides.

4. The *glaucoma* has an oval pellucid body, with both ends plain, or an oval membrane with a diſtinct well-defined edge. The inteſtines are ſo tranſparent, that they can ſcarce be diſcerned when it is empty. When full, they are of a green colour, and there are dark globules diſcoverable in the middle. When there is plenty of water this animalcule moves ſwiftly in a circular and diagonal direction; when it moves ſlowly, it ſeems to be taking in water, and the inteſtines are in a violent commotion. It generates by diviſion.

5. The *nigricans* is very ſmall, pellucid, and flat, with a black margin

Microſcope

6. The *roſtratium* is oval, ſmooth, and very pellucid, with the fore part running out into an obtuſe point, with which it ſeems to feel and examine the bodies to which it comes. The inteſtines are filled with a blue liquor, the colour of which ſometimes vaniſhes, and then they ſeem to be compoſed of veſicles.

7. The *nucleus* reſembles a grape ſeed, the body being pellucid and depreſſed, the fore part obtuſely convex, and the hind part acute.

8. The *hyalinum* has a tremulous kind of motion; the body oval, flat, and bright, without any viſible inteſtines.

9. The *pediculus* is ſcarce ever ſeen but on the hydra pallida, upon which it runs as if it had feet. It is gelatinous and white; the bottom gibbous over the back; the extremities depreſſed and truncated, with one end ſometimes apparently cloven into two, which may be ſuppoſed the mouth.

10. The *dubium* is of an oval ſhape, with one ſide convex, the other concave; the margin pellucid, and the inner part containing a great number of molecules.

VII. *Paramæcium.*

An inviſible, membranaceous, flat, and pellucid worm.

1. The *aurelia* is membranaceous, pellucid, and four times longer than it is broad; the fore part obtuſe and tranſparent; the hind part filled with molecules. It has ſomewhat the appearance of a gimlet by reaſon of a fold which goes from the middle to the apex, and is of a triangular figure. It moves in a rectilinear and vacillatory manner. It is found in ditches where there is plenty of duckweed, and will live many months in the ſame water without any renewal of the latter.

2. The *chryſalis* is found in ſalt water, and differs very little from the former, only the ends are more obtuſe, and the margins are filled with black globules.

3. The *verſutum* is found in ditches, and has an oblong, green, and gelatinous body, filled with molecules; the lower part thicker than the other; and both ends obtuſe. It propagates by diviſion.

4. The *oviferum* is membranaceous, oval, grey, and pellucid, with many oval corpuſcles diſperſed through the body.

5. The *marginatum* is flat, elliptical, and every where filled with molecules, except in the lower end where there is a pellucid veſicle. It is ſurrounded by a broad double margin, and a bright ſpiral inteſtine is obſervable.

VIII. *Kolpoda.*

An inviſible, pellucid, flat, and crooked worm.

1. The *lamella* is very ſeldom met with. It reſembles a long, narrow, and pellucid membrane, with the hind part obtuſe, narrower, and curved towards the top. It has a vacillatory and very ſingular motion; going upon the ſharp edge, not on the flat ſide as is uſual with microſcopic animals.

2. The *gallinula* is found in fetid ſalt water; and has the apex ſomewhat bent, the belly oval, convex, and ſtriated.

3. The *roſtrum* is found though ſeldom, in water where the lemna grows; and has a ſlow and horizontal motion. The fore part is bent into a kind of hook; the hind part obtuſe, and quite filled with black molecules.

Microſcope

4. The *ochrea* is depreſſed, membranaceous, and flexible; one edge nearly ſtraight; the other ſomewhat bent, filled with obſcure molecules, and a few little bladders diſperſed here and there.

5. The *mucronata* is a dilated bright membrane; the apex an obtuſe point, with a broad marked border running quite round it. It is filled with grey molecules within the margin, and has a truncated appearance.

6. The *triquetra* was found in ſalt water, and appears to conſiſt of two membranes; the upper ſide flattened, the lower convex, with the apex bent into a kind of ſhoulder.

7. The *ſtriata* is likewiſe found in ſalt water, and is very pellucid and white, with the upper part rather bent, and terminating in a point; the lower part obtuſely round: there is a little black pellucid veſicle at the apex; and with a very great magnifying power the body appears covered with long ſtreaks.

8. The *nucleus* is of an oval ſhape, with the vertex pointed, and of a brilliant tranſparency, by which the viſcera are rendered viſible. Theſe conſiſt of a number of round diaphanous veſicles.

9. The *meleagris* has a dilated membrane, with very fine folds, which it varies in a moment. The fore part of the body to the middle is clear and bright; the hind part variouſly folded in tranſverſe and elevated plaits and full of molecules. Beneath the apex are three or four teeth; but in ſome the edge is obtuſely notched, and ſet with ſmaller notches. In the hinder part are 12 or more equal pellucid globules.

10. The *aſſimilis* is found on the ſea-coaſt, and has an elliptic maſs in the middle, but is not folded like the former. The margin of the fore part is notched from the top to the middle; the lower part ſwells out, and contracts again into a ſmall point.

11. The *cucullus* is found in vegetable infuſions, and in fetid hay; moving in all directions, and commonly with great vivacity. It is very pellucid, and has a well defined margin, filled with little bright veſicles differing in ſize, and of no certain number. Its figure is commonly oval, with the top bent into a kind of beak, ſometimes oblong, but moſt commonly obtuſe. It has in the inſide from 8 to 24 bright little veſicles not diſcernible in ſuch as are young. Some have ſuppoſed theſe to be animalcules which this creature has ſwallowed; but Mr Muller is of opinion that they are its offſpring. When this creature is near death by reaſon of the evaporation of the water, it protrudes its offſpring with violence. From ſome circumſtances it would ſeem probable that this animalcule caſts its ſkin, as is the caſe with ſome inſects.

12. The *cucullulus* is found in an infuſion of the ſonchus arvenſis. It is very pellucid and cryſtalline, with ſeveral globules, and has an oblique inciſion a little below the apex.

13. The *cuculio* is elliptical, flat on the upper ſide, and convex on the under; the fore part is clear, and from the middle to the hinder part is full of ſilver-like globules. It frequently ſtretches out the fore part, and folds it in different poſitions.

14. The

Microſcope 14. The *ren*, or *craſſa*, is found inan infuſion of hay, commonly about 13 hours after the infuſion is made, and has a quick and vacillatory motion. Its body is yellow, thick, and ſomewhat opaque; curved a little in the middle, ſo that it reſembles a kidney; and full of molecules. When the water in which it ſwims is about to fail, it takes an oval form, is compreſſed, and at laſt burſts.

15. The *pirum* has an uniform and tranſparent body, without any ſenſible inequality; and is of a pale colour, with obſcure little globules. It propagates by diviſion.

16. The *cuneus* is white, gelatinous, and without any diſtinct viſcera; having a bright ſtriated pellucid puſtule on one ſide of the fore part. The apex has three or four teeth; and it can bend the hinder part into a ſpiral form.

IX. *Gonium*.

An inviſible, ſimple, ſmooth, and angular worm.

1. The *pectorale* is found in pure water, and moves alternately towards the right and left. It is quadrangular and pellucid, with 16 ſpherical molecules of a greeniſh colour, "ſet in a quadrangular membrane, like the jewels in the breaſt-plate of the high-prieſt, reflecting light on both ſides."

2. The *pulvinatum* is found in dunghills; and appears like a little quadrangular membrane, plain on both ſides: but with a large magnifier it appears like a bolſter formed of three or four cylindric pillows ſunk here and there.

3. The *corrugatum* is found in various kinds of infuſions; and is ſomewhat of a ſquare ſhape, very ſmall, and in ſome poſitions appears as ſtreaked.

4. The *rectangulum* differs but little from the former: the angle at the baſe is a right one; the larger veſicle is tranſparent, the reſt green.

5. The *truncatum* is found chiefly in pure water, and then but ſeldom. It has a languid motion, and is much larger than the foregoing. The fore part is a ſtraight line, with which the ſides form obtuſe angles, the ends of the ſides being united by a curved line. The internal molecules are of a dark green, and there are two little bright veſicles in the middle.

X. *Burſaria*.

A very ſimple, hollow, membranaceous worm.

1. The *truncatella* is viſible to the naked eye; white, oval, and truncated at the top, where there is a large aperture deſcending towards the baſe. Moſt of them have four or five yellow eggs at the bottom. They move from left to right, and from right to left; aſcending to the ſurface in a ſtraight line, and ſometimes rolling about while they deſcend.

2. The *bullina* is pellucid and cryſtalline, having ſplendid globules of different ſizes ſwimming about with it. The under ſide is convex, the upper hollow, with the fore part forming a kind of lip.

3. The *hirundinella* has two ſmall projecting wings, which give it ſomewhat of the appearance of a bird; and it moves ſomething like a ſwallow. It is inviſible to the naked eye; but by the microſcope appears a pellucid hollow membrane.

4. The *duplella* was found among duckweed, and appears like a cryſtalline membrane folded up, without any viſible inteſtines except a ſmall congeries of Microſcope points under one of the folds.

5. The *globina* has a roundiſh ſhape, and is hollow; the lower end being furniſhed with black molecules of different ſizes, the fore part with obſcure points, the reſt entirely empty, and the middle quite tranſparent. It moves very ſlowly from right to left.

XI. *Cercaria*.

An inviſible tranſparent worm with a tail.

1. The *gyrinus* greatly reſembles the ſpermatic animalcules. It has a white gelatinous body; the fore part ſomewhat globular; the hind part round, long, and pointed. Sometimes it appears a little compreſſed on each ſide. When ſwimming it keeps its tail in continual vibration like a tadpole.

2. The *gibba* is found in the infuſions of hay and other vegetables; and is ſmall, opaque, gelatinous, white, and without any viſible inteſtines.

3. The *inquieta* is found in ſalt water, and is remarkable for changing the ſhape of its body: ſometimes it appears ſpherical, ſometimes like a long cylinder, and ſometimes oval. It is white and gelatinous, the tail filiform and flexible, the upper part vibrating violently. A pellucid globule may be obſerved at the baſe, and two very ſmall black points near the top.

4. The *lemna* varies its form ſo much, that it might be miſtaken for the proteus of Baker, deſcribed under the article ANIMALCULE; though in fact it is totally different. The body ſometimes appears of an oblong, ſometimes of a triangular, and ſometimes of a kidney ſhape. The tail is generally ſhort, thick, and annulated; but ſometimes long, flexible, cylindric, and without rings; vibrating, when ſtretched out, with ſo much velocity, that it appears double. A ſmall pellucid globule, which Muller ſuppoſes to be its mouth, is obſervable at the apex; and two black points not eaſily diſcovered, he thinks, are its eyes. Sometimes it draws the tail entirely into the body. It walks ſlowly after taking three or four ſteps, and extends the tail, erecting it perpendicularly, ſhaking and bending it; in which ſtate it very much reſembles a leaf of the lemna.

5. The *turbo*, with a tail like a briſtle, is found among duckweed. It is of a talcy appearance, partly oval and partly ſpherical; and ſeems to be compoſed of two globular bodies, the lowermoſt of which is the ſmalleſt, and it has two little black points like eyes on the upper part. The tail is ſometimes ſtraight, ſometimes turned back on the body.

6. The *poduria* is found in November and December, in marſhy places covered with lemna. It is pellucid; and ſeems to conſiſt of a head, trunk, and tail: the head reſembles that of a herring; the trunk is ventricoſe and full of inteſtines, of a ſpiral form and black colour. The tail moſt commonly appears to be divided into two briſtles. The inteſtines are in a continual motion when the body moves, and by reaſon of their various ſhades make it appear very rough. There are likewiſe ſome hairs to be perceived. It turns round as upon an axis when it moves.

7. The *viridis* is found in the ſpring in ditches of ſtanding water; and in ſome of its ſtates has a conſiderable reſemblance to the laſt, but has a much greater power of changing its ſhape. It is naturally cylindrical,

Microſcope

lindrical, the lower end ſharp, and divided into two parts; but ſometimes contracts the head and tail ſo as to aſſume a ſpherical figure.

8. The *ſetifera* is found in ſalt water, but ſeldom. It is ſmall, the body rather opaque, and of a round figure. The upper part is bright, and ſmaller than the reſt: the trunk is more opaque; the tail ſharp, and near it a little row of ſhort hairs. It has a ſlow rotatory motion.

9. The *hirta* was likewiſe found in ſalt water. It is opaque and cylindrical; and when in motion, the body appears to be ſurrounded with rows of ſmall hairs ſeparated from each other.

10. The *crumena* has a ventricoſe, cylindrical, thick, and wrinkled body; the lower part ſmall; the upper part terminating in a ſmall ſtrait neck like that of a pitcher; the tail linear, and terminating in two diverging points.

11. The *catellus* has a moveable head fixed to the body by a point. The abdomen is twice as long as the head, full of inteſtines, and has a tail ſtill narrower, and terminating in two briſtles which it can unite and ſeparate at pleaſure. It moves briſkly, but without going far from its firſt place.

12. The *catelina* was found in a ditch where there was plenty of duckweed. It is larger than the preceding, and has a thicker and more cylindrical body; the lower part truncated, with two ſhort diverging points projecting from the middle.

13. The *lupus* is found in water among duckweed, and is larger than moſt of the genus. The head is larger than the body; the apex turned down into a little hook; the tail is like the body, but narrower, terminating in two very bright ſpines, which it extends in different directions. Sometimes it contracts into one half its common ſize, and again extends itſelf as before.

14. The *vermicularis* is long, cylindrical, fleſhy, and capable of changing its ſhape. It is divided into eight or nine rings or folding plaits; the apex either obtuſe, or notched into two points; the hinder part rather acute, and terminating in two pellucid thorns, between which a ſwelling is ſometimes perceived. It often projects a kind of cloven proboſcis from the inciſion at the apex. It is found in water where there is duckweed.

15. The *forcipata* is found in marſhy places, is cylindrical and wrinkled, with a forked proboſcis which it can thruſt out or pull in.

16. The *pleuronectes* is found in water which has been kept for ſeveral months. It is membranaceous, roundiſh, and white, with two blackiſh points in the fore part, the hinder part being furniſhed with a ſlender ſharp tail. It has orbicular inteſtines of different ſizes in the middle; the larger of them bright. The motion is vacillatory; and in ſwimming it keeps one edge of the lateral membrane upwards, the other folded down.

17. The *tripos* is flat, pellucid, triangular, having each angle of the baſe or fore part bent down into two linear arms, the apex of the triangle prolonged into tail. It is found in ſalt water.

18. The *cyclidium* is frequently found in pure water, and has an oval, ſmooth, membranaceous, pellucid body with a black margin. The tail is concealed under the edge, and comes out from it at every motion, but in ſuch a manner as to project but little from the edge. There is alſo a kind of border to the hinder part.

19. The *tenax* appears like an oval pellucid membrane, ſomething larger than the *monas lens*. The fore edge is thick and truncated; the hinder part acute, and terminating in a ſhort tail. It whirls about in various directions with great velocity.

20. The *diſcus* is a ſmall orbicular animalcule, with a bent tail.

21. The *orbis* is round, and has a tail conſiſting of two long briſtles.

22. The *luna* is likewiſe round, and has the forepart hollowed into the form of a creſcent.

XII. *Leucophra.*

An inviſible, pellucid, and ciliated worm.

1. The *conflictor*, with moveable inteſtines, is perfectly ſpherical and ſemitranſparent, of a yellow colour, the edges dark. It rolls from right to left, but ſeldom removes from the ſpot where it is firſt found. It is filled with a number of the moſt minute molecules, which move as if they were in a violent conflict; and in proportion to the number of theſe little combatants which are accumulated either on one ſide or other, the whole maſs rolls either to the right or left. It then remains for a little time at reſt, and the conflict ceaſes; but it ſoon becomes more violent, and the ſphere moves the contrary way in a ſpiral line. When the water begins to fail, they aſſume an oblong, oval, or cylindric figure; the hinder part of ſome being compreſſed into a triangular ſhape, and the tranſparent part eſcaping as it were from the inteſtines, which continue to move with the ſame violence till the water fails, when the molecules ſhoot into a ſhapeleſs maſs, which alſo ſoon vaniſhes, and the whole aſſumes the appearance of cryſtals of ſal ammoniac.

2. The *mamilla* is of a dark colour, and filled with globular molecules; ſhort hairs are curved inwards; and it occaſionally projects and draws in a little white protuberance. It is pretty common in marſhy water.

3. The *vireſcens* is a large, pear-ſhaped, greeniſh-coloured animalcule, filled with opaque molecules, and covered with ſhort hairs; generally moving in a ſtraight line. It is found in ſalt water.

4. The *viridis* is much ſmaller than the former, and cannot lengthen or ſhorten itſelf as it does. Sometimes it appears contracted in the middle, as if it were to be divided in two.

5. The *burſata* is found in ſalt water, and is ſimilar in many reſpects to the former. It is of a long oval ſhape, bulging in the middle, and filled with green molecules, every where ciliated except at the apex, which is truncated and ſhaped ſomewhat like a purſe; the hairs are ſometimes collected into little faſcicles.

6. The *poſthuma* is globular, and covered as it were with a pellucid net; is found in fetid ſalt water.

7. The *aurea* is yellow, oval; has both ends equally obtuſe; little hairs diſcovered with difficulty; and has in general a vehement rotatory motion.

8. The *pertuſa* is found in ſalt water; and is gelatinous

Microſcope

tinous and ſmall, without any molecules. The fore-part is truncated, the hind-part brought nearly to a point, with a kind of oval hole on one ſide.

9. The *fracta* is long, with ſinuated angles, white, gelatinous, and granulated, changing its form conſiderably.

10. The *dilatata* appears like a gelatinous membrane, with a few grey molecules in the fore-part, and a great number in the hinder part. It is ſometimes dilated into a triangular form with ſinuated ſides; at other times the ſhape is more irregular and oblong.

11. The *ſcintillans* was found in December among the leſſer lemnæ. It is of a green colour, oval, round, and opaque. It is ſuppoſed to be ciliated from its bright twinkling appearance, which probably ariſes from the motion it gives the water.

12. The *veſiculifera* is oval, very pellucid, with a defined dark edge and inſide, containing ſome very bright bladders or veſicles. The middle frequently appears blue, and the veſicles appear as if ſet in a ground of that colour.

13. The *globulifera* was found in a ditch where the lemna minor grew. The body is round, very pellucid, without molecules, but with three little pellucid globules, and every where ſet with ſhort hairs.

14. The *puſtulata* is found in marſhy waters; and is white, gelatinous, and ſomewhat granulated; the lower part truncated as if an oblique ſection were made in an egg near the bottom. It is covered with little erect ſhining hairs, and at the lower extremity a few bright puſtules may be diſcovered.

15. The *turbinata* is found in ſtinking ſalt water; and is round, pellucid, ſomewhat of the ſhape of an acorn, with a pellucid globule at the lower end.

16. The *acuta* is found in ſalt water, and is gelatinous, thick, capable of aſſuming different ſhapes; having the apex bright, and the reſt of the body filled with little ſpherules. Sometimes it draws itſelf up into an orbicular ſhape, at others one edge is ſinuated.

17. The *notata* is oval, round, and has a black point at the edge.

18. The *candida* is found in ſalt water; and is membranaceous, flat, very white, with no viſible inteſtines except two oval bodies not eaſily perceived. The whole edge is ciliated.

19. The *nodulata* is oblong and oval, with a double row of little nodules.

20. The *ſignata* is common in ſalt water in the months of November and December. It is oblong and ſubdepreſſed, with a black margin filled with little molecules, but more particularly diſtinguiſhed by a curved line in the middle ſomewhat in the ſhape of the letter S; one end of which is ſometimes bent into the form of a ſmall ſpiral.

21. The *trigona* is found in marſhes, but not commonly. It is a yellow triangular maſs filled with unequal pellucid veſicles, one of which is much larger than the reſt, and the edge ſurrounded with ſhort fluctuating hairs.

22. The *fluida* is ſomewhat of a kidney ſhape, but ventricoſe.

23. The *fluxa* is reniform and ſinuated.

24. The *armilla* is round and annular.

25. The *cornuta* is of the ſhape of an inverted cone, opaque, and of a green colour. This requires to be obſerved for ſome time before we can aſcertain its characters. The body is compoſed of molecular veſicles; the fore part is wide and truncated, with a little prominent horn or hook on both ſides; the hind part being conical, every where ciliated, and the hairs exceedingly minute; thoſe in the fore part are three times longer than the former, and move in a circular direction. The hinder part is pellucid, and ſometimes terminates in two or three obtuſe pellucid projections. At one time this animalcule will appear reniform and ciliated on the fore part; but at another time the hairs are concealed. It diſſolves into molecular veſicles when the water evaporates.

Microſcope

26. The *heteroclita* appears to the naked eye like a white point; in the microſcope as a cylindrical body, the fore part obtuſely round, the middle rather drawn in; the lower part round, but much ſmaller than the upper part. It appears wholly ciliated through a large magnifier.

XIII. *Trichoda*.

An inviſible, pellucid, hairy worm.

1. The *grandinella* is a very ſmall pellucid globule, with the inteſtines ſcarce viſible, the top of the ſurface furniſhed with ſeveral ſmall briſtles not eaſily diſcoverable, as the creature has a power of extending or drawing them back in an inſtant. It is found in pure water as well as in infuſions of vegetables.

2. The *cometa* is a pellucid globule filled with bright inteſtines, the fore part furniſhed with hairs, the hind part with a pellucid globule.

3. The *granata* reſembles the two former; and has a darkiſh nucleus in the centre, with ſhort hairs on the edge.

4. The *trochus* is ſomewhat of a pear-ſhape, and pellucid; each ſide of the fore part being diſtinguiſhed by a little bunch of hairs.

5. The *gyrinus* is one of the ſmalleſt of this genus, and is found in ſalt water. It is ſmooth and free from hairs, except at the fore part, where there are a few.

6. The *ſol* is ſmall, globular, and cryſtalline; beſet every where with diverging rays longer than the diameter of the body; the inſide full of molecules. The body contracts and dilates, but the creature remains confined to the ſame ſpot. It was found with other animalcules in water which had been kept three weeks.

7. The *ſolaris* is orbicular, bright, and filled with globular inteſtines, frequently having in it a moveable ſubſtance of the ſhape of the letter S. It has hairs ſeldom exceeding 17 in number, ſet round the circumference, each of them nearly equal in length to the diameter of the animalcule.

8. The *bomba* is of a yellow colour, and full of clay-like molecules. It moves with ſuch velocity as to elude the ſight, and appears of various ſhapes, ſometimes ſpherical, ſometimes kidney-ſhaped, &c.

9. The *orbis* is compoſed of veſicular molecules; is of a ſpherical figure, ſmooth, pellucid, and a little notched in the fore part. The notched part is filled with long hairs, but there are none on the reſt of the body.

10. The *urnula* is membranaceous, pellucid, ſomewhat in the form of a water pitcher, with the fore part hairy. It moves but ſlowly.

11. The *diota* is of a clay-colour, and filled with molecules;

Microſcope molecules; the upper part cylindrical and truncated, the lower part ſpherical, the upper part of the mouth hairy at the edges.

12. The *horrida* is ſomewhat of a conical ſhape, the fore part rather broad and truncated, the lower part obtuſe, and the whole covered with radiating briſtles.

13. The *urinarium* is egg-ſhaped, with a ſhort hairy beak.

14. The *ſemiluna* is ſmooth, pellucid, and ſhaped like a creſcent.

15. The *trigona* is of a triangular ſhape, a little convex on both ſides, the fore part acute and ciliated, the hind part broader, and having the extremity as it were gnawed off.

16. The *tinea* is round, not very pellucid, narrow in the fore part, and reſembling an inverted club.

17. The *nigra* was found in ſalt water, and has an opaque body; but when at reſt one ſide appears pellucid. When in violent motion, it ſeems entirely black.

18. The *pubes* is found in water where duckweed grows, chiefly in the month of December. It has a bunch above the hind part marked with black ſpots, depreſſed towards the top, a little folded, and ſomewhat convex on the under part. The apex is furniſhed with hairs, but they are ſeldom viſible till the creature is in the agonies of death, when it extends and moves them vehemently, and attempting as it were to draw in the very laſt drop of water.

19. The *floccus* is membranaceous, the fore part rather conical, with three ſmall hairy papillæ projecting from the baſe.

20. The *ſinuata* is found in river water. It is oblong and depreſſed, with one margin hollow and hairy, and the lower end obtuſe. It is of a yellow colour, and the hollow edge ciliated.

21. The *præceps* is pellucid, the fore part formed into a kind of neck; one edge riſing into a protuberance like a hump-back, the other edge convex.

22. The *proteus* is that which Mr Baker diſtinguiſhes by the ſame name, and of which an account is given under the article ANIMALCULE. It is found in the ſlimy matter adhering to the ſides of veſſels in which vegetables have been infuſed, or animal ſubſtances preſerved. That deſcribed by Mr Adams was diſcovered in the ſlime produced from the water where ſmall fiſhes, water-ſnails, &c. had been kept. The body reſembled that of a ſnail, the ſhape being ſomewhat elliptical, but pointed at one end, while from the other proceeded a long, ſlender, and finely proportioned neck, of a ſize ſuitable to the reſt of the animal.

23. The *verſatilis* lives in the ſea, and has ſome reſemblance to the proteus; but the neck is ſhorter, the apex leſs ſpherical, and the hinder part of the trunk acute.

24. The *gibba* is pellucid; the upper part ſwelled out, with numerous molecules, and three large globules on the inſide. The ends rather incline downwards; and when the water begins to fail, a few minute hairs may be diſcovered about the head and at the abdomen; the body then becomes ſtriated longitudinally.

25. The *fœta* ſomewhat reſembles a rolling-pin in ſhape; has both ends obtuſe, and one ſhorter than the other. It can draw in the ends, and ſwell out the ſides, ſo as to appear almoſt ſpherical.

26. The *patens* is found in ſalt water; and is of a long cylindrical ſhape, filled with molecules, the fore-part bright and clear, with a long opening near the top which tapers to a point, and is beſet with hairs. Microſcope

27. The *patula* is ventricoſe, rather inclining to an oval figure, with a ſmall tube at the fore part, the upper part of which is hairy.

28. The *foveata* is oblong and rather broad, with three little horns on the fore part.

29. The *ſtriata* is found in the month of December in river-water. It is a beautiful animalcule, of a fox colour. It is of an oblong ſhape, the lower end ſomewhat larger than the other. It has a ſet of ſtreaks running from one end to the other, and at the abdomen a double row of little eggs lying in a tranſverſe direction.

30. The *uvula* is found in the infuſion of hay and other vegetables. It is ſix times longer than broad, round, flexuous, of an equal ſize, the greater part filled with obſcure molecules; the fore part rather empty, with an alimentary canal and lucid globules near the middle. The margin of the fore part is covered with ſhort hairs.

31. The *aurantia* is of a gold colour, pellucid, and filled with veſicles.

32. The *ignita* is of a fine purple colour, with ſomething of a reddiſh caſt, pellucid, ſplendid, with a number of globules of different ſizes; the fore part ſmall, the hinder part obtuſe, with a very large opening which ſeems to run through the body.

33. The *priſma* is very ſmall, and ſo tranſparent that it cannot eaſily be delineated. It is of a ſingular ſhape; the under part being convex, the upper compreſſed into a kind of keel, and the fore part ſmall.

34. The *forceps* is found about the winter ſolſtice in water covered with lemna. It is of a yellow colour, large, ſomewhat tranſparent, and filled with molecules, with a large opaque globule in the lower part. The fore part is divided into long lobes, one of which is falciform and acute, the other dilated and obliquely truncated. It can open, ſhut, or croſs, thoſe lobes at pleaſure; and by the motion of them it appears to ſuck in the water.

35. The *forfex* is found in river water. It has the fore part formed into a kind of forceps, one of which is twice as long as the other, hooked and ciliated.

36. The *index* is found in ſalt water, and has the under part of the front of the margin hairy; the apex is formed by the fore part projecting like a finger on a direction poſt.

37. The *trichoda* is of a yellow colour, formed of two pellucid membranes ſtriated longitudinally; the lower end obliquely truncated, and the two extremities bent in oppoſite directions.

38. The *navicula* has three corners; the fore part truncated and ciliated, the hind part acute and bent a little upwards. It has a cryſtalline appearance, and a kind of longitudinal keel runs down the middle.

39. The *ſucciſa* is of a flattened oval ſhape, the edge hairy, and hollowed out in ſuch a manner as to form two unequal legs.

40. The *ſulcata* is ovated and ventricoſe, the apex acute, with a furrow at the abdomen, and both ſides of it ciliated.

41. The *anas* is found in pure water; and is ſmooth, five

Microſcope five times broader than it is long, filled with darkiſh molecules. It has a bright neck, under the top of which are a few unequal hairs. It moves but languidly.

42. The *barbata* is round, ſomewhat linear, with both ends obtuſe; the fore part narrower, forming as it were a kind of neck, under which is a row of fluctuating hairs. The trunk is full of grey molecules.

43. The *farcimen* is long, round, pellucid, and covered with very minute hairs, and has a great number of mucous veſicles about the body.

44. The *crinita* is long, round, every where ciliated on the upper part, and the under part likewiſe hairy as far as the middle.

45. The *angulus* is long, more convex than moſt of the genus, divided by a kind of articulation in the middle into two parts equal in breadth, but of different lengths; the apex has ſhort waving hair.

46. The *linter* is found in an infuſion of old graſs. It is egg-ſhaped, oblong, with both extremities raiſed ſo that the bottom becomes convex, and the upper part depreſſed like a boat: it is of different ſhapes at different ages, and ſometimes has a rotatory motion.

47. The *paxillus* is found in ſalt water; and is long, full of grey molecules; the fore part truncated and hairy, and rather ſmaller than the other.

48. The *vermicularis* is found in river water; and is pellucid in the fore part, with the hind part full of molecules.

49. The *melitæa* is found in ſalt water, but very rarely. It is oblong, ciliated, with a globular apex, a dilatable neck, and a kind of periſtaltic motion perceivable within it.

50. The *fimbriata* is ſubovated, the apex hairy, the hinder part obliquely truncated and ſerrated.

51. The *camelus* is found but rarely in vegetable infuſions, and moves in a languid manner. The fore part is ventricoſe; the back divided by an inciſion in the middle into two tubercles; the lower part of the belly ſinuated.

52. The *augur* is oblong, depreſſed, pellucid, and filled with molecules: the vertex is truncated, the forepart forming a ſmall beak with three feet underneath; beyond which, toward the hinder part, it is furniſhed with briſtles.

53. The *pupa* is roundiſh, pellucid, and conſiſts of three parts. The head is broad, and appears to be hooded, the top being furniſhed with very ſmall hairs; on the lower part of the head is a tranſparent veſicle, and over the breaſt from the baſe of the head hangs a production reſembling the ſheath of the feet in the pupa of the gnat.

54. The *lunaris* is round and cryſtalline; the hinder part ſmaller than the other. The edge of the back and the part near the tail are bright and clear. It bends itſelf into the form of an arch.

55. The *bilunis* is arched and flattened with an hairy apex, and two little briſtles proceeding from the tail.

56. The *rattus* is oblong, with a kind of keel; the fore part hairy, and a very long briſtle proceeding from the hinder part.

57. The *tigris* reſembles the former, but differs in the form of the tail, which conſiſts of two briſtles, and likewiſe in having a kind of inciſion in the body a little below the apex.

58. The *perillum* is frequently found in marſhes. It is cylindrical, pellucid, muſcular, and capable of being folded up. It appears double; the interior part full of molecules, with an orbicular muſcular appendage, which it can open and ſhut, and which forms the mouth. The external part is membranaceous, pellucid, dilated, and marked with tranſverſe ſtreaks; and it can protrude or draw in the orbicular membrane at pleaſure. Some have four articulations in the tail, others five; and it has two pairs of briſtles, one placed at the ſecond joint, the other at the laſt. Microſcope

59. The *clavus* has a conſiderable reſemblance to a common nail; the fore part is round and hairy, the hinder part terminating in a ſharp tail.

60. The *cornuta* is membranaceous, elliptical, full of molecules; the fore part lunated, the other round, and terminating in a tail as long as the body.

61. The *gallina* is found in river water. It is of a grey colour, flat, with ſeven large molecules and globules within it; the front obtuſe, ſet with hairs; the hinder part terminating in a tail formed of very fine hairs.

62. The *muſculus* is found in the infuſions of hay which have been kept for ſome months. It is ſmooth, egg-ſhaped, with a double margin drawn underneath it; the fore part narrow, and furniſhed with ſhort hairs which continually play about; having a ſmall tail underneath. It moves ſlowly, and is furniſhed with molecular inteſtines.

63. The *delphis* is found in river water. It is ſmooth, pellucid, having the fore part dilated into a ſemicircle, gradually decreaſing in breadth towards the tail. The front is hairy, the hairs ſtanding as rays from the ſemicircular edge: one of the edges is ſometimes contracted.

64. The *delphinus* is found in hay that has been infuſed for ſome months. It is pellucid, ſmooth, and egg-ſhaped; the hinder part terminating in a tail about half the length of the body, dilated at the upper end, truncated, and always bent upwards. It moves ſometimes on its belly and ſometimes on its ſide.

65. The *clava*, or club trichoda, has the fore part thick, but the hinder part narrow; both extremities obtuſe, pellucid, and replete with molecules; the hind part bent down towards the middle.

66. The *cuniculus* is oblong, the fore part hairy, the hinder part rather acute, and filled with molecules and black veſicles.

67. The *felis* is large and curved, the fore part ſmall, the hinder part gradually diminiſhing into a tail, the under part beſet with hairs longitudinally.

68. The *piſcis* is oblong, the fore part hairy, the hind part terminating in a very ſlender tail. It is ſmooth, pellucid, much longer than broad, and filled with yellow molecules; the fore part obtuſe, the hinder part extremely ſlender and tranſparent, the upper ſide convex.

69. The *larus* is long, round, beſet with hairs, and has the tail divided into two points.

70. The *longicauda* is cylindrical; the fore part truncated, and beſet with hairs; the tail long, furniſhed with two briſtles, and having two joints.

71. The *fixa* has the circumference ſet with hairs, and a little ſolitary pedicle projecting from the body.

72. The *inquilinus* is ſheathed within a cylindrical

Microſcope

transparent bag, having a little pedicle bent back within the bag.

73. The *ingenita* is ſheathed in a depreſſed bag, broadeſt at the baſe. The animalcule itſelf is funnel-ſhaped, with one or more hairs proceeding from each ſide of the mouth of the funnel. It can extend or contract itſelf within the bag, fixing its tail to the baſe, without touching the ſides. It is found in ſalt water.

74. The *innata* is ſheathed in a cylindrical bag, with a pedicle paſſing through and projecting beyond it.

75. The *transfuga* is broad, the fore part hairy, the hinder part full of briſtles; one ſide ſinuated, and the other pointed.

76. The *ciliata* is ventricoſe, the hinder part covered with hair.

77. The *bulla* is membranaceous, the ſides bent inwards; the fore and hind parts both covered with hairs.

78. The *pellionella* is ſomewhat thick in the middle, and pellucid, with a few molecules here and there; the ſides obtuſe, the fore part ciliated with very fine hairs, the hinder part ſet with briſtles.

79. The *cyllidium* has the hinder extremity filled with globules of various ſizes. It vacillates upon the edge, commonly advancing on its flat ſide, and continually drawing in water. It then gapes, and opens into a very acute angle, almoſt to the middle of the body; but this is done ſo inſtantaneouſly, that it can ſcarce be perceived.

80. The *curſor* is oval, the fore part hairy, and the hinder part alſo furniſhed with ſome ſtraight and curved hairs in two faſcicles. Its body is flat, and filled with molecules; and in the fore part is an oblong empty ſpace, into which we may ſometimes ſee the water ſucked in.

81. The *pulex* is egg-ſhaped, with an inciſion in the fore part; the front and baſe hairy.

82. The *lynceus* is nearly ſquare, with a crooked beak and hairy mouth. It is membranaceous, and appears compreſſed, ſtretched out into a beak above, under which there is a little bundle of hairs; the lower edge bends in and out, and is ſurrounded with a few briſtles. The inteſtines are beautiful, and a ſmall bent tube goes from the mouth to them in the middle of the body. There is likewiſe another tube between the fore and hind edge, filled with blue liquor. The inteſtines and other tube are frequently in motion.

83. The *roſa* is orbicular, the fore part notched; one ſide furniſhed with hairs, the hinder part with briſtles.

84. The *roſtrata* is found in water where duckweed has been kept. It is depreſſed, capable of changing its ſhape, yellow, with long ciliated hairs; it has four feet tapering to a point, one of them longer than the reſt. Both feet and hairs are within the margin. The ſhape of the body is generally triangular; the apex formed into an obtuſe beak, which the creature ſometimes draws in ſo that it appears quite round.

85. The *lagena* is round, ventricoſe, with a long neck, and the lower end ſet with briſtles.

86. The *charon* was found in ſalt water. It is oval, and reſembles a boat as well in its motion as ſhape: the upper part is hollowed, the under part furrowed and convex; the ſtern round, with ſeveral hairs proceeding from it. Mircoſcope

87. The *cimex* is about the ſize of the lyncus, has an oval body, with a convex back, flat belly, and inciſion in the margin of the fore part, the edges of which inciſion appear to move. When this animalcule meets with any obſtacles in ſwimming, it makes uſe of four briſtles, which appear on the under ſide as feet.

88. The *cicada* differs but little from the cimex. It is oval, with an obſcure margin, the fore part covered with hairs on the under ſide, and the hinder parts beardleſs.

XIV. *Kerona*.

An inviſible worm with horns.

1. The *raſtellum* is found in river water. It has three rows of horns on the back, which occupy almoſt the whole of it.

2. The *lyncaſter* is ſquare, and its diſc furniſhed with ſhining horns.

3. The *hiſtrio* appears an oblong membrane, pellucid, with four or five black points in the fore part, which are continually changing their ſituation, thick ſet with ſmall globules in the middle, among which four larger ones are ſometimes perceived, which by Mr Adams are ſuppoſed to be eggs. In the middle of the hind part are ſome longitudinal ſtrokes reſembling briſtles, which, however, do not ſeem to project beyond the body.

4. The *cypris* is found in water covered with lemna. It is ſomewhat of a pear ſhape, compreſſed, with a broad and blunt fore part; the front furniſhed with hairs or little vibrating points inſerted under the edge, ſhorter in the hind part, partly extended ſtraight, and partly bent down, having a retrograde motion.

5. The *hauſtrum* is orbicular, with the horns in the middle, the fore part membranaceous and ciliated, with ſeveral briſtles at the hinder part.

6. The *hauſtallum* differs from the preceding only in having the hinder part without any briſtles.

7. The *patella* has an univalved ſhell, is orbicular, cryſtalline; the fore part ſomewhat notched; the fleſhy body in the middle of the ſhell; with horns or hairs of different lengths jutting out beyond the ſhell, and acting inſtead of feet and oars, ſome of which are bent; and the ſuperior ones conſtitute a double tranſverſe row.

8. The *vannus* is oval and rather flat, with one edge bent, the oppoſite one ciliated, the front furniſhed with horns, and the hind part with briſtles.

9. The *pullaſter* agrees in many reſpects with the *trichoda pulex*; the upper part is pellucid, without any black molecules; the front truncated, the whole ſurface of the head covered with hair, and the fore part ſinuous.

10. The *mytillus* is a large animalcule; the fore and hind parts rounded, very pellucid and white, dark in the middle, with black inteſtines intermixed with a few pellucid veſicles; both extremities appearing as if compoſed of two thin plates. It has two ſmall horns, with which it agitates the water ſo as to form a little whirlpool.

11. The *lepus* is egg-ſhaped, compreſſed, pellucid, and

Microſcope

and crowned with ſhort waving hairs; the baſe terminated with briſtles.

12. The *ſilurus* is an oval, ſmooth, animalcule, ſomewhat crooked and opaque, with a faſcicle of vibrating hair on the fore part: it has a ſharp tail furniſhed with unequal rows of moveable hairs, the back being alſo ciliated: the hairs produce a rotatory motion. The figure varies from oval to oblong, and the filaments of the conferva are often entangled in the tail.

13. The *calvitium* is found in the infuſion of vegetables. The body is broad and flat, both ſides obtuſe, filled with black molecules, and there is a black ſpot near the hinder part, where there are likewiſe a few ſhort briſtles.

14. The *puſtulata* is found in ſalt water. It is oval, convex; one edge of the hinder part ſinuated, both ends ſet with hairs, and ſome horns on the fore part.

XV. *Himantopus:*

A pellucid, inviſible, and cirrated worm.

1. The *acarus* is lively, conical, ventricoſe, full of black molecules, with a bright and tranſparent fore part. The lower part of the apex has rows of long hairs on the under part ſet like rays. Four locks of long crooked hair or feet proceed from the belly, and it is continually moving theſe and other hairs in various directions.

2. The *ludio* is a lively diverting animalcule, ſmooth, pellucid, full of ſmall points, the fore part clubbed and a little bent, the hinder part narrow; the baſe obliquely truncated, and terminating in a tail ſtretched out tranſverſely. The top of the head and middle of the back are furniſhed with long and vibrating hairs; three moveable and flexible curls hang down from the ſide of the head at a diſtance from each other. When the creature is at reſt, its tail is curled; but when in motion, it is drawn tight and extended upwards.

5. The *ſannio* is found, though ſeldom, in water where the lemna grows. The cilia are longer than the hairs, and are continually vibrating: it has two moveable curls hanging on the ſide of the head.

4. The *volutator* is ſhaped like a creſcent, and has ſome cryſtalline points; the convex part has a row of hairs longeſt towards the tail, and underneath are four feet. It is very lively, and often turns round with a ſwift circular motion.

5. The *larva* is long and cirrated in the middle; the body is depreſſed and long; the hinder parts acute, and generally curved, pellucid, and filled with granular molecules.

6. The *charon* is found in ſea-water, but rarely. It is oval, pellucid, and membranous, with longitudinal furrows, and ſeveral bent diverging rows of hair below the middle, but none on the hinder part.

7. The *corona* is a membranous lamina, very thin, pellucid, cryſtalline, and ſemilunar: the edge of the baſe thick ſet with molecular inteſtines; the fore part furniſhed with a kind of mane; towards the hind part are three equal curved hairs or ſpines.

XVI. *Vorticella:*

A naked worm with rotatory cilia, capable of contracting and extending itſelf.

1. The *viridis* is viſible to the naked eye, appearing like a ſmall green point; but the microſcope diſcovers it to be nearly cylindrical, a little thicker at the fore part than the other, and obtuſe at both ends. It appears to be totally deſtitute of limbs, notwithſtanding which it keeps the water in continual motion; ſo that it probably has ſome inviſible rotatory inſtrument. It moves ſometimes circularly, ſometimes in a ſtraight line.

2. The *ſpheroida* appears alſo like a point; but thro' the microſcope as a globular maſs of a dark green colour. It occaſions a vehement motion in the water, probably by means of ſome ſhort hairs with which it is furniſhed.

3. The *cincta* is of an irregular ſhape, ſometimes aſſuming an oval figure, and appearing as if girt round with a tranſverſe keel. It is inviſible to the naked eye, ciliated on every ſide; the hairs all moveable, and longer on one ſide than the other.

4. The *lunifera* is found in ſalt water; has the fore-part obtuſe, the baſe broad, and hollowed away like a creſcent, with a ſhort protuberance in the middle of the concave part: the fore part is ciliated.

5. The *burſata* is found in ſalt water, and is ventricoſe, crammed with molecules; the fore part truncated, and both ſides of it pellucid: there is a prominent papilla in the middle, which when the animalcule is at reſt appears notched, the edge of the aperture being ciliated; the hairs are capable of moving in various directions.

6. The *varia* is cylindrical, truncated, opaque, and blackiſh coloured; the fore part ciliated.

7. The *ſputarium* is found in October, with the leſſer lemna, and is one of the moſt ſingular of the microſcopic animalcules. When viewed ſidewiſe, it is ſometimes nearly cylindrical, only tapering a little towards the hinder part, and having a broad pellucid edge. Viewed from the top, it has ſometimes a broad face or diſc, furniſhed with radiating hairs, the under part contracted into a globular ſhape, of a dark green colour, and filled with ſmall grains.

8. The *polymorpha* is viſible to the naked eye, and appears like a green point moving with great agility; but when viewed through a microſcope, it aſſumes ſuch a variety of forms, that it is impoſſible to deſcribe them. The body is granulous; and a ſeries of pellucid points is ſometimes to be obſerved.

9. The *multiformis* is found in ſalt water, and very much reſembles the former.

10. The *nigra* is found in Auguſt in meadows covered with water. It may be ſeen with the naked eye, appearing like a black point ſwimming on the ſurface. Through the microſcope it appears as a ſmall conical body, obtuſe and ventricoſe at one end and acute at the other. When the extremities are extended, two ſmall white hooks become viſible, by the aſſiſtance of which it moves in the water, and it probably has a rotatory organ: it moves continually in a vacillating manner on the top of the water.

11. The *cucullus* is likewiſe viſible to the naked eye: it is of a dirty red colour, of a ſhape ſomewhat conical, and reſembling a grenadier's cap.

12. The *utriculata* is green and ventricoſe; the belly capable of being lengthened or ſhortened; the fore part truncated, much in the ſhape of a common water bottle;

Microſcope bottle; the neck is ſometimes very long, ſometimes very ſhort, and filled with green molecules.

13. The *ocreata* is met with in rivers, though very ſeldom, and in ſhape ſomewhat reſembles the lower part of a boot. The apex of the upper part is truncated and ciliated, the heel pointed, and the foot round.

14. The *valga* is as broad as long, and the apex truncated and ciliated; both angles of the baſe projecting outwards, one ſomewhat like a wart, the other like a finger: It is found in marſhy waters.

15. The *papillaris* is likewiſe found in marſhes where the conferva nitida grows. It is ventricoſe; the fore part truncated, with a papillary tail, and a beautiful papillary excreſcence on the ſide.

16. The *ſaculus* is thick, of an equal diameter every where, and full of molecules. The edge of the mouth is bent back; the hinder part is obtuſe, ſometimes notched and contracted, with cilia to be ſeen on both ſides of the mouth.

17. The *cirrata* is found in ditch-water. It is ventricoſe, the aperture ſinuated, and two tufts of hair on each ſide of the belly.

18. The *naſuta* is inviſible to the naked eye, but the microſcope diſcovers it to be furniſhed with a rotatory organ encompaſſing the middle. It is pellucid, cylindrical, of an unequal ſize; the fore part truncated and ciliated, with a triangular prominence in the middle of the aperture; the hinder part is obtuſe, with a point on each ſide of the middle of the body. When the water is nearly exhaled, two rotatory organs are obſervable; one on the fore part, and the other encompaſſing the middle of the body; the hairs of the latter being in violent motion. Other faſcicles of moving hair are likewiſe to be obſerved; and the quick and various motions of this apparatus are very ſurpriſing.

19. The *ſtellina* is of an orbicular ſhape, with a molecular diſc and ciliated margin.

20. The *diſcina* is likewiſe orbicular, the edge ciliated, with a kind of handle on the under ſide.

21. The *ſcyphina* is bowl-ſhaped, cryſtalline, with an opaque ſpherule in the middle.

22. The *albina* is cylindrical in the fore part, the hinder part tapering, and almoſt ending in a point.

23. The *fritillina* is empty and cylindrical, with a truncated apex.

24. The *truncatella* is of the larger kind of animalcules, with a cryſtalline body, full of black molecules, the ſkin perfectly ſmooth and colourleſs, the hinder extremity rounded, and the anterior part truncated: at this extremity there is a large opening that ſerves for a mouth, which is thickly ciliated.

25. The *limacina* is cylindrical, truncated, and has two pair of cilia.

26. The *fraxinina* is moſtly cylindrical, the hinder part rather tapering, and full of opaque molecules; tranſparent towards the upper end. Within the edge at the top are two ſmall tubercles, from each ſide of which proceeds a pair of ſmall hairs.

27. The *cratægaria* is found in the month of April, both in the mud and on the tail of the monoculus quadricornis. They are generally heaped together in a ſpherical form, and united to one common ſtalk. They are likewiſe often to be found without a pedicle, the body rather contracted, the aperture circular, and ſurrounded with a marked margin. It has two ſmall arms; and with a powerful magnifier a violent rotatory motion may be obſerved. Sometimes an individual will ſeparate from the community, and move in a kind of ſpiral line for a little time, and then go back to the reſt. Microſcope

28. The *hamata* is not ciliated, nor has it any hairs upon it; the body is granulated, the fore part broad and truncated, the hinder part obtuſe, and capable of being contracted or extended.

29. The *crateriformis* is a lively animalcule, pellucid, round, longer than it is broad, approaching ſomewhat to a ſquare figure, with convex ſides: the head is ſituated at the large end, the ſkin ſmooth, and ſome traces of inteſtines may be diſcovered with difficulty. There is a conſiderable opening ſurrounded by hair at the larger end, and the filaments compoſing it are in continual motion. Two of them are ſometimes ſeen joined together, and full of ſmall ſpherules. In this ſtate they draw each other alternately different ways; the ſurface is ſmooth, and the hairs inviſible.

30. The *canaliculata* appears to the naked eye as a number of white points adhering to the ſides of the glaſs. When magnified, the fore part is narrower than the hind one; in the ſide is a kind of inciſion, and the hinder part is notched towards the middle. It excites a continual whirling motion in the water by means of a rotatory organ with which it is furniſhed.

31. The *verſatilis* is a pellucid, gelatinous animalcule, of a greeniſh colour, and furniſhed with ſmall radii about the circumference; ſo that it appears like a very ſmall water hedge-hog.

32. The *ampulla* is contained in a tranſparent bottle-ſhaped bag; the head divided into two lobes. It ſometimes lies at the bottom of the bag, and ſometimes nearly fills the whole of it.

33. The *folliculata* is gelatinous and cylindrical; and when moſt extended, the baſe appears attenuated, and the apex truncated.

34. The *larva* is of a clay colour, the aperture ciliated, with a globular projection at times appearing to proceed from it.

35. The *facculata* has the ſhape of an inverted cone, with an aperture in the figure of a creſcent; the lower part of the trunk notched, forming as it were two teeth; the tail biphyllous. Each of theſe is ſurrounded with a looſe bright ſkin, the head being divided from the trunk by a deep inciſion.

36. The *aurita* is cylindrical and ventricoſe, the aperture deſtitute of hairs; both ſides of it are furniſhed with rotatory cilia, and the tail is biphyllous.

37. The *tremula* has ſomething of a conical ſhape; the mouth being divided into parts which are ſet with ſmall ſpines; and a point projects from the tail.

38. The *ferita* is muſcular, pellucid, folding variouſly; the fore part truncated: round the margin are rows of hairs; but it has alſo ſtiffer hairs or ſpines continually vibrating, with which it draws in all animate and inanimate ſubſtances which it is able to manage.

39. The *lacinulata* is ſhaped like an inverted cone, the aperture lobated, the tail ſmall and furniſhed with two briſtles. When ſwimming, the rotatory organ may be diſcovered. It moves ſwiftly in an oblique direction.

40. The

Microſcope

40. The *conſtricta* is of two kinds; *viz.* of a pale yellow and of a white colour. They move by fixing their tail to the place where they are, and then extending their body as much as poſſible; fixing the fore part to the place to which they intend to move, then drawing the hinder part to it, and ſo on. Sometimes they turn round about upon one of the points of their tail; at other times they ſpring forwards with a jerk. When at reſt they open their mouths very wide.

41. The *togata* has a convex body, filled with molecules, and of a dark colour; the hinder part ſomewhat broader than the forepart; the latter ciliated, and the tail formed of two very thin pellucid ſpines, which are ſomewhat curved, and much longer than the body.

42. The *rotatoria* is the *wheel animal* deſcribed by Mr Baker; and of which an account is given under the article ANIMALCULE.

43. The *furcata* is commonly found in water, and has a cylindric body with a rotatory organ, conſiſting of a row of hairs at the apex: the tail is divided into two parts, turning a little inwards. When at reſt it joins the ſegments of the tail, but opens them when in motion.

44. The *catulus* is commonly found in marſhy waters. It is a little thick muſcular animalcule, folding itſelf up: equally broad throughout, the body diſfigured by longitudinal folds, winding in various directions. The anterior part is connected to the body by a little neck; and it occaſionally ſhows a ſmall rotatory organ. Its motion is rotatory, but in various directions.

45. The *canicula* is cylindrical, the aperture plain, with a ſhort articulated tail divided into two parts.

46. The *felis* has a large body, the apex of an equal thickneſs, obtuſe, with rotatory filaments: the tail is acute, with two pellucid ſpines in length about one-third part of the body, alternately ſeparating from and approaching one another.

47. The *ſtentorea*. See the article POLYPE.

48. The *ſocialis*, when conſiderably magnified, appears like a circle ſurrounded with crowns or ciliated heads, tied by ſmall thin tails to a common centre, from whence they advance towards the circumference, where they turn very briſkly, occaſioning a kind of whirlpool, which brings its food. When one of them has been in motion for a time, it ſtops and another begins; ſometimes two or three may be perceived in motion at once: they are frequently to be met with ſeparate, with the tail ſticking in the mud. The body contracts and dilates very much, ſo as ſometimes to have the appearance of a cudgel, at others to aſſume almoſt a globular form.

49. The *floſculoſa* appears to the naked eye like a yellow globule adhering to the ceratophyllon like a little flower or a heap of yellow eggs. When magnified, they are ſeen to conſiſt of a congeries of animalcula conſtituting a ſphere from a mouldy centre. They contract and extend their bodies either alone or in ſociety, and excite a vortex in the water by means of a diſc. When they quit the ſociety and act ſingly, they may be obſerved to conſiſt of a head, abdomen, and tail; the head being frequently drawn back into the abdomen ſo far that it cannot be ſeen, only exhibiting a broad kidney-ſhaped diſc ſtanding out. The abdomen is oblong, oval, and tranſparent; the tail ſharp, twice as long as the abdomen, ſometimes rough and annulated, or altogether ſmooth.

Microſcope

50. The *citrina* is found in ſtagnant water; the head full of molecules, round, every where of an equal ſize, and very tranſparent. Both ſides of the orifice are ciliated, and each has a rotatory motion appearing ſometimes without and ſometimes within the edge of the mouth.

51. The *piriformis* is ſomewhat oval, with a very ſmall retractile foot, which it can draw within itſelf.

52. The *tuberoſa* has a broad upper part, the under part ſmall, with two projections at the anterior end, furniſhed with a number of fibrillæ, which produce a current of water by their vibration, and thus collect food for the animal.

53. The *ringens* is pear-ſhaped, pellucid, the middle of the aperture convex, both ſides ciliated, the pedicle four times ſhorter than the body. It can contract the orifice to an obtuſe point.

54. The *inclinans* has a pendulous, pellucid, little head; the anterior part truncated, and occaſionally contracting itſelf twice as ſhort as the pedicle. It is ſhaped like a tobacco-pipe.

55. The *vaginata* is erect, of the ſhape of a truncated egg; the pedicle is contained in a ſheath.

56. The *globularia* is frequent among the cyclopa quadricorni. It has a ſmall ſpherical head, the aperture of the mouth ciliated, the pedicle four times larger than the body, which it contracts into a ſpiral form.

57. The *lunaris* has a ſmall goblet-ſhaped head, the margin of the orifice protuberant, ciliated on both ſides, with undulating hairs, and the pedicle eight or ten times the length of the body. The pedicle extends itſelf as often as the mouth is opened, but is twiſted up ſpirally when it is ſhut; and this is frequently repeated in a ſhort ſpace.

58. The *convallaria* is the ſame with the *bell-animal* mentioned by Mr Baker. See the article ANIMALCULE.

59. The *nutans* has a ſimple pedicle; twiſts itſelf ſpirally; is extremely ſlender, with a kind of cap on its head; the margin white and round, and ſeemingly encompaſſed with a lucid ring; the head diminiſhing towards the baſe.

60. The *nebulifera* is narrow at the baſe; open and truncated at the top; the margin ſeemingly ſurrounded with a ring: but, when the aperture is ſhut, the animalcule is of the ſhape of an egg, with a ſimple ſetaceous pedicle, conſiderably longer than the body, and commonly much bent back.

61. The *annularis* is viſible to the naked eye; the head an inverted cone, convex when the mouth is ſhut, but truncated when it is open; with a protuberant edge; the pedicle ſimple, very long, thick, and, whiter at the top than any where elſe; the apex twiſted ſpirally.—When contracted, it appears to be annulated.

62. The *acinoſa* inhabits that whitiſh ſubſtance which often entirely covers plants, wood, ſhells, &c. When this ſubſtance is examined by a microſcope, it appears to be wholly compoſed of living animals of the polype kind. See POLYPE.

7

Microſcope

63. The *faſciculata* has a rotatory organ, which may ſometimes be ſeen projecting beyond the aperture; there is a little head at the apex, and the pedicle is twiſted and very ſlender. A congealed green maſs which is often found ſwimming about in ditches is compoſed of myriads of theſe animals, which are not viſible to the naked eye, and when magnified appear like a bundle of green flowers.

64. The *hians* reſembles a citron; the apex is truncated, the baſe narrow, and a gaping cleft is obſervable, deſcending from the apex to one third of the body.

65. The *bellis* is of a yellow colour, and much reſembles the flower of a daiſy; is ciliated round the margin of the head, and moves in a rotatory manner.

66. The *gemella* has a long pedicle, conſtantly furniſhed with two ſmall heads.

68. The *pyraria*.
69. The *anaſtatica*. } See the article POLYPE.
70. The *digitalis*.

71. The *polypina*, when viewed through a ſmall magnifier, they appear like ſo many little trees: the upper part, or heads, are egg-ſhaped, the top truncated, the lower part filled with inteſtines; the branches thick ſet with little knobs.

72. The *racemoſa* is only diſtinguiſhed from the vorticella ſocialis by always adhering to the ſides of the veſſel in which it is placed. By the microſcope, we diſcover a long pedicle ſticking to the ſides of the veſſels, from which proceed an innumerable quantity of cryſtalline pellucid pearls; which, together with the ſtalk, are variouſly agitated in the water. Sometimes they move ſeparately; ſometimes they are drawn down to the root, and in a moment expanded again.

XVII. *Brachionus*:

A contractile worm, covered with a ſhell, and furniſhed with rotatory cilia.

1. The *ſtriatus* has an oblong, pellucid ſhell, capable of altering its figure. The apex is truncated, with ſix ſmall teeth on the edge of it, twelve longitudinal ſtreaks down the back, the baſe obtuſe and ſmooth. The teeth are occaſionally protruded or retracted; and there are two ſmall ſpines or horns on the other ſide of the ſhell. The animal itſelf is of a yellow colour, cryſtalline, and muſcular; now and then putting out from the apex two or three little bundles of playing hairs, the two lateral ones ſhorter than that in the middle: on the under ſide we may obſerve a forked deglutatory muſcle, and two rigid points when the apex is drawn in. It is found in ſea-water.

2. The *ſquamula* has an univalve orbicular ſhell, a truncated apex, four teeth, ſmooth baſe, and no tail.

3. The *pala* is of a yellow colour; univalved, with an oblong excavated ſhell; four long teeth at the apex; a ſmooth baſe.

4. The *bipalium* is univalved, the ſhell oblong and inflected, ten teeth at the apex, the baſe ſmooth, and a ſpurious tail.

5. The *patina* is extremely bright and ſplendid, has a large body, a cryſtalline and nearly circular ſhell, without either inciſion or teeth, only towards the apex it falls in ſo as to form a ſmooth notch. A double glittering organ, with ciliated edges, projects from the apex; both of them of a conical figure, and ſtanding as it were upon a pellucid ſubſtance, which is divided into two lobes, between which and the rotatory organ there is a ſilver-coloured crenulated membrane. Two ſmall claws may likewiſe be diſcovered near the mouth. Microſcope

6. The *clypeatus* is univalved, the ſhell oblong, apex notched, the tail naked, and baſe ſmooth.

7. The *lamellaris* is univalved; the ſhell extending conſiderably beyond the body; the baſe divided into three ſmall horns, with two hairs at the end of the tail.

8. The *patella* is found in marſhy water in the winter-time. It is univalve, the ſhell oval, plain, cryſtalline, with the anterior part terminating in two acute points on both ſides, though the intervening ſpace is commonly filled up with the head of the animal. By theſe points it faſtens itſelf, and whirls about the body erect. The rotatory cilia are perceived with great difficulty.

9. The *bractea* is univalved, the ſhell ſomewhat orbicular, apex lunated, baſe ſmooth, and the tail furniſhed with two ſpines.

10. The *plicatilis* is univalved, with an oblong ſhell, the apex hairy, and baſe notched.

11. The *ovalis* is bivalved; the ſhell flattened, apex notched, a hollow part at the baſe, the tail formed of two tufts of hair.

12. The *tripos* is bivalved, the apex of the ſhell beardleſs, three horns at the baſe, and double tail. It fixes itſelf to objects by the filaments of the tail.

13. The *dentatus* is bivalved, with an arched ſhell; the apex and baſe are both toothed, and the tail formed of two ſpines.

14. The *mucronatus* is bivalved, ſomewhat of a ſquare form; the baſe and apex pointed; the tail conſiſting of two ſpines.

15. The *uncinatus* is one of the ſmalleſt bivalved animalcules; the apex and anterior part round, the hinder part ſtraight, terminating in a point, furniſhed with a hook on the fore part, a ſmall rotatory organ, a long tail compoſed of joints, and divided at the end into two briſtles. It can open its ſhell both at the fore and hind part.

16. The *cirratus* is larger than the preceding; ventricoſe, ſomewhat tranſparent, the head conical, with a bundle of hairs on both ſides; and it has likewiſe a rotatory organ.

17. The *paſſus* has a cylindric ſhell, with two long pendulous locks of hair proceeding from the front, the tail conſiſting of a ſingle briſtle.

18. The *quadratus* has a quadrangular ſhell, with two ſmall teeth at the apex, two horns proceeding from the baſe, and no tail.

19. The impreſſus has a quadrangular ſhell, a ſmooth undivided apex; obtuſe baſe; notched margin; and flexuous tail.

20. The *urceolaris*. See POLYPE.

21. The *brachionus Bakeri* has a ventricoſe ſhell, four teeth at the apex, two horns at the baſe, and a long tail terminating in two ſhort points. The horns are frequently extended; and the circular end of each is furniſhed with a tuft of little hairs, which ſometimes move in a vibratory manner, at other times have a rotatory motion. Mr Muller has alſo diſcovered in this creature two ſmall feelers and a tongue.

22. The *patulus* has a ventricoſe ſhell, with eight teeth.

Microscopic Objects.

Fig.38.

a

b

Fig.33. Fig.32.

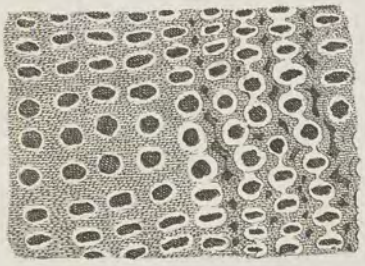


Fig.35.

Fig.36.

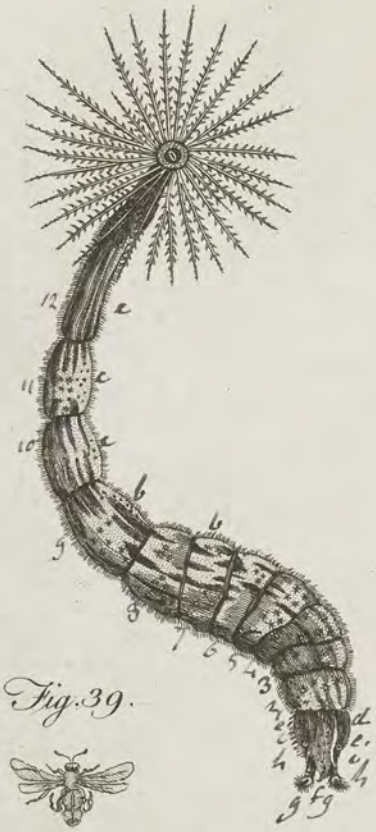


Fig.37.

Fig.39.

Fig.40.

Fig.41.

Fig.34.

A.Bell Prin. Wal. Sculptor fecit

Microſcope

teeth at the apex; the baſe lunated, or hollowed into the form of a creſcent, and furniſhed with four horns; the tail ſhort, with two ſmall points at the end.

These are the different kinds of animalcules which have yet been diſcovered. To what is ſaid of them in general under the article Animalcule, we ſhall here add the following obſervations from Mr Adams.—"How many kinds of theſe inviſibles there may be (ſays he), is yet unknown; as they are diſcerned of all ſizes, from thoſe which are barely inviſible to the naked eye, to ſuch as reſiſt the force of the microſcope as the fixed ſtars do that of the teleſcope, and with the greateſt powers hitherto invented appear only as ſo many moving points. The ſmalleſt living creatures our inſtruments can ſhow, are thoſe which inhabit the waters; for though animalcula equally minute may fly in the air, or creep upon the earth, it is ſcarce poſſible to get a view of them; but as water is tranſparent, by confining the creatures within it we can eaſily obſerve them by applying a drop of it to the glaſſes.

"Animalcules in general are obſerved to move in all directions with equal eaſe and rapidity, ſometimes obliquely, ſometimes ſtraight forward; ſometimes moving in a circular direction, or rolling upon one another, running backwards and forwards through the whole extent of the drop, as if diverting themſelves; at other times greedily attacking the little parcels of matter they meet with. Notwithſtanding their extreme minuteneſs, they know how to avoid obſtacles, or to prevent any interference with one another in their motions: ſometimes they will ſuddenly change the direction in which they move, and take an oppoſite one; and, by inclining the glaſs on which the drop of water is, as it can be made to move in any direction, ſo the animalcules appear to move as eaſily againſt the ſtream as with it. When the water begins to evaporate, they flock towards the place where the fluid is, and ſhow a great anxiety and uncommon agitation of the organs with which they draw in the water. Theſe motions grow languid as the water fails, and at laſt ceaſe altogether, without a poſſibility of renewal if they be left dry for a ſhort time. They ſuſtain a great degree of cold as well as inſects, and will periſh in much the ſame degree of heat that deſtroys inſects. Some animalcules are produced in water at the freezing point, and ſome inſects live in ſnow.—By mixing the leaſt drop of urine with the water in which they ſwim, they inſtantly fall into convulſions and die.

"The ſame rule ſeems to hold good in thoſe minute creatures, which is obſervable in the larger animals, *viz.* that the larger kinds are leſs numerous than ſuch as are ſmaller, while the ſmalleſt of all are found in ſuch multitudes, that there ſeem to be myriads for one of the others. They increaſe in ſize, like other animals, from their birth until they have attained their full growth; and when deprived of proper nouriſhment, they in like manner grow thin and periſh."

The modes of propagation among theſe animalcules are various, and the obſervation of them is extremely curious. Some multiply by a tranſverſe diviſion, as is obſerved under the article Animalcule: and it is remarkable, that though in general they avoid one another, it is not uncommon, when one is nearly divided, to ſee another puſh itſelf upon the ſmall neck which joins the two bodies in order to accelerate the ſeparation.—Others, when about to multiply, fix themſelves to the bottom of the water; then becoming firſt oblong, and afterwards round, turn rapidly as on a centre, but perpetually varying the direction of their rotatory motion. In a little time, two lines forming a croſs are perceived; after which the ſpherule divides into four, which grow, and are again divided as before. A third kind multiply by a longitudinal diviſion, which in ſome begins in the fore-part, in others in the hind-part; and from others a ſmall fragment detaches itſelf, which in a ſhort time aſſumes the ſhape of the parent animalcule. Laſtly, others propagate in the ſame manner as the more perfect animals.

Microſcope

In our obſervations under the article Animalcule, we ſuggeſted ſome doubts whether all thoſe minute bodies which go under the name of *animalcules* really do enjoy animal life; or whether they are not in many caſes to be accounted only inanimate and exceedingly minute points of matter actuated by the internal motion of the fluid. This has alſo been the opinion of others: but to all hypotheſes of this kind Mr Adams makes the following reply. "From what has been ſaid, it clearly appears, that their motions are not purely mechanical, but are produced by an internal ſpontaneous principle; and that they muſt therefore be placed among the claſs of living animals, for they poſſeſs the ſtrongeſt marks and the moſt decided characters of animation; and, conſequently, that there is no foundation for the ſuppoſition of a chaotic and neutral kingdom, which can only have derived its origin from a very tranſient and ſuperficial view of theſe animalcules.—It may alſo be further obſerved, that as we ſee that the motions of the limbs, &c. of the larger animals, are produced by the mechanical conſtruction of the body, and the action of the ſoul thereon, and are forced by the ocular demonſtration which ariſes from anatomical diſſection to acknowledge this mechaniſm which is adapted to produce the various motions neceſſary to the animal; and as, when we have recourſe to the microſcope, we find thoſe pieces which had appeared to the naked eye as the primary mechanical cauſes of particular motions, to conſiſt themſelves of leſſer parts, which are the cauſes of motion, extenſion, &c. in the larger; when the ſtructure therefore can be traced no farther by the eye, or by the glaſſes; we have no right to conclude that the parts which are inviſible are not equally the ſubject of mechaniſm: for this would be only to aſſert, in other words, that a thing may exiſt becauſe we ſee and feel it, and have no exiſtence when it is not the object of our ſenſes.—The ſame train of reaſoning may be applied to microſcopic inſects and animalcula: we ſee them move; but becauſe the muſcles and members which occaſion theſe motions are inviſible, ſhall we infer that they have not muſcles, with organs appropriated to the motion of the whole and its parts? To ſay that they exiſt not becauſe we cannot perceive them, would not be a rational concluſion. Our ſenſes are indeed given us that we may comprehend ſome effects; but then we have alſo a mind, with reaſon, beſtowed

upon

Microſcope upon us, that, from the things which we do perceive with our ſenſes, we may deduce the nature of thoſe cauſes and effects which are imperceptible to the corporeal eye."

Leaving theſe ſpeculations however, we ſhall now proceed to give a particular

Explanation of the figures of the various animals, with their parts, ova, &c. repreſented in the plates.

Plate CCCII. Fig. 32. 33. repreſent the eggs of the phalæna neuſtria, as they are taken from the tree to which they adhere, and magnified by the microſcope. The ſtrong ground-work viſible in many places ſhows the gum by which they are faſtened together; and this connection is ſtrengthened by a very tenacious ſubſtance interpoſed between the eggs, and filling up the vacant ſpaces. Fig. 34. ſhows a vertical ſection of the eggs, exhibiting their oval ſhape.—Fig. 35. is an horizontal ſection through the middle of the egg. Theſe eggs make a beautiful appearance through the microſcope. The ſmall figures *a*, *b*, *c*, repreſent the objects in their natural ſtate, without being magnified.

Fig. 36. ſhows the larva of the *muſca chamæleon*, an aquatic inſect. When viewed by the naked eye, it appears (as here repreſented) to be compoſed of twelve annular diviſions, ſeparating it into an head, thorax, and abdomen; but it is not eaſy to diſtinguiſh the two laſt parts from each other, as the inteſtines lie equally both in the thorax and abdomen. The tail is furniſhed with a fine crown or circle of hair *b*, diſpoſed in the form of a ring, and by this means it is ſupported on the ſurface of the water, the head and body hanging down towards the bottom, in which poſture it will ſometimes remain for a conſiderable time without any motion.—When it has a mind to ſink to the bottom, it cloſes the hairs of the ring, as in fig. 37. Thus an hollow ſpace is formed, including a ſmall bubble of air; by enlarging or diminiſhing which, it can riſe or ſink in the water at pleaſure. When the bubble eſcapes, the inſect can replace it from the pulmonary tubes, and ſometimes conſiderable quantities of air may be ſeen to eſcape from the tail of the worm into the common atmoſphere; which operation may eaſily be obſerved when the worm is placed in a glaſs of water, and affords an entertaining ſpectacle. The ſnout of this inſect is divided into three parts, of which that in the middle is immoveable; the other two, which grow from the ſides of the middle one, are moveable, and vibrate like the tongues of lizards or ſerpents. In theſe lateral parts lies moſt of the creature's ſtrength; for it walks upon them when out of the water, appearing to walk on its mouth, and to uſe it as the parrot does its beak to aſſiſt it in climbing.

The larva is ſhown fig. 38. as it appears through a microſcope. It grows narrower towards the head, is largeſt about that part which we may call the thorax, converges all along the abdomen, and terminates at length in a ſharp tail ſurrounded with hairs, as has already been mentioned. The twelve annular diviſions are now extremely viſible, and are marked by numbers in the plate. The ſkin appears ſomewhat hard, and reſembling ſhagreen, being thick ſet with grains pretty equally diſtributed. It has nine holes, or ſpiracula, probably for the purpoſe of breathing, on each ſide; but it has none of theſe on the tail diviſion *a*, nor any Microſcope eaſily viſible on the third from the head. In the latter, indeed, it has ſome very ſmall holes concealed under the ſkin, near the place where the embryo wings of the future fly are hid. "It is remarkable (ſays Mr Adams) that caterpillars, in general, have two rings without theſe ſpiracula, perhaps becauſe they change into flies with four wings, whereas this worm produces a fly with only two." The ſkin of the larva is adorned with oblong black furrows, ſpots of a light colour, and orbicular rings, from which there generally ſprings a hair; but only thoſe hairs which grow on the inſect's ſides are repreſented in the figure. There are alſo ſome larger hairs here and there, as at *c c*. The difference of colour, however, in this worm ariſes only from the quantity of grains in the ſame ſpace; for where they are in very great numbers, the furrows are darker, and paler where they are leſs plentiful.

The head *d* is divided into three parts, and covered with a ſkin which has hardly any diſcernible grains.—The eyes are rather protuberant, and lie near the ſnout; on which laſt are two ſmall horns at *i i*. It is crooked, and ends in a ſharp point as at *f*. The legs are placed near the ſnout between the ſinuſes in which the eyes are fixed. Each of theſe legs conſiſts of three joints, the outermoſt of which is covered with ſtiff hairs like briſtles *g g*. From the next joint there ſprings a horny bone *h h*, uſed by the inſect as a kind of thumb: the joint is alſo compoſed of a black ſubſtance of an intermediate hardneſs between bone and horn; and the third joint is of the ſame nature. In order to diſtinguiſh theſe parts, thoſe that form the upper ſides of the mouth and eyes muſt be ſeparated by means of a ſmall knife; after which, by the aſſiſtance of the microſcope, we may perceive that the leg is articulated by ſome particular ligaments, with the portion of the inſect's mouth which anſwers to the lower jaw in the human frame. We may then alſo diſcern the muſcles which ſerve to move the legs, and draw them up into a cavity that lies between the ſnout and thoſe parts of the mouth which are near the horns *i i*. The inſect walks upon theſe legs, not only in the water, but on the land alſo. It likewiſe makes uſe of them in ſwimming, keeping its tail on the ſurface contiguous to the air, and hanging downward with the reſt of the body in the water. In this ſituation, the only perceptible motion it has is in its legs, which it moves in a moſt elegant manner, from whence it is reaſonable to conclude, that the moſt of this creature's ſtrength lies in its legs, as we have already obſerved.

The ſnout of this larva is black and hard; the back part quite ſolid, and ſomewhat of a globular form; the front *f* ſharp and hollow. Three membranaceous diviſions may be perceived on the back part; by means of which, and the muſcles contained in the ſnout, the creature can contract or expand it at pleaſure.

The extremity of the tail is ſurrounded with thirty hairs, and the ſides adorned with others that are ſmaller; and here and there the large hairs branch out into ſmaller ones, which may be reckoned ſingle hairs. All theſe have their roots in the outer ſkin, which in this place is covered with rough grains, as may be obſerved by cutting it off and holding it againſt the light

upon

Microſcope

upon a ſlip of glaſs. Thus alſo we find, that at the extremities of the hairs there are grains like thoſe on the ſkin; and in the middle of the tail there is a ſmall opening, within which are minute holes, by which the inſect takes in and lets out the air it breathes. Theſe hairs, however, are ſeldom diſpoſed in ſuch a regular order as is repreſented in fig. 38. unleſs when the inſect floats with the body in the water, and the tail with its hairs a little lower than the ſurface, in which caſe they are diſpoſed exactly in the order delineated in the plate. The leaſt motion of the tail downward produces a concavity in the water; and it then aſſumes the figure of a wine-glaſs, wide at the top and narrow at the bottom. The tail anſwers the double purpoſe of ſwimming and breathing, and through it the inſect receives what is the principle of life and motion to all animals. By means of theſe hairs alſo it can ſtop its motion when ſwimming, and remain ſuſpended quietly without motion for any length of time. Its motions in ſwimming are very beautiful, eſpecially when it advances with its whole body floating on the ſurface of the water after filling itſelf with air by the tail.—To ſet out, it firſt bends the body to the right or left, and then contracts it in the form of the letter S, and again ſtretches it out in a ſtraight line: by thus contracting and then extending the body alternately, it moves on the ſurface of the water. It is very quiet, and is not diſturbed by handling.

Theſe creatures are commonly found in ſhallow ſtanding waters in the beginning of June; but ſome years much more plentifully than others. They crawl on the graſs and other plants which grow in ſuch waters, and are often met with in ditches floating on the ſurface of the water by means of their tail, the head and thorax at the ſame time hanging down; and in this poſture they turn over the clay and dirt with their ſnout and feet in ſearch of food, which is commonly a viſcous matter met with in ſmall ponds and ditches. It is very harmleſs, though its appearance would ſeem to indicate the contrary. It is moſt eaſily killed for diſſection by ſpirit of turpentine.

Fig. 39. ſhows in its natural ſize a beautiful inſect, deſcribed by Linnæus under the name of *Leucopſis dorſigera*, and which appears to be a kind of intermediate genus between a ſphex and a waſp. The antennæ are black and cylindrical, increaſing in thickneſs towards the extremity; the joint neareſt the head is yellow; the head and thorax are black, encompaſſed with a yellow line, and furniſhed with a croſs line of the ſame colour near the head. The ſcutellum is yellow, the abdomen black, with two yellow bands, and a deep ſpot of the ſame colour on each ſide between the bands. A deep poliſhed groove extends down the back from the thorax to the anus, into which the ſting turns and is depoſited, leaving the anus very circular; a yellow line runs on each ſide of the ſting.—The anus and whole body, when viewed with a ſmall magnifier, appear punctuated; but when theſe points are ſeen through a large magnifier, they appear hexagonal. Fig. 40. ſhows the inſect very much magnified. Fig. 41. gives a ſide view of it magnified in a ſmaller degree.

Fig. 42. ſhows an inſect lately diſcovered by Mr John Adams of Edmonton, as he happened to be at an inn. It was firſt ſeen by ſome labouring people who were there at the time, by whom it was conjectured to be a louſe with unuſually long horns, a mite, &c. Mr Adams hearing the debate, procured the inſect; and having viewed it through a microſcope, it preſented the appearance exhibited in fig. 42. The inſect ſeems to be quite diſtinct from the phalangium cancroides of Linnæus. The latter has been deſcribed by ſeveral authors, but none of their deſcriptions agree with this. The abdomen of this inſect is more extended, the claws larger, and much more obtuſe; the body of the other being nearly orbicular, the claws ſlender, and almoſt terminating in a point, more tranſparent, and of a paler colour. Mr Marſham has one in his poſſeſſion not to be diſtinguiſhed from that repreſented in fig. 42, excepting only that it wants the break or dent in the claws, which is ſo conſpicuous in this. He found that inſect firmly fixed by its claws to the thigh of a large fly, which he caught on a flower in Eſſex in the firſt week of Auguſt, and from which he could not diſengage it without great difficulty, and tearing off the leg of the fly. This was done upon a piece of writing paper; and he was ſurpriſed to ſee the little creature ſpring forward a quarter of an inch, and again ſeize the thigh with its claws, ſo that he had great difficulty in diſengaging it. The natural ſize of this creature, which Mr Adams calls the *lobſter-inſect*, is exhibited at *a*.

Plate CCCIII.

Fig. 43. ſhows the inſect named by M. de Geer *Phyſapus*, on account of the bladders at its feet, (*Thrips phyſapus*, Lin.). This inſect is to be found in great plenty upon the flowers of dandelion, &c. in the ſpring and ſummer. It has four wings, two upper and two under ones (repreſented fig. 44.) but the two undermoſt are not to be perceived without great difficulty. They are very long; and fixed to the upper part of the breaſt, lying horizontally. Both of them are rather pointed towards the edges, and have a ſtrong nerve running round them, which is ſet with a hair fringe tufted at the extremity. The colour of theſe wings is whitiſh: the body of the inſect is black; the head ſmall, with two large reticular eyes. The antennæ are of an equal ſize throughout, and divided into ſix oval pieces, which are articulated together.—The extremities of the feet are furniſhed with a membranaceous and flexible bladder, which it can throw out or draw in at pleaſure. It preſſes this bladder againſt the ſubſtances on which it walks, and thus ſeems to fix itſelf to them; the bladder ſometimes appears concave towards the bottom, the concavity diminiſhing as it is leſs preſſed. The inſect is repreſented of its natural ſize at *b*.

Fig. 45. repreſents the *Cimex ſtriatus* of Linnæus, remarkable for very bright and elegantly diſpoſed colours, though few in number. The head, proboſcis, and thorax, are black: the thorax ornamented with yellow ſpots; the middle one large, and occupying almoſt one-third of the poſterior part; the other two are on each ſide, and triangular. The ſcutellum has two yellow oblong ſpots, pointed at each end. The ground of the elytra is a bright yellow, ſpotted and ſtriped with black. The nerves are yellow; and there is a brilliant triangular ſpot of orange, which unites the cruſtaceous and membrana-

ceous

Microſcope

ceous parts; the latter are brown, and clouded. It is found on the elm-tree in June. It is repreſented of its natural ſize at *c*.

Fig. 46. ſhows the *Chryſomela aſparagi* of Linnæus, ſo called from the larva of the inſect feeding upon that plant. It is a common inſect, and very beautiful. It is of an oblong figure, with black antennæ, compoſed of many joints, nearly oval. The head is a deep and bright blue; the thorax red and cylindrical: the elytra are blue, with a yellow margin, and having three ſpots of theſame colour on each; one at the baſe, of an oblong form, and two united with the margin: the legs are black; but the under ſide of the belly is of the ſame blue colour with the elytra and head. This little animal, when viewed by the naked eye, ſcarcely appears to deſerve any notice; but when examined by the microſcope, is one of the moſt pleaſing opaque objects we have. It is found in June on the aſparagus after it has run to feed; and it is ſhown of its natural ſize at *d*. De Geer ſays that it is very ſcarce in Sweden.

Fig. 47. ſhows an inſect of a ſhape ſo remarkable, that naturaliſts have been at a loſs to determine the genus to which it belongs. In the Fauna Suecica, Linnæus makes it an *attelabus*: but in the laſt edition of the Syſtema Naturæ, it is ranged as a meloe, under the title of the *Meloe monoceros*; though of this alſo there ſeems to be ſome doubt. The true figure of it can only be diſcovered by a very good microſcope. The head is black, and appears to be hid or buried under the thorax, which projects forward like a horn: the antennæ are compoſed of many joints, and are of a dirty yellow colour, as well as the feet: the hinder part of the thorax is reddiſh, the fore-part black.—The elytra are yellow, with a black longitudinal line down the future; there is a band of the ſame colour near the apex, and alſo a black point near the baſe, the whole animal being curiouſly covered with hair. The natural ſize of it is ſhown at *e*. It was found in May. Geoffroy ſays that it lives upon umbelliferous plants.

Fig. 48—53. exhibit the anatomy of the coſſus caterpillar, which lives on the willow. The egg from which it proceeds is attached to the trunk of the tree by a kind of viſcous juice, which ſoon becomes ſo hard that the rain cannot diſſolve it. The egg itſelf is very ſmall and ſpheroidal, and, when examined by the microſcope, appears to have broad waving furrows running through the whole length of it, which are again croſſed by cloſe ſtreaks, giving it the appearance of a wicker baſket. It is not exactly known what time they are hatched; but as the ſmall caterpillars appear in September, it is probable that the eggs are hatched ſome time in Auguſt. When ſmall, they are generally met with under the bark of the tree to which the eggs were affixed; and an aqueous moiſture, oozing from the hole through which they got under the bark, is frequently, though not always, a direction for finding them. Theſe caterpillars change their colour but very little, being nearly the ſame when young as when old. Like many others, they are capable of ſpinning as ſoon as they come from the egg. They alſo change their ſkin ſeveral times; but as it is almoſt impoſſible to rear them under a glaſs, ſo it is very difficult to know exactly how often this moulting takes place.—Mr Adams conjectures that it is more frequently than the generality of caterpillars do, ſome having been obſerved to change more than nine times. Microſcope

The coſſus generally faſts for ſome days previous to the moulting; during which time the fleſhy and other interior parts of the head are detached from the old ſkull, and retire as it were within the neck. The new coverings ſoon grow on, but are at firſt very ſoft.—When the new ſkin and the other parts are formed, the old ſkin is to be opened, and all the members withdrawn from it; an operation naturally difficult, but which muſt be rendered more ſo from the ſoft and weak ſtate of the creature at that time. It is always much larger after each change.

From Mr Lyonet's experiments, it appears, that the coſſus generally paſſes at leaſt two winters, if not three, before it aſſumes the pupa ſtate. At the approach of winter, it forms a little caſe, the inſide of which is lined with ſilk, and the outſide covered with wood ground like very fine ſaw-duſt. During the whole ſeaſon it neither moves nor eats.

This caterpillar, at its firſt appearance, is not above one-twelfth of an inch long; but at laſt attains the length of two, and ſometimes of three inches. In the month of May it prepares for the pupa ſtate; the firſt care being to find a hole in the tree ſufficient to allow the moth to iſſue forth; and if this cannot be found, it makes one equal in ſize to the future pupa. It then begins to form of wood a caſe or cone; uniting the bits, which are very thin, together by ſilk, into the form of an ellipſoid, the outſide being formed of ſmall bits of wood joined together in all directions; taking care, however, that the pointed end of the caſe may always be oppoſite to the mouth of the hole: having finiſhed the outſide of the caſe, it lines the inſide with a ſilken tapeſtry of a cloſe texture in all its parts, except the pointed end, where the texture is looſer, in order to facilitate its eſcape at the proper time. The caterpillar then places itſelf in ſuch a poſture, that the head may always lie towards the opening of the hole in the tree or pointed end of its caſe. Thus it remains at reſt for ſome time: the colour of the ſkin firſt becomes pale, and afterwards brown; the interior parts of the head are detached from the ſkull; the legs withdraw themſelves from the exterior caſe; the body ſhortens; the poſterior part grows ſmall, while the anterior part ſwells ſo much, that the ſkin at laſt burſts; and, by a variety of motions, is puſhed down to the tail; and thus the pupa is exhibited, in which the parts of the future moth may be eaſily traced.—The covering of the pupa, though at firſt ſoft, humid, and white, ſoon dries and hardens, and becomes of a dark purple colour: the poſterior part is moveable; but not the fore-part, which contains the rudiments of the head, legs, and wings. The fore-part of the pupa is furniſhed with two horns, one above and the other under the eyes. It has alſo ſeveral rows of points on its back. It remains for ſome weeks in the caſe; after which the moth begins to agitate itſelf, and the points are then of eſſential ſervice, by acting as a fulcrum, upon which it may reſt in its endeavours to proceed forward, and not ſlip back by its efforts for that purpoſe.

The moth generally continues its endeavours to open the caſe for a quarter of an hour; after which, by redoubled efforts, it enlarges the hole, and preſſes forward

Microscopic Objects.

Fig. 54.

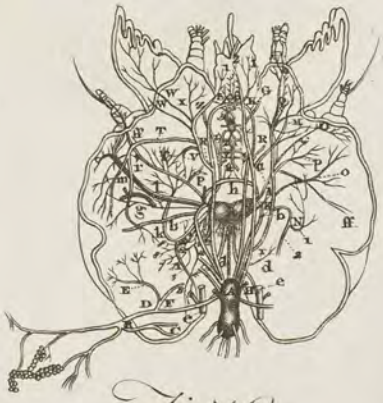


Fig. 42

Fig. 43.

Fig. 44.

Fig. 46.

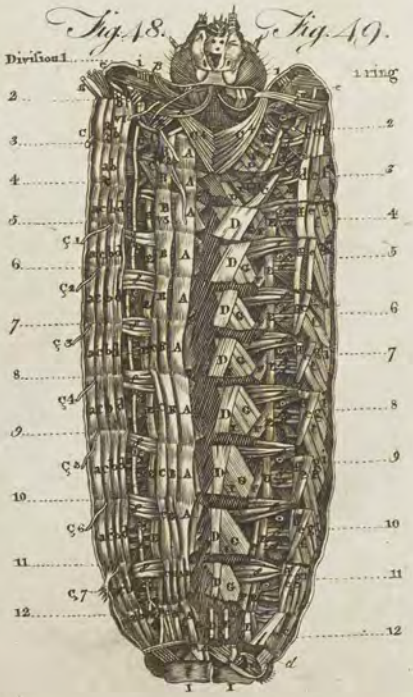
Fig. 45

Fig. 53. Fig. 52.

Fig. 51. Fig. 50.

Fig. 47.

Fig. 48. Fig. 49.



A. Bell Prin. Mal. Sculptor fecit.

Microſcope

ward until it arrives at the edge, where it makes a full ſtop, leſt by advancing further it ſhould fall to the ground. After having in this manner repoſed itſelf for ſome time, it begins to diſengage itſelf entirely; and having reſted for ſome hours with its head upwards, it becomes fit for action. Mr Marſham ſays, that it generally puſhes one third of the caſe out of the hole before it halts.

The body of the caterpillar is divided into twelve rings, marked 1, 2, 3, &c. as repreſented in fig. 48. 49. 50. 51. each of which is diſtinguiſhed from that which precedes, and that which follows, by a kind of neck or hollow; and, by forming boundaries to the rings, we make twelve other diviſions, likewiſe expreſſed in the figures; but to the firſt of theſe the word *ring* is affixed, and to the ſecond, *diviſion*. To facilitate the deſcription of this animal, M. Lyonet ſuppoſed a line to paſs down through the middle of the back, which he called the ſuperior line, becauſe it marked the moſt elevated part of the back of the caterpillar; and another, paſſing from the head down the belly to the tail, he called the inferior line.

All caterpillars have a ſmall organ, reſembling an elliptic ſpot, on the right and left of each ring, excepting the ſecond, third, and laſt; and by theſe we are furniſhed with a further ſubdiviſion of this caterpillar, viz. by lines paſſing through the ſpiracula, the one on the right ſide, the other on the left of the caterpillar. Theſe four lines, which divide the caterpillar longitudinally into four equal parts, mark each the place under the ſkin which is occupied by a conſiderable viſcus. Under the ſuperior line lies the heart, or rather thread of hearts; over the inferior line, the ſpinal marrow; and the two tracheal arteries follow the courſe of the lateral lines. At equal diſtances from the ſuperior and two lateral lines, we may ſuppoſe four intermediate lines. The two between the ſuperior and lateral lines are called the intermediate ſuperior; the two others oppoſite to them, and between the lateral and inferior lines, are called the intermediate inferior.

Fig. 48. 49. ſhow the muſcles of the caterpillar, arranged with the moſt wonderful ſymmetry and order, eſpecially when taken off by equal ſtrata on both ſides, which exhibits an aſtoniſhing and exact form and correſpondence in them. The figures ſhow the muſcles of two different caterpillars opened at the belly, and ſuppoſed to be joined together at the ſuperior lines. The muſcles of the back are marked by capitals; the gaſtric muſcles by Roman letters; the lateral ones by Greek characters. Thoſe marked θ are called, by M. Lyonet, dividing muſcles, on account of their ſituation.

The caterpillar was prepared for diſſection by being emptied, and the muſcles, nerves, &c. freed from the fat in the manner formerly directed: after which the following obſervations were made.

The muſcle A in the firſt ring is double; the anterior one being thick at top, and being apparently divided into different muſcles on the upper ſide, but without any appearance of this kind on the under ſide. One inſertion is at the ſkin of the neck towards the head; the other is a little above; and that of the ſecond muſcle A is a little below the firſt ſpiraculum, near which they are fixed to the ſkin.

The muſcle marked α is long and ſlender, fixed by its anterior extremity under the gaſtric muſcles *a* and *b* of the firſt ring, to the circumflex ſcale of the baſe of the lower lip. It communicates with the muſcle *c* of the ſecond ring, after having paſſed under ſome of the arteries, and introduced itſelf below the muſcle θ.

The muſcle β is ſo tender, that it is ſcarce poſſible to open the belly of the caterpillar without breaking it. It is ſometimes double, and ſometimes triple.—Anteriorly it is fixed to the poſterior edge of the ſide of the parietal ſcale, the lower fixture being at the middle of the ring near the inferior line.

There are three muſcles marked ξ; the firſt affixed at one extremity near the lower edge of the upper part of the parietal ſcale; the other end divides itſelf into three or four tails, fixed to the ſkin of the caterpillar under the muſcle ε. The anterior part of the ſecond is fixed near the firſt; the anterior part of the third a little under the firſt and ſecond, at the ſkin of the neck under the muſcle A. Theſe two laſt paſſing over the cavity of the firſt pair of limbs, are fixed by ſeveral tails to the edge oppoſite to this cavity. In this ſubject there are two muſcles marked ε, but ſometimes there is only one anteriorly; they are fixed to the lower edge of the parietal ſcale, the other ends being inſerted in the firſt fold of the ſkin of the neck on the belly-ſide. Fig. 50. beſt repreſents the muſcles β and ε; as in that figure they do not appear injured by any unnatural connection.

In the ſecond and four following rings we diſcern two large dorſal muſcles A and B. In the 7th, 9th, and 10th rings are three, A, B, and C; in the 11th are four, A, B, C, and D; and in the anterior part of the 12th ring are five, A, B, C, D, and E. All theſe ranges of muſcles, however, as well as the gaſtric muſcles *a*, *b*, *c*, *d*, appear at firſt ſight only as a ſingle muſcle, running nearly the whole length of the caterpillar; but when this is detached from the animal, it is found to conſiſt of ſo many diſtinct muſcles, each conſiſting only of the length of one of the rings, their extremities being fixed to the diviſion of each ring, excepting the middle muſcle *a*, which, at the 6th, 7th, 8th, and 9th rings, has its inſertions rather beyond the diviſion. Each row of muſcles appears as one, becauſe they are cloſely connected at top by ſome of the fibres which paſs from one ring to the other.

The muſcles A, which are 12 in number, gradually diminiſh in breadth to the lower part of the laſt ring: at the 8th and three following diviſions they communicate with the muſcles B, and at the 11th with D. In the lower part of the laſt ring, A is much broader than it was in the preceding ring; one extremity of it is contracted, and communicates with B; the lower inſertion being at the membrane I, which is the exterior ſkin of the fecal bag. The muſcles A and B, on the lower part of the laſt ring, cannot be ſeen until a large muſcle is removed, which on one ſide is fixed to the ſubdiviſion of the ring and on the other to the fecal bag.

The right muſcles B, which are alſo 12 in number, begin at the ſecond ring, and grow larger from thence to the ſeventh. They are uſually narrower from thence to the 12th; the deficiency in width be-

Microſcope

ing ſupplied by the ſix muſcles C, which accompany it from the 7th to the ſubdiviſion of the 12th ring. The muſcles B and C communicate laterally with the 8th, 11th, and 12th diviſions. C is wanting at the ſubdiviſion of the 12th; its place being here ſupplied by B, which becomes broader at this part.

The firſt of the three floating muſcles V originates at the firſt ring, from whence it introduces itſelf under N, where it is fixed, and then ſubdivides, and hides itſelf under other parts. The ſecond begins at the ſecond diviſion, being fixed to the anterior extremity B of the ſecond ring; from thence directing itſelf towards the ſtomach; and, after communicating with the caſe of the *corpus craſſum*, it divides, and ſpreads into eight muſcles which run along the belly. The third begins at the third diviſion, originating partly at the ſkin, and partly at the junction of the muſcles B of the ſecond and third ring. It directs itſelf obliquely towards the belly, meeting it near the third ſpiraculum; and branching from thence, it forms the oblique muſcles of ſome of the viſcera.

The thin, long, muſcle δ, which is at the ſubdiviſion of the laſt ring, and covers the anterior inſertion of the muſcle (*a*) where the ring terminates, is ſingle. It begins at one extremity of the muſcle (*c*); at the fore-part of the ring runs along the ſubdiviſion round the belly of the caterpillar, and finiſhes, on the other ſide, at the extremity of a ſimilar muſcle C.

Fig. 49. ſhows the dorſal muſcles of the coſſus. To view which in an advantageous manner, we muſt uſe the following mode of preparation.

1. All the dorſal muſcles, 35 in number, muſt be taken out, as well as the ſeven lateral ones already deſcribed.

2. All the ſtraight muſcles of the belly muſt be taken away, as well as the muſcular roots (*c*), and the ends of the gaſtric muſcles (*c*), which are at the third and fourth diviſions.

3. At the ſecond diviſion the muſcle ϑ muſt be removed; only the extremities being left to ſhow where it was inſerted.

The parts being thus prepared, we begin at the third ring; where there are found four dorſal muſcles C, D, E, and F. The firſt one C, is inſerted at the third diviſion, under the muſcles ϑ and α, where it communicates by means of ſome fibres with the muſcle *f* of the ſecond ring; proceeding from thence obliquely towards the intermediate ſuperior line, and is fixed at the fourth diviſion. As ſoon as C is retrenched, the muſcle D is ſeen; which grows wider from the anterior extremity: it lies in a contrary direction to the muſcle C, and is inſerted into the third and fourth diviſions. The muſcle E lies in the ſame direction as the muſcle C, but not ſo obliquely: the lower inſertion is at the fourth diviſion; the other at the third, immediately under C. The muſcle F is nearly parallel to D which joins it; the firſt inſertion is viſible, but the other is hid under the muſcles E and G at the fourth diviſion.

In the eight following rings, there are only two dorſal muſcles; and of theſe D is the only one that is completely ſeen. It is very large, and diminiſhes gradually in breadth from one ring to the other, till it comes to the laſt, ſending off branches in ſome places.—E is one of the ſtrait muſcles of the back; and is inſerted under the dividing muſcles ϑ, at the diviſions of its own ring. Microſcope

On the anterior part of the 12th ring there are three dorſal muſcles, D, E, and F. D is ſimilar to that of the preceding ring, marked alſo D, only that it is no more than half the length; terminating at the ſubdiviſion of its own ring. E is of the ſame length, and differs from the muſcle E of the preceding ring only in its direction. F is parallel to E, and ſhorter than it; its anterior end does not reach the twelfth diviſion.

On the poſterior part there is only one dorſal muſcle, faſtened by ſome ſhort ones to the ſubdiviſion of the laſt ring, traverſing the muſcles α; and being fixed there as if deſigned to ſtrengthen them, and to vary their direction.—$\varkappa$ is a ſingle muſcle, of which the anterior inſertion is viſible, the other end being fixed to the bottom of the foot of the laſt leg; its uſe is to move the foot. The anterior part of the muſcle β branches into three or four heads, which croſs the ſuperior line obliquely, and are fixed to the ſkin a little above it. The other end is faſtened to the membrane T.

Fig. 50. and 51. ſhow the muſcles of the caterpillar when it is opened at the back. The preparation for this view is to diſengage the fat and other extraneous matter, as before directed.

The firſt ring has only two gaſtric muſcles (*c*) and (*d*): the former is broad, and has three or four little tails: the firſt fixture is at the baſe of the lower lip, from whence it deſcends obliquely, and is fixed between the inferior and lateral line. The ſmall muſcle (*d*) is faſtened on one ſide to the firſt ſpiraculum; on the other, a little lower, to the intermediate inferior and lateral line; and ſeems to be an antagoniſt to the muſcle P, which opens the ſpiracula. The poſterior fixture of ϑ is under the muſcle C, near the ſkin of the neck: β is fixed a little on the other ſide of C, at the middle of the ring.

In the ſecond ring there are three gaſtric muſcles, *g*, *h*, and *i*: *g* and *h* are fixed at the folds which terminate the ring; but only the anterior part of *i* is fixed there. The muſcle *h* is triple, and in one of the diviſions ſeparated into two parts; that marked *i* comes nearer the inferior line, and is fixed a little beyond the middle of the ring, where the correſponding muſcle of the oppoſite ſide is forked to receive it.

In the third ring, the muſcle *h*, which was triple in the foregoing ring, is only double here, that part which is neareſt the inferior line being broadeſt: it has three tails, of which only two are viſible in the figure. It is exactly ſimilar to that of the preceding ring; and is croſſed in the ſame manner by the muſcle from the oppoſite ſide of the ring.

Throughout the eight following rings, the muſcle *f* which runs through them all is very broad and ſtrong. The anterior part of it is fixed at the intermediate inferior line, on the fold of the firſt diviſion of the ring: the other part is fixed beyond the lower diviſion; with this difference, that at the 10th and 11th rings it is fixed at the laſt fold of its ring; whereas, in the others it paſſes over that ring, and is inſerted into the ſkin of the following one. In all theſe,

Microſcope theſe, the firſt extremity of the muſcle *g* is faſtened to the fold which ſeparates the ring from the preceding one, and is parallel to *f*, and placed at the ſide of it. The ſix firſt muſcles marked *g*, are forked; that of the fourth ring being more ſo than the reſt, nor does it unite till near its anterior inſertion. The longeſt tail lays hold of the following, and is inſerted near the inferior line; the other inſerts itſelf near the ſame line, at about the middle of its own ring. The two laſt do not branch out; but terminate at the diviſions, without reaching the following ring. The muſcle *h*, placed at the ſide of *f*, has nearly the ſame direction, and finiſhes at the folds of the ring.

The anterior part of the 12th ring has only one gaſtric muſcle, marked *e*: it is placed on the intermediate inferior line; and is inſerted at the folds of the upper diviſion, and at the ſubdiviſion of this ring. The lower part has a larger muſcle marked *e*, with ſeveral diviſions; one placed under *b*, with one extremity fixed near the lateral line, at the ſubdiviſion of its ring; the other to the fecal bag, a little lower than the muſcle *b*.

In fig. 51. all the gaſtric muſcles deſcribed in fig. 50. diſappear, as well as thoſe lateral and dorſal ones of which the letters are not to be found in this figure.

In the firſt ring are the gaſtric muſcles, *e*, *f*, *g*, which are beſt ſeen here: the firſt is narrow and long, paſſing under and croſſing *f*: one of its inſertions is at the lower line, the other at the lateral, between the ſpiraculum and neck: *f* is ſhort, broad, and nearly ſtraight, placed along the intermediate line; but between it and the lateral it paſſes under *e*, and is fixed to the fold of the ſkin which goes from the one bag to the other; the lower inſertion is near the ſecond diviſion. There are ſometimes three muſcles of thoſe marked *g*, and ſometimes four: the lower parts of them are fixed about the middle of the ring, and the anterior parts at the fold of the ſkin near the neck. The muſcles *i* and *h* are fixed to the ſame fold; the other end of *h* being fixed under the muſcle II, near the ſpiraculum. Above the upper end of *f*, a muſcular body, *g*, may be ſeen. It is formed by the ſeparation of two floating muſcles.

The ſecond ring has ſix gaſtric muſcles, *k*, *l*, *m*, *n*, *o*, *p*. The firſt is a large oblique muſcle, with three or four diviſions placed at the anterior part of the ring: the head is fixed between the inferior line and its intermediate one, at the fold of the ſecond diviſion; from whence it croſſes the inferior line and its correſponding muſcle, terminating to the right and left of the line. I is a narrow muſcle, whoſe head is fixed to the fold of the ſecond diviſion; the tail of it lying under *n*, and faſtened to the edge of the ſkin that forms the cavity for the leg. The two muſcles marked *m* have the ſame obliquity, and are placed the one on the other: the head is inſerted in the ſkin under the muſcle β, and communicates by a number of fibres with the tail of the muſcle γ; the other end is fixed to the intermediate inferior line at the fold of the third diviſion. The large and broad muſcle *n*, covers the lower edge of the cavity of the limb, and the extremity of the tail of *l*. It is fixed firſt at the ſkin, near the intermediate line, from whence it goes in a perpendicular direction towards *m*, and introduces itſelf under *o* and *m*, where it is fixed. The muſcle *o* is narrow and bent, and covers the edge of the cavity of the leg for a little way; one end terminating there, and the other finiſhing at the third diviſion near *m*. That marked *p* is alſo bent: it runs near the anterior edge of the cavity of the leg; one end meets the head of *o*, the other end terminates at a raiſed fold near the inferior line. There is a triangular muſcle on the ſide of the lateral muſcle *o*, ſimilar to that marked *g* in the following ring: in this figure it is entirely concealed by the muſcle *m*.

The third ring has no muſcle ſimilar to *m*; that marked *k* differs only from that of the ſecond ring in being croſſed by the oppoſite muſcle. Thoſe marked *l*, *n*, *o*, *p*, are ſimilar to thoſe of the preceding one. The muſcle *q* is triangular; the baſe is faſtened to the laſt fold of the ring; on the lower ſide it is fixed to the muſcle *o*, the top to the ſkin at the edge of the cavity for the leg.

The eight following rings have the gaſtric muſcles, *i*, *k*, *l*, and *m*. The muſcle *i* is quite ſtraight, and placed at ſome diſtance from the inferior line: it is broad at the fourth ring, but diminiſhes gradually in breadth to the 11th. In the fourth it is united; but divides into two heads, which divaricate in the following rings. In the ſix next rings theſe heads are fixed nearly at the ſame place with *a* and *f*; and in the other two it terminates at the fold of the ring. The anterior inſertion of the firſt and laſt is at the fold where the ring begins: that of the ſix others is ſomewhat lower under the place where the muſcle *i* terminates. The lower part of the oblique muſcle *k* is inſerted in the ſkin near *i*; the upper part at the intermediate inferior muſcle upon the fold which ſeparates the following ring, but is wanting in the 11th. The muſcle *l* is large, and co-operates with M: in the opening and ſhutting the ſpiraculum, one of its fixtures is near the intermediate inferior line, at about the ſame height as *i*. The tail terminates a little below the ſpiraculum.

The twelfth ring has only the ſingle gaſtric muſcle *d*, which is a bundle of ſix, ſeven, or eight muſcles: the firſt fixture of theſe is at the ſubdiviſion of the ring near the inferior line: one or two croſs this, and at the ſame time the ſimilar muſcles of the oppoſite ſide. Their fixture is at the bottom of the foot; and their office is to aſſiſt the muſcle *a* in bringing back the foot, and to looſen the claw from what it lays hold of. One of the inſertions of this muſcle *a* is obſerved in this figure near *d*, the other near the ſubdiviſion of the ring.

Fig. 52. and 53. ſhow the organization of the head of the coſſus, though in a very imperfect manner, as M. Lyonet found it neceſſary to employ *twenty* figures to explain it fully. The head is repreſented as it appears when ſeparated from the fat, and diſengaged from the neck. HH are the two palpi. The truncated muſcles D belong to the lower lip, and aſſiſt in moving it. K ſhows the two ganglions of the neck united. II are the two veſſels which aſſiſt in ſpinning the ſilk. L, the œſophagus. M, the two diſſolving veſſels. The Hebrew characters דכבא ſhow the continuation of the four cephalic arteries. In fig. 52. the ten abductor muſcles of the jaw

Microſcope

are repreſented by SS, TT, VV, and Z. Four occipital muſcles are ſeen in fig. 53. under *e e* and *f f*. At *a k* is repreſented a nerve of the firſt pair belonging to the ganglion of the neck; *b* is a branch of this nerve.

Fig. 54. exhibits the nerves as ſeen from the under part; but excepting in two or three nerves, which may be eaſily diſtinguiſhed, only one of each pair is drawn, in order to avoid confuſion. The nerves of the firſt ganglion of the neck are marked by capital letters, thoſe of the ganglion (a) of the head by Roman letters; the nerves of the ſmall ganglion by Greek characters. Thoſe of the frontal ganglion, except one, by numbers.

The muſcles of the coſſus have neither the colour nor form of thoſe of larger animals. In their natural ſtate they are ſoft, and of the conſiſtence of a jelly. Their colour is a greyiſh blue, which, with the ſilver-coloured appearance of the pulmonary veſſels, form a glorious ſpectacle. After the caterpillar has been ſoaked for ſome time in ſpirit of wine, they loſe their elaſticity and tranſparency, becoming firm, opaque, and white, and the air-veſſels totally diſappear. The number of muſcles in a caterpillar is very great. The greateſt part of the head is compoſed of them, and there is a vaſt number about the œſophagus, inteſtines, &c. the ſkin is, as it were, lined by different beds of them, placed the one under the other, and ranged with great ſymmetry. M. Lyonet has been able to diſtinguiſh 228 in the head, 1647 in the body, and 2066 in the inteſtinal tube, making in all 4041.

At firſt ſight the muſcles might be taken for tendons, as being of the ſame colour, and having nearly the ſame luſtre. They are generally flat, and of an equal ſize throughout; the middle ſeldom differing either in colour or ſize from either of the extremities. If they are ſeparated, however, by means of very fine needles, in a drop of ſome fluid, we find them compoſed not only of fibres, membranes, and air-veſſels, but likewiſe of nerves; and, from the drops of oil that may be ſeen floating on the fluid, they appear alſo to be furniſhed with many unctuous particles. Their ends are fixed to the ſkin, but the reſt of the muſcle is generally free and floating. Several of them branch out conſiderably; and the branches ſometimes extend ſo far, that it is not eaſy to diſcover whether they are diſtinct and ſeparate muſcles or parts of another. They are moderately ſtrong; and thoſe which have been ſoaked in ſpirit of wine, when examined by the microſcope, are found to be covered with a membrane which may be ſeparated from them; and they appear then to conſiſt of ſeveral parallel bands lying longitudinally along the muſcle, which, when divided by means of fine needles, appear to be compoſed of ſtill ſmaller bundles of fibres lying in the ſame direction; which, when examined by a powerful magnifier, and in a favourable light, appear twiſted like a ſmall cord. The muſcular fibres of the ſpider, which are much larger than thoſe of the caterpillar, conſiſt of two different ſubſtances, one ſoft and the other hard; the latter being twiſted round the former ſpirally, and thus giving it the twiſted appearance juſt mentioned.

There is nothing in the caterpillar ſimilar to the brain in man. We find indeed in the head of this inſect a part from which all the nerves ſeem to proceed; but this part is entirely unprotected, and ſo ſmall, that it does not occupy one fifth part of the head: the ſurface is ſmooth, and has neither lobes nor any anfractuoſity like the human brain. But if we call this a brain in the caterpillar, we muſt ſay that it has *thirteen*: for there are twelve other ſuch parts following each other in a ſtraight line, all of them of the ſame ſubſtance with that in the head, and nearly of the ſame ſize; and from them, as well as from that in the head, the nerves are diſtributed thro' the body. Microſcope

The ſpinal marrow in the coſſus goes along the belly; is very ſmall, forking out at intervals, nearly of the ſame thickneſs throughout, except at the ganglions, and is not incloſed in any caſe. It is by no means ſo tender as in man; but has a great degree of tenacity, and does not break without a conſiderable degree of tenſion. The ſubſtance of the ganglions differs from that of the ſpinal marrow, as no veſſels can be diſcovered in the latter; but the former are full of very delicate ones. There are 94 principal nerves, which divide into innumerable ramifications.

The coſſus has two large tracheal arteries, creeping under the ſkin cloſe to the ſpiracula; one at the right and the other at the left ſide of the inſect, each of them communicating with the air by means of nine ſpiracula. They are nearly as long as the whole caterpillar; beginning at the firſt ſpiraculum, and extending ſomewhat farther than the laſt; ſome branches alſo extending quite to the extremity of the body. Round each ſpiraculum the trachea puſhes forth a great number of branches, which are again divided into ſmaller ones, and theſe further ſubdivide and ſpread through the whole body of the caterpillar. The tracheal artery, with all its numerous ramifications, are open elaſtic veſſels, which may be preſſed cloſe together, or drawn out conſiderably, but return immediately to their uſual ſize when the tenſion ceaſes. They are naturally of a ſilver colour, and make a beautiful appearance. This veſſel, with its principal branches, is compoſed of three coats, which may be ſeparated from one another. The outmoſt is a thick membrane furniſhed with a great variety of fibres, which deſcribe a vaſt number of circles round it, communicating with each other by numerous ſhoots. The ſecond is very thin and tranſparent, without any particular veſſel being diſtinguiſhable in it. The third is compoſed of ſcaly threads, generally of a ſpiral form; and ſo near each other as ſcarcely to leave any interval. They are curiouſly united with the membrane which occupies the intervals; and form a tube which is always open, notwithſtanding the flexure of the veſſel. There are alſo many other peculiarities in its ſtructure. The principal tracheal veſſels divide into 1326 different branches.

The heart of the coſſus is very different from that of larger animals, being almoſt as long as the animal itſelf. It lies immediately under the ſkin at the top of the back, entering the head, and terminating near the mouth. Towards the laſt rings of the body it is large and capacious, diminiſhing very much as it approaches the head, from the fourth to the twelfth diviſion. On both ſides, at each diviſion, it has an appendage, which partly

Microscopic Objects.

Fig. 55.

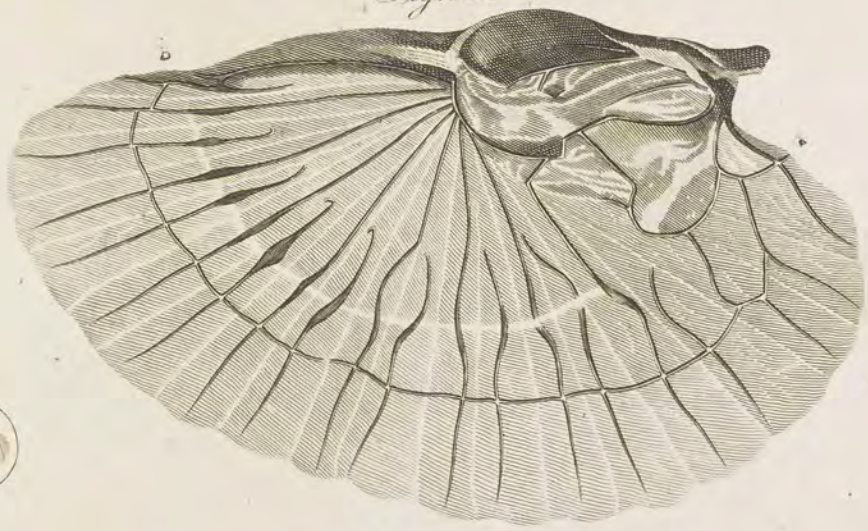


Fig. 58.

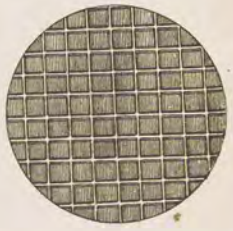
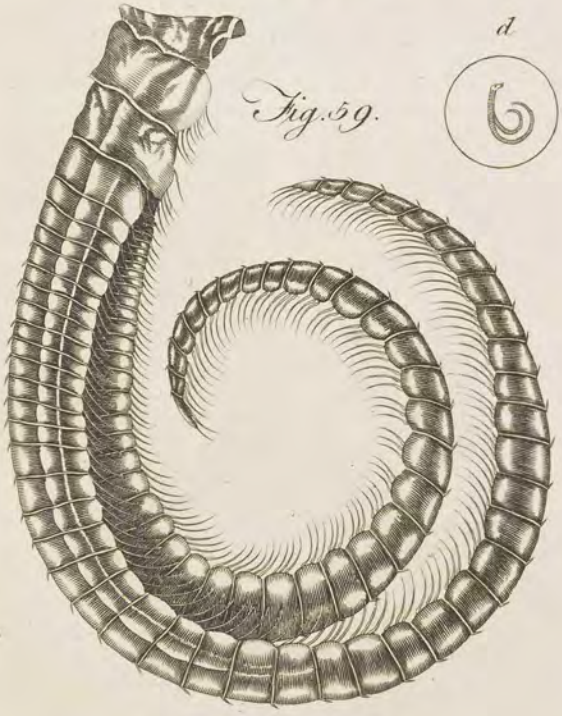


Fig. 57.

Fig. 59.



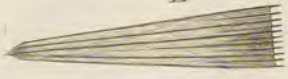
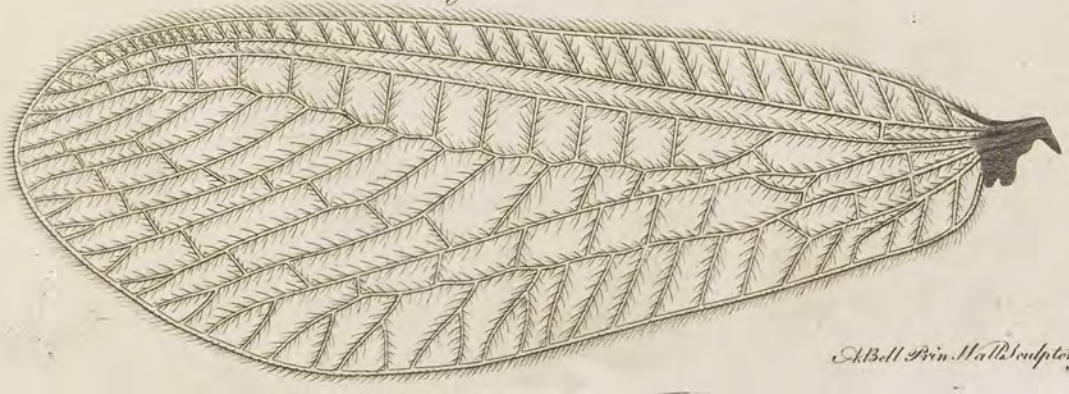


Fig. 56.



J. Bell Prin. Mall Sculptor fecit.

Fig. 62.

h

Fig. 65.

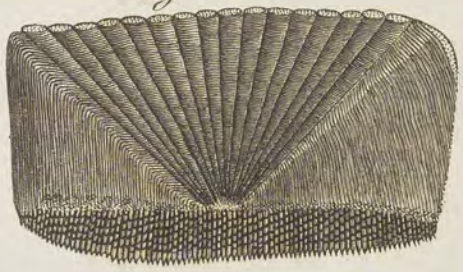
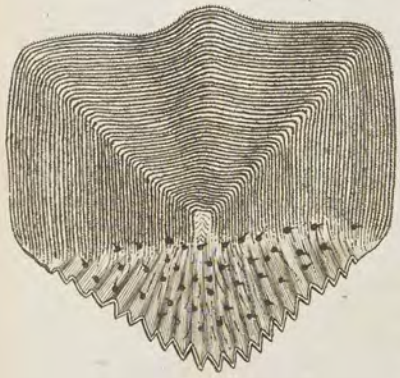


Fig. 64.

l



h

Fig. 61.

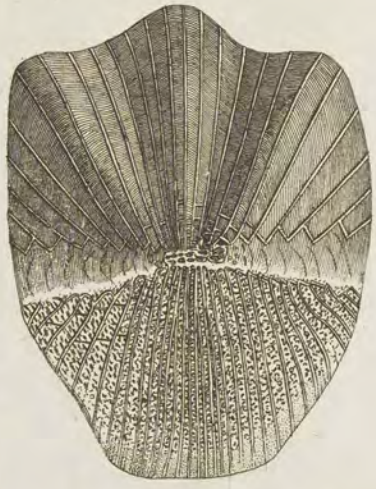


Fig. 63.

g

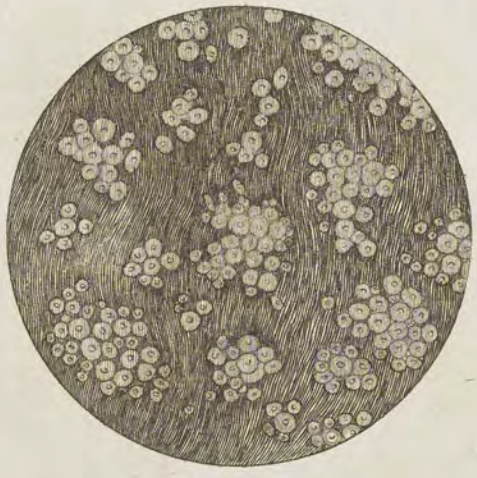


Fig. 60.

f

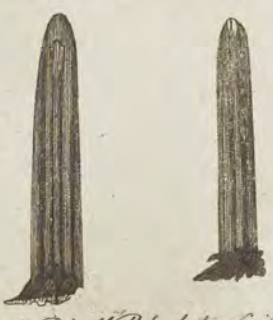
Fig. 66.

l

C

B

a c b d b c a



D

E

A. Bell Prin. Wal. Sculptor fecit.

Microſcope partly covers the muſcles of the back, but which, growing narrower as it approaches the lateral line, it forms a number of irregular lozenge-ſhaped bodies.—This tube, however, ſeems to perform none of the functions of the heart in larger animals, as we find no veſſel opening into it which anſwers either to the aorta or vena cava. It is called the heart, becauſe it is generally filled with a kind of lymph, which naturaliſts have ſuppoſed to be the blood of the caterpillar; and becauſe in all caterpillars which have a tranſparent ſkin, we may perceive alternate regular contractions and dilatations along the ſuperior line, beginning at the eleventh ring, and proceeding from ring to ring, from the fourth; whence this veſſel is thought to be a ſtring or row of hearts. There are two white oblong bodies which join the heart near the eighth diviſion; and theſe have been called *reniform* bodies, from their having ſomewhat of the ſhape of a kidney.

The moſt conſiderable part of the whole caterpillar with regard to bulk is the corpus craſſum. It is the firſt and only ſubſtance that is ſeen on opening it. It forms a kind of ſheath which envelopes and covers all the entrails, and, introducing itſelf into the head, enters all the muſcles of the body, filling the greateſt part of the empty ſpaces in the caterpillar. It very much reſembles the configuration of the human brain, and is of a milk-white colour.

The oeſophagus deſcends from the bottom of the mouth to about the fourth diviſion. The fore-part, which is in the head, is fleſhy, narrow, and fixed by different muſcles to the cruſtaceous parts of it; the lower part, which paſſes into the body, is wider, and forms a kind of membranaceous bag, covered with very ſmall muſcles; near the ſtomach it is narrower, and, as it were, confined by a ſtrong nerve fixed to it at diſtant intervals. The ventricle begins a little above the fourth diviſion, where the oeſophagus ends, and finiſhes at the tenth. It is about ſeven times as long as broad; and the anterior part, which is broadeſt, is generally folded. Theſe folds diminiſh with the bulk as it approaches the inteſtines; the ſurface is covered with a great number of aerial veſſels, and opens into a tube, which M. Lyonet calls the large inteſtine.—There are three of theſe large tubes, each of which differs ſo much from the reſt, as to require a particular name to diſtinguiſh it from them.

The two veſſels from which the coſſus ſpins its ſilk are often above three inches long, and are diſtinguiſhed into three parts; the anterior, intermediate, and poſterior. It has likewiſe two other veſſels, which are ſuppoſed to prepare and contain the liquor for diſſolving the wood on which it feeds.

Plate CCCIV. Fig. 55. ſhews the wing of an earwig magnified; *a* repreſents it of the natural ſize. The wings of this inſect are ſo artificially folded up under ſhort caſes, that few people imagine they have any. Indeed, they very rarely make uſe of their wings. The caſes under which they are concealed are not more than a ſixth part of the ſize of one wing, though a ſmall part of the wing may be diſcovered, on a careful inſpection, projecting from under them. The upper part of the wing is cruſtaceous and opaque, but the under part is beautifully tranſparent. In putting up their wings, they firſt fold back the parts AB, and then ſhut up the ribs like a fan; the ſtrong muſcles uſed for this purpoſe being ſeen at the upper part of the figure. Some of the ribs are extended from the centre to the outer edge; Microſcope others only from the edge about half way: but they are all united by a kind of band, at a ſmall but equal diſtance from the edge; the whole evidently contrived to ſtrengthen the wing, and facilitate its various motions. The inſect itſelf differs very little in appearance in its three different ſtates. De Geer aſſerts, that the female hatches eggs like a hen, and broods over her young ones as a hen does.

Fig. 56. repreſents a wing of the *Hemerobius perla* magnified. It is an inſect which ſeldom lives more than two or three days.—The wings are nearly of a length, and exactly ſimilar to one another. They are compoſed of fine delicate nerves, regularly and elegantly diſpoſed as in the figure, beautifully adorned with hairs, and lightly tinged with green. The body is of a fine green colour; and its eyes appear like two burniſhed beads of gold, whence it has obtained the name of *golden eye*. This inſect lays its eggs on the leaves of the plum or the roſe tree; the eggs are of a white colour, and each of them fixed to a little pedicle or foot-ſtalk, by which means they ſtand off a little from the leaf, appearing like the fructification of ſome of the moſſes. The larva proceeding from theſe eggs reſembles that of the coccinella or lady-cow, but is much more handſome. Like that, it feeds upon aphides or pucerons, ſucking their blood, and forming itſelf a caſe with their dried bodies; in which it changes into the pupa ſtate, from whence they afterwards emerge in the form of a fly.

Fig. E, F, I, repreſent the duſt of a moth's wing magnified. This is of different figures in different moths. The natural ſize of theſe ſmall plumes is repreſented at H.

Fig. 57. ſhows a part of the cornea of the libellula magnified. In ſome poſitions of the light, the ſides of the hexagons appear of a fine gold colour, and divided by three parallel lines. The natural ſize of the part magnified is ſhown at *b*.

Fig. 58. ſhows the part *c* of a lobſter's cornea magnified.

Fig. 59. ſhows one of the arms or horns of the lepas antifera, or barnacle, magnified; its natural ſize being repreſented at *d*. Each horn conſiſts of ſeveral joints, and each joint is furniſhed on the concave ſide of the arm with long hairs. When viewed in the microſcope, the arms appear rather opaque; but they may be rendered tranſparent, and become a moſt beautiful object, by extracting out of the interior cavity a bundle of longitudinal fibres, which runs the whole length of the arm. Mr Needham thinks that the motion and uſe of theſe arms may illuſtrate the nature of the rotatory motion in the wheel-animal. In the midſt of the arms is an hollow trunk, conſiſting of a jointed hairy tube, which incloſes a long round tongue that can be puſhed occaſionally out of the tube or ſheath, and retracted occaſionally. The mouth of the animal conſiſts of ſix laminæ, which go off with a bend, indented like a ſaw on the convex edge, and by their circular diſpoſition are ſo ranged, that the teeth, in the alternate elevation and depreſſion of each plate, act againſt whatever comes between them. The plates are placed together in ſuch a manner, that to the naked eye they form an aperture not much unlike the mouth of a contracted purſe.

Fig. 60. ſhows the apparatus of the *Tabanus* or Gadfly, Plate CCCV.

Microſcope Midas.

fly, by which it pierces the ſkin of horſes and oxen, in order to ſuck their blood. The whole is contained in a fleſhy caſe, not expreſſed in the figure. The feelers *aa* are of a ſpongy texture and grey colour, covered with ſhort hairs. They are united to the head by a ſmall joint of the ſame ſubſtance. They defend the other parts of the apparatus, being laid upon it ſide by ſide whenever the animal ſtings, and thus preſerve it from external injury. The wound is made by the two lancets *bb* and B, which are of a delicate ſtructure, but very ſharp, formed like the diſſecting knife of an anatomiſt, growing gradually thicker to the back.—The two inſtruments *cc* and C, appear as if intended to enlarge the wound, by irritating the parts round it; for which they are jagged or toothed. They may alſo ſerve, from their hard and horny texture, to defend the tube *e* E, which is of a ſofter nature, and tubular, to admit the blood, and convey it to the ſtomach. This part is totally incloſed in a line *d* D, which entirely covers it. Theſe parts are drawn ſeparately at B, C, D, E. De Geer obſerves, that only the females ſuck the blood of animals; and Reaumur informs us, that having made one, that had ſucked its fill, diſgorge itſelf, the blood it threw up appeared to him to be more than the whole body of the inſect could have contained. The natural ſize of this apparatus is ſhown at *f*.

Fig. 61. ſhows a bit of the ſkin of a lump-fiſh (*Cyclopterus*) magnified. When a good ſpecimen of this can be procured, it forms a moſt beautiful object. The tubercles exhibited in the figure probably ſecrete an unctuous juice.

Fig. 62. ſhows the ſcale of a ſea-perch found on the Engliſh coaſt; the natural ſize is exhibited at *h*.

Fig. 63. is the ſcale of an haddock magnified; its natural ſize as within the circle.

Fig. 64. the ſcale of a parrot fiſh from the Weſt Indies magnified; *l* the natural ſize of it.

Fig. 65. the ſcale of a kind of perch in the Weſt Indies magnified; *k* the natural ſize of the ſcale.

Fig. 66. part of the ſkin of a ſole fiſh, as viewed through an opaque microſcope; the magnified part, in its real ſize, ſhown at *l*.

The ſcales of fiſhes afford a great variety of beautiful objects for the microſcope. Some are long; others round, ſquare, &c. varying conſiderably not only in different fiſhes, but even in different parts of the ſame fiſh. Leeuwenhoeck ſuppoſed them to conſiſt of an infinite number of ſmall ſcales or ſtrata, of which thoſe next to the body of the fiſh are the largeſt. When viewed by the microſcope, we find ſome of them ornamented with a prodigious number of concentric flutings, too near each other, and too fine to be eaſily enumerated. Theſe flutings are frequently traverſed by others diverging from the centre of the ſcale, and generally proceeding from thence in a ſtraight line to the circumference.

For a more full information concerning theſe and other microſcopical objects, the reader may conſult Mr Adams's *Eſſays on the Microſcope*, who has made the moſt valuable collection that has yet appeared on the ſubject. See alſo the articles ANIMALCULE, CRYSTALLIZATION, POLYPE, PLANTS, and WOOD, in the preſent Work.

MIDAS (fab. hiſt.), a famous king of Phrygia, who having received Bacchus with great magnificence, that god, out of gratitude, offered to grant him whatever he ſhould aſk. Midas deſired that every thing he touched ſhould be changed into gold. Bacchus conſented; and Midas, with extreme pleaſure, everywhere found the effects of his touch. But he had ſoon reaſon to repent of his folly: for wanting to eat and drink, the aliments no ſooner entered his mouth than they were changed into gold. This obliged him to have recourſe to Bacchus again, to beſeech him to reſtore him to his former ſtate; on which the god ordered him to bathe in the river Pactolus, which from thence forward had golden ſands. Some time after, being choſen judge between Pan and Apollo, he gave another inſtance of his folly and bad taſte, in preferring Pan's muſic to Apollo's; on which the latter being enraged, gave him a pair of aſſes ears. This Midas attempted to conceal from the knowledge of his ſubjects: but one of his ſervants ſaw the length of his ears, and being unable to keep the ſecret, yet afraid to reveal it from apprehenſion of the king's reſentment, he opened a hole in the earth, and after he had whiſpered there that Midas had the ears of an aſs, he covered the place as before, as if he had buried his words in the ground. On that place, as the poets mention, grew a number of reeds, which when agitated by the wind uttered the ſame ſound that had been buried beneath, and publiſhed to the world that Midas had the ears of an aſs. Some explain the fable of the ears of Midas, by the ſuppoſition that he kept a number of informers and ſpies, who were continually employed in gathering every ſeditious word that might drop from the mouths of his ſubjects. Midas, according to Strabo, died of drinking bull's hot blood. This he did, as Plutarch mentions, to free himſelf from the numerous ill dreams which continually tormented him. Midas, according to ſome, was ſon of Cybele. He built a town which he called *Ancyræ*.

Midas || Middleburg.

MIDAS, *Ear-ſhell*, the ſmooth ovato-oblong buccinum, with an oblong and very narrow mouth. It conſiſts of ſix volutions, but the lower one alone makes up almoſt the whole ſhell.

MID-HEAVEN, the point of the ecliptic that culminates, or in which it cuts the meridian.

MIDDLEBURG, one of the Friendly Iſlands in the South Sea. This iſland was firſt diſcovered by Taſman, a Dutch navigator, in January 1742-3; and is called by the natives *Ea-Oo-whe*: it is about 16 miles from north to ſouth, and in the wideſt part about 8 miles from eaſt to weſt. The ſkirts are chiefly laid out in plantations, the ſouth-weſt and north-weſt ſides eſpecially. The interior parts are but little cultivated, though very capable of it: but this neglect adds greatly to the beauty of the iſland; for here are agreeably diſperſed groves of cocoa-nuts and other trees, lawns covered with thick graſs, here and there plantations and paths leading to every part of the iſland, in ſuch beautiful diſorder, as greatly to enliven the proſpect. The hills are low; the air is delightful; but unfortunately water is denied to this charming ſpot. Yams, with other roots, bananas, and bread-fruit, are the principle articles of food; but the latter appeared to be ſcarce. Here is the pepper-tree, or *ava-ava*, with which they make an intoxicating liquor, in the ſame diſguſting manner as is practiſed in the Society Iſlands. Here are ſeveral odoriferous trees and ſhrubs,