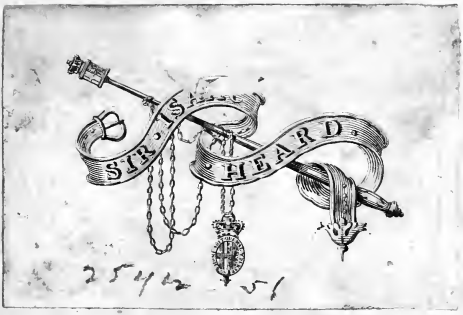

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THE

Young Gentleman and Lady's PHILOSOPHY,

IN A

Continued SURVEY of the WORKS of NATURE and ART;

By Way of DIALOGUE.

John Dowley

VOL. II.

CONTAINING,

I. The Use of the *Celestial* and *Terrestrial* GLOBES.
II. The PHILOSOPHY of LIGHT and COLOURS, and the Use of all Sorts of *Optical* INSTRUMENTS.
III. The PHILOSOPHY of SOUNDS, MUSIC, and the Organization of the EAR.

Illustrated by Nineteen COPPER-PLATES.

By BENJAMIN MARTIN.

LONDON:

Printed and sold by W. OWEN, near *Temple-Bar*, and by the AUTHOR, at his House in *Fleet-street*.

MDCCLXIII.

The CELESTIAL GLOBE

Plate XXXIV

A. Walker Del. et Sc.

The Young GENTLEMAN and LADY's PHILOSOPHY.

PART IV.

CONTAINING

The Deſcription and Uſe of the CELESTIAL and TERRESTRIAL GLOBES, MAPS, and PLANISPHERES.

DIALOGUE I.

The Deſcription of the CELESTIAL GLOBE, *and its* FURNITURE.

Cleonicus.

AS our laſt Converſation finiſhed our Speculation on the Atmoſphere, we are brought, by our propoſed Method, to a View of the artificial Globes.——And that Nothing may be wanting to give you a perfect Idea of the moſt wonderful and obvious Parts of Nature, I mean, the Frame and Conſtitutions of the Heavens and the Earth, and all their ſenſible Motions and Phænomena; I have provided a Pair of GLOBES for that Purpoſe, ſeventeen Inches Diameter.——And here they are———This is called the *Celeſtial Globe*,———and this the *Terreſtrial*.———

Euphroſ. I am infinitely obliged to you, *Cleonicus*, for the Care and Trouble you have on my Account.———They are very beautiful Things indeed! And I queſtion not but they are of equal Uſe.———As we cannot conſider the Uſes of both at once, pray which do we begin with?

Cleon. The *Celestial Globe*, my *Euphrosyne*; for that remains to finish our practical View of the Heavens.——We at first contemplated the Theory of the *Mundane System*——then we took an *actual Survey of the several Bodies* which composed it, and their *Motions*, by the *Telescope*;——after this, we assayed the *Doctrine of the Sphere*;——and then considered, under a more immediate View, the *various Motions and Affections of the Heavenly Bodies*, in themselves, and in regard of each other, in the *Orrery*;——and now it remains, that we contemplate the same Thing in regard to the Earth (or its Inhabitants) only, which is to be done by the *Celestial Globe*; whose Superficies represents the *constellated Canopy of the Heavens*, and its Rotation about its Axis, *the apparent diurnal Motions of the Sun, Moon, and Stars.*——And hence this Globe has the Name *Celestial.*

Euphros. I must wait till you are more particular in the Uses of this fine Instrument;——at present I observe most of the Circles of the Sphere upon it,——and several Figures of *Men, Women, Horses, Dogs, Serpents, Fishes, Crowns*, &c. painted thereon, which, I suppose, are all significant, when understood.——

Cleon. True, Sister; here are all the Circles of the Sphere; and it is little different from the Sphere, in any Thing more than having a continued Surface and the *Constellations* painted thereon.

Euphros. Yes, here is this broad Horizon, with several Circles upon it,——pray, what Circles are they?

Cleon. There are five Circles on the Horizon, *viz.* (1) The inmost, or that next the Globe, is the *Circle of Amplitudes or Azimuths*, and divided each Way from *East* to *West*, towards *North* and *South*, into 90 Degrees. (2) The Circle containing the 32 *Points of the Compass.* (3) The *Calendar* of Months and Days according to the *New Stile.* (4) The *Zodiac*, with the Signs and Degrees of the Ecliptic adapted thereto. (5) The *Calendar* for the *Old Stile* adjusted to the Ecliptic;——the Uses of all these you will see more particularly hereafter.——

Euphros. Very good, *Cleonicus*; and as to the other Circles on its Surface; the *Equinoctial*, the *Ecliptic*, the *Tropics*, and *Polar Circles*, I shall trouble you with no Questions concerning them, having had a perfect Knowledge of them from the Sphere.

Sphere.——But these other Circles, which run athwart and cross the Globe, and cut each other, what are they?

Cleon. They are of two Sorts, *viz. Circles of Longitude*, which pass thro' the Poles of the Ecliptic, and therefore at right Angles to the Ecliptic; of these there are 12, which terminate the 12 Signs; and divide the Surface of the Globe into 12 equal Parts; these equal Parts in the Heavens were called the *Celestial Houses* by *Ptolemy* and other ancient Astrologers. The other Sort are called *Circles of Declination*; these all pass thro' the Poles of the World, and cut the Equinoctial at right Angles at every 30th Degree; they are also 12 in Number, and divide the Surface of the Globe into other 12 equal Parts, which were in the Heavens accounted the 12 *Celestial Houses* by that Astrologer, but other Astrologers in after Times invented other Divisions of the Heavens for their Houses, as their Fancies and Superstition suggested.

Euphros. How came they to call these Divisions *Houses?* And what did they intend thereby?

Cleon. In ancient Times, when the World was very ignorant, *Superstition* was all the Fashion; and Imposture a venerable Thing. Then was the Time for the Men of Front; they invented Schemes and Figures of the Heavens to amuse and surprize the Vulgar, making them believe the Stars were the very Ministers of Fate, having a governing Influence over all Things below. Hear how solemnly *Manilius* talks on this Subject——

When Nature order'd this vast Frame to rise,
Nature, the Guardian of these Mysteries,
And scatter'd lucid Bodies o'er the Skies;
When she the Concave, whence directly fall
Streight Lines of Influence round the solid Ball,
Had fill'd with Stars; and made Earth, Water, Air,
And Fire, each other mutually repair;
That Concord might these differing Parts controul,
And Leagues of mutual Aid support the Whole;
That nothing which the Skies embrace might be
From Heaven's supreme Command and Guidance free,
Long Time she thought, then hung his Fates on Stars,

Those Stars, which plac'd i'th Heart of Heaven display
The brightest Beams, and share the greatest Sway;
Which keeps a constant Course, and now restrain
The Planets Pow'r, now yield to them again;
Thus sometimes ruling, sometimes rul'd, create
The strange and various Intercourse of Fate.

Lib. III.

And every Thing of this Kind was sacred which they said; yea, so credulous were the unthinking Vulgar, that Nothing could be advanced too monstrous and ridiculous for them not to believe. Thus a Modern *French* Astrologer is gibed by *Hudibras*——

Cardan *believ'd great States depend*
Upon the Tip o' th' Bear's Tail's End;
That as she whisk'd it tow'rds the Sun,
Strow'd mighty Empires up and down.

And as to the Imposture and Nonsense of antient *Soothsayers*, see it merrily ridiculed in his 3d Canto of Part II. But we make too long a Digression, were it not that so impious and scandalous a Pretension cannot be too much ridiculed and exploded.——

Euphros. I do not understand Astrology, and if its Pretensions are such as you insinuate, it must indeed be a vain and presumptuous Thing, and borders very nearly on Blasphemy.—— But to the Subject of the Globe, what are those various Figures of *Men*, *Beasts*, &c. on the Globe, and why are they painted there?

Cleon. They are all imaginary Beings, and have their Existence no where but on the Surface of the artificial Globe: they were contrived for the Sake of *Memory* and *Comprehension*; and are of very great Antiquity. For the Stars appearing, as it were, confusedly disseminated or strew'd over the vast concave Expanse of Heaven, could not without some Artifice be well comprehended by the Mind, or remembered with respect to *Magnitude* and *Situation*. To have given Names to each Star, would have been too great a Burthen to the Memory; and to reduce them all to Catalogues, and point them out by their Places, was a Work of Ages, as I have shewed you before. The only Expedient there-

fore

fore to facilitate the Knowledge of the Stars, was to consider and distribute them into various Companies, or Collections, and the better to fix the Idea of these in the Mind, they invested them with the Figures and Characters drawn from Men, Beasts, and Things, as would best fit and suit with each: And to these they properly gave the Name of *Constellations*, or *Asterisms*; and painted them on their Globes and Machines. Concerning which thus *Manilius*.

Now Constellations, *Muse*, *and* Signs *rehearse*,
In order, *let them sparkle in thy Verse*;
Those which obliquely bound the burning Zone,
And bear the Summer, *and the Winter Sun*,
Those first: *Then those which roll a different Way*
From West: *Nor Heaven's diurnal Round obey*;
Which Nights serene disclose, *and which create*
The steady Rules, *and fix the Laws of Fate*.

Book I.

Euphros. How many Constellations are there in all?

Cleon. They are reckoned 56 in Number; *viz.* 12 in the *Zodiac*; 29 on the North of the *Zodiac*; and 25 on the South Side thereof.

Euphros. What are the Names of those in the *Zodiac*?

Cleon. The very same with the Names of the *Signs*, as *Aries*, *Taurus*, *Gemini*, &c. which you know very well already.

Euphros. I do, without a Repetition; —— but what Names do those bear in the northern Hemisphere?

Cleon. The 29 Northern Constellations, are

1. *Ursa Minor*, or the *lesser Bear*.
2. *Ursa Major*, or the *greater Bear*.
3. *Draco*, or the *Dragon*.
4. *Cepheus*.
5. *Cygnus*, or the *Swan*.
6. *Perseus*.
7. *Andromeda*.
8. *Auriga*, or the *Waggoner*.
9. *Coma Berenices*, or *Berenice's Hair*.
10. *Bootes*.

11. *Co-*

11. *Corona Septentrionalis*, or *Northern Crown.*
12. *Hercules.*
13. *Lyra*, or the *Harp.*
14. *Aquila cum Antinoo*; the *Eagle with Antinous.*
15. *Delphinus*, or the *Dolphin.*
16. *Equuleus.*
17. *Pegasus*; the *Winged Horse.*
18. *Triangulus*; the *Triangle.*
19. *Cassiopeia.*
20. *Serpentarius*, or *Ophiuchus.*
21. *Lacerta*; the *Lizard.*
22. *Serpens Ophiuchi*; the *Serpent of Ophiuchus.*
23. *Lynx.*
24. *Sagitta*; the *Arrow.*
25. *Orion cum Scuto*; *Orion with a Shield.*
26. *Camelopardus.*
27. *Anser cum Vulpeculâ*; the *Goose with the Fox.*
28. *Leo Minor*; the *lesser Lion.*
29. *Canes Venatici*; the *Coursing Dogs.*

Euphros. I observe them all in the Order you have named them; and more than these I see which you have not mentioned,———as that Star in the Heart there, *&c.*

Cleon. Very good, Sister; you mean *Cor Caroli*, or *Charles's Heart*, which is a new Star, unknown to the ancient Astronomers, and therefore not contained in any of their Constellations. Besides this, there are divers other Stars of less Note, not reducible to any Constellation, which are therefore by Astronomers called *extra-constellated Stars.*

Euphros. Well, now for the Names of the Constellations on the South Part of the Globe, *Cleonicus*; of which I think you say there are about 25.——

Cleon. Yes; That is their Number by some, by others they are reckoned 28. Their Names are as follow,

1. *Balenus*, or *Cetus*; the *Whale.*
2. *Canis Minor*; the *lesser Dog.*
3. *Centaurus cum Lupo*; the *Centaur with the Wolf.*
4. *Corona Australis*; the *Southern Crown.*
5. *Crater*; the *Water-pot.*
6. *Eridanus*; the *River Po.*

7. *Ma-*

7. *Monoceros*, or *Unicorn*.
8. *Canis Major*; the *greater Dog*.
9. *Argo*; the *Ship*.
10. *Ara cum Thuribilo*; the *Altar and Cenſer*.
11. *Grus*, or the *Crane*.
12. *Lepus*, or the *Hare*.
13. *Pavo*; the *Peacock*.
14. *Phœnix*.
15. *Sextans*; the *Sextant*.
16. *Triangulum*; the *Triangle*.
17. *Toucan*, or *American Gooſe*.
18. *Apous*; the *Indian Bird*.
19. *Columba Noachi*; *Noah's Dove*.
20. *Muſca*; the *Fly*.
21. *Robor Carolinæ*; the *Strength of Caroline*.
22. *Hydrus*, a *Serpent*.
23. *Piſcis volans*; the *Flying Fiſh*.
24. *Chameleon*.
25. *Xiphias*; the *Sword-fiſh*.
26. *Crux*; the *Croſs*.
27. *Indus*; the *Indian*.
28. *Corvus*; the *Raven*.

Theſe Conſtellations, you ſee, are all diſtinctly painted on the Celeſtial Globe, with here and there ſome extra-conſtellated Stars, as I obſerved to you before.

Euphroſ. They are all ſo plain, that they who run may read them. Pray, *Cleonicus*, are not theſe Conſtellations of very great Antiquity?

Cleon. Yes my *Euphroſyne*, for ſome of them are mentioned in the Writings of the moſt antient Hiſtorian in the World.—

Euphroſ. I ſuppoſe you mean *Job*; for in that Book I have read of *Arcturus*, *Orion*, the *Pleiades*, &c.

Cleon. Yes, that is the Hiſtory I mean. It is ſuppoſed by learned Men, that *Job* lived in *Arabia*, and wrote his Hiſtory before the Time of *Moſes*, and therefore is the moſt antient of any extant; and ſince he ſpeaks of the Conſtellations ſo particularly, and by the Names they now bear, it muſt follow, that the Method of computing the Stars, and diſtributing them into Companies or Conſtellations, is of the greateſt Antiquity of any Thing in the liberal

liberal Sciences.——Thus *Job* in the xxxviiith Chap. makes Mention of the *Pleiades*, or *Seven Stars*, ——— of *Mazzaroth*, or the *Zodiac* of the 12 *Signs*, ——— of the Conſtellations *Orion* and *Arcturus*, and the *Ordinances* of Heaven, which he calls the *Chambers of the South*, in Chap. ix. and undoubtedly means the Southern Conſtellations, or Diviſions of the Heavens.——

Euphroſ. I obſerve, as I look over the Conſtellations on the Globe, that ſome Stars are very large, and others very ſmall; pray, how many different Sorts or Sizes of Stars do you reckon?

Cleon. Aſtronomers reckon *ſeven Degrees of Magnitude* in the Stars,——you ſee here an Example of them all, which Mr. SENEX has *fixed on* the Globe in this Row of Stars, gradually diminiſhing from the greateſt to the leaſt.

Euphroſ. The largeſt, I ſuppoſe, you call the *firſt Magnitude*, do you not?

Cleon. Yes, my *Euphroſyne*, the largeſt Stars are thoſe of the firſt Magnitude, which you ſee conſiſt (on the Globe) of ſix large, and ſix ſmall radiant Points or Beams; by which, as well as by their Magnitude, they are very eaſily diſtinguiſhed all over the Globe; as the Stars in the Firmament, which they repreſent, are larger, more ſcintillant, and brillant above the Reſt.

Euphroſ. Yes, I eaſily diſtinguiſh them from the Reſt on the Globe; but I obſerve they are but few in Number; and moſt of them have Names I ſee affixed to them.

Cleon. They are indeed but few in Number; I remember Mr. *Flamſtead*, in his *Hiſtoria Cœleſtis*, makes but 15 in both Hemiſpheres,——but on this Celeſtial Globe of Mr. *Senex*'s, you tell about 16 Stars of the firſt Magnitude. Theſe Stars are, as you obſerve, ſignalized with proper Names, as *Aldebaran*, *Regulus*, *Arcturus*, *Deneb*, *Aſſengue*, *Rigel*, *Sirius*, *Antares*, *Fomahaunt*, &c.

Euphroſ. As to the Stars of the ſecond Magnitude, I obſerve in the Sample, they have ſix large ſingle Beams, but ſomewhat leſs than the other.

Cleon. Yes; and you obſerve too, they are more numerous, and moſt of them without Names,——Stars of the third Magnitude are ſtill more numerous, and nameleſs,—of the fourth Magnitude their Number increaſes,—and of the fifth and ſixth

Mag-

Magnitude, they increaſe very much ;——but of the 7th they are not ſo many. ——— The Number of the Stars of every Magnitude in each Conſtellation, are numbered in *Flamſted*'s *Hiſtoria Cæleſtis* ; which I have tranſcribed in this Table, to give you a more perfect Idea of them.

	Num	Magnitudes. 1	2	3	4	5	6	7
In the Zodiac ———	934	7	11	43	94	169	445	174
In the north. Hemiſph.	1511	4	23	93	227	356	695	113
In the ſouth. Hemiſph.	547	4	20	56	136	145	176	10
Sum of all the Stars —	3001	15	54	192	457	670	1316	297

Euphroſ. The Stars of the 6th and 7th Claſs, I imagine, we muſt have good Eyes to diſcern.

Cleon. They are not diſcernable by the beſt Eyes, but with the Teleſcope only ; and are therefore called *Teleſcopic Stars*, as I have before hinted.———Yea, not one Eye in fifty can ſee Stars of the 5th Magnitude diſtinctly ; and they muſt be tolerable good Eyes to diſtinguiſh and enumerate Stars of the 4th Order.

Euphroſ. Well, I think we have talked of the Magnitude of the Stars, till the Stars of every Magnitude ſhine very bright. ———This is a glorious Star-light Night, but very cold.——

Cleon. It is always obſervable, that the colder the Night, the clearer the Stars ſhine, if there be no Clouds. I cannot help recollecting ſome choice Reflections on the Stars, a Gentleman made, as he obſerved them one Night in a Journey from *Patapſko* to *Anapolis*, and which may ſerve to conclude our preſent Speculation.

Now deep'ning Shades confeſs th' Approach of Night,
Imperfect Images elude the Sight :
From earthly Objects I remove mine Eye,
And view with Look erect the vaulted Sky ;
Where dimly ſhining now the Stars appear,
At firſt thin-ſcatt'ring thro' the miſty Air ;
'Till Night confirm'd, her jetty Throne aſcends,
On her the Moon *in clouded State attends,*

But soon unveil'd her lovely Face is seen,
And Stars *unnumber'd wait around their Queen;*
Rang'd by their Maker's *Hand in juſt Array,*
They march majeſtic thro' th' ethereal Way.
Are theſe bright Luminaries hung on high
Only to pleaſe with twinkling Rays our Eye?
Or may we rather count each Star *a* Sun,
Round which full peopled Worlds *their Courſes run?*
Orb above Orb harmoniouſly they ſteer
Their various Voyages thro' Seas of Air.

DIALOGUE II.

Of the Twelve CONSTELLATIONS *of the* ZODIAC, *with their* Fabulous HISTORY.

Euphroſyne.

I Think, *Cleonicus*, you intimated laſt Night, that we ſhould next take a more particular Survey of the Conſtellations; and of the Origin, Hiſtory, *&c.* of each of them.

Cleon. Yes, my *Euphroſyne*; and To-night we'll begin with the *Twelve Conſtellations of the Zodiac*; for they offer themſelves firſt, as being the moſt conſiderable and noted of all in the Heavens. And here we ſhall imitate the antient poetical Aſtronomer *Manilius*; who, being to give an Account of the Conſtellations, firſt rehearſes them in the following Lines.——

Firſt Aries, *glorious in his golden Wool,*
Looks back, and wonders at the mighty Bull,
Whoſe Back-parts firſt appear: He bending lies
With threat'ning Head, and calls the Twins *to riſe;*
They claſp for Fear, and mutually embrace;
And next the Twins *with an unſteady Pace*
Bright Cancer *rolls: Then* Leo *ſhakes his Mane,*
And following Virgo *calms his Rage again:*
Then Day and Night are weigh'd in Libra's *Scales,*
Equal a-while, at laſt the Night prevails,
And longer grown, the heavier Scale inclines,
And draws bright Scorpio *from the Winter Signs:*
Him Centaur *follows with an aiming Eye,*
His Bow full drawn and ready to let fly:

Next

Next narrow Horns the twiſted Caper *ſhows,*
And from Aquarius' *Urn a flood o'erflows.*
Near their lov'd Waves cold Piſces *takes their Seat,*
With Aries *join, and make the Round compleat.*

Lib. I.

Euphroſ. Well, 'tis very pretty, to ſee, as you turn the Globe, how the Order, Situation, Poſture, and Attitudes of the Conſtellations anſwer to the poetical Deſcription. ——— But to be more particular, and begin with *Aries*, how came this Conſtellation by that Name and Form?

Cleon. Becauſe, as 'tis ſuppoſed, the moſt antient *Chaldean* Aſtronomers obſerving the Sun to enter this Sign, at a Time when the Fields and Hills were moſt remarkably repleniſhed and overſpread with Flocks, vaſtly increaſed with the new Produce of Lambs, which (as the paſtoral Life was then moſt conſiderable) they eſteemed the moſt profitable Part of the New-year's Product; to ſignalize this Seaſon, therefore, they thought fit to call this Sign, or Conſtellation, by the Name of the Principal of the Flock, *Aries*, or the *Ram*. At this Seaſon *Virgil* obſerves———

——————— *An Hundred Lambs*
Attend with bleating Cries their milky Dams.

And in another Place, ſpeaking of the various Products of the Spring, he ſays,

With milder Beams the Sun ſecurely ſhines,
Fat are the Lambs, and luſcious are the Wines.

Georg. I.

Euphroſ. But though this ſeems very natural; yet, if I remember right, the Poets give a different Account of this Matter.

Cleon. Yes, they do ſo; 'tis this *Ram*, and his *Golden Fleece*, of which the Poets tells us ſo many Stories and Fables; the Grounds of all which is thus fabulated. ——— *Athamas*, King of *Thebes* had, by his Wife *Nephele*, a Son named *Phrixus*, and a Daughter named *Helle*; he afterwards married another Wife, *Ino* by Name, who fell in Love with *Phrixus*; but, neglected by him, ſhe had an extreme Averſion to him; and there happening a Dearth of Corn, ſhe perſuaded *Athamas*, that it could not be remedied 'till *Phrixus* and *Helle* were ſacrificed: But as they ſtood at the Altar, *Nephele*, (i. e. a Cloud) took them away,

and gave them a *golden Ram* that ſhe had received from *Mercury*. On this Ram they fled through the Air from *Thebes*, and in their Flight *Helle* fell off into the Sea, which from thence was called *Helleſpontus*. *Phrixus* arrived at *Brixada*, where, laying himſelf down to Reſt, the Barbarians were coming to kill him; but the Ram awaked him, and gave him Notice, with a human Voice, and then carried him to *Colchis*, where he was kindly received by *Æta* the King, who ſacrificed the Ram to *Jupiter*, and hung up his Golden Fleece in the Grove of *Mars*; there it was kept by Bulls, which had brazen Feet and breathed Fire, and alſo by a great Dragon: The Ram was afterwards ſaid to be taken up into the Skies, and made the Conſtellation we are now ſpeaking of.

Euphroſ. In ſome ſuch Manner too, I ſuppoſe, you deduce the Origin of *Taurus*, or the *Bull*, which is the next Conſtellation.

Cleon. You gueſs right; for as *Calves* were the next conſiderable Product of the Spring, which were now (when the Sun entered this Conſtellation) full-grown and fat, and led out from the Stalls to the Fields, the Altars, or the Butchers; ſo the priſtine Aſtronomers and Herdſmen denoted this Seaſon, by attributing the Name of the *Bull* to that Sign the Sun then poſſeſſed. And *Virgil*, by reaſon of a Star in the Tip of each Horn, takes occaſion to call them *Golden Horns*, in the following Verſes.

When with his Golden Horns *in full Career,*
The Bull *beats down the Barriers of the Year.*

Georg. I.

Euphroſ. I ſuppoſe the Poets have a great Deal to ſay of this fabulous *Bull* likewiſe.

Cleon. A great Deal; and very merry too, for the moſt Part; the Story is of *Jupiter*'s carrying away *Europa*, the Daughter of *Agenor*, King of *Phœnicia*, in the Form of a *White Bull*, into the Iſle of *Crete*, where he diſcovered to her his Divinity, and placed the *Bull* among the Stars. *Ovid* relates the Circumſtances of this Story very poetically thus:

The Ruler of the Skies, the thund'ring God,
That ſhakes the World's Foundations with a Nod,
Among a Herd of lowing Heifers ran,
Friſk'd in a Bull, *and bellow'd o'er the Plain.*

Large

Large Rolls of Fat about his Shoulders clung,
And from his Neck the double Dewlap hung.
His Skin was whiter than the new-fall'n Snow;
Small were his Horns, and harmleſs was his Brow:
No ſhining Terrors ſparkled in his Sight,
But his Eyes languiſh'd with a gentle Light;
His ev'ry Look was peaceful, and expreſt
The Softneſs of the Lover in the Beaſt.
Agenor's *royal Daughter, as ſhe play'd*
Among the Fields, the Milk-white Bull *ſurvey'd,*
And view'd his ſpotleſs Body with Delight,
And at a Diſtance kept him in her Sight.
At length ſhe pluck'd the riſing Flow'rs, and fed
The gentle Beaſt, and fondly ſtrok'd his Head.
He ſtood well-pleas'd to touch the charming Fair,
But hardly could confine his Pleaſure there.
And now he wantons o'er the neighb'ring Strand,
Now rolls his Body on the yellow Sand;
And finding all the Virgin's Fear decay'd,
Comes toſſing forward to the Royal Maid;
Gives her his Breaſt to ſtroke, and downward turns
His griſly Brow, and gently ſtoops his Horns.
In flow'ry Wreaths the Royal Virgin dreſt
His bending Horns, and kindly clapp'd his Breaſt.
'Till now grown wanton, and devoid of Fear,
Not knowing that ſhe preſs'd the Thunderer,
She fix'd herſelf upon his Back, and rode
O'er Fields and Meadows, ſeated on the God.
He gently march'd along, and, by Degrees,
Left the dry Meadow, and approach'd the Seas,
Where now he dips his Hoofs, and wets his Thighs;
Now plunges in, and carries off the Prize.
The frighted Nymph looks backward on the Shore,
And hears the tumbling Billows round her roar:
But ſtill ſhe holds him faſt, with one Hand born
Upon his Back, while t'other graſps a Horn.
The Train of ruffling Garments flies behind,
Swells in the Air, and hovers in the Wind.

Thro'

Thro' Storms and Tempeſts he the Virgin *bore,*
And lands her ſafe on the Dictean *Shore;*
Where now in his divineſt Form array'd,
In his true Shape he captivates the Maid;
Who gazes on him, and with wond'ring Eyes,
Beholds the new, majeſtick Figure riſe;
Views his bright Features, and his native Light,
And all the God *diſcover'd to her Sight.*

Metam. II.

Euphroſ. This *Bull* makes a very conſiderable Figure in Poetry, as well as Aſtronomy, I find.——But, pray, *Cleonicus*, what Origin do you give to the *Twins*, or *Gemini?*

Cleon. Theſe owe their Original to the ſame Cauſe, in all Probability, with the two foregoing; for at this Time, *(viz.* about *May*, when the Sun enters this Sign) the Young of *Goats* were in their Maturity and Perfection; and were oftener than any other Beaſts, brought forth by *Pairs*, or *Twins*; which the Goat-herds (in antient Times, being very conſiderable) denoted, by giving the Denomination of *Gemini* to the Sign.—

Euphroſ. Very good;——but what do the Poets ſays of this Sign *Gemini?*

Cleon. They tell us a Story of *Caſtor* and *Pollux*, two Sons of *Leda*, the Latter by *Jupiter*, and was therefore immortal; the Former by her Huſband *Tyndarus*, and therefore mortal.—When *Jaſon* undertook the Expedition for the *Golden Fleece*, among other Heroes were *Caſtor* and *Pollux*; who behaved themſelves very valiantly during the whole Voyage. In a Storm which happened, two ſtrange Fires appeared playing about the Heads of *Caſtor* and *Pollux*, and ſoon after a Calm enſued, which made it thought there was ſomewhat divine in thoſe Youths. It happened afterwards, that *Caſtor*, being mortal, was killed, and *Pollux* begged of *Jupiter* to make him immortal, which not being poſſible, he only obtained, that his Brother ſhould ſhare half his own Immortality, ſo that each Day they alternately lived, the One in Heaven the Other in Hell.—They were at laſt placed among the Stars, and made the Conſtellation *Gemini*, which you ſee on the Globe, denoted by the two

two Youths, with each a bright Star in his Head, and their Names *Caſtor* and *Pollux* to diſtinguiſh them.

Euphroſ. That the firſt Aſtronomers ſhould give the Names of the *Ram*, the *Bull*, and the *Twins*, to theſe Conſtellations, you have given a ſufficient Reaſon; but what ſhould induce them to call the next Conſtellation in the Zodiac, by the Name of *Cancer*, or the *Crab?*

Cleon. You'll obſerve a good Deal of Propriety, even in this, if you conſider, that the firſt Obſervers took Notice of the Sun's gradual Aſcent above the Equinoctial to a certain Height or Meridian Altitude, from which it afterwards declined again, and deſcended as gradually; and then, by what Means could they more pertinently commemorate ſo notable an Obſervation, than by the *Retrograde, or ſide-long Motion of a Crab?* And the Poets afterward, to make good their Part, tell us, that this is the *Crab* which *Juno* ſent to bite and moleſt *Hercules*, while he was deſtroying the *Lernæan Hydra*, for which, when *Hercules* had killed the vexatious Animal, *Juno* placed him among the Stars.

Euphroſ. But how came the *Lion*, a Creature in all Reſpects ſo different from a *Crab*, to ſucceed immediately the *Crab?*

Cleon. As among Animals the *Lion* is the moſt powerful, fierce, and ſtrong; ſo among the Months of the Year, that Seaſon in which the Sun occupied this Sign, the Sun's Heat and Effects were more fierce and violent than in any other, *i. e.* about the latter End of *July*, and the Beginning of *Auguſt*; and from this Similarity, the Conſtellation is ſuppoſed to have had its Name by the firſt Obſervers of Time.

Euphroſ. This ſeems probable enough; and I queſtion not but it furniſhed the Poets with an ample Theme for Invention.——

Cleon. It did ſo; for they tell us, that this is that *Nemæan Lion*, which *Juno* procured from the *Moon*, and ſent againſt *Hercules* to kill him; but *Hercules* tore him to Pieces with his Nails, and made him a Shield and Breaſt-plate with his Skin. This made *Juno* hate him ſtill more, and on the *Lion* beſtowed that celeſtial Dignity he has ever ſince enjoyed.

Euphroſ.

Euphrof. Well, *Cleonicus*, I perceive the Aſtronomers have paid a very early Regard to the Ladies, by the Compliment of placing *Virgo*, or a *Virgin* among the Stars; pray, what was the Occaſion thereof? And whence thoſe Wings, and that Wheat-ſheaf in her Hand?

Cleon. About the Time the Sun entered this Sign, the Harveſt was pretty well over; and now the young Damſels appeared and ſpread themſelves over the Fields, gleaning up the Ears of Corn. And as they made this the moſt agreeable Scene of rural Life, the Aſtronomers did them the Compliment of a Conſtellation of their own Sex, and gave them a Handful of Wheat to ſhew the Occaſion. They alſo depicted her with Wings, to ſhew, the Harveſt had, as it were, taken its Flight, and bid them farewel 'till the *next Year*.

Euphrof. And pray, what have the Poets to ſay on this Occaſion?

Cleon. Enough, you may be ſure; they tell us, ſhe was the Daughter of *Jupiter* and *Themis*, and the *Princeſs of Juſtice*, by Name *Aſtræa*; they feign, that in the *Golden Age* ſhe deſcended from Heaven to the Earth, and being offended at laſt by the Wickedneſs of Mankind, ſhe returned to Heaven again, after all the other Gods who went before her, where ſhe obtained the Dignity of a Conſtellation, as deſcribed in the following Diſtich:

All Duty dies, and wearied Juſtice *flies*
From bloody Earth at laſt, and mounts the Skies.

And *Virgil* thus:——

Juſtice *laſt took her Flight from hence, and here*
The Prints of her departing Steps appear.

Dryd. Geor. II.

Euphrof. As to *Libra*, you have already hinted the Reaſon of the Name, from the *Equality of Days and Nights*; but I want to know what is ſaid of this in fabulous Hiſtory.

Cleon. When *Juſtice* fled from Earth to Heaven, 'tis natural to think, ſhe carried her *Scales* with her, which might be made

made this Conſtellation; and I wonder to find the *Poets* and *Mythologiſts* ſilent in this Particular. However it is ſuppoſed, that the exceeding Uſefulneſs of the Balance, when firſt invented, excited Men to commemorate the ſame, by placing them among the Stars. And indeed what Invention could deſerve it more, than that which is the *Teſt and Standard of Juſtice* among Mankind? Theſe are the celeſtial *Scales*, in which *Jove* is feigned by *Homer*, to weigh out the Fate of Mortals, and in particular, that of *Hector*, in the following Lines.

Jove *lifts the golden* Balances, *that ſhow*
The Fates of mortal Men, and Things below:
Here each contending Hero's Lot he tries,
And weighs, with equal Hand, their Deſtinies.
Low ſinks the Scale, *ſurcharg'd with* Hector's *Fate;*
Heavy with Death it ſinks, and Hell receives the Weight.

And of this *Balance* too, *Virgil* ſpeaks in the following Lines.

But when Aſtrea's Balance, *hung on high,*
Betwixt the Nights and Days divides the Sky;
Then yoke your Oxen, ſow your Winter Grain;
'Till cold December *comes with driving Rain.* Geor. I.

Euphroſ. There are doubtleſs many Things of leſs Merit advanced to the Stars; elſe, pray, how came a *Scorpion* there? Who would have thought to have found ſuch a terrible, ſuch a noxious Animal in the Heavens?

Cleon. When you conſider, that during the Seaſon the Sun is in this Sign, the Weather is generally very bad, and all Kinds of Diſeaſes now begin to invade and infeſt Mankind; as *Colds*, *Agues*, *Aſthmas*, *Fevers*, &c. as alſo that this is the Introduction to the cold and comfortleſs, the dreary and deadly Seaſon of Winter; I ſay, when this is conſidered, you cannot think it ſtrange, that the firſt Obſervers gave this Sign the Name of *Scorpio*, being ſo apt an Emblem of the Seaſon.—— The Poets tell us, this was the *Scorpion* which ſlew *Orion* for his Arrogance and impudent Deſign on *Diana*.

Euphroſ. I think I remember a Paſſage in *Ovid*, where it is ſaid, that *Scorpio* fills the Space of two whole Signs; how is that to be underſtood, *Cleonicus?*

Cleon. Some of the Antients ſeemed not acquainted with the Conſtellation *Libra*, and therefore they aſſigned all the Space

from *Virgo* to *Sagitarius* to the Poſſeſſion of *Scorpio*; and therefore *Ovid* ſays——

There is a Space above, where Scorpio, *bent*
In Tail and Arms, ſurrounds a vaſt Extent;
In a wide Circuit of the Heavens he ſhines,
And fills the Space of two celeſtial Signs.

Metam. II.

This is alſo evident from *Virgil*'s Compliment to *Cæſar Auguſtus*; for when he propoſes to him the Divinity of a Conſtellation, he aſſigns him the vacant Place between *Virgo* and *Scorpio*, in theſe Lines.——

Or wilt thou bleſs our Summers with thy Rays
And, ſeated next the Virgin, *poiſe our Days;*
Where, in the Void of Heav'n, a Space is free
Betwixt the Scorpion *and the* Maid *for thee;*
The Scorpion *ready to receive thy Laws*
Yields half his Region, and contracts his Claws.

Georg. I. *

Euphroſ. Well, I ſee Aſtronomy is uſeful, too, for underſtanding the Poets.——But what does *Sagitarius*'s Bow denote? Is it not the hunting Seaſon?

Cleon. You gueſs very right, my *Euphroſyne*; his *Bow and Arrow* point out the Sportſman, whoſe Seaſon now commences.——

Euphroſ. But how comes he to be repreſented with the hinder Part an Horſe?

Cleon. This is altogether owing to Fable; they tell us of a Centaur, whoſe Name was *Chiron*, the Son of *Saturn* and *Phillyra*, a learned Phyſician, and Preceptor to the famous *Achilles*; *Hercules*'s Dart, dipped in the venomous Blood of the *Lernæan Hydra*, falling on his Foot, gave him an incurable Wound; he deſired to die, but could not, being born of immortal Parents; who therefore took him up to Heaven, and made him a Conſtellation. *Euphroſ.*

* Theſe Paſſages in *Ovid* and *Virgil* ſeem very ſtrange, when we find them in other Places making Mention of *Libra* as a Sign of the *Zodiac*. And it is certain, that the Antients had this Sign of the *Balance* actually depicted on their Globes as long ago as it was at the autumnal *Equinox*, (which is more than 2000 Years ſince) for there it appears on an old celeſtial Globe, found among the Ruins of antient *Italy*, and kept in the *Farneſian Palace* at *Rome*, of which I have a Copy by me.

Euphrof. What monſtrous Things the Poets relate!——And pray, what ſay they of the next Monſter, *Capricorn*, half Goat and half Fiſh?

Cleon. This Conſtellation had its Origin from the wild Goat, whoſe Nature being to ſeek its Food from the Bottom to the Top of Mountains, climbing from Rock to Rock, aptly emblemized the Aſcent of the Sun, from the loweſt Point in the Beginning of this Sign to its higheſt Pitch, or Summit in the Summer Solſtice.——But the Poets feign, that a Goat ſuckled *Jupiter*, and that after it was dead, he made a Shield of its Skin, called *Ægis*, with which he ſingly combated the Giants. At length, he reſtored the Goat to Life again, gave her a new Skin, and placed her among the Conſtellations of Heaven. Others ſay, that *Pan*, a Man upwards, and a Goat below, was at laſt changed into this Conſtellation, as being the God of the Woods and Shepherds, and Guardian of their Flocks. But as to the Fiſh-part of *Capricorn*, I take it to be a Fancy of modern Date.

Euphrof. *Aquarius*, I ſee pouring his Water from Heaven; I'll venture to gueſs once more, that this Figure is an Emblem of a *rainy Seaſon*.

Cleon. And you are very right; for *Virgil* uſes the Term *Aquarius* (by a Metaphor) for *Winter*, as it is alſo tranſlated by Mr. *Dryden*.——

This during Winter's *drifly Reign be done,*
'Till Aries *receives th' exalted Sun.*

Georg. III.

But the Poets tell us, this *Aquarius*, when on Earth, was that beautiful Youth *Ganymede*, Son of *Tros*, whom an Eagle (ſent by *Jupiter*) ſnatched off from Mount *Ida*, as he was hunting, and carried him into Heaven; where *Jupiter* made him his Cup-bearer, and whom he attends at all his Banquets with flowing Cups of Nectar.——Or thus, according to *Ovid*:——

Diſguis'd in Eagle's Plumes he downward flies,
And bears the Phrygian *with him to the Skies;*
There he for Jove (*in Spight of* Juno's *Frowns*)
The flowing Bowls with purple Nectar crowns.

Metam. X.

Euphrof. The Evening grows late, *Cleonicus*; we have but

juſt Time to enquire about the laſt of the twelve Conſtellations, which you call *Pijces*, or the *Fiſhes*; pray, tell me in brief their Original.

Cleon. The Fiſh, being at the Time, when the Sun enters this Sign, moſt in Seaſon, gave Occaſion for the Denomination thereof; though the Poets tell us other Things: They give two Reaſons for the Divinity of the *Fiſhes:* —— The Firſt is, becauſe in the War with the Giants, *Venus* being diſturbed, converted herſelf into a Fiſh;——the Second, becauſe a Dove ſat once upon the Egg of a Fiſh, in the River *Euphrates*, and at length hatched a Goddeſs of great Goodneſs, and merciful to Mankind. On both theſe Accounts the Fiſhes were held ſacred, and placed among the Stars.——And let this ſuffice, my *Euphroſyne*, for the Original and fabulous Hiſtory of the Conſtellations of the Zodiac; the next Evening we will ſpend in purſuing the ſame Enquiries relating to the Conſtellations in the northern Hemiſphere.

DIALOGUE III.

Of the CONSTELLATIONS *of the* Northern HEMISPHERE, *with their* ORIGIN, *and* Mythologic Hiſtory.

Euphroſyne.

THE Pleaſure of our laſt Converſation has made the Time ſeem long e'er the next returned.——I muſt ſtill expect to be indulged the Liberty (though tireſome) of continuing the Enquiries I have begun, in relation to the Reſt of the Conſtellations which I ſee ſpread over the Surface of the Globe. But, pray, which of them will it be proper to begin withal.

Cleon. Thoſe of the Northern Hemiſphere, or on the North Side of the Ecliptic; and then proceed to thoſe on the Southern Side. Theſe will give us Occaſion to rehearſe moſt of the pleaſant Stories of the Poets and Fabuliſts, in relation to their fictitious Original, and this is all we muſt here expect.

Euphroſ. And which of theſe do you hold it proper to begin with?

Cleon. With the two Bears, *viz. Urſa Major* and *Urſa Minor*, as being the moſt northerly. The Greater of theſe was called

called *Arctos* and *Helice* by the *Greeks*; and the Leſſer, *Cynoſura*, becauſe its *Tail* was like that of a *Dog*. The Greater of theſe *Bears*, was once the fair *Caliſto*, Daughter of *Lycaon*, who being deflowered by *Jupiter*, was by the Rage of *Juno*, turned into a BEAR; and her Son *Arcas* into the *Leſſer Bear*; but the Diſgrace was taken away, by *Jupiter*'s advancing them to Heaven, and making them two ſuch remarkable Conſtellations. Theſe *Bears* conſtantly circulate about the North Pole, and never go below our Horizon; on which Account, *Virgil*, ſpeaking of *Draco*, and the *Bears*, ſays;

Around the Pole the ſpiry Dragon *glides,*
And like a winding Stream the Bears *divides;*
The Leſs and Greater, who by Fate's Decree,
Forbidden are to touch the Northern Sea.

Georg. I.

For *Juno* being enraged at their being taken up into Heaven, deſired *Tethys*, (the Goddeſs of the Ocean) that ſhe would never ſuffer *Caliſto* to bathe in her Waters.

When Juno *ſaw the Rival in her Height,*
Spangled with Stars, and circled round with Light,
She ſought old Ocean *in his deep Abodes,*
And Tethys, *both rever'd among the* Gods.
They aſk what brings her there? "Ne'er aſk, ſays ſhe,
What brings me here, Heav'n is no Place for Me.
You'll ſee, when Night has cover'd all Things o'er,
Jove's *ſtarry Baſtard, and triumphant Whore*
Uſurp the Heav'ns; You'll ſee 'em proudly roll
In their new Orbs, and brighten all the Pole.
And who ſhall now on Juno's *Altars wait,*
When Thoſe ſhe hates grow Greater by her Hate?
I on the Nymph a Brutal Form impreſs'd,
Jove *to a Goddeſs has transform'd the Beaſt;*
This, This was all my weak Revenge could do:
But let the God his chaſte Amours purſue,
And, as he acted after Io's *Rape,*
Reſtore th' Adultreſs to her former Shape;

Then

Then may he cast his Juno *off, and lead*
The great Lycaon's *Offspring to his Bed.*
But you, ye venerable Pow'rs be kind,
And, if my Wrongs a due Resentment find,
Receive not in your Waves their setting Beams,
Nor let the glaring Strumpet *taint your Streams.*
The Goddess ended, and the Wish was giv'n.———

Metam. II.

Euphros. But what is that terrible *Serpent*, or *Dragon*, you mention, which I also see between the *Bears?* And how came he there?

Cleon. This was the Watch-*Dragon*, which *Juno* appointed to keep the Garden of the *Hesperides*, three Daughters of *Hesperus*, Brother to *Atlas*. In these Gardens were Trees, that bore golden Fruit, which *Hercules* attempting to steal, first slew the *Dragon*, which was afterwards made this Constellation.

Euphros. On the other Side the *Lesser Bear*, I see some great Personages sure, *Cepheus* and *Cassiope*, *Perseus* and *Andromeda*, are not these very memorable Names in History?

Cleon. Yes, more especially so in fabulous History. *Cepheus* and his Wife *Cassiope*, were King and Queen of *Ethiopia*, and *Andromeda* was their Daughter; she was bound to a Rock to be devoured by a Sea-monster, by the *Nymphs*, because her Mother *Cassiope* proudly preferred her Beauty to theirs.——— You see the Fetters on each Hand. —— The unhappy Case of this fair Nymph reached the Ears of *Perseus*, Son of *Jupiter* and *Danaë*, who, with his Falchion and Wings to his Feet, (which you see) took his Flight through the Air to *Ethiopia*, where he slew the Monster, released *Andromeda*, and then married her. They were all afterwards placed among the Constellations, where they make some of the brightest in the Northern Hemisphere.——This remarkable Story is finely told by *Ovid*, which is in Part thus ———

Now Æolus, the Ev'ning boist'rous Wind
Had in eternal Caves with Bars confin'd,
And Lucifer, *bright Harbinger of Day;*
Perseus, *and all to Bus'ness call'd away:*

When

When to his Feet again he lac'd his Wings,
Girt on his Falchion sure, and boldly flings
Thro' the wild airy Regions of the Skies,
And o'er a Thousand nameless Nations flies;
And, with a slight Survey, those Countries past,
He made th' Ethiopian *Land at last.*
There lay Andromeda, *expos'd along,*
Condemn'd to suffer for her Mother's Tongue,
Whom, when the sharp-ey'd, tow'ring Hero spy'd,
With Arms to rugged Rocks severely ty'd;
But that her flowing Tears her Life betray'd,
And that her Locks with fanning Breezes play'd,
She look'd a finish'd Marble-piece; but now
Soft Flames in his unknowing Bosom glow.
Ravish'd, amaz'd, he views the lovely Maid,
And half forgets his flying, airy Trade.
Then, near her, takes the Rock, and, O! said he,
Bright charming Creature, fitter far to be
In some Kind Lover's softer Arms enchain'd,
Than with the Weight of barb'rous Fetters pain'd;
Tell me, sweet Maid, thy Country's Name and thine,
And why thee thus to Rocks these pond'rous Chains confine?
Silent a-while the blushing Virgin stay'd;
Of manly Converse, rarely us'd, afraid;
Only her Tears, which still she might command,
In her fair Eyes like rising Fountains stand.
Her snowy Hands her modest Looks had hid,
But that rough Chains her snowy Hands forbid;
Oft ask'd, (lest Silence should her Guilt accuse)
At last she both her Name and Country shews.
Scarce half her Tale was told, when sounding Waves
Her Fate foreshew, the hideous Monster laves
His Sides with Seas, which to his Passage yield,
And whelms his Bulk o'er half the wat'ry Field.
The Maid shrieks out; her mournful Father cries,
Her Mother too with equal Plaints replies,
Both wretched now; but much more justly she,
Whose vainer Pride deserv'd her Misery.

No Help, alas! but uſeleſs Tears they bring,
And, crying, round their fetter'd Daughter cling;
When Perſeus *thus; weep thus no more in vain,*
Few Minutes only now for Help remain.
Should I, fair Danaë*'s Son by thund'ring* Jove,
Perſeus, *the Offſpring of his golden Love;*
Perſeus, Meduſa*'s Conqueror, ſhould I,*
Who thro' the Air with certain Pinions fly;
Should I your Daughter for a Wife demand,
I ſure might in your Choice the Faireſt ſtand.
But I to thoſe will greater Merits join,
If Heav'n but ſecond now my bold Deſign;
And beg her as my Love's victorious Deed,
If now from Death by my Aſſiſtance freed.
His Offer gladly both with Pray'rs embrace;
For who'd refuſe it in that deſp'rate Caſe?
And, for a Dow'ry too, that Crown engage,
Too weighty grown for their declining Age.
Now, as ſome Galley, forc'd with Oars and Tides
Plows up the Ocean with its foaming Sides;
So the prodigious Monſter's horrid Force,
Breaks up the Waves with an impetuous Courſe.
And now no farther off than one might fling
A Bullet with a Balearian *Sling,*
The gallant Youth, with ſudden Motion, ſprings
From Earth, and cuts the Air with active Wings;
And as the hov'ring Hero's martial Shade,
With Tremblings on the wat'ry Surface play'd,
The Beaſt enrag'd at the thin Phantom grew,
And at the Shade with utmoſt Fury flew.
But as Jove's *Bird, when from a Cloud he ſpies,*
Where on ſome Plain a Dragon baſking lies,
Stoops, at his Back, and to prevent his Jaws,
Thro's ſcaly Neck his crooked Pounces draws;
So he the Air with nimble Wings divides,
And plies the Monſter's Back and rolling Sides;
And with a lucky Thruſt his Shoulder rives,
And up to th' Hilt, his greedy Falchion drives.

Struck

Struck with so deep a Wound, the Monster raves,
And fiercely bounds above the 'frighted waves;
Then dives again, and with a dreadful Sweep,
With thick black Gore distains the boiling Deep.
And as a Boar, which eager Hounds engage,
So ev'ry Way he vents his baffled Rage;
While from his Fangs the wary Perseus *flies,*
And ev'ry Way the furious Monster plies.
Now on his Back and Ribs like Anvils beats;
Now on his Fish-like Stern his Strokes repeats.
The Beast then spouts such Floods of wat'ry Gore,
Perseus *durst trust his dabbled Wings no more.*
But spies a Rock, which bare in Calms might lie,
But under Water when the Sea ran high.
There strait the fearless Hero takes his Stand,
And grasps the Summit with his swordless Hand;
And then, to crown his Conquest, strongly foins,
And thrusts his Sword oft thro' the dying Monster's Loins.
Now, for the Conquest, mighty Shouts and Cries
Ring round the Shores, and echo to the Skies.
With Joy Cassiope *and* Cepheus *rais'd,*
Him as their Son receiv'd, his Actions prais'd;
Call'd him their Family's Support and Stay,
On whose brave Arms their Hope and Safety lay.
The lovely Maid moves on, now freed from Chains,
The Cause, and fair Reward of all his Pains.

Metam. Book IV.

Euphros. That is indeed a very beautiful Description.—— But what, or whose is that frightful, ill-favoured Face or Head, which *Perseus* holds in his left Hand? And what are those Snakes that proceed like Hair from it?

Cleon. That Constellation is called *Caput Medusæ*, or, the Head of *Medusa:* This *Medusa* was once the fair Daughter of *Phorcus* and *Cete*, who had golden Hair; her Charms tempted *Neptune* to violate her Chastity in the Temple of *Minerva*, which that Virgin Goddess so resented, that she changed the Hair of *Medusa* into Snakes, and such, that whosoever looked on them were turned into Stones; therefore the Gods, out of

Pity, ſent *Perſeus* to cut off her Head; which he did, and gave it to be placed in the Shield of *Pallas* and *Minerva*. This Story is alſo finely told by the ſame Poet:——

Meduſa *once was for her Beauty fam'd,*
At whom a Thouſand jealous Suitors aim'd;
But more than all, her lovely Treſſes charm'd,
Whoſe golden Beams her coldeſt Lovers warm'd.
(I've met with ſome who waited at her Court,
And only Wonders of her Locks report)
Her Neptune *ſeiz'd, with luſtful Paſſions wild,*
And in the chaſte Minerva's *Fane defil'd:*
The Virgin Goddeſs turn'd aſide, and held
Before her modeſt Eyes the ſacred Shield;
But that the Crime might be in one reveng'd,
To horrid Snakes, Meduſa's *Curls ſhe chang'd,*
And that ſhe might in future rolling Years
O'er-awe the vicious World with pow'rful Fears,
The Snakes ſhe made ſtill in her ſhield ſhe bears.

Metam. Lib. IV.

This *Meduſa* was One of thoſe three horrid Monſters of Hell, called *Gorgons*; who ſlew People with their very Looks; the Names of the other Two were *Stheno* and *Euryale*, all Daughters of *Phorcus*. From the Blood which guſhed out on ſtriking off *Meduſa*'s Head ſprang *Pegaſus*, or the winged Horſe, which you ſee depicted (the Fore-part) above the Equinoctial, a little below *Andromeda*.

Euphroſ. I ſee him——and pray, what Stories do the Fabuliſts tell of this ſingular Horſe? And how came He in Heaven?

Cleon. This Horſe belonged to the *Muſes*, who let him ſometimes to the Heroes and Demi-gods, for greater Expedition; this Horſe *Perſeus* rode; and at laſt, *Bellerophon* mounting him, was carried thro' the Heights of Air, where being ſeiſed with Fear and a Vertigo, he fell to the Earth, and the Horſe was made a Conſtellation in the Heavens. To this *Milton* alludes in his Invocation of *Urania*, in the Beginning of the 7th Book of *Paradiſe Loſt*.

——*Upled*

——— ——— ——— *Upled by thee*
Into the Heav'n of Heav'ns, I have presum'd,
An earthly Guest, and drawn empyreal Air
Thy Temp'ring; with like Safety guided down
Return me to my native Element;
Lest from this flying Steed unrein'd, as (once
Bellerophon, *though from a lower Clime)*
Dismounted, on th' Alcian Fields I fall
Erroneous there to wander and forlorn.

Euphros. The Next that makes a considerable Figure on the Globe, is *Auriga*; pray, who was he, and how came the Kids in his Hand behind him?

Cleon. Who he was, or how he came by these Kids is hard to say; Mythologists are quite silent about him: Unless they intend *Phaëton*, who by *Ovid* is called *the Charioteer of Phœbus*, or the Sun; or else, he was some distinguished Person among the Chariot-drivers in Races, so much celebrated among the ancient *Greeks* and *Romans*; and such *Manilius* seems to represent him in the following Lines:———

But when the Ram *first shews thrice five Degrees,*
The Driver *reers his Chariot from the Seas;*
And climbs that Steep, whence blust'ring Boreas *brings*
His North-east Blast, and shakes their freezing Wings.
He keeps his own Concern, and thence bestows
Those various Arts which here on Earth he chose.
To drive the Chariot, to direct the Course,
And hang with forward Lashes on the Horse;
Now press directly, now wheel nimbly round,
Out-strip the Wind, nor raise the dusty Ground;
Or cross athwart, and force the Rest to yield,
Disperse the Croud, and clear the gaping Field;
And tho' out-stript, yet scorn to stop to Fear,
But, drive on Hope, and leave behind Despair.
Or, 'midst the Race from Horse to Horse to leap,
Sport o'er their Backs, and fix the dang'rous Step:

Or, singly *mounted, break the foaming Jaws,*
Throw well the Dart, *and force a juſt Applauſe.*
Aſtr. Book V.

Euphroſ. Be *Auriga* whom he will, the Poet makes a pretty Uſe of the Story. ——— But pray, *Cleonicus*, who is that old Fellow *Boötes*, with a frizly Beard, ſtanding with one Foot on *Mount Mænalus*, holding a Club in one Hand, and two Courſers in a String with the other ?

Cleon. His Name implies an *Herdſman*; but he is more properly called *Arctophylax*, or the *Bear-keeper*; for he conſtantly follows the *Greater Bear* in its daily Rotation about the North Pole. Alſo becauſe the *Bear* is ſometimes called the *Waggon*, *Boötes* is moſtly called the *Waggoner*, by the Poets; thus *Ovid:*

Now Silence o'er the ſlumb'ring World did reign,
And ſlow Boötes *had declin'd his Wain.*
Myrrha *purſues her Guilt.* —— ——— ———
Metam. Book X.

And in the Story of *Phaëton*, he thus deſcribes the Conſternation of the *Serpent* and *Boötes.*——

The folded Serpent *next the frozen Pole,*
Stiff and benumm'd before, began to roll,
And rag'd with inward Heat, and threaten'd War,
And ſhot a redder Light from ev'ry Star.
Nay, and 'tis ſaid, Boötes *too, that Thou*
Would'ſt fain have fled, tho' cumber'd with thy Plough.
Book II.

Euphroſ. The *Swan*, I ſee, makes the next conſiderable Figure; he is in a Poſture of Flight, in the *Milky Way*; for what Reaſon could a Swan come there, *Cleonicus?*

Cleon. Ah, my *Euphroſyne*, while we are on the fabulous Part of Aſtronomy, Fiction is all the Reaſon you muſt expect in Things. And ſo ridiculous are the Fables for the moſt Part, that *Jove* is pretended to have aſſumed the Shape of a Swan, in order to deceive *Leda*, the Wife of *Tyndarus*; which adulterous Story is thus commemorated by *Manilius*, which ſpeaks of this Conſtellation.

Next

Next view the Swan, *which* Jove *advanc'd above,*
That Form's reward by which he caught his Love.
When shrouded in the fair, deceitful Shape,
He cheated trusting Leda *to a Rape:*
Now grac'd with Stars, his Wings stretcht o'er the Skies.

Book I.

Euphros. But I see a much nobler Bird yet, below the *Swan*, I mean the *Eagle*; no Doubt but there was some notable Occasion for his being made a Constellation.——

Cleon. The Eagle being King of Birds, as *Jupiter* was of the Gods, it was always esteemed sacred to that supreme Deity, and was usually called the *Bird of Jove.* The Poets feign, that *Jupiter* was brought up in a Cave in *Crete*, by Doves, who fed him with *Ambrosia*, and an Eagle, who supplied him with *Nectar*, which he drew from a Rock and carried in his Bill; for this he was honoured with celestial Dignity.——Others say, that in the Wars of the Giants, the Eagle brought Thunder to *Jupiter*, with which he quelled them; and is therefore called *Jove's Armour-bearer* by *Virgil.*——Of the *Eagle* as a Constellation, *Manilius* thus speaks.

The tow'ring Eagle *next doth boldly soar,*
As if the Thunder in his Claws he bore;
He's worthy Jove, *since he, a Bird, supplies*
The Heav'n with sacred Bolts, and arms the Skies.

Book I.

Euphros. Who is that old Fellow *Serpentarius*, grasping an hideous Serpent in his Hands?

Cleon. Some think he represents *Æsculapius*, the God of Physicians and Physic; he was worshipped at *Epidaurus*, his Birthplace, first, and afterwards at *Rome*, in the Form of an huge Serpent.——Others think it is *Hercules*, who while an Infant, destroyed with the Grasp of his Hands two Serpents, sent by *Jupiter* to kill him in the Cradle: Hence *Ovid.*——

You kill'd two Serpents with your Infant Hand,
Which then deserv'd Jove's *Scepter to command.*

Epist.

Of

Of this Conſtellation, thus *Manilius.*——

Next Ophinclius *ſtrides the mighty Snake,*
Untwiſts his winding Folds, and ſmooths his Back,
Extends its Bulk, and o'er the ſlipp'ry Scale,
His wide-ſtretch'd Hands on either Side prevail;
The Snake now turns his Back, and ſeems to rage;
That War muſt laſt where equal Pow'rs engage.

Book I.

Euphroſ. What is *Hercules* about, in that kneeling Poſture? What means the Club in his Right-hand, the three-headed Monſter in his Left, and the Lion's Skin hanging over his Arm?

Cleon. This repreſents ſome of the Labours of that wonderous Demi-god, who was the Son of *Jupiter*, by *Alcmena*, the Wife of *Amphitryo*, King of *Thebes*. As he was the greateſt Hero for Feats of Strength; ſo no Doubt, his Fable had its Origin in the Hiſtory of *Samſon.*——The Labours of *Hercules* were many, of which twelve are particularly celebrated, and are contained in the twelve following Verſes.

——*The* Cleonean Lion *firſt he kills,*
With Fire and Sword then Lerna's Hydra *quells;*
Of the wild Boar he clears th' Er'manthean *Fields.*
The Braſs-foot Stag with golden Antlers yields.
He Stympha *clears of Men-devouring Birds,*
And next the bouncing Amazon *ungirds:*
The Stables of King Augeas *he cleans,*
The Cretan *Bull he vanquiſhes and chains:*
Diomede's *Horſes him their Conqu'ror own,*
Then he brings low three-headed Geryon;
Heſperian *Apples next his Name advance,*
And his laſt Labour Cerberus *enchains.*

Of the Lion's Skin he made a Shield, and Breaſt-plate, which you ſee; that three-headed Monſter is *Cerberus*, the Dog who kept the *Gate of Hell*, and whoſe Body was cover'd with Snakes inſtead of Hair; of whom *Virgil* thus ſpeaks:——

Stretch'd

Stretch'd in his Kennel, monſt'rous Cerb'rous *round*
From triple Jaws made all theſe Realms reſound.

And *Horace* thus :———

Hell's griſly Porter let you paſs,
And frown'd and liſten'd to your Lays.
The Snakes around his Head grew tame;
His Jaws no longer glow'd with Flame;
Nor triple Tongue was ſtain'd with Blood:
No more his Breath with Venom flow'd.

Book III. Ode ii.

Euphroſ. Well, to paſs this Monſter a little, I obſerve *Lyra* on the Breaſt of an Eagle, what does that import?

Cleon. *Lyra* is the Lyre, or Harp of *Orpheus*, the Son of *Apollo*, by *Calliope* the *Muſe*; on which he is ſaid to have played and ſung ſo ſweetly, that he tamed wild Beaſts, ſtayed the Courſe of Rivers, and made the Woods follow him.——— Yea, when he deſcended into Hell to fetch back his Wife *Euridice*; he charmed *Pluto* and *Proſerpina*, (King and Queen of Hell) and made the Damned dance, if what *Virgil* ſays be true :———

Th' unhappy Huſband, Huſband now no more,
Did on his tuneful Harp his Loſs deplore,
And ſought his mournful Mind with Muſic to reſtore.
On thee, dear Wife, in Deſerts all alone,
He call'd, ſigh'd, ſung, his Griefs with Day begun,
Nor were they finiſh'd with the ſetting Sun.
Ev'n to the dark Dominions of the Night
He took his Way, thro' Foreſts void of Light;
And dar'd amidſt the trembling Ghoſts to ſing,
And ſtood before the inexorable King.
Th' infernal Troops like paſſing Shadows glide,
And, liſt'ning, crowd the ſweet Muſician's Side.
Ev'n from the Depths of Hell the Damn'd advance,
Th' infernal Manſions nodding ſeem to dance;
The gaping three-mouth'd Dog forgets to ſnarl,
The Furies *hearken, and their Snakes uncurl:*

Ixion

Ixion *ſeems no more his Pain to feel,*
But leans attentive on his ſtanding Wheel.

Georg. IV.

With *Orpheus* 'tis uſual to join the Story of *Amphion*, the Son of *Jupiter*, by *Antiope*; he received a Lute, or Harp from *Mercury*, the Sound whereof moved the Stones ſo regularly, that they compoſed the Walls of the City of *Thebes*, according to *Horace*.——

Amphion *too, as Story goes, could call*
Obedient Stones to make the Theban *Wall*;
He led them as he pleas'd, the Rocks obey'd,
And danc'd in Order to the Tune he play'd.

Art of Poetry.

Euphroſ. How extravagant are the Fictions of the Poets! They could never propoſe to have Credit for ſuch Romances; what could they propoſe, then, *Cleonicus*, in ſuch wild Relations?

Cleon. Their End was to ſhew their Invention, exerciſe their Art, amuſe the Learned, delude the Ignorant, and ſometimes to convey moral Inſtructions in this fabulous and hyperbolical Way, which was much in Vogue in the early Ages of the World. Thus, all they would imply by the wonderful Account of *Orpheus* and *Amphion*, is, that they were ſo eloquent, as to perſuade the wild and ſavage People of their Time to live conformable to the Laws and Rules of civil Society.

Euphroſ. How came the Dolphin to merit a Place among the Stars? Methinks they made Fiſh plently in Heaven?——

Cleon. The Heaven of the Heathen, was a common Receptacle of every Thing; a wild Miſcellany of all Orders of Creatures, without Order or Diſtinction.——But not to digreſs, the Poets tell us of one *Arion*, a Lyric Poet of *Leſbos*, who got great Riches by his Art; and as he was going to *Italy*, the Mariners attempted to rob him, but he deſired he might play one Tune on his Harp before they threw him into the Sea; he played, and then leaped into the Sea, where a Dolphin, (drawn thither by the Sweetneſs of his Muſic) received him on his Back, and carried him to *Tenedos*, with all his Money; for which Kind-

neſs

ness the *Dolphin* was made a Conſtellation, according to *Ovid*.

The Gods beheld the gen'rous Deed, and Jove
Advanc'd him from the Deep to ſhine above
Among the Conſtellations, now divine,
And for his Share of Stars, he gave him nine.

Lib. Faſt. II.

Euphroſ. What is this *Coma Bereniœa* juſt above *Virgo?*

Cleon. It is the Hair of *Berenice*, the Wife of King *Evergetes*, who vowed to cut off her Hair if her Huſband returned from the War Victor; accordingly ſhe did, and ſent it to the Temple of *Venus*, from whence it was ſaid to be taken up into Heaven and made a Conſtellation: On which *Catullus* has wrote a curious Poem in *Latin*.——

Euphroſ. The Evening is now ſo far ſpent, that there is no Time for any further Enquiries; and indeed, if it were not, I believe I have pretty well tired you with Queries for to Night.

Cleon. Not at all, my *Euphroſyne*; but luckily for us, we have taken Notice of all that afford any Thing of Hiſtory or Fable in the Northern Conſtellations, worth Notice; the Reſt are of more modern Invention, and have nothing in them ſignificant. We will, To-morrow, paſs on to the Southern Conſtellations, which will afford us farther Entertainment of this Sort, and conclude this Survey.

DIALOGUE IV.

Of the CONSTELLATIONS *of the* SOUTHERN HEMISPHERE, *with their* FABULOUS HISTORY.

Euphroſyne.

THIS Evening you appoint for finiſhing our View of the Conſtellations.——We are now to deſcend to thoſe of the Southern Hemiſphere, among which, I ſee *Orion* makes a very conſiderable Figure; pray, *Cleonicus*, give me his Story.

Cleon. I will, and it runs thus in Fable; 'tis ſaid that *Jupiter*, *Neptune* and *Mercury*, as they once travelled together,

were benighted, and forced to lodge in a poor Man's Houſe, whoſe Name was *Hircus*; he entertained them as well as he could, which ſo pleaſed the *Gods*, that they promiſed to grant whatever he aſked. He ſaid, he promiſed his Wife on her Death-bed to live a Widower, and yet he extremely deſired to have a Son; they conſented to his Requeſt, and moiſtening an Ox's Hide with their Urine, they commanded him to bury it ten Months. After which Time, digging it up, he found in it a new-born Child, which from thence was called *Urion*, or *Orion*.

Orion was a conſtant Companion of *Diana*, while a Youth; but at length, behaving indecently to her, he was ſtung to Death by a Scorpion. However, *Jupiter* tranſlated him to Heaven, and made him a moſt conſpicuous Conſtellation, which is thus deſcribed by *Manilius*.

Firſt, next the Twins, *ſee great* Orion *riſe,*
His Arms extended ſtretch o'er Half the Skies:
His Stride is large, and with a ſtately Pace
He marches on and meaſures a vaſt Space.
On each broad Shoulder a bright Star's diſplay'd,
And three obliquely grace his hanging Blade.
In his vaſt Head immers'd in boundleſs Spheres,
Three Stars leſs bright, but yet as great, he bears.
But farther off remov'd, their Splendor's loſt,
Thus grac'd and arm'd, he leads the ſtarry Hoſt.

Book I.

Euphroſ. The next Conſtellation I obſerve, is the huge *Whale*, or rather *Sea-monſter*; for he is partly *Beaſt*, and partly *Fiſh*. How came he in Heaven, pray?

Cleon. This is that dreadful Monſter which was to devour *Andromeda*, chained to a Rock; whoſe Story I have before related to you from *Ovid*. The *Whale* is thus deſcribed by *Manilius*:——

Next on his Belly floats the mighty Whale,
He twiſts his Back, and rears his threat'ning Tail;
He ſpouts the Tide, and cuts the foaming Way,
Wide gapes his Mouth, as eager on his Prey;

Such

Such on Andromeda *he ruſht, and bore*
The troubled Waves beyond their uſual Shore.

Book I.

Euphroſ. What horrid *Hydra* is that which carries ſuch a Length on the Globe?

Cleon. It makes indeed, a great Figure, but I cannot certainly tell its Original.———I ſhould have taken it for the *Hydra* of the Lake *Lerna*, which *Hercules* ſlew, but this has but one Head, whereas that is ſaid to have many; of which it is ſaid, that when any one was cut off, another immediately ſprang up in the Place of it, unleſs the Blood which iſſued from the Wound was ſtopped by Fire; this *Hercules* did by the Aſſiſtance of *Iolaus*, the Son of *Iphiclus*, and ſo ſlew the Serpent.——*Iolaus*, you'll find by *Ovid*, was no Loſer by this; for when he was grown old and decrepit, he was reſtored to Youth again by the Prayers of *Hercules*.

At the big Entrance, Iolaus *appears*,
Blooming in Beauty, and renew'd in Years;
Crown'd with a ſecond Youth, and ſprightly Grace,
The doubtful Down ſcarce ſhades his maiden Face.
The Favour to his Uncle's Pray'rs he ow'd,
And Hebe *at her Huſband's Suit beſtow'd.*

Met. Lib. IX.

Euphroſ. Strange Things, ſure, have been done of old: If our *Jugglers*, or *Legerdemain-Gentlemen*, could perform any Feats like this, they would be in better Repute among the People than now they are.———But that *Dog*, there, with a *Collar* about his Neck, how came he in Heaven? And that little one above is ſo very pretty, that I ſhould almoſt fancy it to be a Lap-dog belonging to ſome of their celeſtial Ladyſhips, if I thought any ſuch Thing were the Faſhion in Heaven.———

Cleon. You cannot think any Thing too wild or whimſical, that may not be true, of thoſe whom the Antients have advanced to their poetical Heaven: And in this Particular of the Dog you have conjectured right; for Poets tell us, this was the Dog which belonged to *Icarus*, or rather to his Daughter *Erigone*, who, as ſome will have it, was made the Sign *Virgo*, and

it was permitted her, no Doubt, to take her Dog along with her to Heaven.———But be that as it will, this is certain, no Conſtellation was more notable than this among the Antients, on Account of that moſt obvious and remarkable Star in his Mouth, of which I ſhall ſay more another Time.

Euphroſ. Pray, what mathematical Inſtrument is that which I ſee between the *Lion* and the *Hydra?*

Cleon. It is the Sextant of *Urania*, one of the *Nine Muſes*; it is placed there in Honour of her, as Inventreſs, not only of that, but moſt other aſtronomical Inſtruments, and the Patroneſs of Aſtronomers, and the celeſtial Sciences.——Hence the Poets, when they undertake to ſing of Heaven, and the Works of Nature, invoke the Aid of *Urania*, as *Milton.*

Deſcend from Heav'n, Urania! *By that Name*
If rightly thou art call'd, whoſe Voice divine
Following, above th' Olympian *Hill I ſoar*
Above the Flight of Pegaſæan *Wing*———

And the Author of *Univerſal Beauty*, Mr. *Brooks*, thus invokes this Goddeſs.

———*Thou, whom the antient Seer ſtiles*
Venus Urania! *born the Babe of Smiles;*
When from the Deep thy bright Emergence ſprung,
And Nature on thy Form divinely hung,
Whoſe Steps (by Loves and Graces kiſs'd) advance,
And chearful Hours lead on the ſprightly Dance;
While Time within eternal Durance bound
Harmonious, on golden Hinges moves around:
Such, Goddeſs! as when Silence wond'ring gaz'd,
And ev'n Thyſelf beheld Thyſelf amaz'd;
Such hap'ly by that Coon *Artiſt known,*
Seated apparent Queen on Fancy's Throne;
From thence thy Shape his happy Canvas bleſt,
And Colours dipt in Heav'n, thy heav'nly Form conſeſt.
Such, Goddeſs! thro' this Virgin Foliage ſhine,
Let kindling Beauties glow thro' ev'ry Line,
And ev'ry Eye confeſs the Work divine.———

Euphrof. What is meant by the Word *Crater?* The Figure of the Conſtellation ſeems to me like a rich two-handled Cup, or Bowl.

Cleon. That is the very Thing; it was the Bowl of *Bacchus*, the God of Banquets and Revels. Next which, you ſee *Corvus*, the Raven, or Crow, ſitting on the Serpent's Tail. Below theſe, you obſerve another of thoſe Monſters they call *Centaurs*, ſtriking his Spear into a Wolf; and next to him is *Ara*, the Altar of *Jove*; the Uſe and Occaſion thereof is thus deſcribed by *Manilius:*

The World's great Temple next, and Altar lies,
Grac'd with the Gifts of conqu'ring Deities;
When Earth-born Giants did the Skies invade,
The leſſer Gods implor'd the greater's Aid;
His Pow'r Jove *doubted when he view'd from far*
The threat'ning Force of the unequal War.
When he inverted Nature's Frame beheld,
That Earth roſe upward, and that all rebell'd:
That Hills on Hills heap'd, rais'd their threat'ning Head,
And frighted Stars approaching Mountains fled:
When impious Armies at a monſt'rous Birth,
Broke thro' the Bowels of the gaping Earth,
Of diſagreeing Forms, and frightful Makes,
Vaſt humane Bodies twiſted into Snakes.
E'er this no Danger and no Fear was known,
And wanton Jove *ſat idly in his Throne.*
But leaſt ſome greater Pow'r (ſoft Eaſe betray'd
His Mind to Doubt) ſhould yield the Rebels Aid;
He rais'd this Altar, and the Form appears
With Incenſe loaded, and adorn'd with Stars.

Lib. I.

Euphrof. What great Ship is that I ſee, called *Argo?*

Cleon. This was the Ship in which the famous Expedition was made by *Jaſon* and his Company (hence called *Argonauts*) to *Colchis*, to recover the *Golden Fleece*; and is thus deſcribed by *Manilius:*——

Next Procyon *view, and next the nimble* Hare,
Then Argo *ſailing thro' the liquid Air;*

Advanc'd

Advanc'd from all the Dangers of the Tides,
Which first she stemm'd, she now securely rides.
Heav'n is her Port, and now she rules the Floods,
A Goddess made for saving of the Gods.

Lib. I.

Euphros. I see the *Peacock* is honoured with an Asterism likewise, how came that to pass?

Cleon. You have now quite puzzled me——I cannot tell how it came about, unless it was in Commemoration of *Argus*, whom the Poets feign to have had an Hundred Eyes, two of which slept by Turns, while the others watched; as is thus described by *Ovid*:——

Argus's *Head an Hundred Eyes possess'd,*
And only two at once declin'd to Rest;
The others watch'd, and in a constant Round,
Refreshment in alternate Courses found;
Where'er he turn'd, he always Iö *view'd,*
Iö *he saw, tho' she behind him stood.*

He was slain at last by *Mercury*, and turned by *Juno* into a *Peacock*, who placed his Eyes in the Tail of that Bird.

There Argus *lies; and all that wond'rous Light*
Which gave his Hundred Eyes their usual Light,
Lies bury'd now in one eternal Night.
But Juno *that she might his Eyes retain,*
Soon fix'd 'em in her gaudy Peacock's *Train.*

Metam. Lib. I.

Euphros. This is pretty much of a Piece with other poetical Stories.——But as I remember to have read, that the Peacock was a Bird sacred to *Juno*, (as the Eagle to *Jupiter*) I could not tell whether it might not be on that Account.

Cleon. That may probably be the Case; *Juno* was Supreme of the Goddesses, and her Chariot was drawn by two Peacocks; no Wonder therefore, if this Bird was made a Constellation, and I only think 'tis Pity they had not placed him in such a Part

where

where he might oftener appear, and have a greater Number of Stars to bedeck his Tail.

Euphrof. Well, to paſs him, what ſay you of the River *Eridanus*, I ſee there? Is it a River of *Nectar* that ſupplies the Gods with Drink? Or what is it, and how came it there?

Cleon. The River *Eridanus* was that which is now called the *Po*, in *Italy*; it was placed in Heaven, in Commemoration of the unhappy Fall of *Phaëton*, (whoſe Name at firſt was *Eridanus*) the Son of *Apollo* and *Clymene*. The Fable is this; *Phaëton* wanted *Apollo* to give him ſome Proof that he was his Father. *Apollo* to gratify his Son, bid him aſk what he would, and it ſhould be granted him, and ſwore by the River *Styx*, to confirm it, (which Oath is inviolable.) *Phaëton* aſked Leave to drive his Chariot for one Day; which raſh Requeſt greatly grieved *Apollo*, who deſired him not to inſiſt on it, but in vain, for drive the Chariot he would, and *Apollo* by his Oath was obliged to permit him. So up he mounts, and drives on, regardleſs of his Father's Directions; but the Horſes, not finding their uſual Conductor, took Head, and the Charioteer being dazzled with the Light above, and frighted with the horrid Abyſs beneath, and the terrible Scorpion, let go the Reins, loſt his Way, and would have burnt one Half of the World, and froze the other, if *Jupiter* had not ſtruck him with a Thunderbolt into the River *Eridanus*. This Story is the moſt noble and ſublime of any in *Ovid*, and well worth your reading; the Concluſion of which runs thus:

Jove call'd to witneſs ev'ry Power above,
And e'en the God whoſe Son the Chariot drove;
That what he acted, he was forc'd to do,
Or univerſal Ruin would enſue.
He then aſcended the æthereal Throne,
From whence he us'd to hurl the Thunder down;
From whence his Show'rs and Storms he us'd to pour,
But now could meet with neither Storm nor Show'r.
Full at his Head he ſhot the flaming Brand,
Which ſtopt the Flames, and Fires with Fire reſtrain'd.
At once from Life, and from the Chariot driv'n,
Th' ambitious Youth fell Thunder-ſtruck from Heav'n;

The

The Horſes ſtarted with a ſudden Bound,
And flung the Reins and Chariot to the Ground.
The ſtudded Harneſs from their Necks they broke,
Here fell a Wheel, and here a Silver Spoke;
Here were the Beam and Axle torn away,
And, ſcatter'd o'er the Earth, the ſhining Fragments lay.
The blaſted Phaëton *with flaming Hair,*
Shot from the Chariot like a falling Star;
Which in a cloudleſs Ev'ning from the Top
Of Heav'n drops down, or ſeems at leaſt to drop;
'Till on the Po *his ſmoaking Corpſe was hurl'd,*
Far from his Country, in the weſtern World.

Ovid's Met. Lib. II.

Euphroſ. This is a fine Relation indeed, though fabulous; and I ſuppoſe was intended to admoniſh us of the ill Conſequences of raſh and imprudent Actions. But what is the Meaning of the *Phœnix* in the Flame, which I ſee upon the lower End of the River *Eridanus?*

Cleon. That Bird too is a Fiction; of which *Pliny* thus writes; that ſhe is of the Bigneſs of an Eagle, and never but one; that ſhe lives 660 Years, and then makes a Neſt of hot Spices, which being ſet on fire by the Heat of the Sun, ſhe is burnt, and out of her Aſhes there ariſes a Worm, which afterwards comes to be a *Phœnix.* This we have elegantly deſcribed by *Ovid* thus.

Thus all receive their Birth from other Things,
But from himſelf the Phœnix *only ſprings;*
Self-born, begotten by the Parent Flame
In which he burn'd, another and the ſame:
Who not by Corn or Herbs his Life ſuſtains;
But the ſweet Eſſence of Amomum drains;
And watches the rich Gums Arabia *bears,*
While yet in tender Dew they drop their Tears.
He (his five Centuries of Life fulfill'd)
His Neſt on Oaken Boughs begins to build,
Or trembling Tops of Palm; and firſt he draws
The Plan with his broad Bill and crooked Claws,

Nature's

Nature's Artificers; on this the Pile
Is form'd, and rises round: Then with the Spoil
Of Cassia, Cinnamon, and Stems of Nard,
For Softness strew'd beneath, his funeral Bed is rear'd.
Funeral and bridal both; and all around
The Borders with corruptless Myrrh are crown'd
On this Incumbent, 'till ethereal Flame
First catches, then consumes the costly Frame;
Consumes him too as on the Pile he lies;
He liv'd in Odours, and in Odours dies.
An Infant Phœnix *from the Former springs*
His Father's Heir, and from his tender Wings
Shakes off his Parent-Dust: His Method he pursues,
And the same Lease of Life on the same Terms renews.
When, grown to Manhood, he begins to reign,
And with stiff Pinions can his Flight sustain,
He lightens of its Load the Tree that bore
His Father's royal Sepulchre before,
And his own Cradle; this, with pious Care,
Plac'd on his Back, he cuts the buxom Air,
Seeks the Sun's *City, and his sacred Church,*
And decently lays down his Burden in the Porch.

Dryd. Ovid.

Euphros. A very surprising Account were it true!——— Pray, what is that other Bird called the *Toucan?*

Cleon. Indeed I can say but little of it, it is an *Indian* Bird; but how he, or the *Phœnix*, or the *Indian*, or the *Crane*, the *Sword-Fish*, *Noah's Dove*, and other Constellations not named, came by their Divinity, I cannot particularly say. 'Tis certain, they are all of them of modern Date, since *Manilius*, the antient astronomical Poet, says not a Word of them; nor indeed were the Stars of the Southern Hemisphere, near the South Pole, known in the Registers of Astronomy 'till within a few Centuries past. And as they became discovered and reduced to Constellations, the Astronomers gave them the Figures of such Creatures as they pleased. So that there remains now no more Constellations, of which we may expect any poetical Account, unless we reckon the *Milky-Way* as such;

for that we find the Poets very often exercised their *Muse* upon.

Euphros. You have already given me the true, astronomical Account of the *Milky-Way*; but it will be some Curiosity to hear what the Poets say, or feign on that Head, and therefore pray oblige me so far.

Cleon. I will; *Hercules*, I have told you, was *Jupiter*'s Bastard Child, by *Alcmena*, the Wife of *Amphitryo*, King of *Thebes*, and therefore he was the Object of *Juno*'s Hatred. But after many Ways attempting to destroy him in vain, she was at length, by the Mediation of *Pallas*, reconciled to the noble Babe, and let him suck her Breasts, which he hurt by sucking too violently; wherefore she put him away, and some of the Milk was spilt, but it was not lost; for some of it fell upon the Sky, and running along made the *Milky-Way*. Some of it passed through the Clouds, and fell on the Earth, and where it fell, Lillies sprang up, which are therefore white, and were by some called the *Roses of Juno*. This is the Fable; the poetical Description of the *Milky-Way* I have given you already. To which I shall add the various Opinions of the Ancients concerning the Origin of the *Milky-Way* from *Manilius*, who relates them in the following Lines.

Fond Men the sacred Causes strive to find,
And vainly measure with a feeble Mind;
And yet they strive, they madly whirl about
Thro' various Causes, still condemn'd to doubt
Whether the Skies grown old, here shrink their Frame,
And thro' the Chinks admit an upper Flame:
Or, whether here the Heavens two Halves are join'd,
But oddly clos'd, still leave a Seam behind:
Or here the Parts in Wedges closely prest,
To fix the Frame, are thicker than the Rest;
Like Clouds condens'd appear, and bound the Sight,
The Azure being thick'ned into White.
Or whether that old Tale deserves our Faith,
Which boldly says, that this was once the Path
Where Phœbus *drove; and that in Length of Years*
The heated Track took fire and burnt the Stars.

The

The Colour chang'd, the Ashes strew'd the Way,
And still preserve the Marks of their Decay:
Besides, Fame *tells, by Age Fame rev'rend grown,*
That Phœbus *gave his Chariot to his Son,*
And whilst the Youngster *from the Path declines,*
Admiring the strange Beauty of the Signs;
Proud of his Charge, he drove the fiery Horse,
And would out-do his Father in his Course.
The North grew warm, and the unusual Fire
Dissolv'd its Snow, and made the Bears retire;
Nor was the Earth secure, each Country mourn'd
The common Fate, and in its Cities burn'd.
Then from the scatter'd Chariot Light'ning came,
And the whole Skies were one continu'd Flame.
The World took Fire, and in new kindled Stars
The bright Remembrance of its Fate it bears.
Thus Fame, *nor must the softer Fable die,*
That Juno's *Breast o'erflowing stain'd the Sky,*
And made that Milky-Way, *which justly draws*
Its Name, the Milky Circle *from its Cause.*
Or is the spacious Bend serenely bright
From little Stars, which there their Beams unite,
And make one solid and continu'd Light?
Or Souls, which, loos'd from th' ignoble Chain
Of Clay, and sent to their own Heav'n again,
Purg'd from all Dross by Virtue, nobly rise,
In Æther wanton, and enjoy the Skies.

Book I.

And thus we have finished a fabulous Survey of the Constellations: That which now remains, is to proceed to a more particular Use of the *Celestial Globe*; and that shall be the Subject of our next Leisure.

DIALOGUE V.

Shewing the Use of the CELESTIAL GLOBE *in solving* SOLAR PROBLEMS, *or such as relate to the* SUN.

Euphrosyne.

ACcording to your proposed Method, I am now to learn the Use of the CELESTIAL GLOBE more accurately than I have yet done; but pray, *Cleonicus*, in what Respects, or in what Particulars, may I now expect to be instructed?

Cleon. I shall first shew you how to rectify the Globe for any Place; then, how to find the Place of the *Sun*, *Moon*, or *Planet*, in the Ecliptic for any given Time; and also, how to find the Time of their *Rising*, *Southing*, *Setting*, &c. for that Day: And lastly, I shall shew how, by the Stars on the Globe, you may find any Stars in the Heavens for any Time of the Year, and the Time of their *Rising*, *Setting*, &c.

Euphros. Well, this will be very delightful, and I promise myself a great deal of Pleasure and Advantage in such a Speculation. Therefore, to make a Beginning, pray tell me what you mean by *rectifying the Globe?*

Cleon. To rectify the Globe for any Place, *is to elevate the North Pole of it just so high above the artificial Horizon, as the Pole-Star in the Heavens is above the natural Horizon of that Place.*

Euphros. How must I proceed to rectify the Globe for any particular Place, as *London*, for Instance?

Cleon. You must first learn the Latitude of the Place, either by Observation, or from some Table of the Latitudes. As that of *London* you'll find to be about 51° : 30′, or this you may find on the *Terrestrial Globe*, by bringing *London* to the Brass Meridian, where you observe it passes under 51° : 30′ of North Latitude. Having thus got the Latitude of the Place, take the Brass Meridian, and raise or depress it in the Frame, 'till the Horizon cuts it in 51° : 30′, equal to the Latitude of *London*, there let the Globe rest, and it will be the

true

true Repreſentation of the Poſition of the Earth and Horizon for *London*.

Euphroſ. Well, this I can do immediately.——The Globe is rectified.——What am I to do next?

Cleon. The next Thing is *to find the Sun's Place* in the Ecliptic for any given Time you pleaſe; this you are to do by the Calendar and Ecliptic on the Horizon; in the firſt of which you find the Day, and oppoſite thereto, in the Latter, you find the Degree the Sun poſſeſſes that Day.

Euphroſ. Let me try if I can do this for the preſent Day, which is the 8th of *May*.——Let me ſee! Here I find the Day of the Month,——and then, in the Ecliptic, I find equal with it the 18th Degree of *Taurus*.——Is not that right?

Cleon. Very nearly; for in Inſtruments, however exact, we muſt not ſtand for a few Minutes, which make no ſenſible Alteration from what we behold in Nature.

Euphroſ. Well, as I have found the *Sun's Place*, what am I to do next?

Cleon. In the next Place, turn the Globe about 'till you ſee the ſame Degree of *Taurus* in the Ecliptic on the Globe, and thereon ſtick a ſmall Patch, and bring that Patch to the *Meridian*, and let the Globe reſt there.

Euphroſ. 'Tis done; the Patch is now under the Meridian; but, pray, *Cleonicus*, what does it repreſent there, the Sun?

Cleon. Yes, my *Euphroſyne*, he there repreſents the Noon-tide Sun for the preſent Day: For, as I have ſhewn you by the Orrery, whenever the Sun comes to the Meridian of any Place it is then the Noon of that Day, or 12 o'Clock.——Therefore hold the Globe faſt with one Hand, and with the other bring the *Hour-Hand*, or *Index* to the Hour XII, in the upper Part of the *Hour-Circle*, over the *Meridian*, and there let Things remain.

Euphroſ. This I have done—what next?

Cleonicus. Now you may eaſily ſolve many very uſeful Problems in Aſtronomy; as (1.) The Globe, in this Poſition, ſhews you all the Stars and Conſtellations that were up, or above the Horizon this Day *at Noon*. (2.) Obſerve the Degree the Patch touches upon the Meridian, and that is the *Sun's Declination*. (3.) See what Degree of the Equinoctial is cut

by

by the Meridian, and that will be the Sun's *right Aſcenſion*. (4.) Turn the Globe *Eaſtward*, 'till the Patch touches the Horizon, which then repreſents the *Sun's Riſing*, and the Index upon the Hour-Circle will ſhew the Hour. (5.) At the ſame Time, number the Degrees on the Horizon between the Patch and the *Eaſt-Point*, and that will be *his Amplitude of Riſing* for this Day. (6.) Then turn the Globe *Weſtward*, 'till the Patch again touches the Horizon, and the Index will ſhew the *Hour of his Setting* this Day. (7.) You obſerve on the Horizon his Amplitude of Setting from the *Weſt-Point* towards the *South*. Theſe Things you may practiſe firſt on the Globe, and then we will proceed to ſome other Problems.

Euphroſ. Well then, for the Sun's *Declination*, I ſee the Patch cuts the Meridian in or near the $17\frac{1}{2}$ Degrees *Northward*, and that is his *Declination* for to Day.——Again, I obſerve the Meridian cuts the Equinoctial in about 45° : 30′, which you ſay is the Sun's *right Aſcenſion* this Day.—I have now brought the Patch to the *Eaſtern Side* of the Horizon, and I ſee the Index points to the Hour of VII : 30′ for the *Time of his Riſing*,—and his Amplitude is 27° : 20′ to the South.———The Patch touches the Weſtern Side of the Horizon, and the Index ſtands at the Hour of IV : 30′, which is the Time the *Sun ſet* to Day,——and his *Amplitude* of Setting I ſee is the ſame with that of his Riſing, *viz.* near 27° 20′ to the South.

Cleon. Very good, my *Euphroſyne*; no one could have ſolved theſe Problems on the Globe with more Exactneſs than you have done.———Let us now remove the Patch, and put it on the firſt Degree of *Capricorn*, where the Sun is on the ſhorteſt Day of the Year, *viz.* the 22d of *December*, and we ſhall ſee that his *Riſing*, *Setting*, *Length of Days and Nights*, &c. are the ſame as I ſhewed you by the Theory.

Euphroſ. Pray do;———I'll put the Patch on the firſt Degree of *Capricorn*;——and now let me ſee,———the Sun's *Declination South* is then 23° : 30′;———his *right Aſcenſion* 270°;—his Altitude at Noon 15°;—the Time of his *Riſing is* VIII : 13′;—— and of his *Setting* III : 47′;——his *Amplitude* (now greateſt) Southward, is for his Riſing and Setting, about 40°,——which I ſee is almoſt *South-Eaſt*.——

Cleon.

Cleon. I find you are very ready at solving astronomical Problems; ——— and since on the shortest Day the Sun rises at VIII: 13′, and sets at III: 47′, 'tis evident, the Length of that Day is VII: 34′, and of the Night XVI: 26′, which is just the same as I told you from the Orrery.

Euphros. It is so; and I am pleased to see how exactly this noble Instrument corresponds with the Orrery, and common Observation; for I took Notice this very Day, that the Sun went down by the Clock just at the Time shewn by the Globe.

Cleon. It did so, and had you observed it rising this Morning, you would have found it at the same Time, as by the Globe. —— We have solved the *Phænomena* for the shortest Day; let us now suppose the Sun in the *Vernal Equinox*, that is, in the first Scruple of *Aries*, and see how these Things will fall out for that Time, which you remember is on the 21st of *March*.

Euphros. Very good, *Cleonicus*; it is a remarkable Season. ———I think there needs no Patch to represent the Sun there; the Intersection of the Ecliptic and Equinoctial is a Point sufficiently notable without it.———I'll bring it to the Meridian, and —— then I set the Hour Hand to XII, as before,——and thus the Globe now represents the Noon of that Day.

Cleon. Well, and how do you observe the foregoing Particulars on the Globe for that Day?

Euphros. I see they are very different from what they were before.———Now I observe the Sun's *Meridian*, *Altitude*, or Height at Noon, is 38° : 30′, equal to that of the *Equinoctial*, the Sun being in it;———also, because the Sun is in the first Minute of the *Equinoctial* as well as the *Ecliptic*, it has no *right Ascension*.——Also no *Declination*, for the same Reason.——Also, if I turn the Globe *East* or *West*, I see the Sun will *rise and set just at Six o'Clock*; the *Equinoctial* being the Sun's Path for that Day.——Again, I observe the Sun rises and sets exactly on the *East* and *West Points* of the Horizon; and therefore has *no Amplitude* that Day.

Cleon. You are very right in every Particular, my *Euphrosyne*; and thus you find the Days and Nights are then of equal Length, and all other Things happen just as they were explained to you by the Orrery. And in the same Manner, you'll

observe

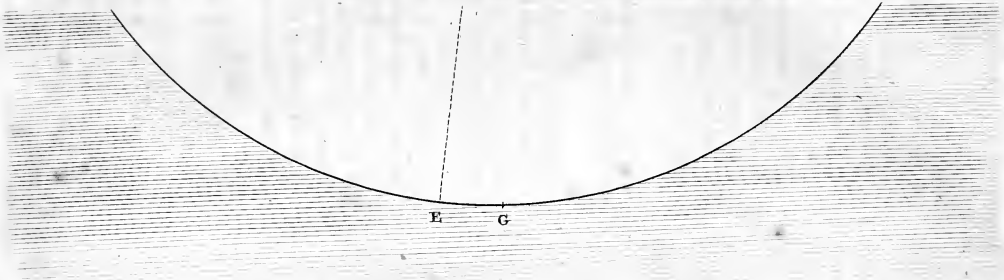
obſerve Things to happen, if you ſuppoſe the Sun in the other *Equinox*, as on *September* 12. Let us now proceed to the *longeſt Day*, viz. when the Sun enters the firſt Degree of *Cancer*, and obſerve the State of Things for that Day, *viz.* the 22d of *June*.

Euphroſ. With a very good Will, *Cleonicus*; and on that Point I'll again ſtick on the ſolar Patch,———which I ſet to the Meridian, — and the Hour-Index to the Hour of XII, for the Noon of that Day.———I now obſerve the Sun's *Meridian Altitude* is very great, being 62 Degrees, —— and his *right Aſcenſion* 90 Degrees;——his *Declination* is now 23° : 30′ *North*, as it was before *South* on the ſhorteſt Day.———I ſee the Tropic of *Cancer* ſhews the Sun's diurnal Path for that Day, and by turning the Globe Eaſtward, when the Patch touches the Horizon, I ſee the Index ſtand at III : 47′, the Hour of the *Sun's Riſing* that Day.——And again, when I bring the Patch to the Weſtern Horizon, the Index points to the VIII : 13′, the Time of *his Setting* that Evening; ——— and his *Amplitude of Riſing and Setting* is now juſt as much Northward, as it was Southward on the ſhorteſt Day.

Cleon. Very right, my *Euphroſyne*; and here again you obſerve alſo, that the Sun now riſes on the Hour in the Morning, as it ſat on the Evening of the ſhorteſt Day; and ſets now at the Hour it did then riſe: And moreover, that the Length of the Night now is equal to that of the Day then; and the longeſt Day now is equal to the then longeſt Night. All which you ſee is perfectly agreeable to the Theory. There are two or three Problems more worth knowing, relating to the Sun, to be reſolved on the Globe by the *Quadrant of Altitude*, which you ſee is ſcrewed on to the Meridian, at the Latitude of 51° : 30′, *viz.* that of *London*.

Euphroſ. Pray what are they, and how reſolved by that moveable Quadrant?

Cleon. One is, to find the Sun's *Altitude* any Hour of the Day, for any Part of the Ecliptic.———As ſuppoſe the Sun in the Beginning of *Cancer*, where the Patch now is, and I would know what Height the Sun is above the Horizon at Six o'Clock.———In order to this, I bring the Patch to the Meridian, and ſet the Index to XII, as uſual; then I turn the Globe 'till the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the Index points to the Hour of VI, where I hold it faſt, and lay the Quadrant over the Patch, and by it I ſee the Patch is about 19 Degrees above the Horizon, which is the Altitude of the Sun at Six, for the Morning and Evening of the longeſt Day.——Alſo, for the ſame Day, you find his *Altitude when he is due Eaſt or Weſt*, thus:——I bring the Quadrant to the Eaſt Point of the Horizon, and turn the Globe till the Patch touches the Edge of the Quadrant,——which you ſee is at the 31°, and that is the Sun's Altitude when due Eaſt or Weſt that Day.——Things remaining as they were, you obſerve the Time ſhewn by the Index, when the Sun is due Eaſt or Weſt, *viz.* VII: 21′ in the Morning; and in the ſame Manner, you will find it to be IV: 39′ in the Afternoon.——And theſe Things you may find for any Day, while the Sun is in the Summer Half of the Ecliptic.

Euphroſ. Yes, I imagine I can, *Cleonicus*;——the Method, by ſeeing you do it, ſeems pretty eaſy.——What other Problems remain?

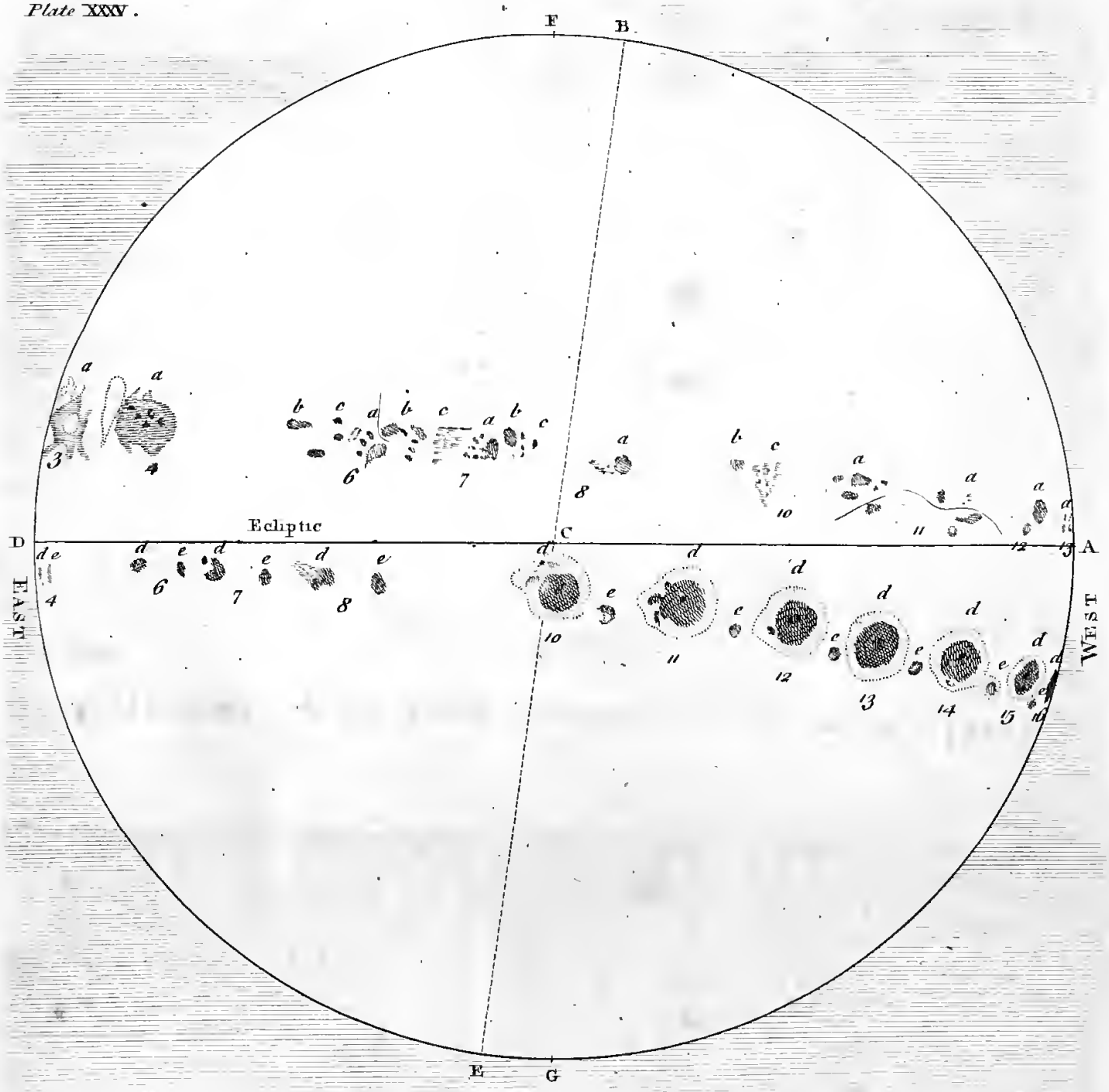
Cleon. If by a common Quadrant, or otherwiſe, I take the Altitude of the Sun on any Day, I can find by the Globe what Time or Hour it was; thus——ſuppoſe on the 12th of *May*, in the Forenoon, I find the Sun's Altitude to be 46°, and would know the Time of Day,——I proceed thus: By the Calendar, I ſee the Sun's Place, on the 11th of *May*, is about 20°: 30′ of ♉; and there I ſtick the Patch on the Globe, which I bring to the Meridian, and ſet the Hour Hand to XII. Then I move the Globe and Quadrant ſo together, that I cauſe the Patch to touch the 46th Degree on the Quadrant, and then holding both ſtill, I obſerve the Index points to IX: 30′, and that was the Hour or Time when the Altitude was taken.

Euphroſ. This ſeems to be an uſeful Problem:——Which is next?

Cleon. By the Globe, you may find the Sun's *Azimuth* for any Hour of any given Day of the Year.——Thus, let us take the laſt Inſtance of *May* the 11th, at Half an Hour after IX in the Morning; bringing the Sun's Place ♉ 20°: 30′ to the Meridian, and ſetting the Index to XII, I turn the Globe till the Index point to IX: 30′, and there hold the Globe;

The COURSE *of the* Solar Maculæ *over the* SUN'S DISK.

Plate XXXV.



the Index points to the Hour of VI, where I hold it fast, and lay the Quadrant over the Patch, and by it I see the Patch is about 19 Degrees above the Horizon, which is the Altitude of the Sun at Six, for the Morning and Evening of the longest Day.——Also, for the same Day, you find his *Altitude when he is due East or West*, thus:——I bring the Quadrant to the East Point of the Horizon, and turn the Globe till the Patch touches the Edge of the Quadrant,——which you see is at the 31°, and that is the Sun's Altitude when due East or West that Day.——Things remaining as they were, you observe the Time shewn by the Index, when the Sun is due East or West, *viz.* VII: 21′ in the Morning; and in the same Manner, you will find it to be IV: 39′ in the Afternoon.——And these Things you may find for any Day, while the Sun is in the Summer Half of the Ecliptic.

Euphros. Yes, I imagine I can, *Cleonicus*;——the Method, by seeing you do it, seems pretty easy.——What other Problems remain?

Cleon. If by a common Quadrant, or otherwise, I take the Altitude of the Sun on any Day, I can find by the Globe what Time or Hour it was; thus——suppose on the 12th of *May*, in the Forenoon, I find the Sun's Altitude to be 46°, and would know the Time of Day,——I proceed thus: By the Calendar, I see the Sun's Place, on the 11th of *May*, is about 20°: 30′ of ♉; and there I stick the Patch on the Globe, which I bring to the Meridian, and set the Hour Hand to XII. Then I move the Globe and Quadrant so together, that I cause the Patch to touch the 46th Degree on the Quadrant, and then holding both still, I observe the Index points to IX: 30′, and that was the Hour or Time when the Altitude was taken.

Euphros. This seems to be an useful Problem:——Which is next?

Cleon. By the Globe, you may find the Sun's *Azimuth* for any Hour of any given Day of the Year.——Thus, let us take the last Instance of *May* the 11th, at Half an Hour after IX in the Morning; bringing the Sun's Place ♉ 20°: 30′ to the Meridian, and setting the Index to XII, I turn the Globe till the Index point to IX: 30′, and there hold the Globe;

then I lay the Quadrant over the Sun's Place or Patch, and that repreſents the Sun's Azimuth for that Time, *i. e.* it ſhews what Point of the Compaſs the Sun is upon; as in this Caſe it is upon the Point of (S. E. by E.) *South-Eaſt by Eaſt*; that is, 3 Points from the *Eaſt* towards the *South*. You are alſo to obſerve, that the Diſtance between the Quadrant and the North and South Part of the Meridian is called the Sun's *Azimuth from the North or South*; and is reckoned in Degrees on the Horizon. But as this Problem is chiefly of Uſe to *Navigators*, we will paſs to another, which more generally concerns all Mankind, and is in itſelf very curious.

Euphroſ. What one is that, *Cleonicus?*

Cleon. Concerning the *Break of Day* and *Twilight*.——— It is found by Obſervation, that after the Sun ſets, 'tis not *dark Night* 'till he is deſcended about 18 Degrees below the Horizon; and when he comes to that Diſtance from the Horizon in the Eaſt, the *Day begins to dawn*.

Euphroſ. This I long to ſee you ſhew by the Globe; for that muſt be exceeding natural.

Cleon. And it will be the more ſo, by fixing this Braſs-wire to the Meridian, encompaſſing the Globe at 18° below the Horizon; for this will repreſent the Boundary between *Twilight* and *dark Night*.———Caſt your Eyes, therefore, below the Horizon, and you will obſerve, while the Globe is turned about, that the greateſt Part of the Ecliptic will go below the Wire, and ſo will admit of dark Night; but ſome of the northern Part does not deſcend below the Wire, and therefore, while the Sun is in that Part, there will be no *dark Night*.

Euphroſ. Very good, *Cleonicus*; I apprehend you very well; but pray let me obſerve more nicely, how much of the Ecliptic is excuſed from that Boundary of Darkneſs.

Cleon. This you will beſt do, if I bring the Beginning of *Cancer* to the Meridian below the Horizon; and then you will eaſily ſee what Degree is cut off on each Side by the Wire. ———I have ſet the Globe; you may make the Obſervation, as I turn it about.

Euphroſ. I will; I obſerve the Ecliptic firſt touches the Wire on the Meridian, in the 2d Degree of *Gemini* on one Side; and in the 28th Degree of *Cancer* on the other;——and I ſee by

by the Calendar, the Sun enters thoſe Points on the 23d of *May*, and 22d of *July*; ſo that for the Space of 60 Days or two Months there is no *dark Night*.

Cleon. In the ſame Manner, if you regard any other Point in the Ecliptic, and ſtick a Patch on it, you will, by turning the Globe, eaſily ſee when it touches the Wire; and conſequently, if you firſt bring the Patch to the Meridian, and then ſet the Index to XII, you may ſee what Time the Day dawns in the Morning, and the *Twilight* ends in the Evening of that Day the Sun is in that Part of the Ecliptic.

Euphroſ. Let me try this;———Suppoſe the Sun in the *Vernal Equinox*, on the 21ſt of *March*;———I bring that Point to the Meridian, and the Index to XII.——Now I turn it Eaſtwards till it touches the Wire, —— when I obſerve the Index points to IV, the Hour when the Day begins to dawn.——Again, I turn it Weſtward till it touches the Wire, and the Index ſhews the Hour of VIII, for the Time when Twilight ends on that Day.———Well! this is a very pleaſant Experiment, indeed!

Cleon. The like you may do for any other Day:———I ſhall only obſerve to you, that ſince the Sun riſes and ſets on that Day at Six o'Clock, the Length of the Twilight is then juſt two Hours.———Thus you may find the Length of the ſame for any other Day, by ſubtracting from the Time the Twilight begins or ends, the Time of the Sun's Riſing or Setting that Day.———For Inſtance, let us take the 2d Day of *March*, when the Sun enters the 12th Degree of *Piſces*; and there putting the Patch, bring it to the Meridian, and ſet the Hour-hand to XII; and then turning the Globe till the Patch touches the Wire, I obſerve the Index points to IV: 41′ in the Morning for the Beginning, and to VII: 19′ at Night for the End of Twilight. Now on that Day the Sun riſes at VI: 38′, and ſets at V: 22′, and the Difference of theſe Numbers from the Former, is I: 57′ for the Length of Twilight; which you know is but little leſs than when the Sun is in the Equinoctial Point; and yet it is now the ſhorteſt of any in all the Year, except on the 12th of *October*, when it is exactly of the ſame Length.

Euphrof. This is a very curious Point.——But, pray, how long is the Twilight on the ſhorteſt Day?

Cleon. You will find the Twilight on the 21ſt of *December* ends at V : 59′, and the Sun then ſets at III : 47′; therefore, the Length of Twilight muſt then be 2 Hours and 12′; which is 15′ longer than in the laſt Caſe when leaſt.——And thus we have ſeen the Method of ſolving the *Problems relating to the* SUN on the CELESTIAL GLOBE. We will, the next Opportunity, proceed to the Problems of the MOON; which I dare ſay, you will think for the moſt Part very pleaſant, and entertaining. But, in the mean Time, I ſhall make you a Preſent of a Map of the Solar Diſk, or Face of the Sun, for the Sake of giving you a clear Idea of the Spots or *Maculæ*, which ſo often appear in the Face of the Sun, and determine its Motion about its Axis; and though I have formerly ſhewn them to you through a Teleſcope, and you may have obſerved them ſeveral Times ſince; yet have you never ſo nicely obſerved their Motions, and the various Mutations, or Transformations they undergo, as to form a right Judgment of theſe curious Particulars. I have therefore ſelected out of 26 Periods of their Motions, obſerved and publiſhed by the accurate *Hevelius*, One, (*viz.* the 20th,) which is the moſt elegant of all, and beſt adapted for your Purpoſe. You will there ſee the Courſe which is taken by two different Sets of *Maculæ*, over the Face of the Sun; one of them below the Ecliptic D C A, and the other above it; both which you will eaſily obſerve, are oblique to the Ecliptic, and conſequently, in their Motions deſcribe Curves on the Sun's Face, ſomwhat like to the Parallels of Latitude, which you ſee on the terreſtrial Maps, the Axis of which Motion is repreſented by the Line B C E, which is diſtant from the Axis or Poles of the Ecliptic F G, about 7½ Degrees, as you ſee in the *Solar Map*. The Obſervation of theſe Spots were begun in the Year 1644, and continued from the 3d to the 16th of *May*. Below the Ecliptic the Spots obſerved were two, repreſented by *d*, *e*, which were but juſt viſible on the 3d Day, on the Eaſtern Limb, or Margin.——On the 4th Day, they appeared as at the Figure 4.——The 5th Day, they were not viſible.——The 6th, 7th, and 8th Days, they were ſomewhat

ſomewhat increaſed in Bulk.———The 9th Day, not viſible.———The 10th, and following Days, the Spot *d* is vaſtly increaſed in Bulk, with an irregular Atmoſphere about it, and a dark central Spot.———The other Maculæ *e*, continued every Day much of the ſame Magnitude and Appearance; but on the 14th, it ſeemed to have a ſmall Atmoſphere, mingling with that of the large one.———On the 15th, and 16th, as they were ſo near the Weſtern Limb of the Sun, their viſible Magnitude leſſened till they diſappeared.———A great Variety of Transfigurations may be obſerved in the Spots marked *b*, *c*, *a*, in that Courſe above the Ecliptic, on the ſeveral Days of the Month there repreſented by Figures.

Euphroſ. I am obliged to you for this Piece of nice Inſtruction; I ſhall put it in a Frame with a Glaſs before it, that I may have this moſt wonderful and glorious *Phænomenon* of the Mundane Syſtem, always in my View.

DIALOGUE VI.

The Uſe of the CELESTIAL GLOBE *in a Solution of* LUNAR PROBLEMS, *or thoſe which relate to the Motion and Phænomena of the* MOON.

Euphroſyne.

I Remember, when heretofore we talked of the Moon, you ſaid her Path, or Tract in the Heavens, was not in the Ecliptic, nor was her Orbit conſtantly the ſame, but always varying; how then can you ſhew the Problems relating to the MOON on the GLOBE?

Cleon. The Taſk of inveſtigating the Reaſon, or Cauſe of her various Motions, and framing a juſt Theory thereof, was, indeed, an arduous one; and reſerved for the great Genius of Sir *Iſaac Newton*. But when once her Theory became eſtabliſhed, it was eaſy to ſhew her Path, and her Place on the Globe, together with her *Nodes*, and their retrograde Motions, and the

Solution

Solution of moſt other Problems of the Moon by a very ſimple and eaſy Contrivance, as an *Appendage* to the Globe.

Euphroſ. Indeed! Pray, what and how is that? I long to know.——

Cleon. It is no more than a Piece of Silk Twiſt, with its two Ends ſo tied together, that, when put on the Globe, it ſhall girt it very tight.———This is the Thing,———and when I put it upon the Globe, it will there repreſent the Moon's Way.

Euphroſ. But ſince the Moon's Orbit lies acroſs the Ecliptic, how can you tell where, and how to fix it?

Cleon. By an *Ephemeris*, (as *Parker*'s, *Weaver*'s, &c.) I can eaſily find the *Place of the Nodes*, or Points of the Ecliptic, in which the Moon's Orbit croſſes it, for any given Time of the Year. By the ſame *Ephemeris*, I alſo find the Latitude, or Angle which the Moon's Orbit makes with the Ecliptic for that Time; but this on the Globe may always be taken about 5 Degrees, without any ſenſible Error.

Euphroſ. Well then, ſince 'tis ſo eaſy a Thing, pray, *Cleonicus*, put on the Silk Cord to repreſent the Orbit of the Moon, for the 14th Day of *Auguſt*, this preſent Year 1759.

Cleon. I willl —— here is *Parker*'s *Ephemeris* for 1759, in which the Moon's Place and Latitude is ſhewn for every Day of the Month at Noon, and the Place of her Nodes for every 5th Day, as you ſee in thoſe Columns reſpectively.——Thus, on the 14th Day of *Auguſt*, the Moon's Place is in *Taurus* ♉ 10° : 13′,———her Latitude is 4° : 14′, and her aſcending Node ☊ in 5° : $4\frac{1}{2}$′ of *Cancer* ♋, and the deſcending Node ☋ is of Courſe in the oppoſite Sign *Capricorn* ♑, —therefore I put on the Silk Line upon the Globe, in ſuch a Manner as that it may interſect the Ecliptic in thoſe two Points.——Laſtly, at the Diſtance of 90 Degrees on each Side the Node, I raiſe the String on one Side, and depreſs it on the other, till it is 5 Degrees diſtant from the Ecliptic.———Thus, you ſee, the ſilken Path of the Moon repreſented for the 14th Day of *Auguſt*.

Euphroſ. I do, and with great Satisfaction, as it gives me the cleareſt Idea of the different Paths of the Sun and the Moon thro' the Heavens. But ſince this is the Caſe, how is it, that the Moon

Moon, said in the *Ephemeris* to be in such a Degree of such a Sign of the Ecliptic?

Cleon. This you must understand is her Place, reduced from her Orbit to the Ecliptic, by a Line conceived to pass through her Center to the Ecliptic, which is called a Circle of Latitude; and this is done by the *Ephemeris*-Makers for every Day in the Year.——Thus, for Instance, the said Circle of Latitude passing through 10° : 13′ of *Taurus* ♉, will cut the silken String in a Point, which will shew the true Place of the Moon in her Orbit for that Day at Noon.

Euphros. I understand you perfectly well; and so, I suppose, if I stick a Patch upon that Point, it will be a true Representation of the Moon's Place, in order for the Solution of such Problems as relate to her Rising, Setting, *&c.* for that Day.——And therefore——

Cleon. But hold, Sister, one Thing you seem not to recollect, which is the large Space which the Moon describes every Day in her Orbit, by which Means it becomes necessary to find her Place, not for the Noon of the Day, but for any Number of Hours, before or after, at which her Appearance is required.——Thus, for Instance, supposing the Time of her Rising on that Day was required, her Place must be sought for about six Hours before Noon, and for the Time of her Setting, her Place must be sought for six Hours after.

Euphros. You do well to put me in mind of so necessary a Point.——I well remember, you shewed me, on the Orrery, that the daily Motion of the Moon was about 13 Degrees at a Mean, but in the *Ephemeris* for the proposed Time, I observe, that the Motion of the Moon, from the Noon of the 14th, to that of the 15th, is 14° : 6′. Therefore about a fourth Part of that Space, *viz.* 3° : 16′ must be added to her Place, the 14th Day at Noon, for her Place at Six in the Evening, which will make 13° : 29′ of *Taurus* ♉, where, I suppose, I may now stick the Patch.

Cleon. That will be the Place of the Moon for the Evening of that Day, and by Means of the Patch, which you have placed under her Orbit, just below that Point of the Ecliptic, you will find her Phænomena for that Evening, much after the

same

ſame Manner you did thoſe of the Sun, in regard to its Riſing, Setting, Southing, &c.

Euphroſ. So I apprehend :———But let me try how ready I am at the Practice. ——— The firſt Thing I have to do, I ſuppoſe, is to rectify the Globe to the Latitude of the Place, ——and then to bring the Moon's Place to the Meridian.——

Cleon. By no Means, Siſter.———It is the Sun's Place you are to bring to the Meridian, and place the Hour Index at XII, and thus it will be rectified for your Purpoſe.

Euphroſ. If I knew how to do the Thing, I ſhould not need a Tutor.———But I ſee the Reaſon of it at once, now you have ſet me right.———Well! let me proceed. ——The Sun's Place I find in the *Ephemeris* for that Day at Noon is 21° : 16′ of *Leo*, which Point of the Ecliptic I bring to the Meridian, and there holding it faſt, I fix the Hour-hand to XII, and thus it is rectified for that Day :———Then I turn the Globe, 'till the Index points to the Hour of VI.——But I ſee no Moon above the Horizon.——Of Courſe, I turn the Globe 'till the Patch comes into the Eaſtern Part of the Horizon, where it ſhews the Moon riſing at a few Minutes after X, upon the E. N. E. Point of the Compaſs nearly, and about 21 Degrees of Amplitude North. — Am I not ſo far right, *Cleonicus?*

Cleon. You are very near the Matter : — But if you would be very exact, you, muſt make ſtill more Allowance for the Moon's Motion for 10 Hours, inſtead of Six, which will carry her a little farther Eaſtward, and make her riſe ſomewhat later.——

Euphroſ. I ſee the Neceſſity of it, from what you have ſaid, and I was going to ſay, that I had Nothing now to do, but to bring the Patch to the Meridian, but I obſerve, that will take up 7 Hours Motion of the Globe, which added to the former 10, make 17 Hours, from the Noon of the former Day; therefore $\frac{3}{4}$ of the Moon's daily Motion, or near 10 Degrees, muſt be added to her Place the foregoing Day, which will give the 20th Degree of *Taurus* ♉, in the Ecliptic, for the Moon's Place in her Orbit juſt below, to which I muſt now remove the Patch, and having brought it under the Meridian, I ſee the Hour-Index points to about Half an Hour after Five,

for

for the Time of her Southing, on the 15th Day; and this, I obſerve, is confirmed by the Time of the Moon's Southing in the common Almanack, prefixed to *Parker's Ephemeris.*——Then next, I obſerve, that in bringing the Patch to the Weſtern Horizon, there will be about $7\frac{1}{2}$ Hours Motion of the Globe required, which muſt likewiſe be allowed for in the Motion of the Moon, which, added to the Former, make out the Motion of the whole Day, or 14 Degrees.——And thus I find the Time of her Setting to be about One o'Clock on the 15th Day.——Hence alſo it appears by the by, that on the Day before, or 14th Day, the Time of her Setting was about Mid-day.

Cleon. I am glad to ſee you are ſo dextrous, my *Euphroſyne*, at the Solution of Lunar Problems; and though they are not ſo readily performed as thoſe of the Sun, yet are they, in their own Nature, more curious, and very eaſy, with a little Practice, by Means of the *Ephemeris*, and the moſt difficult Part is now over. In the Solution of theſe Sort of Problems, there is alſo greater Variety than in thoſe of the Sun; for here we may obſerve, that as the Moon's Orbit makes an Angle with the Ecliptic, we enquire for the Latitude as well as the Longitude of the Moon, and you obſerve, in the *Ephemeris*, that her Latitude, on the 14th Day of *Auguſt*, at 12 o'Clock, is 4° : 14′.—

Euphroſ. Very good; I ſee it is; but what are thoſe numerous Lines croſſing the Ecliptic at right Angles all around the Globe, and others that run parallel to the Number of 8 on either Side, and what is their Uſe?

Cleon. They are called by Aſtronomers the *Zodiac*, and they are drawn at the Diſtance of a Degree from each other, and thoſe which are perpendicular to the Ecliptic ſerve to meaſure the Degrees of Latitude in the Moon and Planets, none of which ever deviate ſo far as 8 Degrees from the Ecliptic; and therefore, wherever the Places of theſe celeſtial Bodies are found, their Latitudes from the Ecliptic are by theſe Lines eaſily ſhewn; as alſo the Longitude, and many other valuable Uſes are to be made of them, as we ſhall find in our future Practice. This *Zodiac* is one of the many great Inventions of the late Dr. *Halley*, and has within about a Year ſince, been

placed upon Mr. *Senex*'s celeſtial Globe, for rendering its Uſe more extenſive and perfect.

Euphroſ. This muſt be a very great Improvement of the Globe, as I myſelf am Witneſs; ſince, by thoſe Lines, I ſee the ſame Latitude of the Moon expreſſed on the Globe, as I do in the *Ephemeris*; whereas, without thoſe auxiliary Lines, I could not have known what her Latitude had been, without the Trouble of meaſuring it by the Degrees on a Quadrant of Altitude.——I likewiſe ſee, at the ſame Time, what Latitudes correſpond to the Place of the Moon in every Part of her Orbit, or Diſtance from her Node, which muſt be a very great Satisfaction and Pleaſure to all Lovers of Aſtronomy.

Cleon. By Means of the ſilken String, you will be enabled, at all Times, to obſerve the Declination of the Moon from the Equinoctial Line, which will be ſometimes leſs than that of the Sun; and be ſometimes North, when that of the Sun is South, and *vice verſâ*.

Euphroſ. Well! let me enquire what the Declination of the Moon is for the 14th Day of *Auguſt* at Noon.——I bring the Patch to the Meridian, and there find it under 11° : 40′, which therefore is the Declination for that Time.——Indeed, by this artificial Lunar Orbit, I can eaſily ſee, that the Declination of the Moon may be ſometimes 5 Degrees greater, and ſometimes ſo many Degrees leſs than that of the Sun.——I alſo ſee, that her Declination may be North, while her Latitude is South, and the Contrary;——and were the Lunar Orbit to interſect the Ecliptic in the Equinoctial Points, it would cauſe the Moon to appear much nearer our *Zenith*, at ſome Times, than ever the Sun has been ſeen; and to ſhew her but at a ſmall Diſtance above the Horizon at other Times:—And ſuch Appearances of the Moon I have really ſeen, and wondered, at the ſame Time, how it came to be ſo; nor do I yet ſee the Reaſon plainly, unleſs I can ſuppoſe the Nodes of the Moon's Orbit to change their Places, and at Times get into the Equinoxes.

Cleon. You have now hit upon the very Thing that cauſes ſuch a pleaſing and wonderful Variety in the Lunar Phænomena.——The Nodes of the Lunar Orbit are not fixed, but conſtantly in Motion in a retrograde Manner; *i. e.* they go backward,

backward, or contrary to the Order of the Signs, and at such a Rate, as to be every Year 20 Degrees more backward in the Ecliptic than before. This you may be easily convinced of by the *Ephemeris*; for the Place of the ascending Node for the first Day of *January*, for the present Year, was in 15° : 51′ of *Cancer*, and through every Month of the Year it retrogrades, 'till the last Day of *December*, it is found in 27° : 30′ of *Gemini*; and thus, in the Space of about 18½ Years, the Nodes go backward through all the Points of the Ecliptic, and consequently, once in that Time the ascending Node will be in the Beginning of *Aries*, and shew the Moon nearer to, or farther from our *Zenith*, by 5 Degrees, than ever the Sun appears; but, when it possesses the autumnal *Equinox*, the Contrary will happen; and there are few People that live to the Age of 30 or 40 Years, but what must remember to have seen this Variety of Lunar Altitudes, as they happen so remarkably different, in the Space of little more than nine Years.

Euphros. I shall not trouble you with it now, *Cleonicus*; but, for my own Amusement at leisure Hours, I shall put this Lunar Orbit into all its different Positions, with regard to the Ecliptic, to see from thence all the Variety of Appearance that can arise, with regard to her Altitudes, Rising, Setting, *&c.*

Cleon. Now you talk of her Rising and Setting, I must observe to you, that there will be something very peculiarly strange and entertaining result from your Experiments of that Kind; especially, if you enquire how these Phænomena will be circumstanced, in regard to the different Parts of the Earth, by rectifying the Globe to many different and extreme Degrees of Latitude.——One Phænomenon of this Kind you have heard much talk of, usually called the *Harvest-Moon*, and sometimes the *Shepherds*, and the *Hunters-Moon*, which, if you remember, I told you I should reserve for an Explication, 'till I came to the Use of the celestial Globe. This being the only Instrument by which it can be naturally represented and clearly understood.

Euphros. Nothing will be more grateful to me, than the Explanation of a Phænomenon I have so long desired to understand, and which is looked upon almost as a Prodigy among Country People.

Cleon. As much as this has amuſed and ſurpriſed many People, and as prolix and tedious as ſome Diſcourſes have been to explain it, you will find, that there is nothing ſtrange or wonderful in the Nature of the Thing itſelf, and that it requires but very few Words to explain it, at leaſt to the Apprehenſion of the Fair Sex.——For this Purpoſe, take your Globe, and rectify it for the Latitude of *England*, and turn it about, 'till the two equinoctial Points are in the Horizon, the Vernal *Equinox* in the Weſtern Part, and the Autumnal *Equinox* in the Eaſt.

Euphroſ. This I have done;——and what follows then?

Cleon. You will then obſerve, that the Ecliptic has a great Elevation above, or makes a very large Angle with the ſouthern Part of the Horizon, *viz.* about 62 Degrees.——Now turn the Globe about, ſo that the *Equinoctial* Points may interchangeably poſſeſs the ſame Parts of the Horizon as before, *i. e.* the Autumnal *Equinox* in the Weſtern Point, and the Vernal *Equinox* in the Eaſtern Point.

Euphroſ. This is eaſily done;——and I gueſs what you have next to tell me.——Is it not to obſerve how ſmall the Angle is which the Ecliptic now makes with the Horizon?

Cleon. That is the very Thing, my *Euphroſyne*; for on theſe two different Poſitions of the Ecliptic, with reſpect to the Horizon the whole Affair depends, which we ſhall render more eaſily to be underſtood, by exemplifying this Matter in the following Manner.——In the firſt Caſe, ſuppoſe there was a Full Moon on the Day of the Vernal *Equinox*,——then I bring the firſt Degree of *Aries* to the Meridian, and ſet the Hour Index at XII.——I turn the Globe, 'till that Point touches the Horizon, and ſhews the Sun Setting therein;——then you will eaſily underſtand, that the Full Moon is in the firſt Point of *Libra*, and Riſing in the Eaſtern Point of the Horizon, and juſt at Six o'Clock.

Euphroſ. All this I perceive very plainly. What am I to obſerve next?

Cleon. You will now recollect, that ſince the Moon moves in one Day about 13°, therefore the next Day at Night, at Six in the Evening, the Moon will be advanced to 13° of *Libra*; and therefore, to ſhew her Riſing in the Horizon, the Globe

muſt

must be turned about, 'till that Degree of *Libra* appears in the Horizon;———then look at the Hour-Index, and you will see it point to 16 Minutes past VII.——Whence you observe, the Time of her Rising is one Hour and a Quarter later than on the Equinoctial Day, or Evening before.

Euphros. All this is very easy; and I presume you are next to shew the same Thing, or the Difference in the Time of her Rising for the other Equinoctial Day.

Cleon. You rightly judge of my Intention.———I bring the Point of *Libra*, which the Sun is now supposed to possess, and place the Index to the Hour of XII.———Then turning the Globe, I bring that Point to the Western Point of the Horizon to shew the Sun there Setting, with the Index pointing to VI.——Then in the Eastern Point of the Horizon, the Moon is rising, at the same Time, in the first Point of *Aries*.——Then, since the Moon will, by Six o'Clock the next Evening, have advanced 13° forward, I must turn the Globe, till the 13° of *Aries* rises;———and I turn it, you see, but a very little before the Moon appears; for look at the Index, and you will see it point out the Time of her Rising, which is but about 22 Minutes after VI.

Euphros. The whole Thing is now unravelled.———By this Experiment, I at once see the Nature of this Phænomenon.———The small Angle which the Ecliptic now makes with the Horizon is the Reason why so small a Motion of the Globe is necessary to make the Moon rise after the setting Sun.———But 22 Minutes Difference in Time now, and 76 in the former Case.———Hence it is very evident, that for several Nights about the Autumnal Equinox, we are no sooner bereft of the Sun-beams, but the Moon illumines the Sky with her silver Light.—The Contrary of all which must happen at the Vernal Equinox, where so large a Space must intervene between the Setting of one Luminary, and the Rising of the other; and consequently, I'm fully satisfied from hence, why those lightsome, pleasant Evenings should occasion the forementioned Appellations of the Moon, as being so particularly serviceable to Shepherds, Sportsmen, and People in the Harvest-field.———And I farther observe, that this small Difference of Time between the Setting of the Sun and the Rising of the Moon, in the autumnal Season,

will

will be ſtill farther leſſened, when the Nodes of the Moon are in the Equinoctial Points, *i. e.* when the aſcending Node poſſeſſes the firſt Point of *Aries*; for then the Moon's Orbit will be moſt oblique to the Horizon, or make the leaſt Angle with it.

Cleon. Your Readineſs in apprehending the Reaſon of theſe Phænomena ſuperſedes the Neceſſity of inſiſting any longer upon this Subject.

Your next Exerciſe will be the Planetary Praxis, which will afford you ſuch Inſtruction, as will be attended with equal Pleaſure and Uſe, and be a convincing Proof, how neceſſary a Part the celeſtial Globe muſt be of an Apparatus for the Education of young Gentlemen and Ladies.

DIALOGUE VII.

The Uſe of the CELESTIAL GLOBE, *in the Solution of* PROBLEMS *relating to the* PLANETS *and* COMETS, *exemplified in that which lately appeared.*

Cleonicus.

THE preſent Hour, my *Euphroſyne*, is deſtined for your farther Inſtruction in the Doctrine of practical Aſtronomy. You know full well how uſeful the Celeſtial Globe is, in the Reſolution of ſuch Problems as relate to the Sun and Moon; and you will now find it very eaſy to apply that excellent Inſtrument, in the ſame Manner, to ſolve all ſuch Queſtions as relate to the Planets and Comets.

Euphroſ. I make no Doubt but I ſhall; and it is a particular Pleaſure to find, that Problems of ſo ſublime a Nature admit of a Solution with ſuch great Facility by the Globe. The happieſt Invention ſure that ever Mankind was bleſt with! And it is no Wonder, when we ſee thoſe noble Inſtruments in the Study of every Gentleman and Lady of Taſte. —— With regard to the Planets, I preſume, there will be no great Difficulty;

culty; but how you are to inculcate the Use of the Globe for the Comets, I am quite at a Loss to guess, as I have scarcely ever heard such a Thing, or ever find the Mention of it in those Authors, you have recommended me, to read upon the Subject.

Cleon. Never fear, my *Euphrosyne*, though the Subject be new, it is not difficult; and you may have the Pleasure of being the first of your Sex, to enjoy the Benefits of the Praxis on Cometary Astronomy. The Comets are, properly speaking, no other than a very large and numerous Class of Planets, whose Motions, performed in the Heavens, I have already explained unto you; and it is the Glory of the present Age to have the first and fullest Confirmation of this new Species of Astronomy confirmed, as we may say, by Experiment. I mean, by the Return of that Comet, which I formerly told you was expected, and which, during the Month of *May* last, made its Appearance above our Horizon, according to the Time calculated, and predicted by the late great Dr. HALLEY.

Euphros. The Novelty, as well as the Usefulness of such a Subject, must give the highest Pleasure to every young Tyro in Astronomy.———The Return of a Comet has a Sound, great as the Event itself; and if I can be so happy, as to understand by the Globe the several Appearances of such a wonderful Phænomenon, in its Passage through the visible Part of our System, it will be the Completion of my highest Expectations.———But, I suppose you will begin with the Planets first.

Cleon. Yes; but that will prove a short and easy Task, as you have been already instructed in the Manner of finding the Places of the Planets for any given Day in the *Ephemeris*; and likewise, at the same Time, the Manner of finding their Places in the Heavens, by an artificial *Planetarium* *, and their Positions and Aspects with respect to each other. The Use of the Globe for this Purpose is only for the Sake of Variety, and shewing the same Things, if possible, in a more natural and easy Manner. —— The first Thing, therefore, that I shall enjoin you is, to take your Paper of Patches and your *Ephemeris*, and

* *See* Dial. XIII, *p.* 85, 86, 87, *of the* Lady's Philosophy.

and lay them before you on the Table by the Globe.——Then find each Planet's Place ſeparately, for the firſt Day of *October* next.——Then ſtick a Patch on each Planet's Place in the Ecliptic, denoting the Size of the Planets.——Then, laſtly, rectify the Globe for the Hour of X, in the Evening of the aforeſaid Day.

Euphroſ. This Problem, I ſee, conſiſts of four Parts, to each of which I ſhall readily addreſs myſelf.——Here are the Patches, in the firſt Place;——and here alſo the Part of the *Ephemeris*.——Now, let me ſee for *October*, the 1ſt Day; I obſerve, in the Column of *Saturn* Retrograde (℞). I find his Place is 10° : 36′ of *Piſces* (♓).——This Place I find in the Ecliptic on the Globe, and there I ſtick a large Patch.——So far I am right, with regard to this Planet, *Cleonicus*.

Cleon. I ſee you are extremely ready at finding the Planets Places. You want none of my Inſtructions, but may proceed in the ſame Manner to find the Places of all the Reſt on the Globe.

Euphroſ. In the next Column, I find *Jupiter* ♃ poſſeſſes 13° : 38′ of *Capricorn* ♑, and becauſe he is the largeſt Planet, I ſhall put a Patch of the largeſt Size on that Point of the Ecliptic on the Globe.——In the following Column, I find *Mars* ♂ in 9° : 29′ of *Leo*; in which Part of the Ecliptic on the Globe I ſtick a ſmaller Patch.——In the next Place, *Venus* ♀, I obſerve, in 12° : 31′ of *Scorpio*; where I ſhall place a Patch one Size larger.——And laſtly, the little puny Planet *Mercury* ☿, is juſt entered the 22° of *Virgo*. On the firſt Minute of that Sign, therefore, I place the ſmalleſt Patch, and thus, I think, *Cleonicus*, we have brought down all the Planets from the Heavens and conſigned them to their proper Places on the Surface of the celeſtial Globe for the Time appointed.

Cleon. You have performed this Part very accurately indeed.——Your next Buſineſs now is to rectify the Globe for the given Day.

Euphroſ. This I can ſoon do.——I elevate the North Pole to 51° ½——in the firſt Column for *October*; againſt the 1ſt Day, I ſee the Sun's Place in 7° : 58′ of *Libra*, on which Point of the Ecliptic I ſtick a Piece of red Paper, to denote the

the Sun, and bring it to the Meridian, placing at the ſame Time the Index to the Hour of XII,———and thus the Globe is rectified as you require.

Cleon. It is ſo.———And now Nothing remains but to turn it round, 'till the Index points to the Hour of X at Night, and then you will ſee which Planets are viſible above the Horizon, and which are not; alſo the Time when they riſe, ſouthe, ſet, *&c.* when they may be ſeen with a Teleſcope, and when not; with many other uſeful Particulars.

Euphroſ. That is done.———And now I obſerve the largeſt Patch at the weſtern Part of the Horizon, which ſhews *Jupiter* near ſetting at that Time.———The next larger Patch, I ſee, is a little on the Eaſt-ſide of the Meridian; by which I am informed, that the Planet *Saturn* is, at that Hour of the Night, nearly South; but, as for the reſt of the Patches, I ſee none above the Horizon, by which I am ſatisfied they are all inviſible below for that Time of the Night.——I learn from hence, that *Saturn* then is in the beſt Situation to be obſerved by the Teleſcope; and that *Jupiter* will be too low in the Atmoſphere, and too near the Horizon to be well obſerved, even at 9 o'Clock.———I move the Globe to bring *Jupiter* on the Meridian, and it ſhews him full South, at Half an Hour after VI, on that Day; at VII nearly, I ſee the Planet *Venus* ſetting,———and the Planet *Mercury* riſing at Half an Hour after XII.———The Planet *Mercury* riſes about V, a little before the Sun.——— And thus I am inſtantly ſatisfied of the Appearance of thoſe Planets for that particular Time; and can eaſily find them for any other.——— What is there farther to be done in the planetary Praxis?

Cleon. Nothing material. One Thing only may be obſerved, that their Orbits do not coincide with the *Ecliptic*; yet, as they deviate to ſuch ſmall Diſtances from it, it is not worth while to conſider it in Practice, as it makes no ſenſible Difference on the Globe *.———We therefore next proceed to the

* But leſt any of our Readers ſhould have the Curioſity of performing theſe Problems according to the preciſe Truth, and would chuſe to repreſent their Orbits by a ſilken String, or Thread, as was directed in the Caſe of the Moon; it will be neceſſary to give here the

Comet, and your Buſineſs now will be to learn, how you trace the Courſe of a Comet through the Heavens, on the Surface of a celeſtial Globe, and ſhew the ſame, during the whole Time of its Appearance. Of this you will have an Example, ſufficiently noble and inſtructive in the Comet, which lately made its Appearance.———This Comet was ſeen at *Boſton* in *New-England*, in the Months of *October* and *November*, 1758, in its Return to the Sun, when the Orbit of the Comet was but a ſmall Diſtance from that of the Earth, in the Part where they obſerved it; after which, it approached ſo near the Sun, as to be loſt in its Beams for ſome Time, 'till after paſſing the *Perihelion*, it became again viſible in its *retrograde* Courſe from the Sun, towards the latter End of *March*; when it was ſeen, and obſerved by many Gentlemen in the *Weſt-Indies*, and particularly by Dr. *Brown* at *Jamaica*, it was obſerved, during the whole Month of *April*, and Part of *May*, whoſe Latitude rendered it viſible to him, while it was for the greateſt Part of the Time inviſible to us, by reaſon of its ſouthern Courſe thro' the Heavens. This Gentleman has given us an Obſervation on the Comet, on the 31ſt of *March*, by which you will eaſily find its Place in the Heavens, on the Surface of the celeſtial Globe.———But firſt, you muſt rectify the Globe for the Latitude of *Jamaica*, which is 17° : 30′, as you will hereafter ſee on the terreſtrial Globe.

Euphroſ. As you give me the Latitude, I can as well rectify the Globe for the Latitude of *Jamaica*, as for that of *England*. ———Therefore, I bring 17° : 30′ to the Horizon, which ſhews the Elevation of the Pole for that Place.———Then on the

the Place of the Nodes, and Inclination of the Orbit for each particular Planet as below.

				°	′
The Place of the Node of the Orbit of	*Mercury*	☊	———	15	2
	Venus	♊	———	14	26
	Mars	☊	———	18	30
	Jupiter	♋	———	7	20
	Saturn	♋	———	21	50
The Inclination of the Orbits of	*Mercury*	———	———	6	54
	Venus	———	———	3	24
	Mars	———	———	1	52
	Jupiter	———	———	1	20
	Saturn	———	———	2	30

the 31st of *March*, I see the Sun's Place is in 10° : 29′ of *Aries* ♈, which, therefore, I bring to the Meridian, and fix the Index to XII.——Thus it is rectified for the Noon of that Day.——What is to be done next, *Cleonicus?*

Cleon. At Five in the Morning, that Gentleman observed the Comet's Altitude was 22° : 50′, and its Azimuth 71° S. E.——By this, you will readily enough find its Place in the Globe, from what you have already learned.

Euphros. I believe I shall be able to assign its Place with a little Recollection.——The Time was Five in the Morning; therefore, I must turn the Globe about, 'till the Index points to the Hour of V.——In the next Place, the Comet's Azimuth, it seems, was 71° from the South towards the East.——This requires the Quadrant of the Altitude to be fixed in the Zenith,——which I have done.——Then I bring the said Quadrant to cut the Horizon in 71° from the South Point;——and lastly, since the Altitude of the Comet was then 22° : 50′ under that Point in the Quadrant, will be the Comet's Place, where of Course I must stick a Patch to represent it:——And I think I am so far right.

Cleon. You are, my *Euphrosyne*, right in every Particular but One.——Your Comet has got no Tail; but that we shall dispense with for the present.——You have justly assigned its Place for that Time, which you'll observe to be in the *Zodiac*, with about 3° N. Latitude from the *Ecliptic*, and in about the 27° of *Capricorn*.——Now, shew me the Time that it rose in the Horizon of *Great Britain*, on the above-mentioned Day.

Euphros. That I shall instantly do.——The Globe is now elevated for the City of *London*.——I next bring the Comet to the western Part of the Horizon, and find it there between Two and Three o'Clock in the Afternoon; therefore, it could not be seen in the Evening.——Next, I bring it to the eastern Horizon, and then observe, the Index points to 45′ after III.——This, therefore, was the Time of its Rising that Day.——But, pray, how came the *British* Astronomers not to observe it, or mention its being seen at that Time in *England?*

Cleon. This I cannot easily account for, unless it was, because the Sun was near the Horizon, and caused a Twilight,

or Dawn, too ſtrong for it to be obſerved; as likewiſe, the Vapours of the Atmoſphere might be another Reaſon for rendering it incapable of being ſeen; but it was quite otherwiſe in the Latitude of *Jamaica*, where the Comet was high, the Sun much below the Horizon, and the Morning dark at the Time of obſerving it. — You have thus found one Place of the Comet, and by finding one other, you will be able to repreſent the Tract which is deſcribed in the Heavens between both.

Euphroſ. For that Purpoſe, I ſuppoſe, it will be neceſſary, that you mention the like Obſervation made on the Comet at ſome other Time.

Cleon. That is a Point certainly neceſſary, and I ſhall give you my own Obſervations for that Purpoſe, which was accurately made the 6th Day of *May*, at Ten in the Evening, by meaſuring its Diſtance from two Stars in the Back of *Hydra*, which you ſee marked with the two *Greek* Letters μ and ν, and by an Azimuth Quadrant, its Altitude was found about 16°, and its Azimuth 37° S. W. from whence you will eaſily find its Place on the Globe, as in the foregoing Caſe.

Euphroſ. I ſhall immediately ſet about it.———I elevate the Pole to the Latitude of *London*.———The Sun's Place, on the 6th of *May*, is 15° : 35′, which I bring to the Meridian, and ſet the Index to XII.——Then I revolve the Globe, 'till the Index points to X at Night.———The Quadrant of Altitude being fixed for the Zenith, I bring it to the 37° in the Horizon, from the South towards the Weſt.———And, laſtly, under the 16°, on the Edge of the Quadrant, I put a ſmall Patch, which muſt, I preſume, repreſent the Place of the *Comet* where you ſaw it.

Cleon. It will ſo, as nearly as any Thing can be done on the Globe:———And you obſerve the Patch is but a little above the two Stars juſt now mentioned.

Euphroſ. I ſee it very plainly: But how am I to draw the *Path* of the *Comet* after all this?

Cleon. You muſt know, that the apparent *Path* of the *Comet* through the Heavens is pretty nearly a great Circle of the Sphere; and therefore, as you have two Places of the Comet repre-

* See the *Print* of the *Comet's Path*, taken from the Globe, in the *Magazine* for the Month of *May*.

represented on the Globe, by the two Patches, if you bring the Centers of both those Patches nicely into the Horizon, you may, with a Pencil, draw a Line from one Patch to the other by the Horizon, and that will tolerably well represent the apparent *Place* of the *Comet*, from one Time to the other; that is, from the 31st of *March* to the 6th of *May*.

Euphros. This I will endeavour to do:———By raising and depressing the Pole, and adjusting the Patches towards the Horizon, I find the Problem not very difficult.———I have, at length, brought them nicely to coincide; one in the eastern, and the other in the western Part of the Horizon.———From the eastern Patch, I draw a Line by the Frame of the Horizon to the western Patch, and it shews a vast Tract of the Heavens, through which the *Comet* passed in so short a Time, *viz.* more than 150°, which shews the *Motion* of the *Comet* to have been very quick; and I observe, it passed through the following Constellations in its Way, *viz.* by the *Tail* of *Capricorn*, the *Tail* of *Piscis Australis*, by the *Head* of *Indus*, the *Neck* and *Body* of *Pavo*, through the *Neck* of *Apus*, below *Triangulum Australem*, above *Musca*, by the Lowermost of the *Croziars*, across the *Hind Legs*, and through the *Tail* of *Centaurus*; from thence between the two Stars in the *Back* of the *Hydra* beforementioned; after this, it passed on to *Sextan*'s *Urania*, and then to the Ecliptic, near *Cor Leonis*, after which, you can better tell what became of it than myself.

Cleon. Your Performance is excellently good, my *Euphrosyne*.———Through those very Constellations, Dr. *Brown* observed it to pass from Day to Day, during the Month of *April*, as appears by his Letter, containing the Observations which he made, and are now published for the Satisfaction of the Curious *.—You will easily observe from the Whole, that the South Latitude of the *Comet* being so very great, appears now to be the Reason why we in *England* could not see it in that Month; and that it was just about the Beginning of *May*, when it emerged again above our Horizon; after which, it regaled our Eyes with a faint Appearance, 'till towards the latter End of that Month, and gradually disappeared by its distant Recess.———Thus much will be sufficient for giving you an Idea of the

* See the Beginning of the *Miscellany* for the last Month.

the Manner, in which the various *Phænomena* of *Comets* may at any Time be repreſented on the Globe: Beſides which, and the *Cometarium* heretofore deſcribed, you may ſtill receive a much clearer Inſight into the *Nature* and *Motions* of a *Comet*, by conſulting the ſeveral Prints which have been publiſhed, with regard to the preſent *Comet*, and particularly that, in which the *Orbit* of the ſaid *Comet* is elevated, and its daily Motion marked out, together with the Ecliptic, divided into all the Months and Days of the Year, which now you are very well qualified thoroughly to underſtand *. There is yet a farther Uſe of the celeſtial Globe, that will afford you ſome Amuſement; at leaſt it will be neceſſary, that a young Lady of your Taſte ſhould not be unacquainted with it; I mean, the Solution of thoſe Problems, which relate to the Stars, which I intend for the Improvement of the next Opportunity.

DIALOGUE VIII.

The USE *of the* CELESTIAL GLOBE, *in the* SOLUTION *of* PROBLEMS *relative to the* STARS.

Euphroſyne.

I Cannot help thinking, whenever I caſt my Eye on the celeſtial Globe, but that it is an amazing Effect of Art. He muſt have had a very happy Thought, who could firſt contrive to repreſent, in ſo natural a Manner, the vaſt expanded Canopy of the Heavens, with all its reſplendent Furniture, in ſo ſmall a Compaſs as the Superficies of an artificial Globe. I have but one Objection, or rather, but one Thing to remark, and that is concerning the Form of the Globe. The Surface of

* *The Prints, here referred to, are a View of the Solar Syſtem and Orbit of the Comet; with its proper Elevation, truly repreſenting all its Appearances for any Part of the Year.*

The Print *of the* Comet *in the* Magazine *for the Month of* May; — *and the* Print, *which we gave, to illuſtrate Dr.* Brown's Letter, *in the laſt* Magazine.

of the Globe is *convex*; and that of the Heavens *concave*; how then can one be an adequate Repreſentation of the other?

Cleon. This is very ingeniouſly obſerved, my *Euphroſyne*; but you will ſee the Anſwer is very eaſy. There is no Difference, in Reality, between the convex and the concave Surface, any more than what the *Metaphyſicians* call *Modal*, and only exiſts in the *Form*; the optical Effect of viewing any Thing, upon a convex or concave Surface, is the ſame to an Eye, placed in the Center thereof: Suppoſe, for Inſtance, you had a Sphere of Glaſs, and your Eye was placed in the Center, it would be the ſame Thing, if the Stars were marked with a Diamond on the external or internal Part of the Surface, *i. e.* on the convex or on the concave Side; and it is the ſame Thing, in regard to the artificial Globe. For, if that Globe was to have Holes pierced through the ſeveral Stars, and the Globe properly rectified for a given Time, an Eye, placed in the Center, would view the Stars in the Heavens through thoſe Holes reſpectively; each Star in the Heaven anſwering to its Repreſentative on the Globe; and therefore the Longitude, Latitude, and other Affections of the Stars, may all be determined by Means of the Apparatus to the artificial Globe, and made to correſpond exactly with what we obſerved in Nature, or in the Heavens themſelves.

Euphroſ. You take a good deal of Pains to inform my unexperienced Judgment in Things of ſo ſublime a Nature:—— But to come to the Point: Is there any Difficulty, ariſing from any different Methods in ſolving Problems, relating to the Riſing, Setting, Southing, *&c.* of the Stars, more than what you have already ſhewn me, in regard to the Sun, Moon, and Planets?

Cleon. Very little, my *Euphroſyne*; for which Reaſon we ſhall ſoon diſpatch that Affair. You have already been ſufficiently taught the Doctrine of the Sphere, and the Uſe of the ſeveral Circles, particularly the *Circles of Latitude*, which belong to the Ecliptic; and therefore will here need no farther Deſcription; and, I dare ſay, if I require you to aſſign me the Latitude and Longitude, the Declination, right Aſcenſion, the Time of Riſing, Southing, *&c.* of any particular Star, you will not need my Aſſiſtance for that Purpoſe. For Example,

ample, you may try your Skill with the Star *Arcturus*; one of the moſt remarkable Stars of the firſt Magnitude, in the *Skirts* of *Böotes*.

Euphroſ. I am proud of the Taſk you have ſet me, and will give you a Proof of my Proficiency in the beſt Manner I can. ——The firſt Thing I have to do, I am aſſured, muſt be to rectify the Globe for this Place; and ſince a Star is the Subject, and can be ſeen only at Night, therefore ſome Hour of the Night muſt be ſuppoſed, which ſhall be Ten o'Clock this very Evening.——And now the Globe is rectified for that Time. And here, I ſee, *Böotes*, with his *Courſers*, and conſequently, that bright Star *Arcturus* ——I remember you told me, if I brought the Pole of the Ecliptic to the Meridian, and fixed the Quadrant of Altitude over it; then, if I laid the Edge of the Quadrant upon the *Phænomenon*, (whether the *Sun* or *Star*) it would give me the Longitude, or Place thereof in, or reduced to the Ecliptic. —— By doing this, I find the Longitude of *Arcturus* is about 20° of *Libra*; or 200°, from the 1ſt Point of *Aries*; and that its Latitude from the Ecliptic is about 30°. ——Again, if I bring the Star to the Meridian, I obſerve its Diſtance from the Equinoctial Line is about 20° : 28′, which is its Declination Northward.——At the ſame Time, I obſerve the Meridian to cut the 211° : 9′, which is therefore the right Aſcenſion of *Arcturus*.

Cleon. Admirably well, my *Euphroſyne*. —— Now for the Time of its Riſing, Setting, and Southing, for the preſent Day, *Auguſt* the 9th.

Euphroſ. That I will proceed to :——But firſt, I muſt look for the Day of the Month on the Horizon, againſt which I ſee 16° : 30′ of *Leo*, the Place of the Sun this Day at Noon, which Point of the Ecliptic I bring to the Meridian, and ſet the Hour-hand to XII. —— Then I turn the Globe, 'till *Arcturus* appears in the eaſtern Horizon, and then the Index points out the Time of his Riſing, *viz.* IX o'Clock this Morning.——I bring this Star to the Meridian, and the Index pointing to V in the Afternoon, ſhews that to be the Time of its Southing.——Laſtly, I turn the Globe, 'till *Arcturus* is in the weſtern Horizon, and the Index pointing to II, gives the Time of its Setting To-morrow Morning.——The

Amplitude

Fig. I.

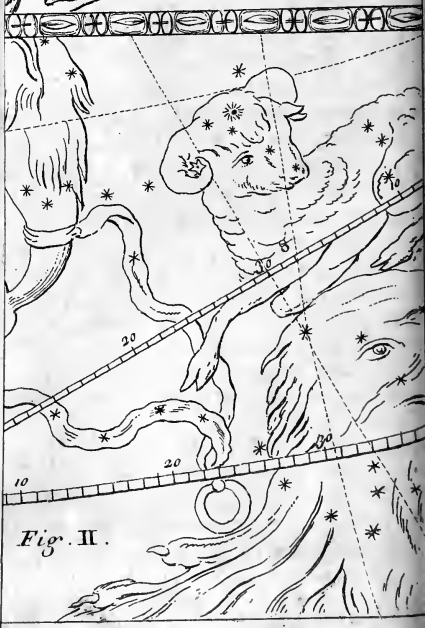


Fig. II.

Amplitude of its Rising is near 34° to the North; and so much is the Amplitude of his Setting of Course.

Cleon. You are so ready in the Praxis of the Stars, that I have little more to observe to you on that Head. It may not be amiss, however, to hint to you, that, when a Star is situate between the Ecliptic and the Equinoctial, its Latitude may be of one Denomination, and its Declination of another; thus, for Instance, *Aldebaran* in the *Bull*'s Eye, has South Latitude and North Declination.——Another Thing I may observe to you, and that is; there is a Sort of *Poetical Astronomy* with regard to the Stars; or, there is what we call the Poetical Rising and Setting of the Stars, which was much taken Notice of by the antient Poets, Historians, and Husbandmen, (which you will readily observe in the Writings of *Hesiod*, *Homer*, *Ovid*, *&c.*) as it was the principal Method, by which People, in that Part of the World, and in those Days, distinguished the Changes and Diversity of the Seasons. Of these Risings and Settings, there were three Kinds, as follow. First, the *Cosmical* Rising of a Star, which is, when it rises with the Sun; but the *Cosmical* Setting is, when it sets at the Time the Sun rises. Secondly, the *Acronical* Rising of a Star is, when it rises at the Time the Sun sets; and the *Acronical* Setting is, when it sets with the Sun.

Thirdly, the *Heliacal* Setting of a Star is, when it approaches so near the Sun, as to disappear in its Beams; and when it emerges from its Beams, or again becomes visible, then it is said to rise *Heliacally*.

But these Things we shall illustrate hereafter. To be farther insisted upon at present would be mispending of Time, and tho' you are well versed in those Poets, yet, till you have learn'd their astronomical Distinctions of the Seasons, by the Rising and Setting of the Stars, and by the Globe properly constructed to shew them, it will not avail you to have any Examples of this Sort to practise; but when you have that, it will open a fine Field for your *Physico-Poetical* Speculation, and View of distant Times.

Euphros. I will make it my Business to prosecute that particular Part of Study, as I apprehend there will be something very curious:——But what other Problem am I next to practise on the Globe?

Plate XXXVI.

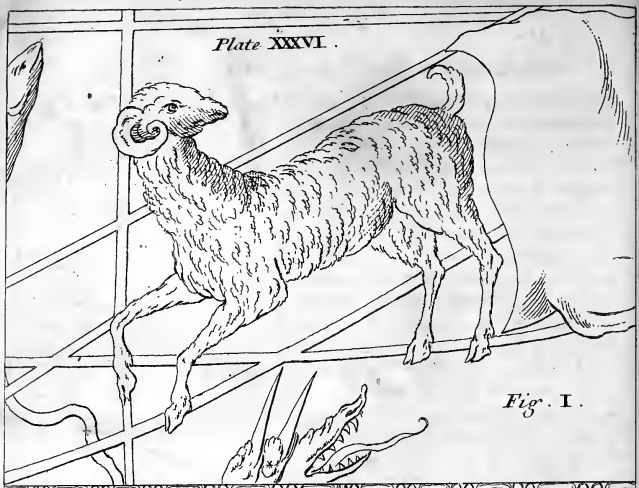


Fig. I.

Fig. II.

Amplitude of its Riſing is near 34° to the North; and ſo much is the Amplitude of his Setting of Courſe.

Cleon. You are ſo ready in the Praxis of the Stars, that I have little more to obſerve to you on that Head. It may not be amiſs, however, to hint to you, that, when a Star is ſituate between the Ecliptic and the Equinoctial, its Latitude may be of one Denomination, and its Declination of another; thus, for Inſtance, *Aldebaran* in the *Bull*'s Eye, has South Latitude and North Declination.——Another Thing I may obſerve to you, and that is; there is a Sort of *Poetical Aſtronomy* with regard to the Stars; or, there is what we call the Poetical Riſing and Setting of the Stars, which was much taken Notice of by the antient Poets, Hiſtorians, and Huſbandmen, (which you will readily obſerve in the Writings of *Heſiod*, *Homer*, *Ovid*, *&c.*) as it was the principal Method, by which People, in that Part of the World, and in thoſe Days, diſtinguiſhed the Changes and Diverſity of the Seaſons. Of theſe Riſings and Settings, there were three Kinds, as follow. Firſt, the *Coſmical* Riſing of a Star, which is, when it riſes with the Sun; but the *Coſmical* Setting is, when it ſets at the Time the Sun riſes. Secondly, the *Acronical* Riſing of a Star is, when it riſes at the Time the Sun ſets; and the *Acronical* Setting is, when it ſets with the Sun.

Thirdly, the *Heliacal* Setting of a Star is, when it approaches ſo near the Sun, as to diſappear in its Beams; and when it emerges from its Beams, or again becomes viſible, then it is ſaid to riſe *Heliacally*.

But theſe Things we ſhall illuſtrate hereafter. To be farther inſiſted upon at preſent would be miſpending of Time, and tho' you are well verſed in thoſe Poets, yet, till you have learn'd their aſtronomical Diſtinctions of the Seaſons, by the Riſing and Setting of the Stars, and by the Globe properly conſtructed to ſhew them, it will not avail you to have any Examples of this Sort to practiſe; but when you have that, it will open a fine Field for your *Phyſico-Poetical* Speculation, and View of diſtant Times.

Euphroſ. I will make it my Buſineſs to proſecute that particular Part of Study, as I apprehend there will be ſomething very curious:——But what other Problem am I next to practiſe on the Globe?

Cleon. One other, the moſt conſiderable and entertaining of all, and that is,———to ſhew me the Face of the Heavens, or what Stars will be viſible on the Firſt Day of *October*, at IX at Night?

Euphroſ. Conſidering the Nature of this Problem, I find it is doing but little more than I have done before; but as it is of ſo general and curious a Nature, I will proceed to it Step by Step.———Firſt, I rectify the Globe to the Latitude of *London*;———then the Sun's Place for that Day at Noon is 7° 30′ of *Libra*, which Point I bring to the Meridian, and ſet the Hour-Index to XII.———Then I turn the Globe about, till the Index points to X at Night,———and there letting it reſt, I ſee, in one View, all the Stars which then appear above the Horizon; together with all the Conſtellations in which they are contained.———This is a noble Problem, *Cleonicus*, indeed! For, as by this, I ſhall be able, on the Evening of any Day, to repreſent the Stars viſible for any Hour of the Night; I can very eaſily learn to diſtinguiſh the Conſtellations in the Heavens, by thoſe on the Globe; at leaſt, I ſhall be able to remember, to what particular *Aſteriſm* any Cluſter, or Aſſemblage of Stars belong, which I at any Time view in the Heavens. Alſo, by this Means, I ſhall imprint in my Memory the Idea of all the principal Stars; eſpecially thoſe of the firſt and ſecond Magnitude, and ſhall ſoon be able to call them all by their Names.

Cleon. This is the grand Deſign and Uſe of the celeſtial Globe, which is, as it were, the *Primer* of Aſtronomy, by which our Youth are inſtructed in the celeſtial Characters, and taught, as it were, to read in the ſtarry Heavens.——— There are yet other nobler Uſes to be made of the celeſtial Globe; one Inſtance I ſhall give you in Navigation, the moſt beneficial of all Sciences, which is, to find the Hour of the Night, by having the Latitude of the Place, and the obſerved Altitude of a Star given.

Euphroſ. As I am not ſo clear in this Problem, as in ſome others, I fanſy, I had better ſee you perform the Thing, than attempt it myſelf, leſt I ſhould blunder about it.

Cleon. The Method is very eaſy. Thus:———Suppoſe in the Night, following the Firſt of *October*, a Perſon was to take the

the Altitude of the Star *Bellatrix*, and find it juſt 30° in the Latitude of 51° : 30′. Then to find the Hour, nothing more is requiſite, than to rectify the Globe for that Day and Latitude.———Then, I bring the Quadrant of Altitude towards the Star *Bellatrix*, in the Left Shoulder of *Orion*, (which is in the Eaſtern Hemiſphere) and then, moving the Globe and Quadrant ſo together, till the ſaid Star comes exactly under the 30° of the Quadrant.———Here I let the Globe reſt; and, if you look at the Index, you will find the Time is thereby ſhewn to be Half an Hour after I. in the Morning.

Euphroſ. By the Manner of your performing this Problem, I ſee it is very eaſy, and will ſhew the Hour of the Night by Land, as well as at Sea; to which Purpoſe, I ſhall now and then apply it by Way of Amuſement.

Cleon. In all theſe Problems of rectifying the Globe for any particular Time, you obſerve, among other Things, the Courſe or Poſition of that remarkable *Phænomenon*, called the *Gallaxy*, or *Milky-way*, among the Stars in the Heavens for that particular Time. Thus, for Inſtance, on the Firſt of *October*, at X at Night, you will obſerve the *Gallaxy* to paſs exactly thro' your *Zenith*, or over your Head in the Heavens, and to cut the Horizon of Courſe at right Angles in the E. N. E. and W. S. W. Points of the Horizon; and it is very rare, that ever you ſee it in ſuch a Poſition, as to divide the viſible Hemiſphere into two equal Parts; as there is but one other Time of the Year in which you can obſerve it.

Euphroſ. This is a curious Affair, and I ſhall diligently attend to ſuch Appearances.———One Thing further I have taken Notice of ſince I have been inured to the Uſe of this Globe; and that is, that ſeveral of the Stars never ſet in our Latitude, but are viſible the whole Night; and, on the other Hand, that ſeveral Stars and Conſtellations never appear above our Horizon, or are ſeen by us at all.

Cleon. It is rightly obſerved, my *Euphroſyne*; and the Reaſon is evident from the very Poſition of the Globe itſelf; ſince all thoſe Stars, which are at a leſs Diſtance from the North Pole, (or whoſe *North Declination* is greater) than the Complement of the Latitude, muſt neceſſarily circulate about the Pole above the Horizon, when on the North Part of the Meridian,

and, on the other Hand, thoſe Stars, whoſe Southern Declination exceed the Complement of the Latitude, can never appear above the Horizon, which you well remember in the Caſe of the *Comet* at our laſt Interview.

DIALOGUE IX.

Of the PRECESSION *of the* EQUINOX, MUTATIONS *of* SEASONS, *and the* Celeſtial Phenomena, *reſulting from the* retrograde MOTION *of the* EARTH'S AXIS *about that of the* ECLIPTIC, *illuſtrated by a* NEW CONSTRUCTION *and* Apparatus *of the* CELESTIAL GLOBE.

Euphroſyne.

I Suppoſe in the preceding Dialogue, you pretty well conſidered the principal Uſes of the ſtellated Globe; not that I am weary of theſe celeſtial Studies; if any Thing farther remains, I ſhall be all Attention to underſtand it.

Cleon. There is only one Particular more of Conſequence to be conſidered, which is a Point of a very curious and ſublime Nature. I have formerly mentioned to you ſomething of this Matter; when I told you, that the North Star, whoſe Motion is now altogether inſenſible, will, in other Ages of the World, have a Motion like the reſt of the Stars, extremely obvious, round other Points in the Heavens.———In ſhort, the whole Affair is this; the Globe of our Earth has another Motion beſides thoſe already mentioned, when we diſcourſed of the *Orrery*, which is properly a *conical Motion* of its Axis about the Axis of the Ecliptic, by which Means, the Poles of the World have a Motion about thoſe of the Ecliptic. This Motion is retrograde, or contrary to the Order of the Signs, and, in Conſequence of this, not only the celeſtial Poles, but the Stars that are near them, and, indeed, all that we ſee in the Heavens,

Heavens, must necessarily appear, in Course of Time, to move forward. This Motion of the Earth's Axis backward is, indeed very slow, being only at the Rate of about 50″ in a Year, or 1° in 72 Years; therefore to move through 360°, or a whole Circle, will require no less than 25920 Years; and in that Space of Time, the Stars will all of them have an apparent Motion quite round the Heavens; from whence you will understand, that those, who live in the different Parts, or Ages of this great Period, will necessarily see the Stars in different Parts of the Heavens; for since the Place of each Star moves forward one whole Degree in 72 Years, the Change of their apparent Places will be very evident in the Space of one Century, and therefore, from one Age to another, the Longitude of the Stars will be continually increasing, till they have compleated one entire Revolution through the Heavens.

Euphros. This to me is a new Doctrine, and as it conveys such wonderful Ideas, I shall think myself extremely happy, if I can understand it by any Means, or mechanical Contrivance, applied to the Globe; for I observe, you have made a Provision of that Kind, as I here see a Globe with such Appurtenances as are not usual or common; by which, I presume, you are to explain this *Phænomenon* to me.

Cleon. That is the Design of this new Construction, my *Euphrosyne.*———There are several Ways, by which this Motion may be easily represented to you; one is, by this new Disposition of the celestial Globe; others you will see hereafter. ———This Globe is so contrived, that the Poles of the Equinoctial are made to move at Pleasure round the Poles of the Ecliptic, and so to represent the Face of the Heavens for any Time of that long Period above-mentioned, namely, *twenty-six Thousand Years.*———The late Mr. *Senex*, among many other Improvements of the Globe, contrived this principal one: By Means of these Pieces of Brass, which you see on either Side of the Globe; in one End of each is a Piece of Iron, fixed and applied to the Brass Meridian as usual, to give the Globe a Motion on the Axis, or Poles of the World.——— The other End of each Brass Arm is applied to the Poles of the Ecliptic, in such a Manner, as that it may be fixed, or moveable at Pleasure. By this Means, the Poles of the World,

World, or of the Equinoctial, may be placed in any Position about the Poles of the Ecliptic; and as they revolve, they will describe a Circle of 47° in Diameter, about the said Poles in the Ecliptic.———And to make the Idea still more easy and familiar to you, I have added to this Invention a *moveable equinoctial Circle* with its *Colures*, and also a *moveable Ecliptic*; whence, by a few Examples of the Use of the Globe, thus furnished and constructed, you cannot but understand——— how all the Stars must have an apparent Motion forward in the Heavens;———how their Longitudes and Declinations must be constantly altering;———how various the Times of their Rising and Setting must be;———how those which are visible, in one Age, become invisible in another;——the Change of Seasons through all the Months of the Calendar;———and what is usually called the *Precession* of the *Equinoxes* by Astronomers. I say, how all these great Phænomena are produced by this one simple Motion, you will now see explained by Example.

Euphros. This will give me the greatest Pleasure. Pray, proceed.

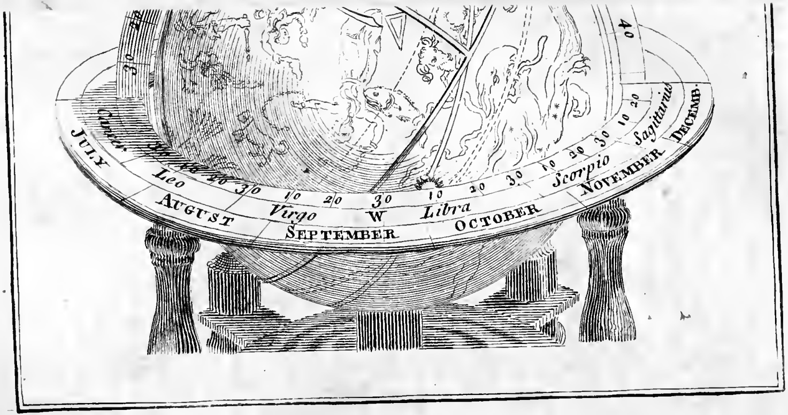
Cleon. The first Thing I do is, to loosen the Brass Arms upon the Poles of the Ecliptic, by which Means, you see how easily I move the Poles of the World to any different Part, from where they now are.— I will move each Pole one fourth Part, or 90° from the Position they are now in, and there fixing the Brass Pieces, the Globe will revolve on the Poles of the World in the same Manner as before, and will exactly represent the Face and Appearance of the Heavens for that Time to come, or future Age, which is One-fourth Part of the forementioned long Period of Time. (*i. e.*) You now see the Globe, as it will be rectified by the People who live 6500 Years hence.———Here the following Particulars you will observe, (1) That the Elevation of the Pole is always the same, the Latitude of the Place not being at all affected by this Motion; therefore I still set 51° : 30′ of the Brass Meridian to the Horizon. (2) You observe, that the equinoctial Points, by this retrograde Motion of the Pole, has receded from the first Point of *Aries* to that of *Capricorn*; for there the moveable Equinoctial intercepts the Ecliptic. (3) From thence you learn, that, at that Time of the World, the vernal Equinox will

will happen about the 22d of *December*, the Time which is now our Mid-winter. (4) That, as the equinoctial Points have moved through three Signs backward; so the Stars must of Course appear to have moved as much forward; that is, their Longitude will be increased 90°. (5) As the moveable Equinoctial now contains an Angle of 34° : 30′ nearly, with the fixed or present Equinoctial; so the Declination of Stars will be much altered thereby; (6) for those which had none before may now have a Declination of any Quantity less than 34°. (7) Those Stars, that had *South* Declination before, may now have their Declination *North*, and the North Declinations may be changed to South. Thus, at present, *Cor Leonis* has about 14° North Declination, in that Age its South Declination will be greater; the same you observe of many other Stars. (8) Those Stars and Constellations, which are now always visible, will then rise and set. Thus *Charles's Wain*, or *Great Bear*, at present, never goes below, or near the Horizon; but in the distant Age, we are speaking of, it will be got almost wholly below the Horizon; as you see by revolving the Globe. (9) On the Contrary, those Stars, which now rise and set, as the Constellations, *Delphinus*, *Sagitta*, *Vulpecula*, *Andromeda*, *&c.* will then be constantly visible. (10) The present Pole-Star, which has now no sensible Motion, and is always nearly the same Height above the Horizon, will then appear to circulate round the then Pole of the World, and will have a Difference of Altitude upon the Meridian, of full 47°. (11) A Star, or Point in the Heavens, now between the Head and Right-hand of *Cepheus*, will then be the North Pole of the World, and appear without Motion. (12) Stars, which are now altogether invisible to us in the Southern Hemisphere, will rise above the Horizon to the View of that Age. Thus *Corona Australis*, *Indus*, *Grus*, *Phœnix*, *Toucan*, *Pavo*, *Ara*, and *Lupus*, will then be among the Number of visible Constellations, which are all of them at present invisible to us. On the other Hand, *Canis Major*, great Part of the *Hydra*, *Crater*, *&c.* will then be invisible to that Age, which are now so conspicuous above our Horizon. (13) In that Age, when the Sun possesses the same Part of the Ecliptic, the same Stars will rise at a very different Time from what

what they now do. Thus, when the Sun is in the firſt Degree of *Cancer*, on the preſent *Midſummer-day*, *Cor Leonis* riſes at about Half an Hour after Eight in the Morning; but in that Age, it will riſe at near Eleven, which will then be the Day of the autumnal Equinox. (14) The Amplitudes and Azimuths likewiſe will then be very different from what they are now. Thus, at preſent, on *Midſummer-day*, *Cor Leonis* riſes on the E. N. E. Point of the Compaſs; but, in that Age, its Amplitude will be South, near two Points and a Half. (15) You will eaſily obſerve, from all that has been ſaid, that the Seaſons of the Year will have changed their Places in the Calendar; for the vernal Equinox will be on the 22d of *December*, *Midſummer-day* on the 21ſt of *March*, the autumnal Equinox the 22d of *June*, and the Middle of Winter about the 23d of *September*. Theſe, and many other Particulars, naturally and neceſſarily follow from altering the Poſition of the Poles of the World.

Euphroſ. It is really very wonderful, to conſider how many ſurpriſing and important Changes happen from ſo ſmall a Cauſe, as one would think that to be: I cannot but ſay, thoſe Things are very evident, by Means of this Apparatus; but I believe, without it, I could never have attained to any diſtinct or clear Ideas of ſuch a new and complicated Syſtem of mundane Changes; and from this firſt Example, I can plainly foreſee, that, if you remove the Poles of the World backward, through another Quarter of a Circle about the Poles of the Ecliptic, thoſe Alterations and Changes will ſtill appear much greater than before, with reſpect to the Times, Seaſons, Motions, and various Phænomena of the heavenly Bodies.

Cleon. Indeed they will; and you ſhall ſee by my removing the Poles to the Places you mentioned, what an Aſpect the Heavens will have in ſo diſtant a Period as 13000 Years hence. ———The Poles are now fixed diametrically oppoſite (on the other Side of the Poles of the Ecliptic) to the Place they at preſent poſſeſs;———and now, as the Globe revolves, you ſee what wonderful Mutations enſue; for now that very Star, which is our North Pole, and appears fixed, will, in that Age of the World, appear to deſcribe a Circle round the then North Pole


JULY
Cancer
Leo
AUGUST
Virgo
SEPTEMBER
W
Libra
OCTOBER
Scorpio
NOVEMBER
Sagittarius
DECEMB.
40

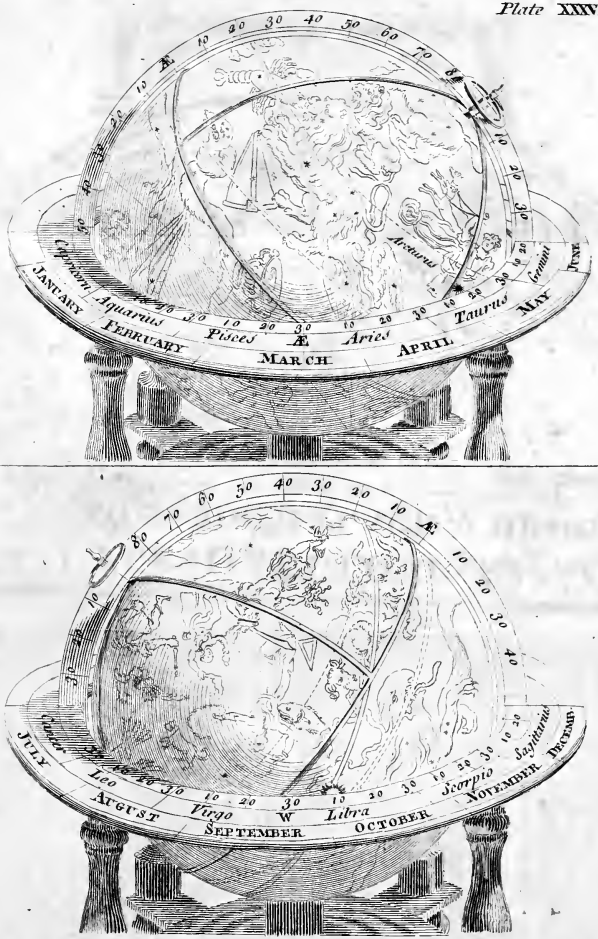
Pole of 94° Diameter; —— that it will tranſit the Meridian at 8° : 30′ to the South of our Zenith, on one Part, and deſcend ſo low as to be within 5° : 30′ of the Horizon on the other. —— The Seaſons of the Year are then diametrically oppoſite to what they now are in the Calendar; our *Midſummer-day* will then be when the Sun enters the firſt Sine of *Capricorn*, and the firſt Degree of *Cancer* will be farther diſtant from the North Pole at that Time, and will then be the Winter Solſtice: Alſo, the Vernal and Autumnal Equinoxes will then have interchanged their Days. —— The Conſtellations within 23° : 30′ of the Southern Pole of the Ecliptic on one Part, will then be viſible above our Horizon; as *Muſca*, *Croſiers*, *Apus*, *Triangulum Auſtrale*, *&c.* and, on the other Hand, many Stars of the firſt Magnitude will then entirely diſappear from our View, as *Sirius*, the *Dog Star*, *Regel*, thoſe in *Orion*'s *Belt*, will be Stars unknown, at leaſt unſeen, by the People of that Age, though, at preſent, they ſhine with the greateſt Luſtre in our beſpangled Canopy. —— There will, likewiſe, be then the greateſt Difference in the Declination of Stars; as thoſe which have now 23° : 30′ of North Declination may then have juſt as much South; all which you readily perceive without enlarging further on Particulars.

Euphroſ. This is, indeed, a moſt noble Invention, and muſt certainly be reckoned amongſt the moſt curious Improvements of the Globe. I ſee, by this Means, it is eaſy to repreſent every paſt and future Age to our View, with regard to the celeſtial Phænomena. I make no Doubt, but the Learned can convert ſuch a Doctrine as this to ſome very uſeful Purpoſes. If there be any ſuch, that I could be informed of without too much Trouble, I ſhould be very glad.

Cleon. The Uſes that are made of this Motion of the Earth are ſome of them very conſiderable; for hence you learn at once, that, ſince the equinoctial Points move *backwards*, it will eaſily account for the Motion of the Stars and Conſtellations *forward*. Thus, for Inſtance, you ſee, upon all the celeſtial Globes, the Conſtellations *Aries*, *Taurus*, *Gemini*, *&c.* are now placed at the Diſtance of one whole Sign from the preſent equinoctial Point, and have changed the Signs that

The CELESTIAL GLOBE rectified for the AGE & BIRTH-PLACE of HESIOD.

Plate XXXVII.



Pole of 94° Diameter; —— that it will tranſit the Meridian at 8° : 30′ to the South of our Zenith, on one Part, and deſcend ſo low as to be within 5° : 30′ of the Horizon on the other. —————— The Seaſons of the Year are then diametrically oppoſite to what they now are in the Calendar; our *Midſummer-day* will then be when the Sun enters the firſt Sine of *Capricorn*, and the firſt Degree of *Cancer* will be farther diſtant from the North Pole at that Time, and will then be the Winter Solſtice: Alſo, the Vernal and Autumnal Equinoxes will then have interchanged their Days. ———— The Conſtellations within 23° : 30′ of the Southern Pole of the Ecliptic on one Part, will then be viſible above our Horizon; as *Muſca*, *Croſiers*, *Apus*, *Triangulum Auſtrale*, *&c.* and, on the other Hand, many Stars of the firſt Magnitude will then entirely diſappear from our View, as *Sirius*, the *Dog Star*, *Regel*, thoſe in *Orion*'s *Belt*, will be Stars unknown, at leaſt unſeen, by the People of that Age, though, at preſent, they ſhine with the greateſt Luſtre in our beſpangled Canopy. —— There will, likewiſe, be then the greateſt Difference in the Declination of Stars; as thoſe which have now 23° : 30′ of North Declination may then have juſt as much South; all which you readily perceive without enlarging further on Particulars.

Euphroſ. This is, indeed, a moſt noble Invention, and muſt certainly be reckoned amongſt the moſt curious Improvements of the Globe. I ſee, by this Means, it is eaſy to repreſent every paſt and future Age to our View, with regard to the celeſtial Phænomena. I make no Doubt, but the Learned can convert ſuch a Doctrine as this to ſome very uſeful Purpoſes. If there be any ſuch, that I could be informed of without too much Trouble, I ſhould be very glad.

Cleon. The Uſes that are made of this Motion of the Earth are ſome of them very conſiderable; for hence you learn at once, that, ſince the equinoctial Points move *backwards*, it will eaſily account for the Motion of the Stars and Conſtellations *forward*. Thus, for Inſtance, you ſee, upon all the celeſtial Globes, the Conſtellations *Aries*, *Taurus*, *Gemini*, *&c.* are now placed at the Diſtance of one whole Sign from the preſent equinoctial Point, and have changed the Signs that

bear the Names of thoſe Animals. Thus, the Conſtellation *Aries* is moved forward in the Sign of *Taurus*, *Taurus* into *Gemini*, and ſo on.

Euphroſ. By this, I ſuppoſe, you would have me underſtand, that, in ſome Ages paſt, the Vernal Equinox was in that Part of the Ecliptic where now the Conſtellation of *Aries* is, and that then, the Conſtellation and its Sign were both of one Name. Pray, how long ſince may that be, do you ſuppoſe?

Cleon. It was upwards of 2000 Years ago, at which Time, ſome great Men, who firſt obſerved the heavenly Bodies, lived; particularly *Hipparchus*, from whom we learn the equinoctial Colure paſſed not far from the bright Star in the Head of *Aries*. ——— And to gratify your Curioſity, as well as to inform your Underſtanding, I have here the Copy of a very antique Globe, found in the Ruins of antient *Rome*, and is now in the *Muſæum* of the *Farneſian* Palace, as the moſt curious Monument of Antiquity. Upon this Globe, you ſee the various Aſteriſms as they were depicted by the Antients, and amongſt them the 12 Conſtellations of the Zodiac; all of them placed in their proper Signs, and near to the Beginning of them. Thus, you ſee, the equinoctial Colure paſſing through the right Horn and Foot of *Aries*, not far from the equinoctial Point; the ſolſtitial Colures likewiſe paſs through *Cancer* and *Capricorn*, and not through *Gemini* and *Sagittarius*, as they now do; and the ſame you obſerve of all the Reſt*.

Euphroſ.

* As very few of our Readers can have the Sight of this antique Globe and its Conſtellations, and thereby an Opportunity of obſerving the Difference between that and the preſent celeſtial Globe, we have thought it proper (to aſſiſt the Imagination as much as poſſible) to add a Copper-plate Print, repreſenting the Conſtellation of *Aries* on both Globes: Eſpecially, as it will repreſent to the View the different Poſitions of the equinoctial Points, with regard to that Conſtellation; for in Fig. I. of this Plate, the Poſition of *Aries* is repreſented, as it appears on the antique Globe in its proper Sign, near the Equinox; but in Fig. II. the ſaid Conſtellation is repreſented, as it appears on the modern Globe, removed from its own Sign into that of *Taurus* more than 30° from the equinoctial Point, by which a clear Idea of the Receſſion of the Equinox is plainly exhibited to the View; and this we thought neceſſary ſhould be done, as it is a Subject of the greateſt Importance and Conſequence in the Sciences. (See Plate XXXVI.)

Euphrof. I think, I may truly ſay, this is one of the moſt curious Things I ever ſaw.———One may learn from hence almoſt the Age of the Globe.———But I obſerve the equinoctial Point is removed backward from the Colure which paſſes through the Foot of the *Ram*, whence it ſhould ſeem, that this Globe was made ſome Time after the equinoctial Point was in that Colure. Pray, how do you conjecture concerning the Age of this Globe?

Cleon. Probably we may reaſon thus. The equinoctial Colure, (paſſing thro' the bright Star in the Head of *Aries*, and its Foot,) appears about 5° from the equinoctial Point on the Globe, which, at the Rate of 50″ *per Annum*, will give about 360 Years from the Time it had that Situation, to the Time the Globe was made. The bright Star of *Aries* is now not quite 30° from the preſent equinoctial Point; this Point has therefore probably receded through 25°, ſince the Time this Globe was made; but 25° reduced to Time will give 1800 Years for the Age of the Globe; ſo that it ſeems probable, this Globe was made about 40 Years before *Chriſt*; to which, if we add the 360 before-mentioned, it will give 400 Years before Chriſt, for the Time in which the ſaid Colure paſſed thro' the bright Star of *Aries*; but in ſuch Computations we muſt not ſtand for a few Years.

Euphrof. You not only ſhew me theſe wonderful Things in Theory, but confirm them by real Facts. This antique Globe is itſelf a real Demonſtration of all your aſtronomical Theory of the retrograde Motions of the equinoctial Points, and the mutable Phænomena of the Heavens depending thereon. Are there any other Uſes to which this Affair may be applied?

Cleon. Yes; very great Uſes in Chronology; when you are dextrous in the Uſe of this new conſtructed Globe, you will be able, pretty nearly, to give a Gueſs at the Diſtance of Time in which any Poet or Hiſtorian lived, whom you find mentioning the Riſing and Setting of the Stars, the Places of the Equinoxes, Solſtices, *&c.* becauſe you have nothing to do, but to alter the Poſition of the Poles of the World, till the Globe, by its Revolution, ſhall give the ſame Time of the Riſing and Setting of thoſe Luminaries, and then the Diſtance

between the preſent equinoctial Point and that on your Globe, ſo rectified, will, when turned into Time, give the Age in which they lived.

Euphroſ. This being a Thing of ſo curious a Nature, and what, I apprehend, I can perform myſelf on the Globe, when I have ſeen the Proceſs by you, I don't know any Thing would be more highly grateful than your illuſtrating this Matter by an Example.

Cleon. It muſt certainly afford you a pleaſing Satisfaction, to know, from your Globe, the Age, or Time, in which any of our celebrated Heroes of Antiquity lived, and how the Face of the Heavens appeared to them; and that you may thoroughly comprehend the Thing, I ſhall give you for a Problem, to determine the Age and Time of *Heſiod*, from a Paſſage in his Poem, wherein he deſcribed the *acronical* Riſing of the Star *Arcturus*, in the following Lines.

When the glad Sun, approaching with his Rays,
Has from the Tropic *run out ſixty Days*;
Arcturus, *riſing from his ſacred Bed,*
Is firſt diſcover'd in his Ev'ning's Shade.

From theſe Lines it is evident, that in *Heſiod*'s Time, when the Sun had paſſed the Winter Tropic, by the Space of 60 Days, and was then of Courſe in the Beginning of the Sign *Piſces*, the Star *Arcturus*, was riſing in the Eaſt at Sun-ſet.—But in the preſent Age, if you take the common Globe, and rectify it for the Latitude of *Aſcra*, the Birth-place of *Heſiod*, in *Greece*, whoſe Latitude is about 38°, you will find, when the Sun has juſt entered *Piſces*, and is ſetting in the weſtern Horizon, that there is no Appearance or Riſing of *Arcturus* in the Eaſt;———but that Star will appear then at a great Diſtance below the Horizon, and riſes not to the Inhabitants of *Greece* till near three Hours after Sun-ſet, on the 20th of *February* in the preſent Age *. *Euphroſ.*

* As there has never yet been any Print of this new Apparatus of the celeſtial Globe, I thought it would be very acceptable to the ingenious Reader, to have a View of the celeſtial Globe, as conſtructed with the ſaid Apparatus of moveable Poles, Ecliptic, Equinoctial, and Colures, rectified for the Age and Birth-place of *Heſiod*, agreeable

Euphrof. All this I plainly underſtand from the Uſe of the common Globe.———I muſt readily infer from thence, that ſome Alteration muſt be made in the Diſpoſition of the Globe, that ſhall ſhew that Star riſing in the Latitude of *Greece*, when the Sun is ſetting in the Beginning of *Piſces*.——Let me have the Pleaſure of ſeeing how that is performed.

Cleon. As many Ages have paſſed ſince *Heſiod*'s Time; and, ſince I have before ſhewn, that, in every 72 Years, the equinoctial Points go backward *one Degree*, you will find no Difficulty of underſtanding that, in order to repreſent the Face of the Heavens for any Time paſt; the ſaid equinoctial Points muſt be moved forward, at the Rate of *one Degree* for every 72 Years, till you arrive at the Time propoſed; and by this Means, the Phænomena of any Age deſcribed may be ſoon repreſented; ſince, by moving the equinoctial Points, and thereby giving a new Poſition to the Equator, and Signs of the Ecliptic, you will at length find them ſuch as will exactly anſwer to, and ſolve the Appearances mentioned.———Thus, you ſee, I looſen the Braſs Arms upon the Poles of the Ecliptic, and gently revolve the Globe about them, till ſuch Time I have made the Equinoxes advance forward in the Ecliptic to about 6° of *Taurus*,———and there, rectifying the Globe, for the Latitude of *Aſcra*, 38°, and bringing the Sun's Place in the Beginning of *Piſces* to the weſtern Horizon, if you caſt your Eye on the eaſtern Side, you will there ſee *Arcturus* riſing; and

agreeable to the above-mentioned Example. In the 1ſt Fig. of this Plate, is repreſented a View of the eaſtern Hemiſphere of the Globe, ſhewing *Arcturus* riſing in the North-eaſt Part of the Horizon, and in the 2d Fig. is a Repreſentation of the weſtern Hemiſphere, ſhewing the Setting of the Sun at the ſame Time that *Arcturus* riſes; both theſe together exhibit a View of the Conſtellations, ſuch as they appear on the Surface of a Globe, 3 Inches in Diameter; and the Reader will farther obſerve, that the Circles repreſented by two black parallel Lines are the Colures, Ecliptic, and Equinoctial, as they were poſited on the Globe in *Heſiod*'s Time; but the double dotted Line ſhews the Equinoctial, as it is now placed on the preſent Globes, and the ſingle dotted Lines ſhew our preſent Tropics. By this Means, the Reader will eaſily perceive the Difference between the Poſitions of the great Circles of the Globe at thoſe two diſtant Periods of Time, and conſequently, will thereby become more eaſily inſtructed in the *Rationale* of the above *Praxis*, or Uſe of this new conſtructed Globe.

and as this is the very Thing which *Hesiod* affirms he saw, 'tis evident, that this was the proper Disposition of the Globe; or, that the Poles of the World, the Equator, the Equinoctial and the Ecliptic, had the same Position then, with regard to the Stars in the Heavens, as you now see they have to those on the Surface of the Globe.

Euphros. I observe all that you mention with the highest Satisfaction, and am readily convinced, that the Face of the Heavens, now represented, is the same that was in *Hesiod*'s Time.———But how do you infer from thence, the Number of Years that has since elapsed?

Cleon. Very easily; because you will observe, the equinoctial Point has been moved forward from the Place, where it now is, in the Beginning of *Aries*, thro' 36° and 15′ into *Taurus*, and for every Degree we must allow 72 Years; therefore $36\frac{1}{4}$ Degrees will give 2600 Years, which is the Distance of Time from hence, that *Hesiod* lived, which was therefore 840 Years before the Christian Æra; which makes him contemporary with *Jehu*, King of *Israel*, and *Jonah* the Prophet, according to our best Chronologers.

Euphros. Well! this is a most delightful Solution and Discovery to me. I little thought any such Use could have been made of the Globe. I can scarce help fansying myself living at that Time, as every Thing appears to me in this artificial View, as it did to them in Reality.

Cleon. By another Passage from *Hesiod*, you will find this Disposition of the Globe further confirmed, to answer the Appearances of his Time.

But when Orion *and the* Dog-star *come*
To the Mid-region of the heav'nly Dome,
The Morn, that blushing draws away the Night,
Beholds Arcturus *in the dawning Light.*

From whence 'tis plain, that in *Hesiod*'s Days, when the three bright Stars in *Orion*'s *Belt* were upon the Meridian, *Arcturus* then appeared in the eastern Horizon;———and just the same Thing you see upon the Globe.———The Constellation of *Orion* is on the Meridian, the *Dog-star* near it, and *Arcturus* upon the North-east Point of the Horizon, all exactly answer

anſwer to *Heſiod*'s poetical Delineation.——I might farther inſiſt on thoſe uſeful Problems, by pointing out the particular Seaſons of the Years, with regard to the Stars, as deſcribed by *Heſiod* and other Poets. Thus in another Part of *Heſiod*'s Poem, we find the following Lines:

Begin the Harveſt as the Pleiads *riſe*;
And take the Plough, when they withdraw the Skies;
For forty Days and Nights their glimm'ring Light,
Obſcur'd to us, no longer chears the Sight.

Here we have a beautiful Deſcription of the *Heliacal* Riſing and Setting of theſe Stars, and ſhews how different their *Plowing and Harveſt Seaſons* were from ours.——In like Manner, many other Illuſtrations of poetical Paſſages and Deſcriptions, from ſuch an Apparatus of the celeſtial Globe, may be derived.——Thus, for Inſtance, when *Virgil* tells us in his *Georgics*,

Around our Pole the ſpiry Dragon *glides*,
And like a winding Stream the Bears *divides*;
The Leſs and Greater, who, by Fate's Decree,
Abhor to dive beneath the Northern Sea.

Now theſe Lines are much more properly applied to the *Dragon* and *Pole-ſtar*, in *Virgil*'s Time, than in our own; becauſe the *Dragon* did then, in ſome Meaſure, encompaſs the Pole, and divide the Pole from the *Greater Bear*, as you eaſily ſee, by rectifying the Globe for the Time of *Virgil*, which was about 1780 Years ago; at which Time, the Equinoxes were in 23° of *Aries*, and gave the North-ſtar that Poſition, with regard to the *Bear* and the *Dragon*, which he mentions; but in our Age, the North Pole is ſituated entirely without the Folds, or Windings of the *Dragon*'s *Tail*; nor is it now between the *Leſſer* and the *Greater Bear*; as it was very exactly in his Days.——I muſt leave you to improve, in this ſo ſublime a Praxis on the Globe, at your Leiſure, having ſaid enough, I am well aſſured, to give you the general *Rationale* of Procedure in all ſuch Caſes; and ſhall conclude with the Words of an eminent

Author,

Author, which are as follow. " But the Inſpection of the " Globe, when it is fixed in a proper Poſition, will convey " the beſt Idea of all theſe Appearances; for we derive this " Advantage from the new Conſtruction of it, that it will en- " able us to place the ſeveral Phænomena before every Eye; " by which Means, thoſe, who have the leaſt Acquaintance " with theſe Studies, muſt be greatly ſurprized, and pleaſed, " to obſerve the antient Accounts minutely verified; it is a " Sort of living over again the former Ages, allowing 1° : 23′ " 30″ for every 100 Years, according to *Flamſted.*"——I ſhall not now ſuggeſt ſome other Purpoſes that might be ſerved by this Method. It is ſufficient, to recommend the Invention, that it throws ſo much Light on the common Claſſics, and anſwers ſuch very great Purpoſes in Aſtronomy, Hiſtory, and Chronology.

DIALOGUE X.

Of the DESCRIPTION *and* USE *of the* TERRESTRIAL GLOBE.

Euphroſyne.

AS the manifold Uſes of the *Celeſtial Globe*, which in our former Converſations you have been ſo good as to make me acquainted with, have ſo much enlarged the Ideas of my Mind, and given me a rational Delight and Improvement, ſo much beyond my Expectation, I gladly embrace the preſent Opportunity of continuing ſuch uſeful Speculations, though on a different Subject from the Former.——We now deſcend from the ſpangled Heavens, to contemplate the variegated Figure of the Earth, and to obſerve the Analogy between the real Globe, on which we live, and that artificial one, in Miniature, which I ſee here on the Table,

Cleon. The preſent Minutes will, I hope, afford you a pleaſant Survey, as well as compendious View of the ſeveral Parts of our Earth, exhibited on the Surface of this terreſtrial Globe; and

and the firſt Thing that I think proper to obſerve to you here, is, the Form of it.

Euphroſ. The Form, I preſume, will not require much to be ſaid of it, as it is evidently of a round, or ſpherical Figure.

Cleon. It is ſo, indeed, with reſpect to the *artificial Globe*, you here ſee, which is as perfectly ſpherical as Art can make it. ——— But you are not to ſuppoſe, that the Figure of our Earth is, therefore, ſo too; for this is found, by Experience, to differ conſiderably from the Figure of a Globe; in other Words, the Diameter of the Earth, at the Equator, exceeds that conſiderably which paſſeth through the Poles, as I ſhall farther obſerve to you by and by; ſo that the true Figure of the Earth is, what the Mathematicians call, a *Spheroid*, and not a *Sphere*.

Euphroſ. How then can this artificial Globe be an adequate Repreſentation of the natural One, *Cleonicus?* Or, why do you repreſent a *Spheroid* by a *Sphere?*

Cleon. You will eaſily ſee the Reaſon of that, when you conſider, that the Difference of 70. or 80 Miles is conſiderable between the Diameters of the Earth, whoſe Dimenſions are nearly 8000 Miles; but altogether inconſiderable and imperceptible, in the ſmall Dimenſions of a Globe, whoſe Diameters exceed not 20, or 30 Inches. ———'Tis true, if Gentlemen, who are poſſeſſed of large Fortunes, were diſpoſed to expend thoſe Sums of Money this Way, which are oftentimes, with great Profuſion, laviſhed away on many uſeleſs Subjects, we might then expect to have Globes of ſuch a Size, as might ſenſibly repreſent the Difference in Diameter, or the true *ſpheroidical* Figure of the Earth. For this Purpoſe, a Globe, ten Feet in Diameter, would ſuffice: ———On ſuch a Globe, you would obſerve the Iſland of *Great Britain* have a different Poſition, with regard to its Diſtance from the Equator, than what it would have, if the Globe was truly *ſpherical:* ——— But theſe large Globes we can better ſuſtain the Want of, as their Uſe is, in a great Meaſure, ſupplied by Maps, or Projections of ſome particular Parts of the Surface, as we ſhall hereafter ſee; and, at the ſame Time, ſhew, that tho' the Neglect of the true Figure of the Earth be excuſable in Globes, it is, nevertheleſs, unpardonable in Maps, where it may be ſo eaſily

provided for, and where the Position, Distance, and Dimensions of Places so evidently require it.

Euphros. I must stay till then for farther Instructions in that Point.———As to the Dimensions of the Globe, I think, you observe, it is near 8000 Miles in Diameter; but, pray, how do you find that by Experiment?

Cleon. In this Manner, my *Euphrosyne.*———If the Earth were a perfect *Plane*, you might go ever so far North or South, without observing any Alteration in the Height of the Polar Star above the Horizon;———but if the Surface of the Earth be of a *spherical* Form, you move in the Arch of a Circle, and, as you move, your Horizon will move through an equal Arch in the Heavens.———If you move northward, your Horizon will descend below the North-star, and therefore that Star will appear to rise above your Horizon;———but, if you go directly South, your Horizon will descend in the southern Part, and rise in the northern Part; so that, the Distance between the North-star and the Horizon will be thereby lessened, and this will be the Case every where.———Lastly, it is found, by Experience, that, if you walk $69\frac{1}{2}$ of our *English* Statute Miles directly towards the North or South, you will elevate or depress the Polar-star just one Degree; and since there are 360° in the whole Circumference, it will produce 25020 Miles, for the Dimensions of a great Circle on the Surface of the Earth, from whence its other Dimensions may be easily deduced.

Euphros. What you have said, in regard to the Dimensions of the Earth, I can understand, without trying such a tedious and fatiguing Experiment. And, I can, at the same Time, perceive the Reason why the Globe is thus moveable in the Horizon; because the Pole-star is, by this Means, elevated or depressed, according to the different Part of the Globe, in which we are supposed to be.—And from thence too, I infer, that the Distance which I am from the Equator must necessarily be equal to the Height of the Pole-star above the Horizon, measured in Degrees; for, if I suppose myself at the Equator, then, of Course, my Horizon will pass thro' both the North and South Poles; and, if I am supposed to be placed just under the Pole-star, then

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my Horizon coincides with the Equator; and conſequently, wherever I am poſited upon the Surface of the Earth, the Arch of a Circle, which meaſures my Diſtance from the Equator, muſt be equal to that which meaſures the Height of the Pole-ſtar above the Horizon.

Cleon. Your Ideas are all very right, in regard to that Affair. ——The Latitude of the Place is your Diſtance from the Equator, which, being always equal to the Elevation of the Pole, is the Reaſon why, when you rectify either Globe, you place the ſame Degree on the North Part of the Meridian to the Horizon, as expreſſes your Latitude from the Equator on the South Part;——and as you are already acquainted with the Nature and Uſes of the various Circles, I need only juſt obſerve to you here, that, with regard to the Horizon, there are but three different Poſitions of the Sphere, *viz.* The Firſt is, a *Right Poſition*, viz. when the Poles are in the Horizon, and the Equator and Parallels are perpendicular thereto, or interſected at *right Angles* Such a Poſition of the Sphere have all thoſe who live under the Equator. — Secondly, a *Parallel Poſition* of the Sphere is, when the Equator coincides with the Horizon, and the Parallels of Latitude are, of Courſe, parallel thereto: Such a Poſition of the Sphere you would have, if you were (as you juſt now ſuppoſed yourſelf to be) placed under the Pole.—— Thirdly, the *Oblique Poſition* of the Sphere is, that alone which is worth conſidering, as being general to all the Inhabitants of the Globe, except thoſe before-mentioned; and is ſo called, becauſe of the *oblique* Poſitions of the Equator, and its Parallels to the Horizon. But on theſe Things there will be no Occaſion to enlarge to you.

Euphroſ. You make me a Compliment, *Cleonicus*,——but tho' it be true, theſe Things are not difficult to be underſtood, and are almoſt obvious by Inſpection; yet a few of your geographical Definitions reſpecting the Inhabitants of the Earth, and the Diviſion of the Globe into Land and Water, will not be amiſs, as I am now to form a regular Idea of this Science. ——I ſhall leave you, therefore, to proceed in that Method which you judge beſt for my Information.

Cleon. You may always depend on my doing that; and, in the firſt Place, it will be neceſſary to obſerve, that the Surface

of the Globe is divided into five Parts, or *Zones*, *viz.* the *Torrid Zone*, the two *Temperate Zones*, and the two *Frigid*, or *Frozen Zones*.

1. The *Torrid Zone* is so called, from the Inhabitants being, as it were, torrified, or scorched with the Sun's Heat; for this Part of the Earth is all that, which lies between the two *Tropics* of *Cancer* and *Capricorn*; and over which, the *Ecliptic Line* is obliquely posited; from whence you will easily observe, that the Inhabitants of this *Zone* will have the Sun perpendicularly over their Heads two Days in the Year, in passing from *Tropic* to *Tropic*, in each Half of the *Ecliptic*.

Euphros. I readily understand you, and I farther observe, that such People as inhabit *this Zone*, may, in some Sense, be said to have two Summers; for since the Sun, twice in the Year, passeth over them, those two Days, in which the Sun is in the *Zenith*, will be their *Mid-summer* Days, and the two *Tropical* Days, are those, in which the Sun will recede to the greatest Distance from them, and therefore may be called their *Mid-winter* Days.

Cleon. At the same Time too, you will understand, that, when the Sun is vertical to them, they can, at Noon-day, have no Shadow; in which Case, they were antiently called by the *Greeks*, *Ascii*, which imports the same Thing. But, at other Times of the Year, they have their Shadows falling North or South of them, according to the Place of the Sun in the *Ecliptic*; and they are then called the *Amphiscii*.———Also it may be observed, that only those People, who live just under each *Tropic*, have only one *Mid summer*, in which the Sun is vertical, or over their Heads; they have also one Winter only, *viz.* when the Sun is in the opposite *Tropic*.

Euphros. I find, from what you say, that the Seasons of the Year very much depend on the Situation of the Inhabitants, in regard to those *Zones*, please, therefore, next, to shew me how they are circumstanced, who live in the *Temperate Zones*.

Cleon. The *Temperate Zones*, are all those Parts of the terraqueous Globe, which lie between the *Tropics* and *Polar Circles*, and consequently, there is one of these in the *northern* and another in the *southern Hemisphere*, as you see, they are easily distinguished on the Surface of the Globe.——— As we ourselves

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are Inhabitants of the *North Temperate Zone*, we find the Seasons of the Year in a temperate Degree; our Summer Suns are at a Distance from our *Zenith*, and we do not therefore experience the greatest Force of his Beams. ——— Again, we are never without his enlivening Influence the Space of one natural Day; so that, upon the Whole, we must reckon our Situation the best that the Surface of the Earth can afford; especially, the *Paradisical* Situation of *England*, which is in the most temperate Part of the *Temperate Zone*.

Euphros. I have always thought, that *England* was, on many Accounts, a favourite Country of Providence. Our Sex have particular Reason to think so. The ardent Beams of the Sun, on the one Hand, in regard to our Complexion, would be very unfriendly, and the Cold of remoter Climes would by no Means suit the Tenderness and Delicacy of our Nature; most blissful, therefore, is our Department on the *British Isles*.

Cleon. It was an antient Observation, that we should think ourselves almost too happy, if we were thoroughly sensible of all the comparative Benefits we enjoy above other Inhabitants of the Earth.———Since the Noon-tide Shadows of the Inhabitants of either *Temperate Zone* fall always one Way, they have been usually called by Geographers *Heteroscii*.———By revolving the Globe upon its Axis, you will see, that by far the greatest Part of the habitable Earth is situate in these two *Zones*, and both together make the greater Part of the whole Globe.

Euphros. The very Name of the *Frigid Zone* is enough to make one shudder.———Their Situation, distant from the Sun, must prove them a hardy Race of Mortals; and yet, I have heard, there are such to be found within a few Degrees of the *Pole*.

Cleon. You mean the *North Pole*, my *Euphrosyne*; for about the *South Pole*, no Land has been yet discovered within the *Polar Circle*, as you will see, by casting your Eye upon that Part, and turning the Globe about at the same Time.———As these *Circles* circumscribe each *Pole*, at the Distance of 23° 30′, (the same Distance as the *Tropics* lie from the *Equator*) it will follow, that, when the Sun is in the *southern Tropic*, it will be 90° distant from the *North Polar Circle*, and consequently, all that

that Space, contained within it (improperly called the *Zone*) will be entirely bereft of the Sun-beams for one Day, or involved in Darkneſs.———Alſo, as the Sun advances from *Capricorn* to *Aries*, the Parts within the *Polar Circle* will be more and more enlightened, and of Courſe, the intenſe Cold, occaſioned by the great Diſtance of the Sun, while in the ſouthern Parts of the *Ecliptic*, will abate by Degrees, or become leſs ſevere.———As the Sun advances from *Aries* to *Cancer*, it will appear to the Inhabitants of the Polar Regions to be wholly above the Horizon, as you gradually paſs from the *Polar Circle* to the *Pole*.———And, when the Sun is in the *Tropic* of *Cancer*, the conſtant Heat, upon all thoſe Parts about the *Poles*, will be exceſſive great; and thoſe Parts of the Earth that are coldeſt, at one Time of the Year, will alternately be hotteſt at another.———But, upon the Whole, the Effects of Cold are more durable and prevalent than thoſe of Heat; and therefore, theſe Parts of the Earth ſtill deſerve the Epithet, or Title, which they bear.———The Inhabitants, who live in theſe *Circles*, have their Shadows fall all around them, when the Sun ceaſes to ſet in their Latitude, and therefore were antiently called the *Periſcii*.

Euphroſ. What other geographical Diſtinctions have you with regard to the Inhabitants?

Cleon. Thoſe which follow. (1.) Such as live diametrically oppoſite to each other are called ANTIPODES, as they are 180° diſtant from each other. The Times and Seaſons will be contrary to each, *i. e.* when it is Noon to one, it will be Midnight to the other; and when it is Winter to one, it will be the Summer-Seaſon to the other. They have the ſame Latitude; but one is North, and the other South: All which is evident, by viewing any two ſuch Places on the Surface of the Globe. (2.) Thoſe, who live in two oppoſite Points of the ſame Parallel of Latitude, are called PERIÆCI. They have the ſame Length of Day and Night, the ſame Seaſons of the Year, and, when it is Noon to one, it is Mid-night to the other. This likewiſe is evident on the Globe. (3.) They, who live under the ſame diurnal Meridian, but in two different Parallels, equally diſtant from the *Equator* on either Side, are called ANTÆCI. They have the ſame Noon-tides, but differ

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in all Things elſe: The Nights of one are equal to the Days of the other; and, when it is Summer with one, it is Winter with the other: All which Particulars are too eaſily obſerved on the Globe to need any farther Account.

Euphroſ. Theſe Things I ſhall make myſelf very well acquainted with by a little Practice. Is there any Thing farther for me to know by Way of Definition?

Cleon. It may be proper juſt to mention, that there is a Diſtinction of the ſeveral Parts of the Earth, under the Title of CLIMATES. The Geographers call that Part of the Earth, contained between two Parallels of Latitude, a *Climate*, in which the Length of the Days differs by *Half an Hour*, of which there are of Courſe 24, on each Side of the *Equator*, all of a different Breadth from each other; for, according to the different Obliquities of the Sphere; the Differences of Latitude will be unequal among themſelves, that ſhall produce equal Differences in the Length of Days. This is a Point, in which you will be eaſily ſatisfied, by a little Practice on the Globe; and particularly, you will obſerve the Extent of each to be, as ſpecified in the following *Table*, in the lower Part of which, you will find the *Climates* are differenced by the Space of a Month in the *Polar Circles*, of which there are ſix from the *Circle* to the *Pole*.

CLIMATES

CLIMATES between the EQUATOR and the POLAR CIRCLES.

Climates.	Hours.	Latitude. D.	M.	Breadth. D.	M.	Climates.	Hours.	Latitude. D.	M.	Breadth. D.	M.
1	12½	8	25	8	25	13	18½	59	58	1	29
2	13	16	25	8	00	14	19	61	18	1	20
3	13½	23	50	7	25	15	19½	62	25	1	07
4	14	30	25	6	30	16	20	63	22	0	57
5	14½	36	28	6	08	17	20½	64	06	0	44
6	15	41	22	4	54	18	21	64	49	0	43
7	15½	45	29	4	07	19	21½	65	21	0	32
8	16	49	01	3	32	20	22	65	47	0	26
9	16½	52	00	2	57	21	22½	66	06	0	19
10	17	54	27	2	29	22	23	66	20	0	14
11	17½	56	37	2	10	23	23½	66	28	0	08
12	18	58	29	1	52	24	24	66	31	0	03

CLIMATES between the POLAR CIRCLES and the POLES.

Length of Days.	Latitude.		Length of Days.	Latitude.	
Months.	D.	M.	Months.	D.	M.
1	67	21	4	78	30
2	69	48	5	84	05
3	73	37	6	90	00

Euphrof. If I underſtand this Matter right, I find, by the *Table*, that the firſt *Climate* ends at 8° 25′, and, of Courſe, is 8° 25′ broad; alſo, that the 10th *Climate* ends at the Latitude of 54° 27′, and its Breadth is 2° 29′; and becauſe 10 Half Hours make 5 Hours, theſe, added to 12, make 17 Hours, for the Length of the Day, where that *Climate* ends, as ſhewn in the 2d Column.

Cleora

Cleon. You have a very clear Conception of this Affair, which, in itſelf, is of no great Conſequence; but, as we uſually ſpeak of the *Climes*, or *Climates*, of different Countries, it is proper, that every one ſhould have ſome geographical Idea, or Notion, of the Thing.

Euphroſ. You juſt now mentioned the geographical Deſcriptions of Land and Water. Theſe, I ſuppoſe, come next in Order; and, in the firſt Place, pleaſe to let me know the Diviſion, or Diſtinction, of thoſe Parts you call Land.

Cleon. It is cuſtomary with Geographers to make a Diſtribution of the Land into the following Claſſes.

(1.) Of CONTINENTS, which are the large Tracts of Land, including many Kingdoms and Countries, not any where ſeparated by the Sea, of which we may reckon five; namely, *Europe*, *Aſia*, *Africa*, *North America*, and *South America*.

(2.) Of ISLANDS: Theſe are Tracts of Land every where environed with Water; ſuch as you ſee here on the Globe, *viz.* the Iſland of *Great-Britain*, *Madagaſcar*, *Sicily*, *Borneo*, *Nova-zembla*, &c.

(3.) Of PENINSULAS: Theſe are Tracts of Land ſurrounded by Water on every Side, but one ſmall Part, which joins it to the Continent. Thus you ſee, on the Globe, the Country called *Morea*, joined to *Greece*. Thus you ſee alſo, *Africa* is a Sort of Peninſula, joined to *Aſia*, by a narrow Tract of Land, between *Egypt* and the *Red Sea*.

(4.) Of ISTHMUS's: Theſe are the narrow Necks of Land, by which the *Peninſulas* are connected with the Continent: As the *Iſthmus* of *Corinth*, which joins the *Morea* to *Greece*, as you ſee on the Globe.

(5.) Of PROMONTORIES; Theſe are large Heads, or Capes of Land, which ſtand out into the Sea; ſuch as the *Cape of Good Hope*, in *Africa*; *Cape Horn*, in *America*; *Cape Finiſtre*, in *Spain*, &c. which readily ſhew themſelves on the Globe: And theſe are all the great Forms of Land, the Surfaces of which are diverſified with high and low Parts, commonly called Hills, Mountains, Vales, &c. of which there need no Deſcription, as you have ſo lately read an Account of the *Alps*, of *Mount Veſuvius*, and of the *Pike of Teneriff*, which are the moſt remarkable in the World.

Euphros. These Subjects afford me the highest Pleasure, even while I am a Novice in Geography. But, when I become better acquainted with the Science, the Delight in Reading will increase in Proportion: Therefore, next, pray tell me what are the Divisions of Water, which I see covers so great a Part of the Globe's Surface?

Cleon. The Proportion of Water, to that of Land, is much about three to one; or, in other Words, three Parts in four of the whole Surface of the Globe are covered with Water, which are divided into the following Denominations.

(1.) OCEANS: These are the vast Collections of Water that surround the Continents, and receive different Names, according to the different Parts of the World, in which they lie: As the *Eastern*, or *Western Ocean*, &c. the *Indian*, or *German Ocean*, according to the Countries they are contiguous to.

(2.) SEAS: These are such Parts of the Ocean as lie between several Islands, or Parts of Continents, as the *Mediterranean*, the *Baltic*, the *Red* and *White Seas*, &c. Also, those great Collections of Water, entirely surrounded by Land in the Continents, are called Seas, as the *Euxine*, or *Black Sea*, the *Caspian Sea*, &c.

(3.) LAKES: These are any smaller Collections of Water on the Land; such as you here see on the Globe, *viz.* the *Lake of Geneva*; and particularly those fine, large, remarkable *Lakes* above the *River St. Lawrence*, in *Canada*, which are the Basis of so great a Traffic with the *North American Indians*.

(4.) GULPHS: Such Parts of the *Ocean* as are almost surrounded by Land. It is in Form analagous to a Peninsula, such you observe is the *Gulph of Venice*, the *Red Sea*, &c.

(5.) CREEKS: These are those narrow Parts, or Arms of the Sea, running a little Way up into the Land. If they are wide and spacious, they are then called

(6.) BAYS. Of which the most remarkable and easy to be distinguished on the Globe, are *Hudson's Bay*, in *North America*; the *Bay*, or *Gulph, of Mexico*; the *Bay of Biscay*; with many others.

(7.) STRAITS: These are sometimes called CHANNELS, which are those Parts of Seas that run between two Shores, or Coasts;

Coasts; as the *Straits of Gibraltar*, the *British Channel*, the *Straits of Magellan*, &c.

(8.) RIVERS: These are large Streams of Water, which arise from several Fountain-heads, and run towards some Lake, or Sea, where they dissembogue their Water. Such are the *River Thames*, in *England*; the *River Nile*, in *Egypt*; the *River St. Lawrence*; the *Danube*; and many others of very great Note; which you see diversifying the Surface of the Land, like the Veins and Arteries in the membraneous Parts of Animals.

Euphros. I shall endeavour to retain all these Distinctions and Definitions, by an Application to my Books and Globe. ——I fear you have exhausted your Spirits too much at present, and shall with Pleasure dismiss you from any farther Attendance on me now.——I promise myself great Satisfaction in our next Leisure, which you tell me is to be employ'd in a practical Solution of the most useful geographical Problems on the Globe.

DIALOGUE XI.

Containing the Solution of the PRINCIPAL PROBLEMS *on the* TERRESTRIAL GLOBE.*

Cleonicus.

AT our last Interview, I endeavoured to prepare your Mind with every necessary Preliminary for understanding the right Use of the *Terrestrial Globe*, and as you are well acquainted with all the Circles, and the Manner of rectifying the Globe for any particular Place, we may now address our selves immedi-

* In this *Dialogue*, I shall give the Solution to *geographical Problems*, as they are performed on the *Terrestrial Globe* of the usual Form; the Examples here are accommodated to those of Mr. *Senex*'s Make, particularly those of 12 and 17 Inches Diameter; but in the following *Dialogue*, the Reader will find, that the same *Problems* will receive a much more natural Solution, or Representation, from a new Construction and Apparatus of a nine Inch Terrestrial Globe, which is moved by Clock-work, and by which the general *Rationale* of the *Problems* pertaining to both the Globes will most evidently appear.

ately to the Solution of such *Problems*, as will sufficiently shew how very rational, beneficial, and entertaining, the Use of this Instrument must be, and how highly Mankind are indebted to the first Inventors of it.

Euphros. The very Pleasure of seeing the World in *one View*, is not small; it gives me such a distinct and adequate Idea of the several Parts of Land and Water, that no Maps, or other Contrivances could ever equal. ——— I have rectified the Globe to the Latitude of *London*, by placing 51° 30′ to the Horizon, which makes it ready, I presume, for the Solution of *geographical Problems*. ——— Pray, which is the first to begin with?

Cleon. The *First Problem* usually is, *To find the Latitude of any given Place*; and this is done by bringing the Place to the graduated Edge of the *Meridian*, where its Distance from the *Equator* will appear in Degrees. Thus, suppose I require the Latitude of *Jerusalem*, *Petersburgh*, and *Pekin*, in *China*.

Euphros. This I think I can easily perform. ——— *Jerusalem*, I find upon the Globe, and placing it under the *Meridian*, I observe its Latitude 32° 00′ N. from the *Equator*. ——— Again, I find *Petersburg*, in *Russia*, just in the Parallel of 60° 00′. ——— And as for *Pekin*, in *China*, when I bring that to the *Meridian*, I see it lies just under the 40° 00′; and in the same Manner, I could tell you the Latitude of every other Place that is marked on the Globe. ——— I suppose the next *Problem* will be of Course, *To find the Longitude of a Place*.

Cleon. It is certainly so, as it is so closely connected with the Latitude. ——— To do this is nothing more, than to observe what Degree of the *Equator* is intersected by the *Meridian*, when the given Place is brought to it. ——— And here I must observe to you, that the Degrees of Longitude on all Mr. *Senex*'s Globes are reckoned from that *Meridian*, which passeth thro' *London*, (and which is usually called the FIRST MERIDIAN) these Degrees of Longitude run all round the Globe to 360.

Euphros. I understand you, and observe the *first Meridian* you speak of. When I bring *Jerusalem* to the *Meridian*, it cuts the 36th Degree of *East* Longitude on the *Equator*. ——— *Pekin* being brought to the *Meridian*, cuts the 116th Degree as before. ——— After the same Manner, I observe, that any Place which lies Westward of us, being brought to the *Meridian*, both the

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Latitude and Longitude thereof will inſtantly appear. Thus, *Port-Royal*, in *Jamaica*, being placed under the Braſs *Meridian*, is ſhewn to have 17° 30′ Latitude N. and its Longitude will be ſhewn to be 282° 30′, which taken from 360, makes 77° 30′ of Weſt Longitude from *London*.

Cleon. In all this you are very right.——A *Third Problem* is, *Having the Latitude and Longitude given, to find that Place on the Globe.*

Euphroſ. This I apprehend is nothing more than the Reverſe of the foregoing Problem.——Thus, ſuppoſe I find in a *Gazetteer*, or *Table* of Latitudes and Longitudes, that *Jeruſalem* was in 30° 00′ of North Latitude, and 36° 00′ of Eaſt Longitude;——then I bring the 36° of Longitude to the Edge of the General *Meridian*, and am ſure to find the City of *Jeruſalem* under the 32 Degree of Latitude on the ſaid *Meridian*.—— Again, if I know the Longitude of *Port-Royal* to be 77° 3′ Weſt of *London*, and to have 17° 30′ of N. Latitude, then, by bringing the ſaid Degree of Longitude to the *Meridian*, I obſerve the Town juſt under the given Latitude.

Cleon. Very good, my *Euphroſyne*.——The *Fourth Problem* is, *To find the Diſtance between two given Places on the Globe in Engliſh Miles*, as for Inſtance, between *London* and *Jeruſalem*.——To effect this, you ſcrew the *Quadrant* of Altitude to the Braſs *Meridian*, with its fiducial Edge to 51° 30′ the Latitude of *London*, to which Point you bring the City of *London*, where let the Globe reſt; then lay the graduated Edge of the *Quadrant* upon the given City, and you will ſee upon the *Quadrant* 32° 30′ which, by allowing 69 Miles and an half to a Degree, will amount to near 2259 Miles.

Euphroſ. The *Praxis* of this *Problem* is very eaſy, and will, at the ſame Time, exerciſe me in the little Skill I have in the Rules of *Arithmetic*.——But let me ſee, if I can find the Diſtance from *London* to *Port-Royal*.——The Globe remaining as before, I bring the Edge of the *Quadrant* to the Place, and I obſerve it is 69° from *London*, which multiplied by $69\frac{1}{2}$, gives $4795\frac{1}{2}$ Miles.——Thus, I can ſatisfy my Curioſity at any Time, in regard to the Diſtance of any Part of the World.—— Pray, what is the *Fifth Problem?*

Cleon.

Cleon. To find the Point of the Compaſs, on which any Place bears from London?

Euphroſ. I need not give you the Trouble of ſhewing me how to perform this *Problem*; for it is ſelf-evident.——For, as I ſee the *Compaſs* on the Horizon, when *London* is brought to the *Meridian*, and the *Quadrant* laid over any Place, it ſhews, at the ſame Time, the Point on which that Place bears from *London*.——Thus, the *Quadrant*, laid over *Port-Royal*, ſhews it to bear on the *Weſt Point* of the Compaſs.——If laid over *Jeruſalem*, it cuts the E. S. E. Point of the Compaſs for the Bearing of that City.——The *Quadrant* removed to *Pekin*, in *China*, ſhews it to bear within a Degree or two on the N. E. Point of the Compaſs.——This is a Matter of no ſmall Curioſity, which I ſhall practiſe for many other Places at my Leiſure. What is the next *Problem*, *Cleonicus?*

Cleon. The *Sixth Problem* is, *To find all thoſe Places that have the ſame Latitude and Longitude with a given Place.*

Euphroſ. This, again, is ſo eaſy at firſt Sight, that I wonder you learned Gentlemen ſhould make any *Problem* of it.——For 'tis only bringing the given Place, as *Pekin*, for Inſtance, to the *Meridian*, and all thoſe Places that lie under the Southern Half of the *Meridian*, muſt, of Courſe, have the ſame Longitude.——After this, if I turn the Globe about, 'tis evident, all thoſe Places which paſs under the ſame Point of the *Meridian* with *Pekin*, muſt have the ſame Latitude.

Cleon. You will find ſome *Problems*, by and by, that you may think ſufficient to exerciſe your geographical Genius; tho' by you they may be eſteemed only Paſtime.——The *Seventh Problem* is none of the moſt difficult, and you muſt let me ſee if you can do it without my Direction. It is, *To find all thoſe Places where it is Noon at any given Hour of the Day, in any Place propoſed.* For Example, you are to find in what Places of the Earth it is Noon, when it is Nine in the Morning at *London*.

Euphroſ. I believe you have now puzzled me.——Muſt not I begin with finding the Sun's Place?

Cleon. No, my *Euphroſyne*, all *Problems* of Time do not require the Sun's Place to be known;——but ſince you tacitly aſk

ask my Assistance, you will readily find it. Therefore proceed as follows:———Bring *London* to the *Meridian*, and set the Hour-*Index* to the given Hour IX in the Morning.———Then turn the Globe about, till the *Index* points to the upper XII.———Then see what Places lie under the *Meridian*; for in all those Places, it will be Noon at the given Hour.

Euphros. Well, this is a pretty *Problem*; let me practise it in the given Example.——— I bring *London* to the *Meridian*, ———set the *Index* to IX,———and then turning the Globe, till it points to XII, I observe, that the middle Part of *Russia*, *Circassia*, the middle Parts of *Arabia*, and *Madagascar*, all lie under the *Meridian*; to all which Places therefore it must be Twelve o'Clock, or Noon, when it is Nine in the Morning with us.

Cleon. The Eighth *Problem* is but the Reverse of this, *viz. when it is Noon at any one Place, to find what Hour it is at any other given Place.* And therefore in the Solution of this, you will readily know how to proceed.

Euphros. Yes, surely I do.———Supposing it Noon at *London*, I can tell what o'Clock it is at *Jerusalem* for Instance; ———for, if I bring *London* to the *Meridian*, and set the Hour-*Index* to the upper XII; then by revolving the Globe, till *Jerusalem* comes to the *Meridian*, I observe the *Index* points to II. 30′. But, as this is on the western Part of the Hour-Circle, it shews, that it is about Half an Hour after Two in the Afternoon.———Again, for a second Example; if I turn the Globe till *Port-Royal* comes to the *Meridian*, the Hour-*Index* will point to VII. nearly, which shews, that it is Seven o'Clock with them at *Jamaica*, when it is Twelve at Noon with us.———Again, for a third Example, I shall reverse the *Problem*, and bring *Pekin*, in *China*, to the *Meridian*, where, holding it fast, I place the Hour-*Index* at XII; then I bring *London* to the *Meridian*, and find the *Index* point to Four o'Clock in the Morning.———Such *Problems* as these are very entertaining. What is your Ninth *Problem?*

Cleon. By your last Example, you have robbed Geographers of one *Problem*, and, by the same Freedom, you might as well have taken that which follows, which may now call the Ninth,

viz.

viz. For any given Hour of the Day, in the Place where you are, to find the Hour in any other Place?

Euphrof. This, indeed, is hardly worth conſidering as a ſeparate *Problem.*——For, when it is Five o'Clock with us, in the Afternoon, if I would know what o'Clock it is then in *Port-Royal* in *Jamaica*, I need only bring *London* to the *Meridian.*——Set the Hour-*Index* to V, on the Weſt Side;——then revolving the Globe, till *Port-Royal* comes to the *Meridian*, the *Index* points nearly to XII. ——This ſhews, *Cleonicus*, that when we ſit down to Tea at Six, they begin to think of their Dinner at *Jamaica.*

Cleon. Theſe *Problems*, I ſee, you are ſufficiently ready at.——I believe the Tenth will be very agreeable to you, which is, *To find all thoſe Places in the Torrid Zone, to which the Sun is vertical for any given Day.*

Euphrof. In the Solution of this *Problem*, I foreſee your Direction will be neceſſary. Pleaſe to ſay how I muſt proceed.

Cleon. Let the given Day be the 20th of *April*; oppoſite to which Day, upon the Calendar in the Horizon, you will ſee the firſt Degree of *Taurus* in the *Ecliptic* placed by it, which ſhews the ſame Degree in the *Ecliptic* on the Globe, is the Place of the Sun for that Time.——Therefore, I bring the Sun's Place, or Beginning of *Taurus*, to the *Meridian*, which it interſects in the 11th Degree: Then turning the Globe quite round, you obſerve all thoſe Places upon the Surface, which paſs under the ſaid 11th Degree of the *Meridian*, are the Places required, or thoſe which have the Sun paſſing over their Heads for that Day.

Euphrof. This *Problem* is more curious than difficult; by which I learn, that every Place in the *Torrid Zone*, whoſe Latitude is equal to the Sun's *Declination*, will find him in their *Zenith* at Noon.——What is your Eleventh *Problem, Cleonicus?*

Cleon. To find the Midſummer-days *for any given Place in the Torrid Zone.* This Problem I ſhall ſhew you the Solution of as follows:——Let theſe two Days be required for *Port-Royal*, in *Jamaica.*——Then, I bring that Town to the *Meridian*, and obſerve what Degree it cuts, which is 17° 30′.——Then, turning the Globe, I obſerve what Part of the *Ecliptic*,

next

next to *Aries*, touches that very Point of the *Meridian*, and find it to be the 20° of *Taurus* ♉.——This Degree I look for on the Horizon, and find againſt it, the 10th of *May*, which therefore is their firſt Midſummer-Day.——Then, I turn the Globe farther about, till ſome Part of the ſecond *Quadrant* of the *Ecliptic* comes under the ſame Part of the *Meridian*, which I find to be the 10th Degree of *Leo* ♌.——Then, againſt that Degree of the *Ecliptic* in the Horizon, I find correſponding to the 3d Day of *Auguſt*, which therefore is their ſecond Midſummer-Day.

Euphroſ. I ſee, by the Manner of your Solution, that I ſhall find but little Difficulty in performing the ſame Thing for any other Place.——What *Problem* ſucceeds to this?

Cleon. The *Twelfth Problem finds all thoſe Places in the North Frigid Zone, where the Sun begins to ſhine, conſtantly, or without ſetting, on any given Day.*——The Solution is in this Manner.——Let the given Day be the 26th of *April*.——Then, the Sun's Place for that Day will be in 6° 00′ of *Taurus* in the *Ecliptic* on the Horizon.——Which Place I find in the *Ecliptic* on the Globe, and bring it to the *Meridian*, which ſhews the *Declination* of the Sun for that Day to be 13° 00′.——Then it is evident, that all thoſe Places which are the ſame Number of Degrees from the Pole, or which are in the 77th Degree of North Latitude, are the Places required.

Euphroſ. I can plainly ſee the Reaſon of that, as the Circle of conſtant Illumination muſt neceſſarily be the ſame Diſtance from the *Pole*, as is equal to the Sun's *Declination*.

Cleon. The Thirteenth *Problem* is ſomewhat a-kin to the foregoing.——*It conſiſts in finding on what Day the Sun begins to ſhine conſtantly, or without Setting on any given Place in the Frigid Zone, and how long it continues ſo to do.*——To ſolve which, let the Time required be for Point *Look-out*, or the ſouthernmoſt Part of *Greenland*.——Then firſt, I find the Latitude of that Cape, which is 77° 00′.——Secondly, I rectify the Globe to the Latitude of the Place.——Thirdly, turning the Globe about, I obſerve what Point in the firſt Quarter of the *Ecliptic* coincides with the North Point of the Horizon, which, I obſerve to be the *ſixth Degree* of *Taurus*.——Fourthly, I ſeek the ſame Degree of *Taurus* in the *Ecliptic* on the Horizon, and

find againſt it in the Calendar, the 26th Day of *April*, which ſatisfies the firſt Part of the *Problem*.——Fifthly, I turn the Globe back again, to obſerve what Point, in the ſecond Quarter of the *Ecliptic*, exactly coincides with the North Point in the Horizon, and I find it to be the 24° 00′ of *Leo*.—Sixthly, I ſeek the ſaid Degree in the *Ecliptic* on the Horizon, and find it anſwers to the 17th Day of *Auguſt*.—Therefore, from the 26th of *April* to the 17th of *Auguſt*, the Sun ſhines conſtantly on the Inhabitants of the moſt ſouthern Parts of *Greenland*.

Euphroſ. By the particular and gradual Proceſs you have uſed in the Solution of this *Problem*, I find, not only the Method for any other of the like Kind is very eaſy, but, alſo, the *Rationale* thereof is very evident; and therefore you may proceed more conciſely in what other *Problems* remain.

Cleon. The remaining *Problems* are but few; that, which you may reckon the Fourteenth, is *To find the Place over which the Sun is vertical on any given Day and Hour*.——In order to this, you are to find the Sun's Place in the Ecliptic, and bring it to the Meridian, and mark the Degree of Declination for the given Hour.——After this, find thoſe Places which have the Sun in the Meridian at that Moment;——and, among them, that particular Place which lies under the Degree of the Sun's Declination, is the Place deſired.

Euphroſ. As you have given me the Clue, I can proceed through the Whole of this Problem without your farther Inſtruction, at leaſt I will attempt it.——I therefore ſuppoſe it was required, to find the Place to which the Sun is vertical on the 20th of *April*, at Nine at Night preciſely.——The Sun's Place, at that Time, I find on the Horizon of the Globe to be in the firſt Degree of *Taurus*;——this I bring to the Meridian, and there obſerve his Declination to be about 10° 30′, ——Then will all thoſe Places, that paſs under that Degree, have the Sun vertical to them that Day.——In the laſt Place, I find all thoſe Places where it is Noon at Nine o'Clock at Night on that Day:——And amongſt them, that which lies under 10° 30′ of the Meridian is the Place required; and this I find is in the *Pacific Ocean*, or *Great South Sea*, and, as it accidentally happens, in the very Tract of Lord *Anſon*'s Voyage from

from *Aquapulco* to *China*, which has 135° Weſt Longitude from *London*.

Cleon. It is with Pleaſure I ſee how great a Miſtreſs you are of geographical Solutions.———I believe it will not now be in my Power to mention any future Problem that will be too difficult for you. However, the Fifteenth will ſtill extend your Ideas of this Kind, which is, *To find, for any given Day and Hour, thoſe Places wherein the Sun is then Riſing, or Setting, or in the Meridian; alſo, thoſe Places which are enlightned, and thoſe which are not*; and for an Example, you may take the ſame Day and Hour of the laſt Problem, *viz. April* the 20th at Nine at Night.

Euphroſ. I fear what you ſay to encourage me, will rather tend to diſpirit me; for, if I may have the World for my Pains, I know not which Way to go about this, which you think ſo eaſy a Problem.——

Cleon. You have no Reaſon to be diſheartened, it is but a Trifle that you want to recollect, to make the Problem as clear as the Day.———For only find the Place to which the Sun is vertical at the given Hour, (which you know by the laſt Problem) and bring the ſame to the Meridian, and elevate the Pole to the Latitude of the Place, then all the Reſt will be eaſy.

Euphroſ. This I will do.———The Latitude of the Place is 10° 30′;———therefore I elevate the Pole to the ſame Number of Degrees above the Horizon,——— and thence, ſince the Sun is vertical to the middle Point of the Hemiſphere about the Horizon, it is evident, (1.) That all thoſe Places which are in the weſtern Semi-circle of the Horizon ſee the *Sun Riſing*, as they are 90° 00′ diſtant from the Braſs Meridian. (2.) For the ſame Reaſon, thoſe who are in the eaſtern Semi-circle ſee the *Sun Setting*. (3.) And to thoſe who are under the Meridian it is XII o'Clock, or *Noon*. (4.) and laſtly, All Places above the Horizon are enlightened by the Sun, and to them it is *Day*; and all that are below it, of Courſe, are in Darkneſs, or *Night*.——— Upon the Whole, I think this a very curious Problem.

Cleon. It is as uſeful as curious, ſince, by Means thereof, you readily ſolve the Sixteenth Problem, which is, *To exhibit, in a general Manner, all thoſe Places on the Earth to which a ſolar,*

or lunar Eclipſe is viſible, when the Time thereof is known.——— If you remember, ſome Time ſince I was mentioning to you, a very great Eclipſe of the Sun, which will happen the 1ſt of *April*, 1764: This I propoſe to you as an Example.———This Eclipſe begins at IX, and ends at XII nearly.

Euphroſ. By this I know what my Taſk will be,———for, in the firſt Place, I muſt find the Place to which the Sun is vertical at Half an Hour paſt X on the firſt Day of *April*, that being the Middle of the Eclipſe;——— this I find to be near the Middle of the Continent of *Arabia*:———to which, when I rectify the Globe, I obſerve all the midland Parts of *Norway*, *Poland*, *Turkey* in *Europe*, and the vaſt Continent of *Africa*, lie under the general Meridian, and obſerve the Middle of the Eclipſe at Noon.———Alſo, all the Hemiſphere above the Horizon ſhews me all thoſe Parts of the World, in which the Eclipſe can be viſible. Therefore I am convinced, it will be ſeen in all Parts of *Europe* and *Africa*, as alſo all *Aſia*, except the eaſtern Part of *Tartary*, *China*, *&c.* But the eaſtern Parts of *South-America* only can ſee any Thing of this Eclipſe.——— If I caſt my Eye on the weſtern Part of the Hemiſphere, I obſerve the Countries in *North* and *South-America*, which lie upon the Horizon, to be thoſe People who ſee the Sun Riſing at the Middle of the Eclipſe.——— And in the eaſtern Part of the Horizon, the ſeveral Countries upon the Horizon there view the Sun Setting at the ſame Time.—Again, if I bring *London* to the Meridian, and place the Hour Index to IX in the Morning, and then revolve the Globe till the Index points to XII, I view all thoſe Countries under the Meridian, where the Eclipſe begins at Noon; particularly at *Madagaſcar*, the inland Parts of *Arabia*, the *Perſian* Gulph, the *Caſpian* Sea, and of all the eaſtern Part of *Ruſſia* in *Europe*; but ſcarce any inhabited Part of the Earth view the Beginning of the Eclipſe at Sun-Riſing, ſince the weſtern Horizon lies almoſt wholly on the *Great Atlantic*, and *Southern Oceans*. On the other Hand, a few of the eaſtern Iſlands only of *Aſia* can ſee the Beginning of the Eclipſe at Sun Set.———In the laſt Place, I bring *London* to the Meridian, and place the Index to the upper XII, which gives me a View of all thoſe Places under the Meridian, who view the dark Diſk of the Moon going off from the Sun at XII o'Clock. On the

weſt-

weſtern Horizon, I view the Countries where the Sun is riſing, when the Eclipſe ends: and in the eaſtern Part of the Horizon I ſee in what Parts of the World the Sun appears to ſet, with its entire enlightned Diſk. ——— Are not theſe the general Phænomena of this Eclipſe, as repreſented on the Globe, *Cleonicus?*

Cleon. They are, my *Euphroſyne*, and very ſcientifically repreſented; I could not have done it better myſelf. ——— I ſee you want no more of my Inſtructions, in regard to the Uſe of the Terreſtrial Globe; for though there may be a great Diverſity of Problems propoſed, yet they will all become very eaſy in Practice, and their general *Rationale* will appear to any one who has been exerciſed in thoſe which I have ſelected for your Inſtitution in this Science, for they are all of them of a fundamental and general Nature. ——— If any Thing farther remains, there is yet a few Minutes to ſpare; therefore be free to aſk of me any Thing you think proper, relative to the Uſe of this Globe, while it is before us.

Euphroſ. I ſee but one Thing more on the Globe to trouble you with, and that is, that long Slip of Paper, which is paſted on the Globe, acroſs the Equator, containing the Calender, or Months and Days of the Year: I ſhould be glad to know the Uſe of that, as you have ſaid Nothing hitherto about it.

Cleon. It is very proper you ſhould be acquainted with the Uſe of it, as it is a curious Appendix to the Globe, and the Invention of the ingenious Mr. *Harris*, Author of *A Treatiſe on the Globes*. It has been lately affixed to the Globe; it may be called a *General Rectifier* (though it is otherwiſe called the *Analemma.*) The Uſe of it is thus, (1.) you bring it to the General Meridian, and, at one View, you obſerve on that Paper the Sun's Declination for any particular Day in the Year, whether North or South. (2.) You rectify the Globe to the Latitude of any Place, and then bringing the Rectifier to the eaſtern Part of the Horizon, you place any given Day of the Month to the Edge of the Horizon, and you ſee the Point of the Compaſs on which the Sun, that Day, riſes; and conſequently, the Amplitude of the Sun is inſtantly known: The Time of its Riſing is alſo ſhewn by the Index of the Hour Circle, and conſequently the Length of Day and Night.—And ſince

theſe

these Things are shewn, as it were, by Inspection, for one whole Year, it gives a Summary of the Problems relative to the Sun, and most properly belongs to the Celestial Globe.

Euphros. This I think is a great Curiosity indeed.——I could not have thought so many Problems of Importance could have resulted from so small a Slip of Paper.——But I shall trouble you no further at Present, with these Things, your Lecture, at this Time, having been of an uncommon Length.

DIALOGUE XII.

The DESCRIPTION *and* USE *of a New* APPARATUS *to the* TERRESTRIAL GLOBE, *by which the true* diurnal Motion *of the Earth on its Axis, the apparent* annual Motion *of the Sun in the Ecliptic, the various Phænomena of* Days *and* Nights, *the* Seasons *of the Year, and of a* Solar Eclipse *are exhibited by proper Machinery.*

Euphrosyne.

WELL, *Cleonicus*, I am sure I have lost no Time, since our last Interview, in making myself perfect in the Use of the Globes.——I have practised every Problem, over and over again, on both the Globes, and now I may say, with the rich Man in the Gospel, *What lack I yet?*

Cleon. Why, to answer according to your own Stile, tho' you have been indeed busy about many Things, yet *one Thing is needful*:——You have been long engaged in learning how the Phænomena of Nature may be artificially represented by Globes, and in this you find great Assistance from the Labours of many ingenious Men; but with little Attention, it will appear, that those Things will admit of a much more natural Representation with a little Contrivance and small Expence of Machinery; and you will readily allow, that the more natural

any

any Phænomenon can be ſhewn, the more Satisfaction and greater Inſtruction it muſt give to every inquiſitive Mind.

Euphroſ. No one can doubt the Truth of that, and I ſee you have provided here a beautiful Machine for that Purpoſe; and I flatter myſelf, I ſhall have great Pleaſure in being inſtructed in the Uſe of it.

Cleon. To ſay the Truth, I have employed my utmoſt Skill to contrive it for your Inſtruction; for though there has been two or three Inventions of this Kind already propoſed to the Public, yet I think them by no Means ſo ſimple and elegant as ſuits with the Nature of the Deſign, and worthy the delicate Genius of your Sex.

Euphroſ. Compliments but ill ſuit with philoſophical Inſtructions; therefore, without any further Ceremony, explain to me the Uſe of the Machine, for I am impatient to know it.

Cleon. I will oblige you in this, and every Thing elſe I can, to the utmoſt of my Power.

Firſt then, By opening a Door in the Side of the Machine, you obſerve a Train of Wheel-work, put in Motion in the ſame Manner as that of a Spring-Clock. This may be called, the *Primum Mobile* of the Machine.

Secondly, On the upper Part of the Machine, you obſerve a Terreſtrial Globe is placed, which is moveable on its Axis by the Hand, yet ſo as to remain in any Poſition where it is placed.

Thirdly, By the Machinery within, a Motion is communicated to the Globe, about its Axis, by Means of that Wheel which you ſee on the Top of the Box, and fixed to the Axis of the Globe. This is the diurnal Motion of the Globe, performed in the ſame Time with that of the natural Globe, *viz.* in 24 Hours.

Fourthly, On the Surface of the Globe you obſerve an artificial, moveable Horizon, by which the Globe may be rectified to the Latitude of any given Place.

Fifthly, The Axis of the Globe makes an Angle with the Axis of the *Ecliptic* of 23° 30′.

Sixthly, The Globe has another Motion communicated to it, by which the Plane of the Ecliptic is gradually moved round in the Space of one Year, or 365 Days.

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Seventhly, In Conſequence of this, a Braſs Ball repreſenting the Sun, placed on a Stem upon one Side of the Machine, and juſt in the Plane of the Ecliptic, will appear to move through every Sign and Degree of the Ecliptic in the Space of twelve Months, juſt as the real Sun appears to move in the Heavens.

Eighthly, A Braſs Circle is placed about the Globe at the Diſtance of 90° every Way from the Sun, which may be called, the *Solar Horizon*, or *Circle of Illumination*, becauſe it conſtantly divides the Globe into the enlightened and dark Hemiſpheres.

Ninthly, On the Wheel affixed to the Axis you obſerve a moveable Hour Circle, and a fixed Index, by which Means the Time of any Phænomenon is ſhewn, and the Globe rectified in regard thereto.

Tenthly, By removing the Sun, I place theſe two Braſs Arms to the Sides of the Machine, which, by Means of Screws, are moveable up and down, ſo that the long Piece of Braſs, you ſee moveable upon the Ends of each, may be placed either horizontally, that is, parallel to the Plane of the Ecliptic, or inclined thereto, in any Angle leſs than 6°. So that it may be placed parallel, at any Time, to the Path of the Moon.

Eleventhly, To the middle Part of this tranſverſe Piece is fixed another, at right Angles, with Spring-Sockets, through which ſlides a long Slip of Braſs, on the Top of which is fixed a dark Circle, repreſenting the Moon's penumbral Shadow, at the Surface of the Earth, in a Solar Eclipſe; and in ſuch Proportion to the Globe, as the real *Penumbra* of the Moon has to the Globe of the Earth.

Twelfthly, The Slip of Braſs which carries the lunar Shadow is divided, from a certain Point each Way, into a Scale of Minutes, by which Means, in any Eclipſe, the neareſt Diſtance between the Center of the Penumbra, and the Earth's Diſk, or the Latitude of the Moon in an Eclipſe at the Time of a true Conjunction, may be truly expreſſed, and thereby the lunar Penumbra properly adjuſted to the Diſk of the Earth, and its true Paſſage over it ſhewn in that Eclipſe.

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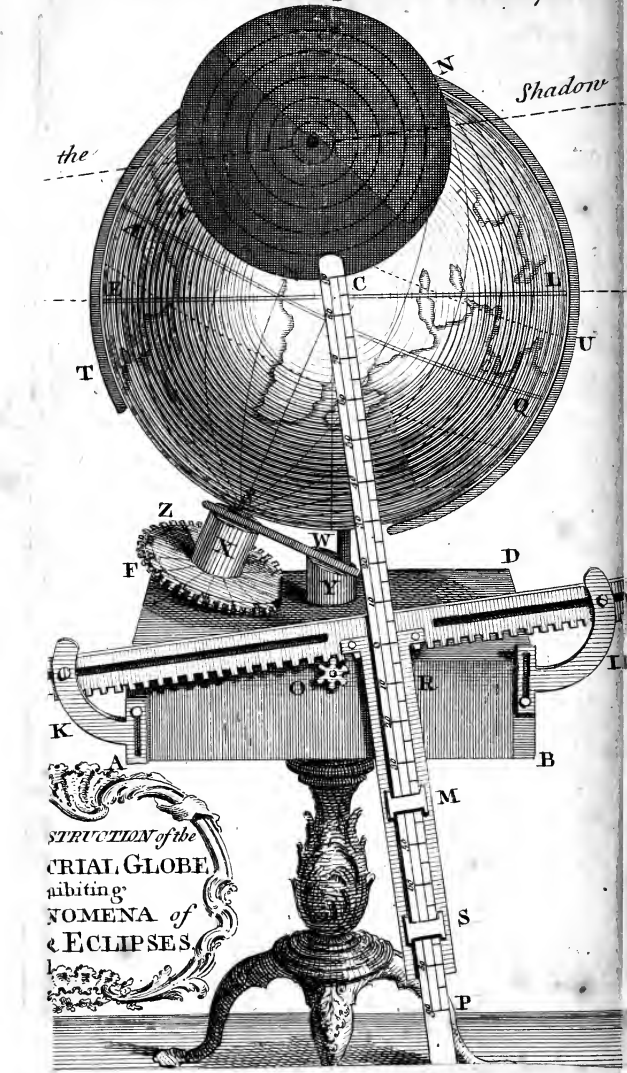
OLAR ECLIPSE *April 1st A.D. 1764.*



STRUCTION of the
RIAL GLOBE,
ibiting
NOMENA of
ECLIPSES.

Thirteenth, The lower Part of the tranſverſe Piece is divided into Teeth, adapted to a ſmall Pinion that you ſee in the Side of the Machine, by which Means this Piece, when the Machine is in Motion, carries the penumbral Shadow over the Earth's Diſk with the proper Velocity of Motion which the Moon really has at that Time in her Orbit, or which the penumbral Shadow really has on the Diſk of the Earth.

Fourteenth, But as the Moon's Motion is ſometimes quicker, and ſometimes ſlower, if we would be very accurate, there ſhould be three of thoſe tranſverſe Pieces, containing each a different Number of Teeth of the ſame Length, and fitted to expreſs the greateſt, mean, and leaſt Velocity of the Moon's Motion.

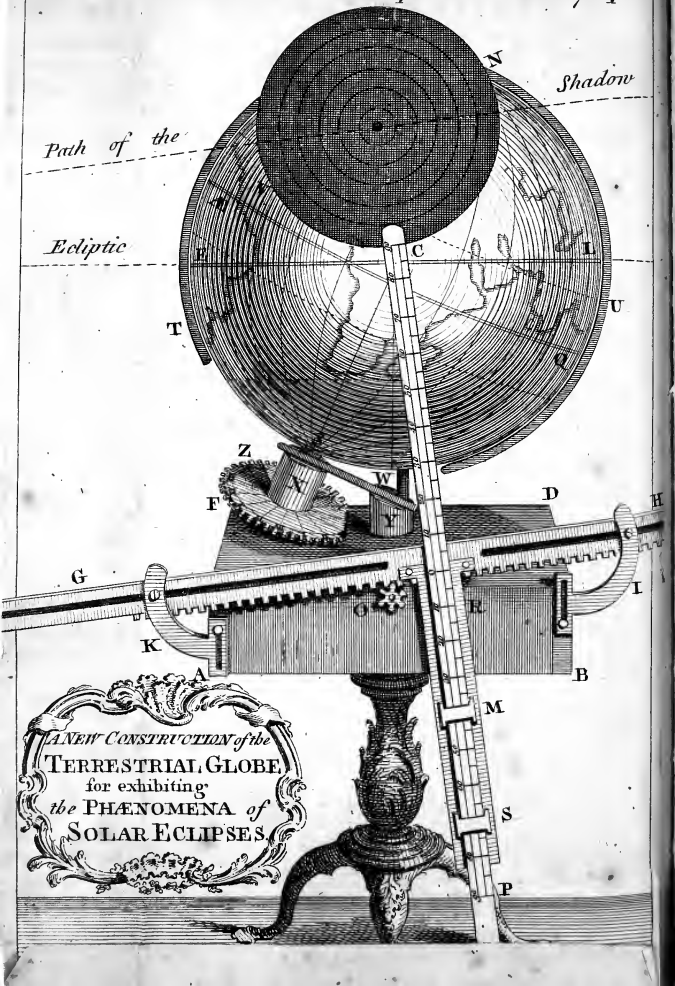
Fifteenth, The Machinery is ſo contrived, that the diurnal Motion of the Earth, and annual Motion of the Sun may be performed in a ſhort Space of Time, *viz.* The annual Motion in ſix Hours, and the Diurnal in nearly one Minute.——And now, my *Euphroſyne*, you are prepared for viewing the great Phænomena of Nature, juſt as they happen in the Courſe of Things, or otherwiſe, at Pleaſure *.

* *An* EXPLANATION *of the* MACHINE.

A B D F, Is the Body of the Machine.
C, The Center of the Globe.
Æ Q, Equator.
E L, The Ecliptic.
N S, The Axis of the Globe.
G H, The tranſverſe Piece, with Teeth.
I K, The circular Arms, on which it moves.
O, The Pinion which moves it.
R S, The fixed perpendicular Piece.
M S, The Sockets upon the ſame.
C P, The long graduated Slip of Braſs, carrying
N V, The penumbral Shadow of the Moon.
T U, The Circle of Illumination.
W, The Stem, or Foot thereof.
X, The Part on which the Globe reſts.
Y, The Part on which the Globe is ſupported.
Z, The horary Circle, which gives Motion to Globe.

In the Print we have exhibited the Apparatus for repreſenting the *Solar Eclipſe*, *April* 1, *A. D.* 1764, as being the moſt remarkable that will happen, for many Years to come. We have not repreſented the *Sun*, the moveable *Horizon*, *Crepuſcular Circle*, *&c.* to avoid Confuſion, eſpecially as they are eaſily ſupplied by the Imagination, and ſo particularly deſcribed in their Uſes above.

The SOLAR ECLIPSE April 1st A.D. 1764.



A NEW CONSTRUCTION of the
TERRESTRIAL GLOBE,
for exhibiting
the PHÆNOMENA of
SOLAR ECLIPSES.

Thirteenth, The lower Part of the transverse Piece is divided into Teeth, adapted to a small Pinion that you see in the Side of the Machine, by which Means this Piece, when the Machine is in Motion, carries the penumbral Shadow over the Earth's Disk with the proper Velocity of Motion which the Moon really has at that Time in her Orbit, or which the penumbral Shadow really has on the Disk of the Earth.

Fourteenth, But as the Moon's Motion is sometimes quicker, and sometimes slower, if we would be very accurate, there should be three of those transverse Pieces, containing each a different Number of Teeth of the same Length, and fitted to express the greatest, mean, and least Velocity of the Moon's Motion.

Fifteenth, The Machinery is so contrived, that the diurnal Motion of the Earth, and annual Motion of the Sun may be performed in a short Space of Time, *viz.* The annual Motion in six Hours, and the Diurnal in nearly one Minute.——And now, my *Euphrosyne*, you are prepared for viewing the great Phænomena of Nature, just as they happen in the Course of Things, or otherwise, at Pleasure *.

* *An* EXPLANATION *of the* MACHINE.

A B D F, Is the Body of the Machine.
C, The Center of the Globe.
Æ Q, Equator.
E L, The Ecliptic.
N S, The Axis of the Globe.
G H, The transverse Piece, with Teeth.
I K, The circular Arms, on which it moves.
O, The Pinion which moves it.
R S, The fixed perpendicular Piece.
M S, The Sockets upon the same.
C P, The long graduated Slip of Brass, carrying
N V, The penumbral Shadow of the Moon.
T U, The Circle of Illumination.
W, The Stem, or Foot thereof.
X, The Part on which the Globe rests.
Y, The Part on which the Globe is supported.
Z, The horary Circle, which gives Motion to Globe.

In the Print we have exhibited the Apparatus for representing the *Solar Eclipse, April* 1, *A. D.* 1764, as being the most remarkable that will happen, for many Years to come. We have not represented the *Sun*, the moveable *Horizon, Crepuscular Circle, &c.* to avoid Confusion, especially as they are easily supplied by the Imagination, and so particularly described in their Uses above.

Euphrof. In regard to the Uſe of this new conſtructed Globe, I muſt be entirely paſſive, as I know not yet which Way to go about ſolving any one Problem; but ſhall be very glad to ſee thoſe natural Phænomena ariſe from the Direction of your own Hand.

Cleon. I will ſhew them to you in their natural Order; and, Firſt, you are to obſerve, that ſince the Pole of the Ecliptic is the higheſt Point of the real Globe of the Earth, as it revolves about the Sun in its annual Orbit, ſo the ſame Pole of the Ecliptic muſt always be the higheſt Point, and therefore, what we may call the *Zenith* of this artificial Globe, the nether Pole of the Ecliptic being the *Nadir*.

Euphrof. This I plainly ſee; and in Conſequence of which, the Ecliptic may be called the Horizon; at leaſt, I ſee it parallel with the Horizon of the common Globe, and will always remain ſo.

Cleon. Your Remark is juſt.——Secondly, to rectify this Globe, I fix the Ball, repreſenting the Sun in the Plane of the Ecliptic, on its Stem, at a ſmall Diſtance from the Globe.——Then, by turning the Winch, I cauſe the Ecliptic Circle to move round; ſo that any Part which the Sun occupies at any Time, may be placed againſt the Braſs Ball, or artificial Sun.—Thus, for Inſtance, on the firſt Day of *April* the Sun being in the twelfth Degree of *Aries*, I bring that Point exactly againſt the Ball; and thus the Globe is rectified for that Day of the Year.

Euphrof. This is a different Rectification of the Globe, from what you ſhewed me before; but I ſuppoſe it is ſuch as correſponds to the reſpective Situation of the Sun, and the Earth in its Orbit for that particular Day.

Cleon. It does ſo very exactly; for the Earth being in the twelfth Degree of *Libra*, if we look at the Sun in the Center it muſt neceſſarily appear in the oppoſite Point, or twelfth Degree of *Aries*, as you very well know.——Thirdly, I put the Machinery in Motion, and, in the Space of nearly one Minute, you ſee the Earth revolve once round upon its Axis with an equable Motion, which exhibits to you a natural Idea of the Manner in which the real Earth does turn upon its Axis, as it proceeds in its Orbit, about the Sun.

Euphrof.

Euphrof. This is a very curious Repreſentation, indeed, of the Earth's diurnal Motion; and I obſerve the Index below points out the ſeveral Hours of the Day, and Night, on the horary Circle in its Revolution.

Cleon. You will next obſerve, my *Euphroſyne*, that when the Sun again comes into the Plane of the Ecliptic, after one Rotation of the Earth about its Axis, that it is found to poſſeſs the next, or thirteenth Degree of the Ecliptic; ſo that you are convinced of the fourth Phænomenon by occular Demonſtration, *viz.* That in the Space of one natural Day, the Sun has an apparent Motion in the Ecliptic of one Degree nearly.

Euphrof. This I obſerve with Pleaſure, as it is very natural to ſee how the apparent Motion of the Sun, in this little Globe, anſwers to that of the real Sun in the Heavens :——But as there are 365 Days in the Year, and only 360 Degrees in the Ecliptic, the apparent Motion of the Sun, at a Mean, cannot be quite one whole Degree in a Day; but the Difference is too ſmall to be inſiſted on here.

Cleon. It is, indeed, very ſmall for one Day; but in the Space of the whole Year you will find every Part of the Ecliptic will be paſſed over by the Sun.——The fifth Phænomenon you will next obſerve, is the Paſſage of that Part of the Earth's Surface under the Sun, to the Inhabitants of which the Sun is ſucceſſively vertical on that Day.

Euphrof. This appears extremely natural, indeed; I plainly ſee, that for the firſt Day of *April* all the midland Parts of *Africa*, the *Indian* Sea, the Iſle of *Ceylon*, the Kingdom of *Mallacca*, the *Philippine* Iſlands, the vaſt Tract of Ocean between them and *America*, the large Continent of *South America*, called *Terra Firma*, *&c.* all paſs under the Sun, and therefore view him in their Zenith.——I muſt needs own, this Repreſentation far exceeds that for the ſame Purpoſe on the common Globe.

Cleon. The ſixth Phænomenon is the variable Length of Days and Nights, according to the different Times of the Year, which offers itſelf to the View here juſt as it does in Nature; for when I bring the Meridian of any Place to paſs thro' the Sun, I then move the Hour of the Noon-Tide XII to the Index, and rectify the Moon's Horizon by the Latitude of that Place; for then the Globe, in Motion, naturally

ſhews you the Length of the Day and Night, at any given Time of the Year.

Euphroſ. I apprehend it muſt be ſo: But an Example will ſtill make it clear, which, I think, I am able to perform my ſelf.——I ſhall take our capital City, *London*, for the Place; and therefore rectify the moveable Horizon by fixing it at 51° 30′ from the North Pole, by the general Meridian drawn on the Globe:——And now, I will firſt adjuſt the Sun to the Beginning of the Ecliptic, by turning the Globe about till the vernal Equinox is right againſt it;——Then, pleaſe to put the Machine in Motion.

Cleon. It is done.

Euphroſ. And very plainly I obſerve, that at the End of ſix Hours the Weſtern Part of the Horizon is againſt the Center of the Sun:——That in twelve Hours more, the Eaſtern Part of the Horizon is upon the Sun:——And after another ſix Hours, the Equinox returns to the Sun and plainly ſhews me the Length of the Day and Night is the ſame on that Day of the Year.——Alſo, I ſee the Sun naturally Setting, or apparently paſſing below the Weſtern Part of the Horizon at Six in the Evening,—— and riſing above the Horizon at Six in the Morning, juſt at the Point due Eaſt.——All this I can eaſily ſee will follow from the Motion of the Earth, carrying the Horizon of *London* along with it, over the Body or Diſk of the Sun.

Cleon. And one Thing farther you will take Notice of, as a ſeventh Phænomenon, which will more illuſtrate this Doctrine, which is, the *Circle of Illumination* fixed to the Machine, and ſurrounding the Globe in ſuch a Manner, as to divide it into the enlightened and dark Hemiſpheres. This Circle may, with ſome Propriety, be called the ſolar Horizon, as it is every where exactly 90° diſtant from the Sun.

Euphroſ. I readily ſee what Conſequences will attend this Obſervation:——Becauſe it muſt neceſſarily happen from hence, that when the Horizon of any Place is upon the Sun, the Place itſelf will be under the Circle of Illumination; and, therefore, juſt entering into the darkened Hemiſphere.—— The Reaſon, therefore, of Day and Night, and all their Variations is, from

from hence, extremely obvious, and more ſo, by much, than in the Orrery itſelf.

Cleon. You cannot be too well apprized of the Nature of this grand Phænomenon; and therefore it will be proper to repeat the Experiment for the longeſt Day in the Year in the Latitude of *London*, which will preſent you with a View of the greateſt Inequality of Days and Nights that can happen here.

Euphroſ. This, I preſume, I can eaſily do, by moving the firſt Degree of *Cancer* to the Sun,—and then turn the Globe on its Axis till the Sun comes to the Meridian of *London*,—— where letting it reſt, I turn the Hour Circle till the Meridian XII is at the Index:——Then giving Motion to the Machine,——I ſee the Globe revolves in ſuch a Manner, that the Tropic of *Cancer* conſtantly paſſes under the Sun, from Weſt to Eaſt, till at Length the Weſtern Horizon comes upon the Sun:——At the ſame Time I obſerve the City of *London* is under the *Circle of Illumination*, and goes into the darkened Hemiſphere at the ſame Moment of Time that the Sun is ſeen below the Horizon.——When this happens, the Index points to VIII o'Clock, and ſomewhat more.——Again, the Globe, continuing in Motion, carries the Iſland of *Great Britain* thro' the darkened Hemiſphere, till at Length it appears on the other Side of the *Circle of Illumination*, and the Eaſtern Part of the Horizon revolves to the Sun;——At which Moment of Time I ſee the Index pointing nearly to the Hour of IV in the Morning:——So that from hence it is evident, that the longeſt Day with us is a little more than XVI Hours, and the ſhorteſt Night nearly VIII, and therefore but half as long as the Day:——The Manner in which theſe Things appear ſo nicely according with Nature itſelf, redoubles the Pleaſure of Inſtruction.——But what is that ſmall Circle, which I ſee every where at an equal Diſtance from the moveable Horizon?

Cleon. That may be called the *Crepuſcular Circle*, or *Circle of Twilight*. It is placed at 18° 00′ below the Horizon, becauſe, till the Sun has deſcended ſo far, ſome of his Beams will be refracted by the Atmoſphere, and make a Twilight, or a decreaſing Mean between Day and Night: But when the Sun has reached that Circle, we find it dark Night; and, therefore, as

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the Globe revolves, at the ſame Time that you obſerve the Time of the Beginning of Day and Night, you ſee alſo the *Beginning*, *Duration*, and *End* of *Twilight*; which is the eighth Phænomenon in this Machinery.

Euphroſ. Well, this is a Curioſity over and above what I expected; a Piece of Knowledge that does not pleaſe me a little: for, tho' I had ſome indirect and faint Ideas before, my Notions of it are vaſtly enlarged and improved by this natural Repreſentation. ——— And what delights me very much is, that in the laſt Example of the longeſt Day, I ſee there can be no dark Night at all; ſince the Sun, at Midnight, is not by many Degrees ſo far below the Horizon of *London* as is the *Circle of Twilight*. ——— Nor, indeed, for many Day before, and after the longeſt Day, the Depreſſion of the Sun, at Midnight, will not be ſo great as the Diſtance of that *Crepuſcular Circle* from the Horizon; and that, for that Space of Time, there will be *no dark Night*, which there muſt be, more or leſs, at all other Times of the Year.

Chron. At your Leiſure, you may practice this Problem for the ſhorteſt Day, in the ſame Manner as for the longeſt; and likewiſe, for the Times of the Beginning and End of Twilight at any Time of the Year. What I muſt next obſerve is, the ninth Phænomenon, which is of the greateſt Importance of all, *viz.* The *various* SEASONS *of the Year*: ——— For, by what we have already ſeen, you learn, (1ſt,) That when the Sun, in its apparent Motion, poſſeſſes the Beginning of the Ecliptic, or firſt Point of *Aries*, then alſo the Poles of the World appear under the *Circle of Illumination*, and then the Days and Nights are not only equal, but the Sun being at an equal Diſtance from either Pole, his Light and Heat is then of a mean Degree, and makes that delightful Seaſon which we call the SPRING. (2dly,) As the Sun advances in its annual Courſe gradually towards *Cancer*, the North Pole, by degrees, is brought ſtill farther into the enlightened Hemiſphere, till, at laſt, when the Sun arrives to the firſt Degree of *Cancer*, the North Pole is then 23° 30′ within the illumined Hemiſphere, or by ſo much nearer the Sun than it was before; and conſequently its Light and Heat will now be the greateſt of all, in all the Northern Latitudes, as well as the Days the longeſt; and therefore you

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ſee the Nature of the Seaſon we call SUMMER, demonſtrably plain. (3dly,) The Globe continuing in Motion, the Sun appears to advance towards *Libra*; and the North Pole retreats, by degrees, and gets a ſecond Time under the *Circle of Illumination:* —— At that Inſtant the Sun arrives at *Libra*, and then it cauſes the *autumnal* SEASON. (4thly,) The Motions of the Globe continuing, you ſee the Sun gradually advance, from Day to Day, towards the Beginning of *Capricorn*; and the North Pole going farther and farther into the darkened Hemiſphere, till, at Length, when the Sun comes to the firſt Scruple of *Capricorn*, the North Pole will be then 23° 30′ from the *Circle of Illumination* in the darkened Hemiſphere, and that of Courſe, in this Poſition of the Globle, the Days will not only be the ſhorteſt, but the Light and Heat of the Sun will be the leaſt it ever can be in Northern Latitudes, and therefore makes the *Winter* SEASON. —— Hence, in a ſhort Time, you ſee all the Succeſſion of Seaſons, with all their Variety of Incidents, in the Courſe of a whole Year.

Euphroſ. This is not only a compendious, but a beautiful View of Nature's great Events, reſulting from the moſt ſimple Cauſes. —— Not only the Seaſons, and different Length of Days and Nights, but likewiſe many other curious Subjects offer themſelves to my View, in this Speculation of a Globe in Motion: —— I ſee the Parts of the Earth, or Circum-polar Regions, alternately, wholly enlightened, or wholly in the Dark at oppoſite Times of the Year. —— I ſee when the Sun begins to ſhine without Setting, and to ſet without ſhining any more to the different Inhabitants within the polar Circle: —— I obſerve, how naturally all the different Parts of the Torrid Zone come under the perpendicular Beams of the Sun, in the Courſe of a Year. —— But I ſhall no longer detain you with theſe common Subjects. —— There is yet an Apparatus remaining, which, I ſee by the Form of it, has Relation to the Nature of Eclipſes; pray, am I, at preſent, to learn the Uſe of that?

Cleon. By all Means, it being the principal Part of the Deſign of this Conſtruction, to give you a more natural View of a ſolar Eclipſe, and the Manner in which it happens, than by any Contrivance of the common Globes, Orreries, &c. eſpecially

what

what relates to an Explication of the particular Phaſes thereof; for, to anſwer ſuch Purpoſes in the beſt Manner, you ought to know in what Manner the Shadow of the Moon goes over the Surface of the Earth in the Time of the Eclipſe. Altho' I have formerly illuſtrated this, by a Copper-plate Print, in a general Way, * yet that will by no Means ſuffice for a full and adequate Notion of this Matter. It was there, indeed, ſhewn, what was the *Total*, and what the penumbral Shadow of the Moon; but it ſtill required the Surface of a Globe, to ſhew the Proportion of the dark and penumbral Shadow, when compared therewith; alſo what is the particular Courſe over, and Figure of the Shadow upon the Surface of the ſaid Globe, ſo that it may have the ſame Appearance as if you was actually to ſee it on the Surface of the Earth itſelf. —— The Aſtronomers have Methods whereby they can, at all Times, aſcertain the true Dimenſions of the Moon's Shadow at the Surface of the Earth, and, conſequently, can aſſign the Proportion it bears to the Earth's Surface: Therefore, whatever the Size of the Globe you make Uſe of may be, we can immediately adapt a Shadow to it, by cutting out a circular Piece of black Crape, which ſhall bear the required Proportion to the Surface of the Globe. This Crape will denote the penumbral Shadow. —— In the Center of this Crape we can fix one of your ſmall Patches, to repreſent the dark Shadow of the Moon, in a proper Proportion to the penumbral Shadow; and here, let me tell you, it is much more properly applied than when it is placed on your own Face, to eclipſe ſome of the natural Beauty thereof. —— In the next Place, the Inclination of the Moon's Orbit to the Plane of the Ecliptic, is at all Times known; and therefore the Latitude of the Moon, or its perpendicular Diſtance from the Ecliptic, is known at the Time of any given Eclipſe, and, conſequently, the Path of the Center of the Shadow may be thereby aſſigned on the Surface of the Globe: —— Conſequently, the Time when the Shadow firſt enters on the Diſk of the Earth, or Surface of the Globe, and alſo the Time when it goes off; and therefore, the Beginning, the Middle, and End of the Eclipſe, with the Quantity thereof, may eaſily be determined and repreſented by this Machinery.

Euphroſ.

* See Plate XVIII. Page 151. Vol. I. of the *Gentleman and Lady's Philoſophy.*

Euphros. I must confess that, till you have put your ecliptic Apparatus in Order, and applied it to the Machine, I cannot have so clear an Idea of the Design of it as I then may; for, I presume, the Use of each particular Part will then more fully appear.

Cleon. It will so:——But before we can proceed any farther in this Speculation, we must adjourn to a Sun-shiny Morning, when we can view the various Phases of a Solar Eclipse to the best Advantage; and till then you may ruminate on the Subjects that have, at present, passed between us, and render yourself more perfect in the Uses of the Globe each different Way.

DIALOGUE XIII.

On the Use of the New Apparatus *to the* TERRESTRIAL GLOBE, *in explaining the Nature and various Phænomena of* SOLAR ECLIPSES, *exemplified in that which is to happen in* 1764.

Euphrosyne.

I WAS scarcely ever more impatient for any Event, than of the Sun-shiny Morning, to which you adjourn'd. And now the wish'd for Hour is come, the Air is serene and clear, and we have the fairest Prospect of an entire fine Day: And you will be mindful of the old Proverb, *To make Hay while the Sun shines*, and apply the solar Apparatus as speedily as you can, and thereby give me the Pleasure of seeing Nature anticipated in that future great Phænomenon.

Cleon. I will do so; and therefore first, I apply the two circular Arms to the Side of the Box, which are moveable up and down, at Pleasure; and on these Arms, the long transverse sliding Piece, with Teeth on the lower Part, to the Number of Eighty; to the middle Part of this Piece I apply the Crape, or Shadow of the Moon, placed on the Top of a long Stem, or

Slip of Brass, before described, and lowering one of the Brass Arms, and raising the other, I fix the Sliding-piece exactly parallel to the Orbit of the Moon, which is done by the Divisions on the Sliding-part of the Arms; then I move the Arm which carries the Shadow up, or down, in the Sockets, till such Time the Number which expresses the Latitude of the Moon from the Ecliptic, in the Middle of the Eclipse, touches the upper Socket, and there screw it fast. ——— A Motion is then communicated to the Slider by a small Pinion, which you see on the Outside of the Box, working in the Teeth of the Slider; and as twelve Teeth in the Slider answers to one Hour's Motion, there will be six Hours and an half Motion upon the whole, if required, which is somewhat more than the Time of any generally Solar Eclipse. ——— And now, to make every Thing clear and plain, by Example, I shall give you a Representation of that remarkable Solar Eclipse that will happen on the 1st Day of *April* in the Year 1764.

Euphros. That I understand, by what you have said, is the largest Eclipse we are to expect for many Years to come, and therefore a Representation of it, in your new, and natural Method, must certainly be very agreeable.

Cleon. That you may have the clearest Idea of this Matter, you are to suppose yourself, at the Time of the Eclipse, translated to the Moon; and from thence to view her Shadow passing over the Surface of the Earth, which Surface, or Disk of the Earth, will appear sixteen Times as large, to your eye placed there, as the full Moon appears to you here; and all the enlighten'd Surface of the Earth will, in such a Case, be turned directly to your Eye in the Moon; and you would in that Case, see the penumbral Shadow of the Moon gradually coming on, and traversing over the upper, or northern Parts of the Earth's enlighten'd Disk, together with the dark central Spot in the Middle. ——— This Appearance of the Earth's Disk, as I said before, may be represented by a Globe of any Size, and the Crape to represent the penumbral Shadow, with the Patch in the Middle to represent the dark Shadow being proportioned thereto, will, when the Machine is in Motion, exhibit to you very nearly the same Appearance as you would observe from the Moon. ——— Therefore, in the first Place, as

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it is known by Calculation that this Eclipſe will happen when the Sun is in the twelfth Degree of *Aries*, I adjuſt the Globe ſo, that that Point of the Ecliptic may be juſt in the Middle of the enlightened Hemiſphere, or every Way 90° from the Circle of Illumination, and juſt at that Point of the Ecliptic I place the artificial Sun: Then I bring the Meridian of *London* to paſs thro' the Sun, and move the hour Circle till the Index points to XII; and as the general Eclipſe begins about twenty Minutes after VII, I turn the Globe about till the Index points to the Hour of VII.—And ſince the Middle of the Eclipſe happens a few Minutes after X, I move the Shadow on the ſliding Piece towards the left Hand, or weſtern Side of the Globe, by a little more than the Space of half the Duration of the Eclipſe, which is ſhewn by the Hours and Minutes placed on the Slider, each Way from the Middle. ——— Then having raiſed the Shadow, by the Scale of the Moon's Latitude placed on the Stem, the Machine is ready for Motion.

Euphroſ. By all this Preparation, I plainly perceive an Eclipſe of the Earth is at hand. When the Machine is in Motion, I cannot help ſeeing, that the Shadow of that Crape will very naturally repreſent the Shadow of the Moon, as it paſſeth over the Surface of the Earth: But how do you adjuſt that Shadow? ——— The Sun ſhines, 'tis true; but his Beams are ſo oblique, that I do not ſee how they are to anſwer the Purpoſe, as they at preſent will fall over the Circle of Illumination, when the Globe is turned towards the Sun, and ſo the enlightened, and dark Hemiſpheres will not be the ſame as repreſented by the Machinery.

Cleon. To all this, the Anſwer is ready and eaſy; ——— for the artificial Day and Night may be truly made at any Time by the Sun Beams, or Candle-light: ——— For if I place the Globe toward the Sun, and place a Looking-glaſs on the Table, (between the Sun and the Globe,) inclined in a proper Degree, it will throw the Sun Beams parallel to the Horizon, and, conſequently, every where perpendicular to the Plane of the Circle of Illumination; by which Means, that Part of the Globe will be enlightened, and repreſent the Day juſt as it is in Nature.——— The ſame Thing alſo, is to be done by placing a Candle in the Focus of a large Lens, or Specu-

lum, which, by that Means, will be directed parallel to illuminate the Hemiſphere required. ——— But as the Sun Beams are moſt natural, and fitted for our Purpoſe at preſent, your Dreſſing-glaſs will be the moſt proper to diſpoſe the Rays for making the artificial Day, which you can bring me down and ſet on this Table.

Euphroſ. I will inſtantly go and fetch it; ——— here it is; and, by the Screws, you will place it in the Poſition which you know to be neceſſary.

Cleon. I have duly placed the Table, and put up the Saſh, and now the Sun Beams fall on the Glaſs. ——— I move it up and down, till ſuch Time I find the Rays go parallel to the Horizon, and fall on the Globe as they ought. ——— And now, you have nothing to do but to obſerve the general Phænomena of the Eclipſe, which, upon my putting the Machine in Motion, you will obſerve to be as follows:

I. You ſee the eaſtern Edge of the Shadow come upon the weſtern Part of the Earth's Surface, and firſt touch it on the weſtern Parts of *Africa:* Alſo, that the eaſtern Part of the Shadow gradually paſſes along on the Circle of Illumination; and deſcribes a Tract on the Surface of the Earth, ſhewing all that Part, whoſe Inhabitants view the Sun beginning to be eclipſed at the Horizon, or that the eaſtern Limb of the Moon touches the weſtern Limb of the Sun, juſt riſing above the Horizon.

II. Soon after this, you obſerve the vertical Line on the Crape (which divides the Shadow into the eaſtern and weſtern Semi-circle) will come upon the Circle of Illumination, and denote that Tract upon the Surface of the Earth where the Sun will appear to riſe with the Moon, as far advanced on its Surface as ſhe can be, and where the Eclipſe will appear greateſt of all at Sun-riſing.

III. The Middle of this Line, or central Spot of the Shadow, will come upon the ſaid Circle at its Entrance on the illuminated Diſk; and thoſe who inhabit that particular Spot, you will eaſily obſerve, muſt ſee the Sun riſe centrally eclipſed.

IV. As the Shadow advances, you ſee the weſtern Part coming on upon the Earth's Surface, and in every Part, where the

the weſtern Edge of the Shadow comes upon the Circle of Illumination, the Inhabitants of that long Tract will obſerve the Sun riſing, with the weſtern Limb of the Moon juſt touching the Sun on the loweſt, or eaſtern Part in the Horizon, *i. e.* they will ſee the Moon go off, or the Eclipſe end juſt as the Sun is riſen. ——— And theſe will be the Appearances of the Eclipſe, at Sun-riſing, to the Inhabitants of the weſtern Parts of *Africa* and *Europe* to the North Pole, or a little beyond it, including a large Space on the Surface of the Earth.

V. As the Shadow advances, the greateſt Part is received on the Surface of the Earth; but all the upper Part falls off into the Expanſe over the northern Regions: And as it riſes higher and higher above the Plain of the Ecliptic, ſo the Center of the Shadow goes northerly till it has deſcribed a Tract, obliquely, from the Weſt of *Africa* to the northern Parts of *Moſcovy*, where it goes off from the Earth.

VI. By the black Circles on the Crape, round the Center, is ſhewn how much of the Sun's Surface will be eclipſed from the View of the Inhabitants who live on thoſe Parts, where the Circles paſs. Thus they who live in the Tract of the Center will ſee no Part of the Sun's Diſk, but the Sun will be centrally eclipſed to them. ——— Thoſe who live under the Shadow of the firſt Circle from the Center, will view ten Digits eclipſed, or ten Parts out of twelve of the Sun's Diameter. ——— Thoſe who live under the Shadow of the ſecond Circle from the Center, will view but eight Digits eclipſed. ——— Thoſe who live under the Shadow of the third Circle, ſee but ſix Digits, or half the Sun's Diameter eclipſed, and ſo in Proportion to the other Circles.

VII. Becauſe the Sun's Diameter does a little exceed the Moon's, therefore the Eclipſe, where central, will not be total; but there will be a Ring of Light all round on the Edge of the Sun, which occaſions ſuch an Eclipſe to be called *Annular*. In ſome Caſes, the apparent Surface of the new Moon is larger than that of the Sun, and then the Eclipſe is central, and total.

VIII. You will next obſerve, there is a certain Point in the Meridian of the enlightened Diſk, a little beyond the Pole, which, while the Globe is turning upon his Axis, does only juſt touch

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the Circle of Illumination, but goes not beyond it; in that very Part they view the Sun, in the South Point of the Horizon, neither Setting nor Riſing, with the ſouthern Limb of the Moon juſt touching it on the northern Edge; and this is the Term where the Beginning of the Eclipſe ceaſes at Sun-riſing, and begins at Sun-ſetting: For,

IX. When the eaſtern Edge of the Shadow has paſſed this Point, it will come upon thoſe Parts of the Surface of the Earth on the eaſtern Side, which are paſſing under the Circle of Illumination, into the dark Hemiſphere; and in all thoſe Places which are traced out by the Eaſt Edge of the Shadow, applying to the ſaid Circle, the Inhabitants will view the Eclipſe begin juſt as the Sun ſets, or they will view the eaſtern Limb of the Moon, and Weſt Limb of the Sun touching in the Horizon.

X. The vertical Line of the Shadow, as it ſucceſſively applies to the ſeveral Parts of the Circle of Illumination, will trace out all that Part on the eaſtern Side of the Globe, to whoſe Inhabitants the Sun will appear eclipſed, in the greateſt Quantity that can be to them, at Setting; and in that particular Part where the Middle of the Line, or Center of the Shadow, touches the Circle, the Sun will appear centrally eclipſed at his Setiing.

XI. As the Shadow paſſes on, the weſtern Edge comes, by Degrees, on the eaſtern Part of the Circle of Illumination, and the Inhabitants of all thoſe Parts which are on the Edge of the Shadow, under the Circle, ſee the Eclipſe end, or the Moon paſſing off the upper Limb of the ſetting Sun.

XII. During the Paſſage of the Shadow over the Earth's Surface, you will obſerve the Earth keeps regularly moving on upon its Axis, the ſame Way with the Moon's Shadow, from Weſt to Eaſt, by which Means it happens, that a much leſs Quantity of the Surface of the Earth is obſcured by the Shadow, than would have been, had there been no diurnal Motion.

XIII. With regard to any one particular Place, as *London*, for Inſtance, you will obſerve, that when the eaſtern Edge of the Shadow comes upon it, the Eclipſe begins; and when the weſtern Edge of the Shadow touches it, the Eclipſe ends: And when the vertical Line of the Shadow is upon it, the Eclipſe is

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the greateſt of all, and the Circle neareſt to it will ſhew the Digits eclipſed.

XIV. The Time of any particular Phaſe is obſerved for any given Place, by the Hour Circle: Thus the Beginning of the Eclipſe at *London* is there ſhewn to be a few Minutes after IX, the Middle about twenty Minutes after X, and end at about three Quarters after XI, and that there will be nearly eleven Digits eclipſed. ——— Such, my *Euphroſyne*, are the Appearance of a Solar Eclipſe, the general Rationale of all which, as exhibited in this Manner, I make no Doubt, will be ſufficiently evident to you.

Euphroſ. I think, every Particular you have mentioned, we may, with proper Attention, deduce from bare Inſpection :—— But your Leſſon has been ſo long, and conſiſts of ſuch a Number of Particulars, that I muſt take an Opportunity of recollecting, reconſidering, and practiſing them, at my Leaſure; for tho' it gives me the higheſt Satisfaction, to have but a general View, or Notion of Things of ſo ſublime and intricate a Nature, yet it cannot be expected that I, or any one, ſhould at once become acquainted with the Nature and Doctrine of Eclipſes. I think myſelf extremely happy, that I have it in my Power to repeat theſe Phænomena whenever I pleaſe, by the Inſtruments you have been ſo kind as to provide for my Improvement in this Sort of Knowledge.

Cleon. My Endeavours ſhall never be wanting to give you the beſt Idea of Things in my Power, and, e'er long, I may put ſomething more into your Hands, that will contribute to facilitate your Knowlege of theſe Things; but it will be previouſly neceſſary, that you ſhould have ſome diſtinct Notion of what we mean by the Doctrine of thoſe *Projections* of the Surface of the Globe which we call MAPS and CHARTS: And this will be the Subject of our next Converſation.

DIALOGUE

DIALOGUE XIV.

On the Nature and Uſe of Geographical PROJECTIONS, *uſually called* MAPS *and* CHARTS; *with a Specimen of one of a* New Conſtruction, *comprehending the Weſtern, or Atlantic Ocean, and his* Britannic Majeſty's Dominions *on the Continents of* EUROPE *and* AMERICA.

Cleonicus.

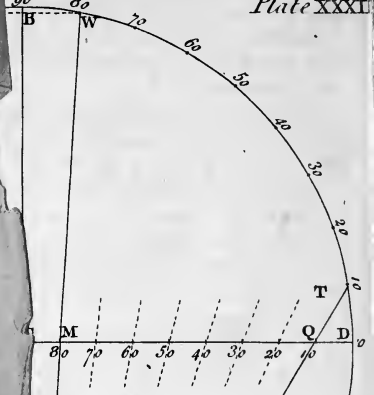
YOU may think it, perhaps, ſuperfluous, my *Euphroſyne*, after we have dwelt ſo long on the Uſe of the Globes, to trouble you with any Thing more of a Geographical Nature; but, as I have hinted to you in a former Converſation, the Globes themſelves will not ſuffice for all Geographical Purpoſes. On the other hand, we are obliged more frequently to have Recourſe to what we call Geographical Projections of the ſeveral Parts of the Surfaces, on a Plain, which go by the common Names of MAPS and Sea CHARTS; the former of which contain a Part of the Earth's Surface only, the other of the Sea Coaſts and Oceans.

Euphroſ. You need not be afraid of my being tired with ſuch uſeful and pleaſant Studies, as the Science of Geography affords; eſpecially, as I apprehend the Uſe of Maps is ſo very conſiderable, that the greateſt Part of our Pleaſure in reading Books, that gives us an Account of the ſeveral Parts of the World, is derived from thence; for without them, ſuch Treatiſes muſt be very dry and unentertaining: Therefore, let me know as much of their Nature and Uſe as you poſſibly can.

Cleon. I will relate to you every Particular that I think can be of Service concerning them, and, in the firſt Place, we may obſerve, that they are of two Sorts, General and Particular; a general Map is a Projection of the globular Surface of the Earth, on two circular Planes, which are uſually called MAPS

of

Plate XXXI.



of the WORLD. The particular Sorts, are only Maps of ſome particular Countries, Sea Coaſts, Seas, *&c.* How theſe are made, I ſhall ſhew in their Order, and obſerve to you, the Deficiencies and Excellencies of each, and then preſent you with a new, and general Map of a Kind, that has never yet been publiſhed.

Euphroſ. Theſe are Particulars I ſhould be very glad to be inſtructed in; and, in the firſt Place, pleaſe to let me know, how the general Maps of the World are formed.

Cleon. I will; but, for this Purpoſe, you muſt call to your Aſſiſtance the Power of Imagination, and ſuppoſe, that you had a Hemiſphere, or Half Globe of Glaſs, and that the Baſe of this Hemiſphere was every where terminated by the general Meridian that paſſes thro' the Iſland of *Ferro* in the weſtern Ocean. ——— Then you muſt imagine, that over all the Surface of this glaſs Hemiſphere the various Continents, Kingdoms, Countries, Oceans, Seas, *&c.* are all nicely drawn, in Water-Colours, ſo as to repreſent compleatly the eaſtern Hemiſphere of the Globe, divided by ſuch a Meridian. ——— Then, in the next Place, ſuppoſe a glaſs Plane were placed upon the Baſe of this Hemiſphere, and then both placed in a perpendicular Situation to the Eye, you can eaſily conceive that all the Parts of the painted Hemiſphere will appear upon the glaſs Plane, as if they were there projected by the Rays of Light drawn from every Part of the painted Hemiſphere to the Eye.

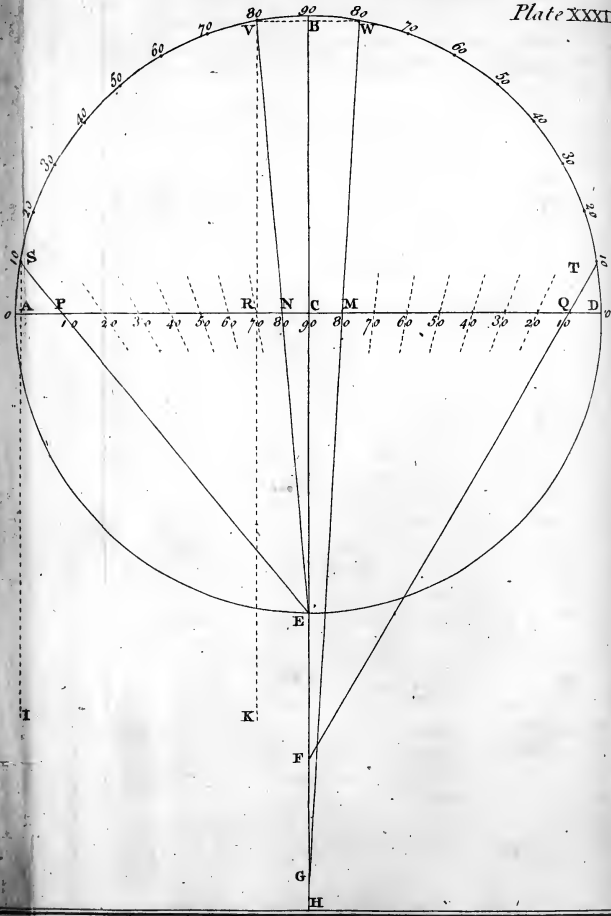
Euphroſ. All this I can eaſily image to my Mind: I could wiſh nothing was more difficult, than the Power or Art of Imagination. ——— But where about, and at what Diſtance muſt the Eye be placed to view them as they appear in Maps? For I readily underſtand, that this glaſs Plane, with the Geographical Delineations upon it, is the Map you are ſpeaking of.

Cleon. That is the very Thing. ——— The Eye, at a certain Diſtance, views the tranſparent Hemiſphere, and projects its variegated Surface on the Plane: ——— But, according to the different Diſtance of the Eye, different Sorts of Projections will ariſe, and conſequently different Maps of the Hemiſphere will thereby be formed.

Euphroſ. Well, but ſince the common Map of the World is in all our Houſes, my Curioſity induces me, firſt, to inquire,

A DIAGRAM, *demonstrating the* NATURE *of Geographical* MAPS *and* PROJECTIONS.

Plate XXXIX



of the WORLD. The particular Sorts, are only Maps of ſome particular Countries, Sea Coaſts, Seas, *&c.* How theſe are made, I ſhall ſhew in their Order, and obſerve to you, the Deficiencies and Excellencies of each, and then preſent you with a new, and general Map of a Kind, that has never yet been publiſhed.

Euphroſ. Theſe are Particulars I ſhould be very glad to be inſtructed in; and, in the firſt Place, pleaſe to let me know, how the general Maps of the World are formed.

Cleon. I will; but, for this Purpoſe, you muſt call to your Aſſiſtance the Power of Imagination, and ſuppoſe, that you had a Hemiſphere, or Half Globe of Glaſs, and that the Baſe of this Hemiſphere was every where terminated by the general Meridian that paſſes thro' the Iſland of *Ferro* in the weſtern Ocean. ——— Then you muſt imagine, that over all the Surface of this glaſs Hemiſphere the various Continents, Kingdoms, Countries, Oceans, Seas, *&c.* are all nicely drawn, in Water-Colours, ſo as to repreſent compleatly the eaſtern Hemiſphere of the Globe, divided by ſuch a Meridian. ——— Then, in the next Place, ſuppoſe a glaſs Plane were placed upon the Baſe of this Hemiſphere, and then both placed in a perpendicular Situation to the Eye, you can eaſily conceive that all the Parts of the painted Hemiſphere will appear upon the glaſs Plane, as if they were there projected by the Rays of Light drawn from every Part of the painted Hemiſphere to the Eye.

Euphroſ. All this I can eaſily image to my Mind: I could wiſh nothing was more difficult, than the Power or Art of Imagination. ——— But where about, and at what Diſtance muſt the Eye be placed to view them as they appear in Maps? For I readily underſtand, that this glaſs Plane, with the Geographical Delineations upon it, is the Map you are ſpeaking of.

Cleon. That is the very Thing. ——— The Eye, at a certain Diſtance, views the tranſparent Hemiſphere, and projects its variegated Surface on the Plane: ——— But, according to the different Diſtance of the Eye, different Sorts of Projections will ariſe, and conſequently different Maps of the Hemiſphere will thereby be formed.

Euphroſ. Well, but ſince the common Map of the World is in all our Houſes, my Curioſity induces me, firſt, to inquire,

where the Eye is to be placed for viewing the Hemiſphere ſo as to produce ſuch a Map on the glaſs Plane? ——

Cleon. The Situation of the Eye in that Caſe, my *Euphroſyne*, is exactly againſt the Middle of the Hemiſphere, and that the Diſtance is half of the Diameter of the ſaid Hemiſphere, or Globe: Thus, for Example; ſuppoſe the Globe were twelve Inches in Diameter, then the Point of Sight, or Place of the Eye, is juſt ſix Inches from the Center of the Hemiſphere in the glaſs Plane. —— The Eye, in that Poſition, or at that Diſtance, views, upon the tranſparent Plane, the Surface of the eaſtern Geographical Hemiſphere exactly the ſame as you ſee in a twelve Inch Map of the World, in the right-hand Circle.

Euphroſ. I very clearly underſtand your Meaning; and in the ſame Manner, the Map in the left-hand Circle, including *America*, is alſo formed; you need ſay no more to me on this Head, as I am fully ſatisfied of the Manner of making theſe Maps: But their peculiar Properties, or Character, I ſhould be glad to hear you rehearſe.

Cleon. Theſe I will enumerate in Order; and firſt, it muſt be obſerved, that the globular Surface of the Earth cannot by any Means be ſo repreſented on a Plane, as to preſerve that Proportion and Relation of all the Parts to each other, as they have on the Globe itſelf; but in this common Map, or Projection, we are now ſpeaking of, that Proportion and Relation is leſs preſerved, or the Countries more diſtorted, than in any other Sort of Maps in common Uſe, even to ſuch Degree, that you obſerve * the Meridians and Parallels are almoſt twice as near together in the middle Parts of the Map, as they are on the Outſide: Whereas, on the Globe, they are every where at an equal Diſtance, which Equality of Diſtance ought, as much as poſſible, to be obſerved in Maps: Since, when thoſe Diſtances are ſo very unequal, the Magnitudes of the ſeveral Parts of the Country will vary greatly from the Truth, or from the Porportion which they have among themſelves. Thus, for Inſtance, the Iſle of *Madagaſcar*, in the Middle of ſuch a Map, appears near four Times leſs than it would do if placed on the Out-

* The Reader is here ſuppoſed to have his Eye upon one of thoſe common Maps of the World, as that in the Beginning of *Salmon's Geographical Grammar*, &c.

Outside; and the Island of *Great Britain*, near the Meridian, appears, in Proportion, as much larger than what it would do placed in the Middle of the Map. —— Not only, therefore, the particular Dimensions, but also the Bearings, Distances, and other Geographical Relations of Places, are hereby very much perverted, which, as they give wrong Ideas of Geography, and lead the Mind to Error, must certainly prove this Sort of Map of very ill Consequence to the literary Republic, and fit only for the Amusement of ignorant Persons.

Euphros. If those Maps justly deserve so bad a Character, as you have plainly proved, I would be glad to know how they came into such general Use?

Cleon. It is in this as in all other Cases, bad Things generally have their Rise in Ignorance, and are continued by Custom.

> *Custom, that Mankind into Slavery brings;*
> *The dull Excuse for doing silly Things.*
>
> ROSCOMMON.

And there can be no other Apology for such a vicious Sort of Maps, which are the standing Opprobrium of the learned World; —— but of these we have said enough, and more than they deserve.

Euphros. What Sort of Projection, or Map, would you then recommend as approaching nearest to the Properties of a Geographical Map on the Globe?

Cleon. To this I will give you an Answer in few Words: — There are certain Positions of the Eye, in which the Meridians will be projected, on the transparent Plane, at equal Distances from each other; but there is no *one* Position of the Eye in which they appear so. However, it was always easy, by the Rules of Art, to draw them in this Manner, as well as all the Parallels, equally distant in the middle Parts of the Map; and since, in this Case, the Inclination of Meridians is every where the same as on the Globe, and the Distance of the Parallels in all the middle Parts the same as on the Globe, therefore this Projection has deservedly merited the Title it bears, *viz.* the *Globular Projection* or Map of the World, —— of which

this is a particular Specimen †, which I present to you for your Use.

Euphros. I am greatly obliged to you for this curious Present, and for the Care you take that my Ideas are formed on the justest Plan. ——— I can, indeed, so readily percieve a Difference between these and the common Maps, that I cannot but wonder how one of so much Beauty, Elegance, and Truth, should have been so little regarded, in Comparison to that vulgar, erroneous, and deformed one in common Use. ——— I can easily perceive, that in this new Map of the World the Countries have the same Proportion, nearly, as they have on the Surface of the Globe, so much, indeed, that when I compare them with the Globe itself, I can scarcely perceive the Difference. ——— Pray, what other Maps of the World are there, besides those you have already mentioned?

Cleon. There are none of general Use; some have been made, by projecting the Surface of the Earth on the Plane of the Horizon, which have their particular Uses. ——— Others are made on a particular Scale, called *Mercator's Projection*; in which the Meridians are all strait Lines and parallel to each other; and in which the Degrees of Latitude increase in Proportion as the Degrees of Longitude decrease, in going towards the Poles; but these are chiefly in Use in Navigation, tho' not altogether unworthy the Notice of any young Lady, or Gentleman, inclined to Philosophical Studies. I need not insist any longer on the Nature of general Maps, or their Uses in finding the Latitude, Longitude, *&c.* of particular Places, since these are common Topics you are, by this Time, full well acquainted with. ‡

Euphros.

† See the NEW GLOBULAR PROJECTION, or Map of the World, with a Solution of all Geographical Problems in a circular Space about each Hemisphere: Also, the Map of the World at the Beginning of the *Philosophical Geography*, Page 33.

‡ Such of our Readers who desire a more particular Illustration of this Affair, may please to cast their Eye upon a *Diagram* in Plate 39, where A B D is the Hemisphere above described, and A C D the transparent Plane on its Base; the Point E is the Place of the Eye to view the several Parts of that Hemisphere upon the Plane, according to the common Projection, that is, E C is equal to A C. The middle Point of the Hemisphere at 90° will be projected on the Point C in the glass Plane; and if from the Point V the Line V E be drawn, it will

Euphrof. You intimated, there were different Sorts of particular Maps: I ſhould be glad to know their Difference and Peculiarities.

Cleon. Theſe, with reſpect to particular Places, are a much juſter Repreſentation of particular Places than general Maps can

will repreſent the Ray of Light projecting the 80° in the Point N; and if from the Point S we draw the Line S E, it will be that Ray of Light which projects the 10° upon the Point P in the ſaid Plane. Now from a Table of natural Tangents it may be ſhewn, that A P, the Projection of 10° on the Side of the Plane, is almoſt twice as large as N C, the projected Diſtance of 10° in the Middle of the Plane; and if Lines were drawn from E to 20, 30, 40, 50, 60, and 70° in the Hemiſphere, they would interſect the Plane in the dotted Lines which you ſee placed there by the ſame Numbers, and the Intervals between thoſe Lines on the Plane will be all unequal: But theſe are the ſeveral Points thro' which the Meridians are drawn, which ſhews the Reaſon why all the Meridians are at unequal Diſtances in the Equator of our common Maps.

But if you now caſt your Eye on the other Side of the Hemiſphere, you will there preceive the Line C D divided into 9 equal Parts, and the 80° at W will be projected on the Point M in the Plane, by a Ray drawn from W to the Point M, and meeting with the Axis of the Hemiſphere (continued out) in the Point G, which, therefore, will be the Place of the Eye in this Caſe. Then, on the Hemiſphere, from 10° at T draw a Line thro' the Diviſion at Q, this will meet with the Axis of the Hemiſphere in the Point F, where the Eye muſt be placed from the Projection of the firſt 10°; and ſince all the Intervals are equal between Q and M, the dotted Lines paſſing thro' their Diviſions, there marked and directed to the correſpondent Numbers in the Quadrant D B, will all be directed to Points between F and G; and therefore, in Caſe of the globular Projection, the Eye has not one Poſition, but muſt be conceived to move thro' the Space F G, to view the ſeveral Parts which lie between D and B, in the ſame Proportion and Diſtance on the Plane C D, as they have in the Hemiſphere itſelf between D and B. If the Radius of the Globe C E be ſuppoſed to conſiſt of 100 equal Parts, then C F will be 160, and C G will be 175.

If the Eye be ſuppoſed removed to an infinite Diſtance, then will all the Rays which proceed from the ſeveral Diviſions 10, 20, 30, *&c.* as S I, V K, will be parallel among themſelves; and therefore the Projection of 10° in the Middle of the Hemiſphere, by the Ray V K, will be R C equal to V B, the Sine of 10°: But on the Side of the Hemiſphere the Projection of 10°, by the Line S I, is no more than o A, which is the verſed Sine of 10°, and is very ſmall in Compariſon of R C in the Middle. In this Projection the Meridians are Ellipſes, and conſtitute the *Analemma*, or Orthographical Projection of the Sphere, of conſiderable Uſe in Aſtronomy, and will be hereafter more fully explained.

can be; for, if only one Kingdom or Country is to be repreſented, this may be done, nearly, with as much Truth as on the Globe itſelf, and is of much greater Advantage in one Reſpect than even the Globe, as it will admit of a much larger Scale, and, of Courſe, a more ſpacious, diſtinct, and exact Delineation of any ſuch particular Country.

Euphroſ. This I immediately ſee the Reaſon of, ſince a ſmall Tract, or Area, on the Surface of a Globe differs very inſenſibly from a Plane. ——— Thus, the circular Space of ten Degrees on the Surface of a twelve Inch Globe, differs but very little from a Plane, and yet comprehends the Iſland of *Great Britain*, and all the adjacent Country and Coaſt about it. ——— On larger Globes, it muſt differ ſtill leſs from a Plane; and therefore the Parts of *Great Britian*, the *Engliſh* and *Iriſh* Channel, *German Ocean*, &c. when laid down from a large Scale, muſt be conſidered as Part of the Surface of a very large Globe.

Cleon. What you obſerve is very juſt, and you may eaſily know how large the Globe muſt be, to have the Country of the ſame Dimenſions upon it as you ſee in the Map. ——— Thus, for Inſtance; if you ſee a Map in which the Degrees of Latitude on the Side thereof are juſt one Inch in Length, then a Globe, of which that Map is a Part of its Surface, will be ten Feet in Diameter; for there will be 360 Inches in its Circumference; becauſe each Degree is one Inch in Length, and the Diameter of ſuch a Globe being a third Part of its Circumference, nearly, or 120 Inches, which is juſt 10 Feet: ——— Therefore a Map, where the Degrees of Latitude are half an Inch in Length, will be the Part of the Surface of a Globe half ſo much in Diameter, or five Feet: ——— If the Degrees in a Map are $\frac{1}{4}$ Inch each, the Diameter of the Globe will be thirty Inches. ——— On the other hand, if the Degrees of Latitude are two Inches long on any Map, then ſuch a Map is Part of the Surface of a Globe twenty Feet in Diameter, and ſo in Proportion for Degrees of any other Length.

Euphroſ. By this, I am at once convinced of the great Utility of particular Maps of Countries, ſince they preſent us with a juſt View of the ſeveral particular Parts of the World, as they would

would appear to the Eye on the Surface of such very large Globes, which it is not in our Power to have. ———

Cleon. But besides what you have now very pertinently observed, there is one considerable Advantage accruing from such particular Maps which we could by no other Means become possessed of: ——— I mean, that in such Maps we can easily express the true Form and Dimensions of Countries, together with the Lengths of the several Degrees of Latitude in the same Proportion as they lie on the Surface of the Earth itself, that is, on the Surface of a *Spheroid*, and not of a Sphere or Globe: For, as any Globe we are capable of making will be much too small to shew that Difference which would be very sensible in Globes of 20, 30, or 40 Feet in Diameter, we still enjoy that Advantage in Representations of the particular Parts of such very large Globes, in our common Geographical Maps of Countries.

Euphros. If I understand you right, our Maps of Countries should be taken from the Surface of a Spheroid, and not a Sphere; and that the Degrees of Latitude in them should not be precisely equal, as we find them in common Maps.

Cleon. That is the Case. Our Maps are supposed to be the Representations of Spheres, when they might, at the same Time, be as well made to represent a Spheroid of the same Dimensions, wherein not only the Degrees are of an unequal Length, but likewise the Extent, Situation, and Form of Countries are very different, on a Spheroid, to what they are on a Globe. ——— Thus, for Instance, the Situation of *England*, on the Surface of a Spheroid 10 Feet, is almost a whole Inch nearer to the Equator, than it is on a Globe of the same Diameter: ——— Also, a Map of 10 Degrees Extent, in the middle Parts of the temporate Zone, will be larger than one of 10 Degrees Latitude near the Equator, and less than another of 10 Degrees within the polar Circle; whereas, our common Maps of 10 Degrees Extent, for any Part of the Globe, are always equal.

Euphros. Such a material Point as this one would think would greatly excite the Curiosity of all the Critics in Geography, and I wonder it has as yet been so very little attended to.

Cleon. It would be a Wonder with every one, as well as with yourself,

yourſelf, were it not conſidered how great the Difficulty is to conquer any Thing eſtabliſhed by common and univerſal Practice. ——— Our Logic extends to little more than this: *They have ever been made ſo*, and *therefore they ever muſt*. And our very Critics themſelves have ſo much Candour and Ingenuity as to treat every Thing with a ſupercilious Sneer, and to repreſent as a Novelty, of no Importance or Uſe, whatever they have not the Fortune to hit upon themſelves: However, we ſhall always find Numbers who are candid and judicious enough to encourage any Invention which tends to the Perfection of any Art or Science, tho' there were nothing elſe to recommend them: It has been largely ſhewn, that the Diſcovery of the true Figure of the Earth is of this Kind, and that Geography, Navigation, Aſtronomy, and many other Sciences, receive very great Improvements in many Particulars from it: And therefore ſuch a noble and important Diſcovery ought not to be omitted, or neglected in our Maps; for which Reaſon, a NEW SYSTEM OF GEOGRAPHY, for the Uſe of our *Britiſh* Youth, whoſe Maps are all formed upon a Plan of the new Diſcovery abovementioned, becomes abſolutely neceſſary, if we regard either the Truth or Honour of this delightful Science of Geography.

Euphroſ. Such a Set of Maps I ſhould greatly rejoice ‖ to ſee, as I have no Notion of being ſatisfied, or contented with a bad Thing, when better may as well be had; for I apprehend there is no more Expence or Difficulty attending the one, than the other.

Cleon. There is not in the leaſt; and you will ſhortly be gratified in this Reſpect. ——— There is yet one other Species of particular Maps, which is quite of a *new Invention*; and as it is the greateſt Curioſity of this Kind, and no Map has been hitherto conſtructed on the Plan, I have been at the Trouble of drawing one myſelf, on Purpoſe to make you a Preſent

‖ The *New Syſtem of Geography*, for the Uſe of Schools, is that which we are now publiſhing in our *Magazine*, under the Title of PHILOSOPHICAL GEOGRAPHY. In which all the Maps are ſtrictly the Repreſentations of ſo many Parts of the *ſpheroidical Figure* of the Earth, and the Degrees of Latitude divided into Minutes; alſo the Difference between thoſe Degrees, as they lie on the *Spheroid* and *Sphere*, is ſpecified in every Map.


Plate XL.
AME
NEW MEXICO
R. del Norte
LOUISIANA
GULF of MEXICO
St. Bernard B.
St. Joseph I.
C. Condecedo
C. Flor.
C. St. Anthony
C. Catoche
Honduras B.
Honduras
Fonseca B.
Nicaragua
JAMAI
Carthagen
VI
Bay of Biscay
de Oleron
The Channel
GERMAN
BRITAIN
London
Pampelona
PORTUGAL
of Gibraltar
SENAG
L. de Cay
JALOFS
I
This
CHART is
that Projection of
Spherical ZON
Surface of a CO
R^D. M^R. MURDOC

mple Bar

(NB)
This is the First MAP or CHART of this Kind ever Published, Engraved by
-man! Bowen Geographer to his Majesty.
BALTIC SEA
POLAND
LESSER TARTARY
GERMANY
EUROPE
BLACK SEA
ASIA
TURKY in EUROPE
Gulf of Venice
ITALY
THE MEDITERRANEAN SEA
AFRICA
BARBARY
Land of Dates
FESSAN
BOURNO
Bourno Desart
Great Desert of BARBARY
ZAARA
NIGRITIA
WANGARA
Seth Desart
Barca Desart
EGYPT
Holy Land
Cyprus
Candia
Sicily
Sardinia
Corsica
Minorca
Majorca
Malta
C. Rasat
Syrtis
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Vienna
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Asof
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Trapezund
Scanderoon
Smyrna
Troy
Nice
Constantinople
Belgrade
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S 1760.

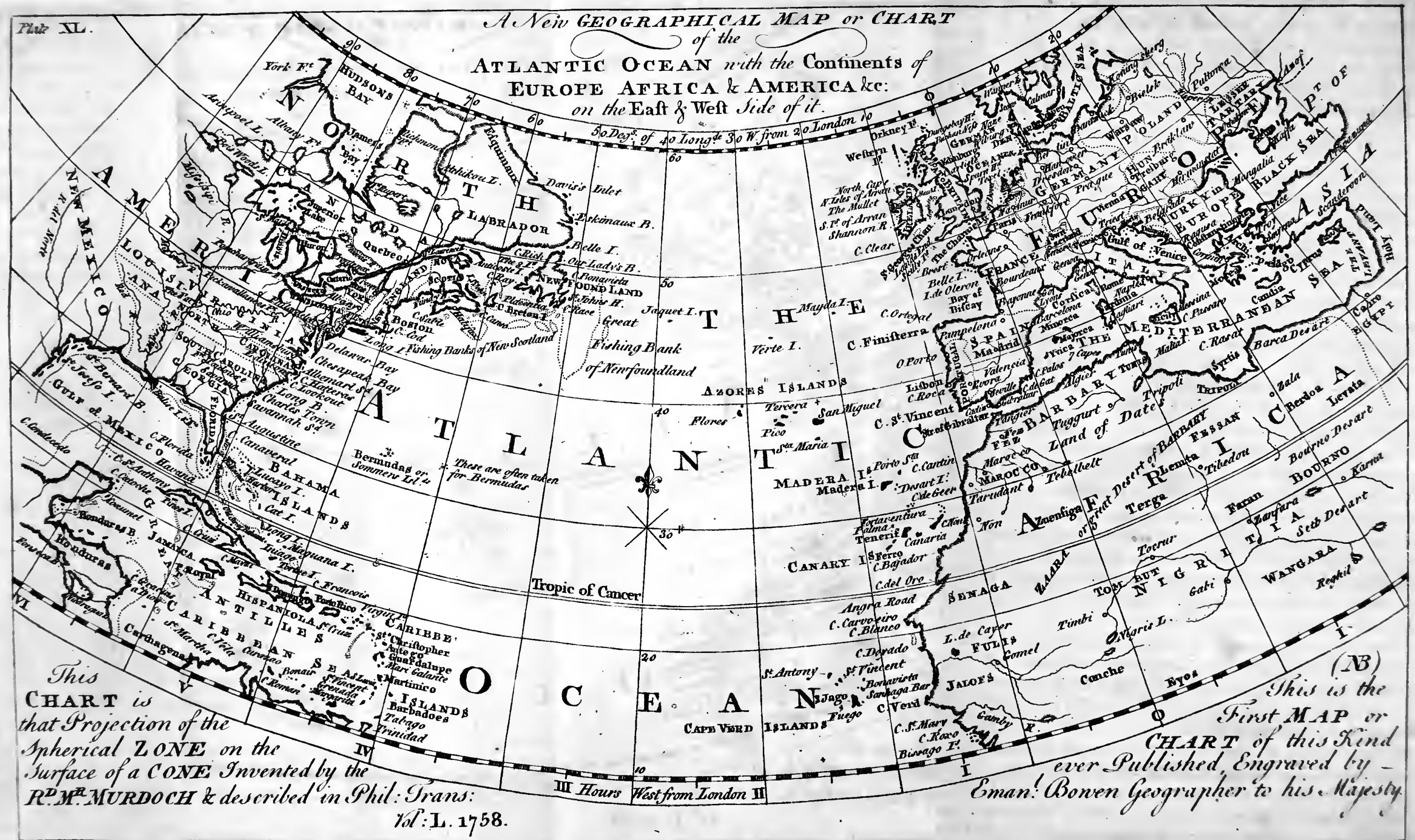
Preſent of it, as I wiſh to have nothing new or curious go beſide you, or come to you at Second-hand.

Euphroſ. Pray, let me look at it. ——— It ſeems to be an elegant Deſign, and differs manifeſtly from the Appearance of other Maps; but in ſuch Particulars, as I can hardly tell what they are. ——— I ſee it is very capacious, and takes in large Tracts of the Continent of *Europe*, *Aſia*, and *Africa*, on one Side, and of *North America* and the *Weſt-Indies* on the other Side, with a View of all the *Atlantic Ocean* between them; and yet, methinks, the Map is not large for ſuch an extenſive View.

Cleon. There is ſomewhat very ſingular in the Conſtruction, as well as the Form of this Map. ——— Would you ever have thought of a Repreſentation of the Surface of the Globe, by a Part of the Surface of a Cone? And yet you will eaſily underſtand that this is the Caſe in regard to the Map under Conſideration; for you may plainly ſee, that the Form of the Map itſelf beſpeaks it to be a Part of the Surface of a Cone; — and the Surface of a Cone, you know, may be eaſily formed of any plain Piece of Paper, cut into a circular Form or Baſe; and you will as eaſily conſider, that if a Cone, about twice the Height of the Semi-diameter of the Globe, were to be conceived as ſtanding on the ſame Baſes with the Hemiſphere, that is, on the Equator, the Surface of ſuch a Cone would in Part lie within the Surface of the Globe; and then, nothing can be eaſier than to ſuppoſe that the Surface of the Globe, at ſo ſmall a Diſtance from the Surface of the Cone, might be very eaſily projected and delineated upon it; and in ſuch a Caſe, the Proportion of the Countries and their Bearings, Diſtances, *&c.* will be nearly the ſame on the Surface of the included Part of the Cone, as on that of the Globe itſelf; and when ſuch a geographical conic Surface is cut out, and expanded, it makes the Map which you have in your Hands. ——— The principal Peculiarities of this Map are as follows,

I. All the Meridians are right Lines, but converge towards the Vertex of the Cone, as the circular Meridians on the Globe converge towards the Pole.

II. The Diſtances, North and South, are exact; and any Meridian will ſerve as a Scale, to meaſure theſe Diſtances by, in



Engrav'd for the General Magazine, of Arts & Sciences; for W. Owen at Temple Bar 1760.

Present of it, as I wish to have nothing new or curious go beside you, or come to you at Second-hand.

Euphrof. Pray, let me look at it. ——— It seems to be an elegant Design, and differs manifestly from the Appearance of other Maps; but in such Particulars, as I can hardly tell what they are. ——— I see it is very capacious, and takes in large Tracts of the Continent of *Europe*, *Asia*, and *Africa*, on one Side, and of *North America* and the *West-Indies* on the other Side, with a View of all the *Atlantic Ocean* between them; and yet, methinks, the Map is not large for such an extensive View.

Cleon. There is somewhat very singular in the Construction, as well as the Form of this Map. ——— Would you ever have thought of a Representation of the Surface of the Globe, by a Part of the Surface of a Cone? And yet you will easily understand that this is the Case in regard to the Map under Consideration; for you may plainly see, that the Form of the Map itself bespeaks it to be a Part of the Surface of a Cone; — and the Surface of a Cone, you know, may be easily formed of any plain Piece of Paper, cut into a circular Form or Base; and you will as easily consider, that if a Cone, about twice the Height of the Semi-diameter of the Globe, were to be conceived as standing on the same Bases with the Hemisphere, that is, on the Equator, the Surface of such a Cone would in Part lie within the Surface of the Globe; and then, nothing can be easier than to suppose that the Surface of the Globe, at so small a Distance from the Surface of the Cone, might be very easily projected and delineated upon it; and in such a Case, the Proportion of the Countries and their Bearings, Distances, *&c.* will be nearly the same on the Surface of the included Part of the Cone, as on that of the Globe itself; and when such a geographical conic Surface is cut out, and expanded, it makes the Map which you have in your Hands. ——— The principal Peculiarities of this Map are as follows,

I. All the Meridians are right Lines, but converge towards the Vertex of the Cone, as the circular Meridians on the Globe converge towards the Pole.

II. The Distances, North and South, are exact; and any Meridian will serve as a Scale, to measure these Distances by, in

this Reſpect; ſo far as the Map extends, it is, indeed, as true as the Globe, on which the Degrees of Latitude are all equal; but neither this, or any other Map, or Chart, can have the Diſtances, North and South, ſo true as thoſe which are made from a Projection of the Spheroid, as I have before obſerved to you.

III. The Parallels of Latitude, in this Map, are all Equidiſtant, or truly parallel to each other, as they are on the Globe.

IV. The Meridians and Parallels interſect each other at right Angles, as on the Surface of the Globe.

V. As ſuch a Cone, on which this Map is made, is ſuppoſed to paſs thro' the Surface of the Globe in two Places, the Parallels of Latitude, in thoſe Places where the Cone interſects the Globe, will be the ſame in the Map as on the Globe itſelf, *i. e.* all Diſtances Eaſt and Weſt may as truly be meaſured upon them; which Parallels, in the Map before you, are thoſe of 20 and 50° Latitude.

VI. But ſince the middle Part of the Map on the Surface of the Cone lies within the Globe, the Meridian on that Part of the Globe will be at a greater Diſtance than thoſe Parts of the Meridians projected on the Map, and, conſequently, the Parallel of 35°, and thoſe near it, will be deficient from the Globe, or give a leſs Diſtance than what is juſt; or any two Places on the Middle of ſuch a Map muſt be repreſented ſomething nearer together, than they are upon the Globe, if their Longitudes be exactly expreſſed.

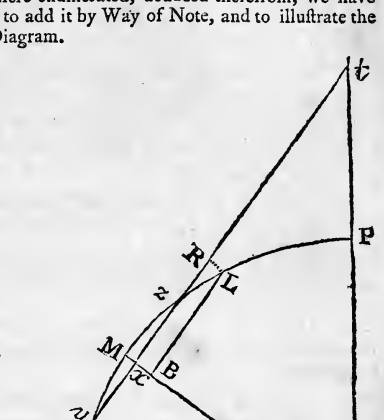
VII. On the other hand, thoſe Parallels which terminate the Map have an Error in Exceſs: Thus the Parallel of 10 and 60°, as they are projected from Parts of the Globe which lie within the Cone, muſt have a greater Space between the Meridians than their correſponding Parallels on the Globe have: And thus, Places in thoſe Parts of the Map are repreſented at too great a Diſtance from each other.

VIII. The quadrangular Spaces formed by the Meridians and Parallels have their Diagonals equal to each other, as on the Globe itſelf; which is a Property peculiar to this Projection, which is not a rectilineal one.

IX. The Quantity of Surface repreſented on this Map is exactly the ſame as that of the ſame Extent on the Globe itſelf, and

and therefore differs no more from the Truth of the ſpheroidical Projection, than a Globe does from a Spheroid, which is the true Figure of the Earth.*

* As ſome of our Mathematical Readers may be deſirous of ſeeing a Demonſtration of the Nature and Conſtruction of this Map, and the ſeveral Properties here enumerated, deduced therefrom, we have thought proper here to add it by Way of Note, and to illuſtrate the ſame with a proper Diagram.



The learned Author of this Invention has given us the Theory thereof from *Archimedes*; but as we can eaſily derive it from our own Inſtitutes, we apprehend that will be moſt agreeable to our Readers. Let E M P be the Quadrant of a Meridian of a Globe 12 Inches Diameter; whoſe Center is C, and Pole P. E *l*, E L, the Latitudes of two Place in that Meridian; E M their middle Latitude. Draw C M and therein find *the Center of Gravity* (*x*) of the Arch L *l*, (by 1077) and thro' *x* draw Q *t* perpendicular to C M, it will interſect the Arch L *l* in the Points *y* and *z* equidiſtant on each Side from the Point M. Laſtly in the Line Q *t*, make *x* R, and *x r*, equal to the Arches M L and M *l*, reſpectively; *then the conical Surface generated by the right Line* R *r*, *while the Figure revolves about the Axis* C *t*, *will be equal to the Surface of the Zone of the Globe that is deſcribed at the ſame Time by the Arch* L M *l*, (by Inſt. 1085.)

For Example, by the Problem (Inſt. 1077) we have $C\,x = \frac{C\,M \times L\,B}{M\,L}$, which gives this Analogy; *as any Arch* M L *is to its Sine* L B *ſo is Radius* C M *to* C *x*, *the Diſtance of the Center of Gravity x of twice that Arch*, L *l*.

In this new Map, the Extent or Difference of Latitude is $\cdot 50^{\circ} = L\,l$; therefore $M\,L = 25^{\circ} = 2{,}6179$ Inches to a Radius of 6 Inches (ſee Inſt.

X. As the Errors in one Part of the Map are in Exceſs, and the other in Defect, and the Extent of each nearly equal, they will, upon the Whole, in a great Meaſure compenſate each other, and are in general of the leaſt Quantity they can have in the Map deſigned.

XI. As a Thread extended from any one Place to another, on the Map, will, when the Map is reſtored to its conic Surface, ſtill paſs thro' the ſame Points, therefore the ſhorteſt Diſtance between any two Points on this Map is the right Line that joins them; and therefore ſuch Diſtances applied, by the Compaſſes, to a graduated Meridian, will very nearly ſhew the true Diſtances of the Places repreſented in Degrees, Miles, or Leagues, as is done by the Quadrant of Altitude on the Surface of the Globe itſelf.

XII. In Maps of this Kind, which are but of ſmall Extent in Latitude, as 10, 15, or 20°, the Errors in Geography will be extremely ſmall, and may be looked upon as ſufficiently exact for any common Geographical Purpoſes.

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(ſee Inſt. 885.) Alſo, the Sine B L of the ſame Arch is 2,5358 Inches, therefore ſay,

As the Arch M L = 2,6179	——	0,417953
Is to its Sine B L = 2,5358	——	0,404099
So is Radius C M = 6	——	0,778151
		1,182250
To the Diſtance C x = 5,8116	——	0,764297

So that the Side of the Cone Q t falls within the Zone L M l about $\frac{1}{5}$ of an Inch = M x, which is the verſed Sine of 14° : 24′ = M z or M y.

From this Conſtruction it is evident, that in a Map made on the conic Surface between R and r, the Diſtance of the Meridians in the middle Part at x will be leſs than on the Globe at M; and on the extreme Parts at R and r, they will be wider aſunder than on the Zone of the Globe at L and l; and laſtly, at z and y they will be Equidiſtant on the Cone and Globe.

It is farther evident, that as the Point M advances to the Equator E, the Point l will arrive at and paſs the Equator into ſouthern Latitude; till at laſt it coincides with E, the Cones becomes a Cylinder, and the Map takes in equal Degrees of both Latitudes, but its Properties otherwiſe continue the ſame. Upon the Whole it appears that a Map in no Kind of Projection can be ſo true and perfect as on the Globe itſelf.

I might enlarge further on the Novelty and Peculiarities of this Map, and ſhew its Uſe likewiſe as a *nautical Chart*; but as theſe Things will not immediately concern you, I ſhall wave them for the preſent, as I fear I have almoſt tired your Patience already, by ſo tedious an Harangue.

Euphroſ. You know my Propenſity to Science, and the Pleaſure I take in being acquainted with all new and uſeful Inventions, will ever render your Diſcourſes, on ſuch Subjects, grateful and acceptable: And as this Map is not only ſingular in its Kind, but likewiſe contains ſo large a View of all the Continents of the World, and that Part of the vaſt Ocean which *England* is more particularly intereſted in, it gives me the higheſt Pleaſure to peruſe it. ——— I here ſee our Situation with reſpect to neighbouring Nations, and other Parts of the World. ——— I view his *Britannic* Majeſty's Dominions in all Parts of *Europe* and *America:* I ſurvey the Coaſts, Roads, and Tracts which our Fleets purſue in their deſtined Departments in the remoteſt Parts of the World. ——— The Ocean is chequered with Iſlands, the *Azores*, *Madera*, *Cape Verd*, *Canary*, the *Bermudas*, the *Caribbee* and *Bahama* Iſlands; with the *African* and *American* Coaſts. ——— In ſhort, I ſhall always look on this Map as one of the greateſt Curioſities in my Poſſeſſion, eſpecially as it is an Improvement in that Science which of all others, tho' the moſt uſeful, has been the moſt neglected by Men of Genius and Learning, as you have more than once informed me.

DIALOGUE

DIALOGUE XV.

The various Phænomena *of the* TRANSIT OF VENUS *over the* SUN, June 6, 1761; *together with the Uſes thereof, in diſcovering the* PARALLAX *and Diſtance of the* SUN *and* PLANETS: *Exhibited and illuſtrated by the* TERRESTRIAL GLOBE, *and an aſtronomical* Diagram.

Cleonicus.

THE Drift of my Endeavours, in all our paſt Converſations, has been to embue your Mind with the Principles of Aſtronomy and Geography, ſo far as they could be ſuppoſed uſeful and becoming to one of your Sex; and my Experience has ſatisfied me, that thoſe Topics have afforded you an agreeable Amuſement and Pleaſure.

Euphroſ. Indeed, *Cleonicus*, they have; and I ſhall always reckon the Hours, ſo ſpent, make the happieſt and moſt pleaſurable Part of my Life: ——— I begin to ſuſpect, by what you ſay, that you are coming to a Concluſion of thoſe moſt entertaining Studies.

Cleon. When they are finiſhed, others will offer equally agreeable; but there is, my *Euphroſyne*, one *Phænomenon* yet to come, that is both of an aſtronomical and geographical Nature: ——— A Phænomenon by far the nobleſt that all Nature affords, and on which the greateſt Things depend: ——— It is what I was the other Day mentioning to ſome Gentlemen when you was in Company, and I obſerved you paid a more than ordinary Attention to it at that Time.

Euphroſ. You need ſay no more, *Cleonicus*; I recollect, and ſhall never forget what you told us at that Time, of the Tranſit of *Venus* over the Sun's Diſk. ——— I can aſſure you, it has been in my Thoughts almoſt ever ſince; and there is ſcarce any Thing at which I more rejoice than the Thoughts of its being ſo near at Hand, tho', from ſome Part of your Diſcourſe to thoſe Gentlemen, I am afraid of two Things: The 1ſt is, whethe

whether we may be permitted to enjoy so curious a Sight, on Account of the Weather; and, 2dly, whether I may be capable of understanding so much of the Nature of it, as to be apprized of its great Usefulness and Advantage to Mankind, on which you then so largely descanted.

Cleon. The first of your Fears it is not in my Power to remove, we must hope for the best; I am as full of Apprehensions on that Account as you yourself can be: No Event to Astronomers will be so malignant and disastrous as a cloudy Day on the 6th of *June*, 1761; ——— *Avert it, Heavens:* Ought to be the Prayer of all that wish well to the Sciences.— But as to the other Affair, your Capacity of understanding the Circumstances of this Phænomenon (excepting the Mathematical Part only) is out of Dispute, especially when you are assisted by the Use of the terrestrial Globe, and a proper Diagram representing the Motion and Parallaxes of those Luminaries.

Euphros. You are always ready to encourage me in the Pursuit of these Studies; but in regard to this particular Phænomenon, I observe, you make Use of some Words of which I have not the least Idea, the Parallaxes of *Venus* and the *Sun*, which so frequently occurred in your Discourse, are what I know nothing of. ——— You told them, that the Parallax of *Venus* would be discovered by Means of that Transit; ——— that by the Parallax of *Venus* the Parallax of the *Sun* would be discovered; ——— that the Parallax of the *Sun* being known, the Distance of the *Earth* and all other Planets from the *Sun*, and from each other, would become known also. ——— These are great Things, tis true; but as they all result from Parallaxes, it is at present all parallatical Mystery to me.

Cleon. You seem to be much gravelled with the Word Parallax, my *Euphrosyne*; I own, it is *Greek*, and has a harsh Sound: But this is not the only *Greek* Word that has a hard Sound, and an easy Signification; for the Idea it conveys is as simple and as easy as any Word can possibly have: ——— It means nothing more than the Difference of Place in which any Thing will appear when seen from two different Positions of the Eye, as will be easy to illustrate by Example. ——— I take this Candle and set it on the Table against the Wainscot, on the other Side of the

the Room ; —— Then, as you ſit on that Side the Fire-place, and I on this, if we both look at the Candle at the ſame Time, we each of us ſee it in a different Place, or on different Parts of the Wainſcot ; for the Place here meant is not the real Place of the Candle, but that on which it appears on a Plane, placed on one Side or the other : —— and thus you may conceive, if an Eye was placed in the Center of the Earth, and another on the Surface, and both together were to view the Planet *Venus* as ſhe paſſes over the *Sun*, then the Face of the *Sun* is to be conſidered as a Plane placed beyond the Planet, and on which the Planet will appear in two different Parts, as viewed by the Eye in two different Poſitions, *viz.* the Center and Surface; and this Difference of Place is what we call the *Parallax* of that Planet. But this will be much eaſier to conceive from the Diagram in which you will, by and by, ſee this whole Affair repreſented. —— At preſent, your Buſineſs muſt be to familiariſe this Phænomenon to your Mind, by a Repreſentation thereof, under all its various Circumſtances, by Means of the terreſtrial Globe, in which you will find no Sort of Difficulty.

Euphroſ. You will firſt put me in a Method how I muſt go about it ; for without ſome previous Inſtruction, notwithſtanding all you have ſaid concerning the Uſe of the Globe, it will ſtill remain uſeleſs to me in this Particular.

Cleon. What you now ſay proceeds only from your not conſidering one Thing, *viz.* that the Subject, or Tranſit of *Venus* is on the Face of the *Sun*, and, conſequently, that you have little more to do than to practice thoſe Problems over again which require you to find all thoſe Parts of the Earth where the *Sun* is viſible in the Meridian, or in the Horizon, as Riſing or Setting, on any given Day or Hour.

Euphroſ. By what you now ſay, I ſuppoſe the firſt Thing I have to do is to find the *Sun*'s Place in the Ecliptic for *June* 6, 1761 : But to what Hours of that Day is the Problem limited ?

Cleon. The Moments of the Beginning and End of the Tranſit are the principal Times to be regarded, and all the Time between them, of Courſe : —— Theſe Moments, according to the ſagacious Dr. *Halley*'s Account, are 24′ after two o'Clock in the Morning for the Beginning, and End at 29′ after IX in the Forenoon, *i. e. Venus* will be ſeen a round black Spot

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in the Face of the *Sun*, touching the eaſt and weſt Limb thereof at thoſe Moments, juſt in the Manner you ſee here repreſented in this large Print, in which I have repreſented the Sun's Diſk, or Face, 15 Inches Diameter, and the Planet more than $\frac{1}{2}$ an Inch *, together with its Path or Tract over the ſolar Diſk, in the ſame Manner as, in all Probability, you will have the Pleaſure of ſeeing it at that Time; the Hours and Quarters are alſo therein mark'd, to ſhew the particular Places in which the Planet will appear in any particular Moment during the Time of the Tranſit.

Euphroſ. This gives me a pleaſing Idea of the Phænomenon, and now I ſee diſtinctly what you mean;——I ſee the Planet wholly within, yet touching the Diſk on the eaſtern and weſtern Side at the Time you mention; and I obſerve farther, that the Middle of the Tranſit is there marked at 55′ after five in the Morning: ——— But what mean all thoſe other Lines, which ſeem to indicate many other Tranſits of the ſame Planet?

Cleon. There are no leſs than 17 Tranſits of this Planet over the Sun's Face, from the Year 918 to the Year 2117, and among them all only two will be viſible in any conſiderable Degree to us. Thoſe two are denoted by black Lines; the firſt of theſe was, as you ſee, in the Year 1639, ſeen only by Mr. *Horrox* and Mr. *Crabtree*. ——— But to return to the Globe: As the Tranſit begins at the Time ſpecified, the firſt Thing you have to do will be to find all thoſe Places of the Earth where the Beginning of the Tranſit will be viſible.

Euphroſ. In order to that I obſerve, for the given Day, the Sun's Place is in the 16° of *Gemini*, and its Declination 22° 30′. — Now, as the Globe muſt be rectified to that Degree of Declination, I muſt bring the ſaid 22° 30′ on the north Part of the Meridian to the Horizon: Then I bring the City of *London* to the Meridian, and hold it there while I place the hour Index

* This alludes to a large Copper-plate Print intitled, a VIEW of 17 TRANSITS of the Planet VENUS, over the FACE of the SUN, *viz.* from the Year 918 to 2117 incluſive, and particularly that which will next happen in the Year 1761, by which the Parallax and Diſtance of the Sun will be nicely determined, and the Dimenſions of the ſolar Syſtem accurately aſcertained. This Print is now contrived to be uſed as a Screen, on which the Sun's Diſk may be formed by a ſolar Teleſcope at the Time of the Tranſit, and *Venus*'s Latitude, Place, the Node, &c. obſerved to a Minute.

to twenty Minutes after II in the Morning: —— This done, I revolve the Globe till the Index points at the Hour of XII, and then I obſerve that all the Hemiſphere above the Horizon will ſee the Sun at that Time, and conſequently view the Beginning of the Tranſit, which therefore will be viſible to almoſt all *Aſia* and a great Part of *Europe*; but to the weſtern Part of *North America* only. ——— By caſting my Eye below the Horizon, I ſee the whole Continent of *Africa*, with great Part of *Aſia*, *Europe* and *America* deprived of this glorious Sight, the *Ingreſs of Venus upon the ſolar Diſk*, and amongſt them is the Iſland of *Great-Britain*.

Cleon. So far you have performed very well, my *Euphroſyne*; but with regard to this Tranſit, it is a material Point to know in what Parts of the Earth the Ingreſs or Beginning of the Tranſit is viſible at Sun-riſing, and Sun-ſetting.

Euphroſ. This is ſeen in the ſame Poſition of the Globe; for all thoſe who are in the weſtern Horizon of the Globe obſerve the Sun riſing, with the Planet *Venus* juſt entering upon its Diſk: Such are all the Inhabitants of the midland Parts of *Sweden*, *Muſcovy* in *Europe*, *Aſia Minor*, and *Arabia*. ——— And thoſe to whom the Tranſit begins at Sun-ſet are ſuch as lie under the eaſtern Edge of the Horizon, ſuch are all the Parts of *New Britain*, *New Wales*, and the more weſtern Parts of *North America*.

Cleon. Very good, Siſter, ——— you will particularly obſerve, that *Hudſon's Bay* is among the Number of thoſe laſt mentioned Places, and eſpecially Port *Nelſon* at the Mouth of *York* River, as it has a little Elevation above the Horizon, and therefore will ſee the Beginning of the Tranſit about $\frac{3}{4}$ of an Hour before Sun-ſet: The Reaſon why I obſerve this, you will ſee by and by. ——— You will next let me ſee all the Parts of the Earth where the Middle of the Tranſit will be viſible, which happens at 55′ paſt five in the Morning with us.

Euphroſ. For this I have nothing more to do than only to bring *London* to the Meridian, and placing the hour Index to the given Time; then by revolving the Globe till it points to XII at Noon, I view all the Parts of the Earth where the middle Moment of the Tranſit will be viſible, which will be in all *Europe*, *Aſia*, the greateſt Part of *Africa*, but ſcarcely in any Part of *America*, unleſs *James's* Iſle and *Greenland* be reckoned ſuch. ——— It is farther evident, that all thoſe Places that are

in

in the weſtern Horizon, *viz.* the weſtern Parts of *Africa*, ſee the Sun-riſing with *Venus* half Way advanced in her Path over his Diſk: ——— But in the eaſtern Horizon there is no Land, and conſequently none to obſerve this Part of the Phænomenon at Sun-ſetting, but ſuch as are ſailing on the Ocean there.

Cleon. All this is ſo far very well, my *Euphroſyne*; but there is one Thing farther to be obſerved, while the Globe remains in this Poſition, and that is, you are to take particular Notice of thoſe Places which lie under the Meridian at the ſame Time, and conſequently ſee the Middle of the Tranſit at XII o'Clock, and amongſt them, to obſerve that Place more eſpecially to whom the Sun is then vertical.

Euphroſ. The Places which lie under the Meridian are all the midland Parts of *Aſia* from *Nova Zembla* to the *Eaſt Indies*, and thoſe whoſe Latitude is equal to the Sun's Declination, *viz.* 22° 30′, muſt have the Sun vertically over their Heads, which I ſee is a Place I have heard much talked of, the eaſtern Parts of the Kingdom of *Bengal*, near the Mouth of the River *Ganges*.

Cleon. This Particular you will bear in Mind for a few Minutes. ——— You will, in the laſt Place, ſhew all thoſe Places of the Earth where the Tranſit ends at Sun-riſing, at XII o'Clock, and at Sun-ſet.

Euphroſ. The End of the Tranſit, if I remember right, you told me was half an Hour after IX, ——— therefore I bring *London* to the Meridian, and place the Index to the given Time, then turning the Globe about till the Index points to XII, and caſting my Eye on the weſtern Horizon, I obſerve, that a few Inhabitants of *North America* and the eaſtern Part of the *Brazils* in *South America* will view the Sun riſing, with the Planet juſt making its Exit from its Diſk. ——In the eaſtern Parts of the Horizon there is very little Land except *New Guinea*, *New Holland*, and the Iſlands called the *Ladrones* on the Eaſt of *Aſia*, to view the End of the Tranſit at Sun-ſet. And thoſe Perſons who lie under the Meridian, as all the midland Parts of *Muſcovy* in *Aſia*, of *Syria*, the *Red Sea*, and eaſtern Coaſt of *Africa*, view the End of the Tranſit at Noon: And amongſt them, thoſe at *Jodda*, on the eaſtern Coaſt of the *Red Sea*, have the Sun then vertical to them.

Cleon. Indeed, my *Euphroſyne*, you have excellently well executed what relates to the Geographical Part of this Tranſit, as far as we have hitherto conſidered it. It remains now, that we make the proper Uſe of it in diſcovering the different Times of the Continuance, or Duration of the Tranſit, as it may be obſerved from different Parts of the Earth's Surface. —— But in order to this, it will be neceſſary you ſhould be advertiſed of one Thing, and that is, that when we behold any Body in Motion, the Celerity, or Quickneſs of the Motion will be different, according to the Circumſtances of our own Situation, in regard to Reſt or Motion: For (1.) If we ourſelves are at Reſt, we ſee the Body move with its true, or real Celerity of Motion. (2.) But if we ourſelves move, and the ſame Way with the Object, its Motion, or Celerity will appear to us to be leſs, or ſlower than it really is. (3.) If we move the contrary Way to the Object, it will appear to move much quicker, or with a greater Celerity of Motion than it really has.

Euphroſ. This laſt Obſervation I remember to have often ſeen verified in a Stage Coach; for as I have been going to, or coming from Town, the Coaches which we have met on the Road have always appeared to paſs by us with a Motion much ſwifter than we were well aſſured they really had. —— As to the firſt Obſervation, it is evident to common Senſe; —— but the ſecond requires ſome Attention, tho' not a great deal, when I conſider that oftentimes going upon the *Thames* in a Boat, I have obſerved the Boats that we meet always appear, like the Coaches, to paſs by us with a Motion much greater than our own; but thoſe which we overtake appear to move as much ſlower.

Cleon. I imagine you would eaſily recollect how commonly thoſe Poſitions are verified by Experience; and you will, at the ſame Time, make this natural Inference, that the ſwifter any Motion is, the leſs Time will be ſpent in paſſing over any given Space, and the ſlower the Motion, a longer Time will be required.

Euphroſ. This alſo is too plain to admit of any Heſitation; but what is all this to the Tranſit of *Venus?*

Cleon. Theſe Things rightly conſidered, are ſo much to our Purpoſe, that they contain the whole *Rationale* of that great Phænomenon.

For

For (1.) If an Eye be placed at the Center of the Earth, (or any where on its Surface without Motion) then it is plain, if it views the Planet paſſing before the Diſk of the Sun, it will ſee it move with its proper, or real Velocity of Motion, ſo as to tranſit the Diſk in about *ſeven Hours and twenty Minutes:* ——— But (2.) If the Eye be placed on the Surface of the Earth, conſidered in Motion, then it is plain, that while the Globe moves on its Axes, thoſe Parts of its Surface which paſs under the ſouthern Part of the Meridian moves in a contrary Direction to thoſe which paſs under the northern Part, with reſpect to any particular Point, or moving Body at a Diſtance in the Heavens: Thus in the Time of the Tranſit, you ſee on the terreſtrial Globe, that all the Part of *Arabia* and the *Indies* move under the ſouth Meridian from Weſt to Eaſt, and thoſe in *North America* at the ſame Time move (with reſpect to *Venus* upon the Sun) in a contrary Direction, *viz*, from Eaſt to Weſt, under the northern Part of the Meridian. ——— And therefore (3.) it is plain, that ſince the Motion of *Venus* is from Eaſt to Weſt upon the Sun, the Inhabitants of the *Indies*, who move in a contrary Direction, will view the Planet moving with a ſwifter Motion over the Sun than it really has; ſo that the Time of the Tranſit to them will be ſhorter than before, *viz.* it will continue about *ſeven Hours nine Minutes:* — But as the Inhabitants of *North America*, about *Hudſon's Bay*, move the ſame Way with the Planet, ſhe will appear to them to move ſlower, and therefore will be a longer Time in paſſing over the Diſk, *viz.* about *ſeventeen Hours twenty-ſix Minutes.*

Euphroſ. Well, one would not imagine that the Nature and Theory of ſuch important Doctrines depend on ſuch trivial Obſervations as you mentioned; but I am thoroughly ſatisfied now of their neceſſity and Utility. ——— But why does Dr. *Halley* delegate us to thoſe diſtant Regions for viewing this Phænomenon; cannot the Philoſophers do it as well at home as abroad? thoſe Climates are very different in their Nature, and may neither of them be agreeable to *Engliſh* Conſtitutions, beſides the Danger, Difficulty, and Expence attending long Voyages.

Cleon. There are Reaſons enough for his doing this, my *Euphroſyne*; the (1ſt) is, that ſuch Places ought to be choſe for the Obſervation, where the Beginning and End of the Tranſit

can

can be seen; but the Beginning cannot be seen in any Part of *Great Britain*. ——— For once more turn the Globe about, to view those Places where the Beginning is visible, and you will see the northernmost Parts of *Scotland*, the *Orkney* Isles, and even *Shetland* itself, all below the Horizon at that Time.

Euphros. I see they are; but how then am I to understand the Doctor, when he says, perhaps the Ingress may be seen at Sunrising by that very People who I now see are below the Horizon at that Time?

Cleon. I confess, I know not how to answer your Query, unless the Doctor supposes the Refraction of the Atmosphere is sufficient to elevate the Sun to their View, before it be really risen.

Euphros. The Reason which you have given is very sufficient for going to some one Place to observe the Transit; but why is any one Place, for Instance, *Bengal*, more eligible then another?

Cleon. The Doctor does not recommend *Bengal* as more proper for the Observation than any other Place in the *East Indies*, but he mentions that in particular, as being an *English* Factory, and that particular Part of the Earth's Surface over which the Sun will be vertical at the Time of the Middle of the Transit: He represents it as an indifferent Matter, whether the Observavation be made at *Bengal*, or Fort St. *George*, commonly called *Madras*, or at *Bencoolen*, on the western Coast of the Island of *Sumatra*, near the Equator: He also recommends *Pondicherry*, on the western Coast of the *Gulph* of *Ganga*, to the *French*; and *Batavia*, the famous *Emporium* in the Island *Java*, to the *Dutch*, as being very proper Places for observing the Transit, by the People residing there; and there is very good Reason for making as many Observations as possible, in the several Parts of the *Indies*, and as near the Equator as may be; because they will be there farther from the Earth's Axis, and observe the Transit to the greatest Advantage that can be, on that Account.

Euphros. If those Parts are so advantageous, which are near the Equator, why then are not both the Observations to be made there, and so make one Trouble serve for all?

Cleon. You will easily see the Reason why that cannot be, by casting your Eye on the Globe; for if you now rectify it as you did before, for the Beginning of the Transit, you will find that the

the nocturnal Observation, or that which is to be made at Sun-set, impossible in any less Latitudes than 23° North, and there only in the southern Parts of *California*, there being nothing but the great *South Sea* in all the Equator that can see the Setting-sun: Besides, suppose there was ever so fair an Opportunity of viewing the Transit at Sun-set, it would answer no Purpose, because it must necessarily be over before Sun-rising, the Length of the Night in all those Parts being much greater than the longest Duration of the Transit.

Euphros. You have thoroughly convinced, and satisfied me in that Particular; I plainly see the Latitude for the second Observation must be such, where the Length of the Night is shorter than the Duration of the Transit; and as the Globe is now rectified, I can plainly see that among all the Places in *North America*, in the eastern Part of the Horizon, the first that offers itself for viewing the Transit at Sun-set is that which you mention'd, just now, *viz. Port Nelson*, at the Entrance of *York* River, all other Parts, or Places being inaccessible to us; and, indeed, that is the first Place that will circulate below the Horizon, and rise again above it on the western Side before the Transit ends, and consequently will be the least Latitude in which we can observe the Duration of the Transit, including both the Beginning and the End. At the same Time, I understand now more plainly than before, why no other Places even in those northern Latitudes will answer for this Purpose, because they will necessarily be below the Horizon, either at the Beginning or End of it.

Cleon. That is very well observed, my *Euphrosyne*; for in the Island of *Great Britain* we lose the Beginning of it, and to observe the Time when it ends is not sufficient; and it happens very well for us, that *Hudson's Bay* provides us with this Port for the Purpose; for we should have found it attended with much greater Difficulty, to have had Recourse to Places in the frigid Zone: For tho' there are Places enough in *Lapland*, the northern Parts of *Russia*, *Nova Zembla*, *Iceland*, &c. where the Sun will not at that Time disappear, yet being near the Earth's Axis, the Difference between the Times of the Transit will not be so great, for an Eye placed any where in the Axis of the Earth will see the Transit of equal Duration; and, therefore, to an Eye placed at the Center, or upon the Surface at either Pole, the

the Appearance will be the same in regard to Time, and this will lead us from the Globe to a Diagram, which I have provided for a farther Explanation of the Particulars of this Phænomenon, as they are to be astronomically considered.

Euphros. I cannot but think myself greatly obliged to you for your Care, in contriving every Way to facilitate the Knowledge of this uncommon Affair. ——— As to the Diagram, I can readily perceive at first View the Design of a great Part of it: Thus I observe *A*, *B*, *C*, represents one half of the Sun, the Center of which is *C*, and the Diameter *A E*. ——— I imagine also, that the two black Circles on each Side of the Sun at Y and Z, represent the Planet just within the Sun's Disk in those Places; and further, that Y *D* Z is the Path, or Tract of *Venus* over the Disk: ——— Also, that *G*, *H*, is a Part of the Orbit of *Venus*, and that Planet in two Positions at P and X. ——— And, lastly, I suppose that the Circles A F E G, and others within it, may represent the Earth. Am I so far right, *Cleonicus?*

Cleon. You are, my *Euphrosyne*; the great Circle you mention is the Equator, the next Circle B I D H is the Parallel of 22° 30′ Latitude, answering to the Bay of *Bengal*; the inmost, or lesser Circle *c e d f* is the Parallel of 56°, answering to Port *Nelson* in *Hudson's Bay*; and C is the Center of the Earth, or Pole of the Equator, which you please.

Euphros. But what is the Use of all those Lines drawn from the Earth to the dark Planet on the Sun?

Cleon. Those I shall point out to you in Order; and first, suppose an Eye was placed in the Center of the Earth in C, to view the Planet as it passes along in its Orbit from P towards X. It is evident, when the Planet arrives to the Point S, it would be seen just within the Sun by the Ray of Light C S Y; and when it has advanced to the Point V, it will then be seen to touch the Edge of the Sun on the other Side, by the Ray C V Z; so that while the Planet describes that Part of its Orbit between S and V, it will appear, to an Eye at C, to pass over the Disk of the Sun from Y to Z.

Euphros. So far I apprehend you extremely well; ——— but, pray, what Time passes between the Beginning at Y, and the End of the Transit at Z, as viewed from the Earth's Center at C?

Cleon.

The TRANSIT of VENUS over the SUN'S DISK

June 6. 1761.

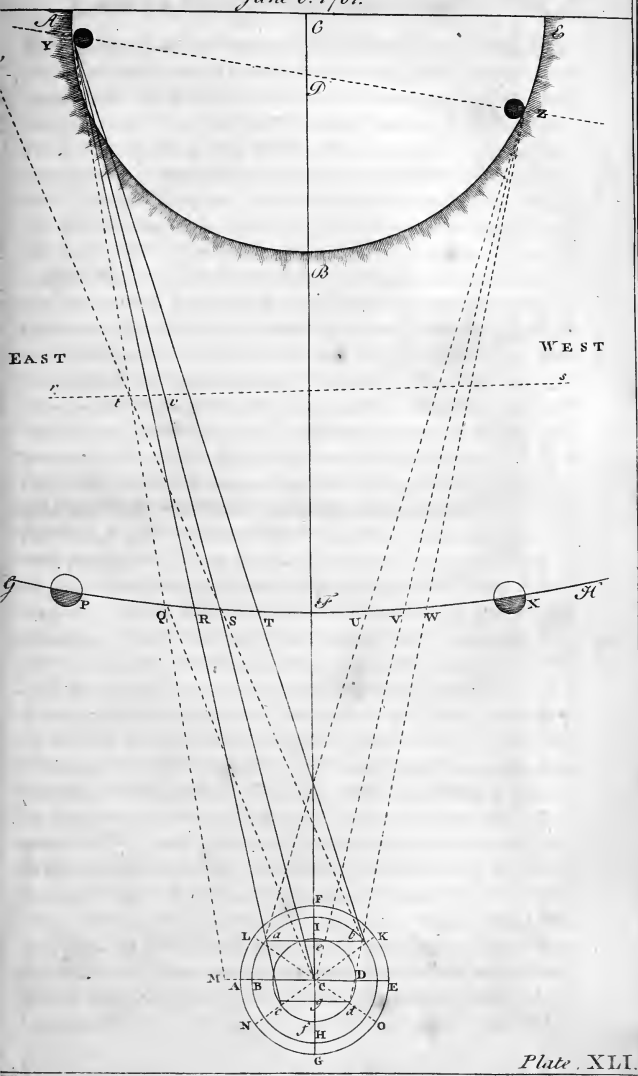


Plate XLI.

An APPARATUS *adapted to the* REFLECTING TELESCOPE
for shewing The TRANSIT *of* VENUS.

Cleon. You have been long, 'ere now, inſtructed in the Meaſures of Aſtronomy; ——— you know the Diameter of the Sun is, at a Mean, a little more than half a Degree; but at the Time of the Tranſit, it will be very nearly 32′ of a Degree: And therefore, ſuppoſing that the Diameter A E be divided into thirty-two equal Part, the Planet will appear to paſs over four of them in an Hour, *i. e.* her horary Motion is after the Rate of four Minutes an Hour; and therefore, in paſſing from Y to Z, the Time ſpent will be equal to about ſeven Hours and twenty Minutes; ſuch will be the Time of the Tranſit, to an Eye at the Center C. In this Time a Spectator at the Equator will, by the diurnal Motion of the Earth, be carried thro' 110° of Longitude, equal to the Arch K F L.

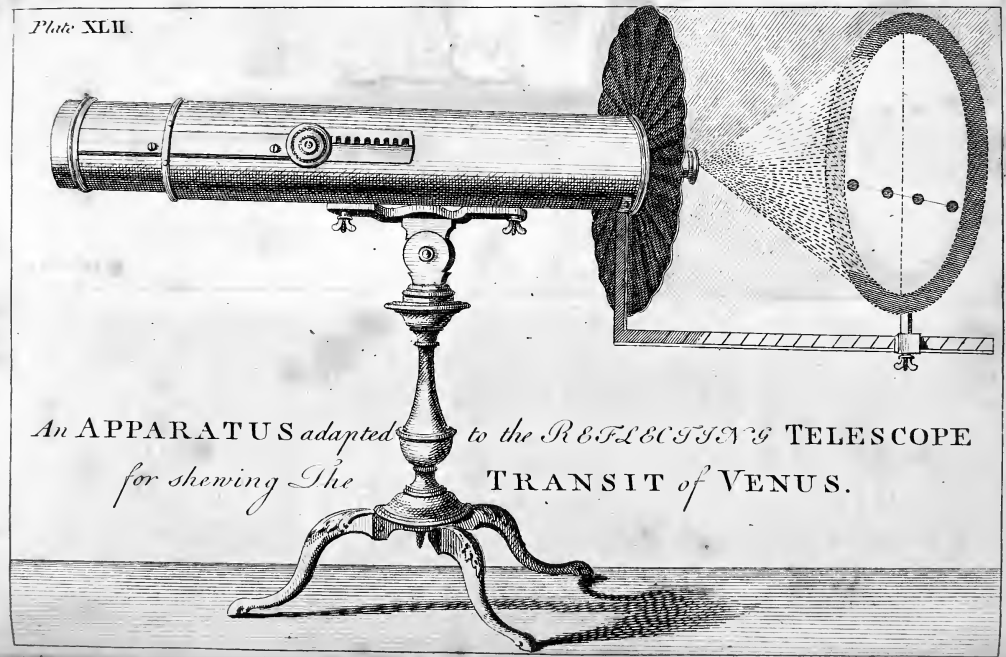
Euphroſ. Very good, *Cleonicus*, I underſtand you; but now let me view the Tranſit from *Bengal*, in your Diagram.

Cleon. That you ſhall do; and for this Purpoſe you muſt ſuppoſe your Eye to be placed in the Point of the Parallel proper to that Place, to view the Beginning of the Tranſit at Y; which of Courſe will be on the weſtern Side of the Globe, becauſe in half the Time of the Tranſit you will be carried from *b* to I, where you will view the Planet in the Middle of its Paſſage over the Sun at *D* nearly. From I you will be then revolved to (*a*) on the eaſtern Side of the Globe, to view the Egreſs of the Planet at Z; from whence it is evident, that the Beginning or Ingreſs will appear to you in the Line *b* T Y, and the Egreſs in the Line *a* U Z; therefore the Planet muſt be in its Orbit at T in the firſt Caſe, and at U in the latter; and, that its Paſſage from T to U, as it is ſhorter than that from S to V, ſo it will be performed in leſs Time, and therefore you will at *Bengal* obſerve the Tranſit of a leſs Continuance, than if your Eye was placed at the Center C, by about *eleven Minutes*.

Euphroſ. I think, I pretty clearly underſtand you; for I ſee the Motion from *b* towards *a* is in a contrary Direction to that of the Planet from Y to Z, and therefore muſt cauſe her apparent Motion to be quicker, in the Manner you have now explained.

Cleon. As you cannot underſtand theſe Things too well, I ſhall exemplify it otherwiſe by the parallatic Angle in a Caſe ſimilar to that of the Candle on the Table, which I before mentioned to you: ——— Thus, ſuppoſe a Plane was placed

Plate XLII.



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Euphroſ. Very good, *Cleonicus*, I underſtand you; but now let me view the Tranſit from *Bengal*, in your Diagram.

Cleon. That you ſhall do; and for this Purpoſe you muſt ſuppoſe your Eye to be placed in the Point of the Parallel proper to that Place, to view the Beginning of the Tranſit at Y; which of Courſe will be on the weſtern Side of the Globe, becauſe in half the Time of the Tranſit you will be carried from *b* to I, where you will view the Planet in the Middle of its Paſſage over the Sun at *D* nearly. From I you will be then revolved to (*a*) on the eaſtern Side of the Globe, to view the Egreſs of the Planet at Z; from whence it is evident, that the Beginning or Ingreſs will appear to you in the Line *b* T Y, and the Egreſs in the Line *a* U Z; therefore the Planet muſt be in its Orbit at T in the firſt Caſe, and at U in the latter; and, that its Paſſage from T to U, as it is ſhorter than that from S to V, ſo it will be performed in leſs Time, and therefore you will at *Bengal* obſerve the Tranſit of a leſs Continuance, than if your Eye was placed at the Center C, by about *eleven Minutes*.

Euphroſ. I think, I pretty clearly underſtand you; for I ſee the Motion from *b* towards *a* is in a contrary Direction to that of the Planet from Y to Z, and therefore muſt cauſe her apparent Motion to be quicker, in the Manner you have now explained.

Cleon. As you cannot underſtand theſe Things too well, I ſhall exemplify it otherwiſe by the parallatic Angle in a Caſe ſimilar to that of the Candle on the Table, which I before mentioned to you: ——— Thus, ſuppoſe a Plane was placed

beyond the Planet's Orbit in the Line *r s*, then when the Planet is at S, it will be seen on that Plane at *v* by an Eye at C; but to an Eye placed at *b*, the Planet would appear on the said Plane at *t*, by the Ray *b* S *t*: So that the Planet in the same Point S will be seen in two different Parts of that Plane, by the Eye in these two different Positions; all which is occasioned, you see, by the Distance of the two Points C and *b*; and the Angle C S *b* or *t* S *v* is what the Astronomers call the parallatic Angle, or that Angle which makes *the apparent Difference of the Planet*'s Place: — From whence it is evident, that the less the Distance C *b* from the Earth's Axis is, the less will be the parallatic Angle, and consequently in the Pole, where it vanishes, there will be no Parallax at all, as I observed to you before.

Euphros. I partly see the Reason of all that you now say; and farther, if the Plane *r s* be taken away at the same Time that the Planet appears upon the Sun at Y, to an Eye at C, it will appear at a Distance from the Sun eastward at *w*, to an Eye at *b*, by the Ray *b* S *w*: ——— And lastly, that as we go nearer to the Equator, the Distance C *b* will be greater, and therefore will occasion a greater Difference in the Place of the Planet, and Time of its Transit, and consequently will so much the better answer your Purpose. ——— But now for the Appearance at Port *Nelson*, *Cleonicus*.

Cleon. As your Motion is now to be considered in the same Direction with the Planet, you must conceive your Eye to be placed on the eastern Side of the Globe at *c* in the Diagram, to view the Ingress of the Planet at Y, which, it is evident, will appear by the Ray *c* R Y. ——— After this the Eye will be carried, by the Motion of the Globe, by the northern Part of the Meridian round to *d*, where it will view the End of the Transit at Z, by the Ray *d* W Z, and consequently the Time of the Transit at this Place will be all that is spent while the Planet describes the Arch R W (greater than S V,) which will be about seven Hours and twenty-seven Minutes nearly, which therefore will be about *eighteen Minutes* longer than the Time of the Transit at *Bengal*, all which is occasioned by the Distance of the Points *b* and *c* from the Earth's Axis, and the contrary Directions in which they are moved.

Euphrof. I ſee nothing difficult to underſtand in all this; but how is this Difference in Times of the Tranſit applied, to finding the Parallax and Diſtance of the Sun?

Cleon. Very eaſily, a by Proceſs in Trigonometry,* as it requires nothing more than common Skill in the Doctrine of plain Triangles: But as you have not yet learned any Part of the Mathematics, I ſhall not pretend to trouble you with that Affair now; you will find it not difficult to underſtand hereafter. ——— At preſent it may ſuffice to ſay, that by knowing the Difference in the Times of the Tranſits, they can eaſily know the Parallax of the Sun; and if it appears from Obſervation, that there is a Difference of ſeventeen Minutes only, that will give a Parallax of 12 $\frac{1}{2}$ Seconds, conſequently for each Second of the Parallax there will ariſe a Difference of more than 80 Seconds of Time; and therefore if this Difference be had true to half its Quantity, the ſolar Parallax will be had to within the 40th Part of one Second, and conſequently within a 500th Part of the whole, becauſe 40 Times 12 $\frac{1}{2}$ is juſt 500.

Euphrof. I muſt take another Opportunity of talking with you farther on this Subject; for tho' I have the Satisfaction to underſtand the general *Rationale* of this important Subject, from what you have now ſaid, I am ſatisfied it requires ſtill farther Reflection, and ſome mathematical Inſtruction, to underſtand it ſo compleatly as I could wiſh; for the acquiring of which, I ſhall be ready to devote any future Part of my Leiſure.

Cleon. Theſe Things, it is true, are much of a mathematical Nature, and therefore we ſhall at preſent proceed no farther in the deſcriptive Part. ——— But one Thing remains for you to know, and that is, a Method of ſhewing this Phænomenon in a moſt eaſy and delightful Manner, by Means of a new Apparatus adapted to the reflecting Teleſcope: And this ſhall be the Subject of our Converſe at the next Interval.

* All the phyſical and mathematical Parts of this Doctrine are explained in the Comment on Dr. *Hally*'s Diſſertation, in the *Miſcellany*.

DIALOGUE XVI.

The DESCRIPTION *of a new* SOLAR APPARATUS, *adapted to the* reflecting TELESCOPE, *for ſhewing the* TRANSIT OF VENUS *over the* SUN's DISK, *without darkening the Room.*

Euphroſyne.

I Have ever ſince been mindful of your Promiſe, to entertain me with the Manner of exhibiting this curious and rare Phænomenon, by a new Apparatus applied to the reflecting Teleſcope. I hope this Morning will favour the Deſign, as the Heavens are clear and ſerene, and the Sun ſhines forth with its uſual Splendor and Glory.

Cleon. We could not have wiſhed for a finer Day than this is like to prove. — The Teleſcope I have choſe for this Purpoſe is of the reflecting Sort, as it is moſt convenient to uſe for this Purpoſe by Means of its Foot or Stand, the Conſtruction of which is alſo different from the common Sort, and is thereby rendered more convenient for the Application and Uſe of this new Apparatus.

Euphroſ. I am not much acquainted with the Structure of thoſe Inſtruments, but I plainly ſee a Difference between this and that which ſtands in my Father's Study, thro' which I have often uſed to view diſtant Objects, and in which you have ſhewn me, before now, the Spots on the Sun's Face.

Cleon. That is a very good reflecting Teleſcope of the common Form; but this Teleſcope, which I ſhall now make uſe of, is much preferable for all the common Purpoſes of a Teleſcope in general, and it has many peculiar Advantages above the other, and of which they are not capable, as you will hereafter be fully ſenſible of, when we come to treat of the Nature and Uſe of this Inſtrument more directly.

Euphroſ. I obſerve this Teleſcope conſiſts of two braſs Tubes, and that the interior one is made to move backward and forward,

by

by Means of a ſmall Piece of Rackwork on the Side of the outer one: This, I preſume, anſwers the ſame Purpoſe as the long Wire on the Side of the common reflecting Teleſcope, which we turn one Way or the other, for adjuſting the Inſtrument to a proper Focus in viewing Objects.

Cleon. That is the Deſign of it in general; but this Conſtruction, as I ſaid before, is much better adapted to our preſent Purpoſe on other Accounts than a Reflector of the common Form, tho' that will do very well.

Euphroſ. But what, and where is the new Apparatus you ſpeak of?

Cleon. I have not yet applied it to the Teleſcope, as I intend to ſhew you the ſeveral Parts of it in the firſt Place: —— It is of a very ſimple Form, as it conſiſts but of few Parts, which I ſhall now proceed to deſcribe. — (1.) I take off the common Eye-piece of the Teleſcope, and ſcrew on another in its Room, of a ſhorter or leſſer Size. (2.) I have adapted the common Candle Screen, made of black Silk, and which, in the uſual Manner, expands itſelf into a circular Form, to the End of the Teleſcope, where you obſerve it is eaſily faſtened on. (3.) This ſquare Piece of Braſs, which is about ſix Inches and a half long, is ſcrewed on to a Piece fixed upon the under Part of the Teleſcope. (4.) Into the lower Part of this, another long ſquare Piece of Braſs is firmly fixed by Means of a ſquare Shoulder, Nut, and Screw; upon this is a Scale of Inches to the Number of thirteen. (5.) Upon this long Arm is a moveable Socket of Braſs, with a Screw to fix it to any Part, on the Top of which is a tranſverſe Piece, into which are fixed two upright Wires of a proper Length. (6.) Upon theſe Wires is applied a Screen of white Paper, of a circular Form, on which is drawn a black Circle of twelve Inches Diameter, divided into 360 Degrees, with two Diameters, one Vertical, and the other Horizontal. The firſt of theſe is divided into 1900 equal Parts, and numbered each Way from the Center 100, 200, 300, &c. †

Euphroſ. You will pleaſe to put them together, and then I ſhall have a more compleat Idea of the Nature and Deſign of the whole.

Cleon. This I ſhall inſtantly do: — Firſt, I apply the Screen to the End of the Teleſcope; — then I ſcrew on the perpendicular Piece of Braſs; —— into this I fix the horizontal Piece, — then I apply the Socket to N° XII, and there ſcrew it faſt; —— after this, I apply this circular Screen to the upright Wires: — And then, laſtly, I ſcrew into the End of the Teleſcope

† We apprehend the ſeveral Parts of this Apparatus are ſo plainly repreſented in the Print, as to need no Deſcription, by Letters of Reference.

ſcope the Braſs Piece, containing the Magnifiers, —— and thus the whole is fitted for Uſe.

Euphroſ. I ſee the Deſign of it is to form the Diſk, or Face of the Sun upon that circular Paper Screen; — but is not the Room to be darkened for this Purpoſe?

Cleon. No; the black Screen ſupercedes the Neceſſity of that troubleſome and inconvenient Circumſtance: ——— You will by Means of this Apparatus, in the moſt lightſome Room, have the Pleaſure of viewing the Face of the Sun, and every Thing that may appear in or upon it, with as much Pleaſure, and almoſt as perfectly as in the *Camera Obſcura* itſelf.

Euphroſ. If this be the Caſe, it muſt render the Opportunity of viewing the Tranſit of *Venus* extremely eaſy and agreeable, in every Place where they ſhall be favoured with a Sun-ſhiny Morning, like this.

Cleon. And that this is the really Caſe I ſhall ſoon convince you by an Experiment or two with this Apparatus, and that in a different Way or Manner from any Thing that has hitherto been ſhewn of the like Kind: For all Objects that have been uſually magnified in the ſolar Microſcope, are repreſented in a Beam of the Sun's Light, very much dilated upon the Side of a Room or Screen; but here you will ſee Objects repreſented on the real Face, or the Diſk of the Sun itſelf; ſo that by this Means we might properly make the bright magnified ſolar Diſk the real Screen for ſhewing Objects upon; by which Means they will become vaſtly more vivid and diſtinct in all their Parts, and will make a much richer Appearance. ——— In order to ſatisfy you of what I now ſay, I ſhall, in the firſt Place, ſhew you the Face of the Sun upon the Screen, in various Degrees of Magnitude, according to the Diſtance of the Screen from the magnifying Glaſs, and you will always know the Diameter of the magnified Image of the Sun by the Number of Inches to which the Screen is placed on the Scale.

Euphroſ. That is, I ſuppoſe, if the Screen be placed at N° 2, then will the Sun's Image be two Inches in Diameter; if at N°. 6, it will be ſix Inches in Diameter; and if the Screen be placed at N°. 12, then will the ſolar Diſk be 12 Inches, or juſt fill the graduated Circle.

Cleon. I perceive you have a very clear Notion of this Matter, and therefore ſhall preface no more concerning it, but ſhall proceed, in the firſt Place, to ſhew you the ſolar Diſk, with the Spots upon it, if any; and accordingly, ——— firſt, I fix the Screen at N°. 1, and then directing the Teleſcope to the Sun, I turn the little Wheel on the Side of the Teleſcope till I make the Sun's Face appear very diſtinct, and well defined on the Surface of the Screen,

Screen, where it appears small indeed, as being now but one Inch in Diameter.

Euphrof. Well, it is very curious to see the little Sun so very distinct: ——— I really can see two or three small Spots upon its Surface.

Cleon. Those Spots are not small, but large, as you will see when I move the Screen backward to N°. 4: ——— For now turning the Pinion, the Sun's Image appears very distinct, and just four Inches in Diameter, and the Spots appear now in Proportion larger and plainer. ——— I remove the Screen to N°. 8, there the Sun's Face is enlarged to eight Inches in Diameter. ——— Lastly, I place it at N°. 12, and by adjusting the Telescope, you there see the noble Appearance which the Disk of the Sun makes on the Screen, and just fills the graduated Circle drawn upon it.

Euphrof. A glorious Sight indeed, and the Spots now appear to great Advantage. — This Method of viewing them is greatly preferable to that of poring thro' the Telescope itself at the Sun.

Cleon. As the Sun's Face and Spots are so easily and so distinctly observed, you will readily understand that the Planet *Venus*, in transiting the Sun's Disk, will be as distinctly represented and viewed.

Euphrof. I can easily apprehend she will; for when the Disk of the Sun itself is perfectly formed, the Planet *Venus*, as well as the solar *Maculæ*, must also be delineated in the same Degree of Perfection, by that exquisite Instrument.

Cleon. It will not be disagreeable to you, if I illustrate this by an artificial Representation of this famous Transit: ——— For which Purpose you must provide me with four of the smallest black Patches you can get.

Euphrof. These I have at Hand, and will this Instant go for them: —— These are the smallest I have, will they answer the Purpose?

Cleon. They will do very well; — I have here an Ivory Slider, with a round Piece of Talk, on which I have drawn two Diameters, and likewise the Path of *Venus*, at each End of which I stick a Patch, and place the other two in the said Path, so that they may represent four Positions of that Planet on the Disk of the Sun, formed upon the Screen as before. — I put the Slider in its Groove, and then, by turning the Screw, you see those Patches gradually come to a perfect Form on the Face of the Sun: —— They appear very black, round, and nearly in Proportion, as *Venus* herself will be seen in Comparison of the Sun.

Euphrof. This is very natural indeed, as well as artificial. — I see *Venus* now at her Ingress and Egress, in the same Manner as

as she is delineated on the Print of the Transit at large; and since this artificial Representation is so perfect, it will in a great Measure supply the Deficiency of the natural Transit, if the Weather should prevent our Enjoyment of that most desirable Sight.

Cleon. A Sight, that mortal Eyes never more than once beheld! The famous *Jeremiah Horrox*, who lived at *Hoole* in *Lancashire*, by his great Skill in Astronomy, foresaw and predicted the Transit of *Venus* before the Sun, *November* 24, in 1639. He gave Notice of this to his Friend Mr. *Crabtree*, who attended him at the Time, and they both together in a darkened Room, where the Sun's Image was formed at large on a Screen, saw *Venus* just at nineteen Minutes after three o'Clock in the Afternoon enter the Disk; but the Sun setting before the Transit was compleated, prevented their having an entire View of it, so that this next Transit will be the first that will afford a View of the Phænomenon compleat.

Euphros. I should almost envy those Gentlemen the partial View they had, were not ours likely to be more compleat; for an entire View even at this next Transit, will be impossible, I find, to the Inhabitants of *Great-Britain:* ——— But since the periodical Time of *Venus*'s Revolution about the Sun is so short, I think it is a Wonder that we do not oftener observe her to transit the Sun's Disk.

Cleon. If you were very attentively to consider the Laws of the planetary Motions, the Wonder would soon cease: There is, indeed, a Period of eight Years only between two Transits; but then, one of them is so very small as to be altogether inconsiderable. Thus, for Instance, there was a Transit in the Year 1631, in which *Venus* did but just, at it were, dip into the Disk of the Sun: And in the Year 1769 she will again pass by the Sun in the same Manner, appearing to some Parts of the Earth just within the Disk, and, to others, but just touching it on the upper, or northern Part of the Limb: Which Transits, or rather Appulses, will be Matters of greater Curiosity than Use. ——— I have now informed you of every Thing I think necessary, relating to this Subject, for the present: ——— The farther Use of this Apparatus, for magnifying Objects in the Nature of a solar Microscope, I shall explain to you at another Season, which will be very shortly: As our next Subjects of philosophical Conversation will be those of the Description, and practical Uses of the several Kinds of Microscopes, Telescopes, and other optical Instruments, which, I doubt not, will afford you as great Pleasure and Improvement as they have done to myself for many Years past.

The END *of this* PART.

The Young GENTLEMAN and LADY'S PHILOSOPHY.

PART V.

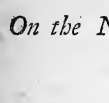
CONTAINING

A Practical TREATISE on the Use of OPTICAL INSTRUMENTS.

DIALOGUE I.

On the Nature, Construction, and Use of SINGLE MICROSCOPES.

Euphrosyne.



HAVE spent all the Time I could conveniently spare, in looking over those Tracts which you recommended to my Perusal, preparatory to my understanding the Construction and Use of Optical Instruments; and as you was pleased, in the Dissection of the Eye, to shew me the particular Parts described in the Treatise, it gives me, upon the whole, such an Idea of the Nature of Vision, as I easily find must be the Ground-work of all our Knowledge in Optics. A Person who has not a distinct Knowledge of the several Parts of the Eye, can by no Means attain to a *Rationale* of the Use of Optical Glasses, since the Eye appears to me very plainly to be nothing more or less than two or three such Glasses properly put together, in order to form an Image on that wonderful Membrance at the Bottom of the Eye, which you call the *Retina.*

Cleon. The Eye is undoubtedly the principal and moſt perfect of all the Organs or Inſtruments of Viſion; and I have taken the more Care to inſtruct you in the Uſe of every Part of the Eye, becauſe you will find the Rules and Precautions which Nature has obſerved in its Conſtruction, for perfecting the Sight, are alſo to be moſt ſcrupulouſly regarded in the Mechaniſm of all Sorts of Optical Inſtruments, eſpecially thoſe which we call Microſcopes and Teleſcopes: And it is no uncommon Thing to obſerve, that thoſe Inſtruments are often faulty in theſe eſſential Points, when no Deficiency appears in their external Structure. The moſt exquiſite Skill in Optics is employed about thoſe Parts and Particularities of an Inſtrument which lie quite out of Sight.

Euphroſ. The Nature and Uſe of Optical Glaſſes are ſo familiarly deſcribed and explained by Figures, that I was at no Loſs in verifying their ſeveral Properities by Experiments, which I made with the ſeveral Lenſes and Mirrors which you lent me for that Purpoſe. ——— I can now take any ſingle Lens or Speculum, and therewith form the Image of any given Object at Pleaſure. ——— I obſerve their various Magnitudes in Proportion to the focal Diſtances of the Glaſſes; ——— I ſee the inverted Poſition of each on the Paper; ——— and if I fix the Glaſs, I make all thoſe Images greater or leſs, by removing the Object nearer to, or farther from it. ——— I obſerve, with great Pleaſure, what I think we may properly call the very Life or Soul of the Picture; I mean the natural *Motions* and *Colours* of every Part, the firſt of which no Paintings can pretend to, and the latter they but faintly imitate. ——— I delight myſelf ſo much with theſe philoſophical Entertainments, that I wonder very much how ſo many of my Sex can be ſo eaſy and ſatisfied, without ſharing with me in the Felicity which thoſe Sentiments afford, ariſing from ſuch an experimental Speculation of the Sciences.

Cleon. It is principally for want of ſuch Speculations being *experimental*, that ſo many People appear indifferent about them. Matters of mere Theory are generally dry and jejune to any but thoſe who have a particular Taſte for the Subject; but the Science of Optics is converſant about ſuch Subjects as are founded, not only in the moſt perfect Geometry of Nature,

ture, but are capable of being illuſtrated, and rendered in the higheſt Degree entertaining and uſeful, by the moſt eaſy and obvious Experiments. ——— This Science extends the Uſe of the Eye to an amazing Degree; — tho' this excellent Organ is by Nature conſtructed to produce the moſt uſeful Senſation, yet it is in a limitted Degree: It is left to human Skill to perfect it in almoſt as much higher Degree as we pleaſe. ——— Whatever is neceſſary, Nature has ſupplied us with, in regard to Viſion, with reſpect to the common Conveniencies of Life: ——— But if we would look far before us, and take a Proſpect of the remote Scenes of Nature, and view her numberleſs Curioſities in her ſecret Receſſes, we muſt make uſe of the artificial Means of Viſion, I mean, *Optical Glaſſes* and *Inſtruments:* —— And I don't know any Thing in the whole Courſe of my Obſervation that appears to me of ſo extraordinary a Nature as the great Eſtimation or Value we ſet upon common Sight, and at the ſame Time ſo little regard the Improvement of it.

Euphroſ. I fancy it muſt be in this Caſe, as in many others, what we don't perceive the Uſe, Pleaſure, or Neceſſity of, we are not ſenſible, and therefore do not regard the Want of it; and a great many People appear to be naturally deſtitute of any Taſte for the Refinements and Pleaſures ariſing from the Study or Extenſion of the Sciences, either Optical, or any other Kind.

Cleon. Your Obſervation is juſt; to which I may farther add, that it is neceſſary it ſhould be ſo, and that we ought not to look on thoſe Things as any Faults or Deficiencies in Mankind: Thoſe who want a Genius are not to be blamed on that Account, nor are we to wonder when we find them ſo frequently expatiating on the Pleaſures ariſing from the Senſations of the *Guſtatory Nerves*, and ſo little ſenſible of thoſe of the *Optical* ones. — But to the Point: I have here brought you ſeveral MICROSCOPES of different Forms and Conſtructions, on Purpoſe to acquaint you with the different Ways and Means that have been invented and contrived for their Application, in viewing *Minute Objects.* Theſe the *Opticians* uſually call *Single Microſcopes*, and are to be held in the Hand.

Euphroſ. They ſeem to be curious Inſtruments, and neatly diſpoſed in their Caſes, with a Number of little Trinkets about

them, all of elegant Workmanship. ——— I see they are of different Form and Make, and I presume all answer one, and the same End, *viz. to magnify any small Object:* ——— But one Query I must beg you to satisfy before we proceed farther, and that is, how it is in the Power of a Glass to make an Object bigger or less.

Cleon. The Glass, my *Euphrosyne*, can do no such Thing, the real Magnitude of the Object continues the same; however it may be viewed by the Glass, the magnifying Power, as we usually call it, is only apparent. — The Eye, by Means of the Glass, views an Object under a larger Angle than it can do without, and consequently will see it, in Appearance, larger; for by the Principles of Optics, which you have perused, if you recollect, it appears, that any Object subtends a larger Angle in Proportion, as it is nearer to the Eye, and that Angle is the Measure of the apparent Magnitude of the Object; thus, for Instance, if you extend your Arm, and hold up your Figure against the Ball under the Cross, on the Top of St. *Paul*'s Cathedral, it will appear much bigger than that Ball does, because it subtends a much greater Angle to the Eye than that Ball does at so great a Distance, tho' it be six Feet in Diameter.

Euphros. There is something very curious and surprising in your Doctrine of apparent Magnitudes, I find by Experiments, which I little thought of before; but admit that the Glass only shews the Object larger, yet there is one Thing farther that must be the Subject of another Query, *viz.* how it comes to pass that the Glass shews the Object distinctly at such a Distance from the Eye, where it cannot be seen without it, unless very confusedly?

Cleon. You will remember the Experiment which you made in the Sun Beams with the Glass, whose focal Distance was one Inch, *viz.* that it collected together the Beams into one Point, called the Focus; and that another Glass of the same Sort, held just as far beyond that focal Point, received the diverging Rays, and made them all parallel again. *

Euphros. I remember it very well; but what do you deduce from thence?

Cleon. On

* See Figure I. Plate I. of Optics.

Cleon. On that Experiment depends all the *Rationale* of Vision by a single Glass; for the Eye is so formed by Nature, that unless Rays of Light fall nearly parallel upon it, they will not be converged to a Focus upon the *Retina* in the Eye, and therefore no perfect Image can be there formed, but by those Rays which come from Objects so far removed from the Eye, that they may be considered as nearly parallel; and therefore, as I said before, there is a Limit to perfect Vision by the naked Eye, and this you will find in general to be about six or seven Inches from the Eye, with regard to near Objects: This is confirmed by Experience, because any Object held nearer to the Eye will appear confused, as the Rays coming from any particular Point must be considered in a converging State, and consequently tend to a Point or Focus beyond the Bottom of the Eye, and therefore the Image must be very imperfectly formed on the *Retina*, and so produce a confused Appearance of the Object: ——— For Example; I hold a Piece of Wire at three Inches distant from my Eye, and it appears large, but very confused and indistinct; but if I take a Glass, whose focal Distance is three Inches, and hold it close to my Eye, the Rays will by that Means be made to fall upon the Eye in a parallel Direction, and by that Means be nicely united on the *Retina*, and there forming a perfect Image of the Wire, will cause a distinct View of it.

Euphros. I seem to have a tolerable clear Idea of this Matter: ——— And since the Wire appears distinctly at the Distance of three Inches from the Eye, by Means of the Glass, it will be seen of Course under an Angle twice as large as it subtends to the naked Eye at the Distance of six Inches, and therefore will appear twice as large; consequently, an Object in such a Case may be said to be magnified twice. ——— For the same Reason it will follow, that if a Glass of one Inch focal Distance be applied to the Eye, the Wire in that Case must be placed in its Focus, or at one Inch from the Eye, and then the Rays being rendered parallel upon the Eye will cause a distinct View of the Wire at that near Distance, which, as it is six Times less than six Inches, it will appear so many Times magnified by such a Glass.

Cleon. What you have now said, you instantly prove by Experiment; and the same Reason holds for any Glasses of shorter

ſhorter focal Diſtances, they always magnify more in Proportion. ——— But let us reflect a little on the magnifying Power of a Glaſs, whoſe focal Diſtance is one whole Inch: ——— You ſee it magnifies the Diameter of the Wire ſix Times; but as you increaſe the Length or Breadth of an Object, the Surface will increaſe in Proportion to the Square thereof, and conſequently will appear ſix Times ſix, or thirty-ſix Times as large as it appears to a naked Eye, and conſequently ſuch Glaſſes will exhibit a very agreeable View of many of the larger Kind of ſmall Objects; for which Reaſon they are very much in Uſe, in obſerving the Works both of Nature and Art, and may be properly called a MEGALASCOPE: ——— Thus all the ſmaller Sort of Flowers appear extremely fine when viewed thro' ſuch a Glaſs. ——— All Kinds of Inſects, as Flies, Bees, Waſps, *&c.* make a noble Appearance thus magnified, and ſeem quite different Creatures than what they appear when viewed diminutively with a naked Eye. ——— The Texture and Veſſels of Plants and Animals are exquiſite Subjects of the Megalaſcope; ——— and when we apply them to view the Works of Art, their Benefit is ſufficiently known to the Watchmaker, the Draper, the Engraver, *&c.* under the Denomination of the Watchmakers Glaſs; Cloth-microſcope; *&c.* and for a pretty Experiment of this Kind, I need only propoſe to you this ſmall Circle, in which is contained the ten Commandments, which the beſt of Eyes can not decypher, but with a Glaſs you ſee to read the whole diſtinctly.

Euphroſ. This Glaſs is of excellent Uſe, I find by this Experiment; and this, which you have been ſo kind as to make me a Preſent of, will afford me great Entertainment, as I ſhall frequently apply it to the Purpoſes you have mentioned.

Cleon. There is one Thing farther to be conſidered, with regard to the magnifying Power of this Glaſs, *viz.* that the Solidity, or the whole Bulk of a Body is magnified in Proportion to Cubes of the Diameter or Side: Thus, ſuppoſe any Globule, or other ſmall Object were to be viewed thro' the ſame Glaſs, the whole Bulk will be apparently increaſed ſix Times thirty-ſix, or 216 Times, or ſo much larger it would appear thro' the Glaſs than to the naked Eye. ——— I have brought with me two or three Marſh-mallow Flowers for a Specimen of this Kind;

Kind; you ſee a little white Part ſtanding up in the Middle, pray, view it with your megalaſcopic Glaſs, and tell me what you ſee.

Euphroſ. I ſee a great Number of very beautiful, ſmall, white Globules beſet with thick Briſtles, and growing in Cluſters at the Tops of long white Stalks; a moſt agreeable Spectacle this, and what I could never have thought of from the naked Eye.

Cleon. As another Inſtance, take this Leaf of Sage, and view it with the ſame Gaſs.

Euphroſ. I do; and am amazed to ſee the numberleſs Globules all over its Surface, in Appearance like ſmall white waxen Balls; ——— others upon the Mint Leaf I ſee have a different Appearance, but require to be magnified ſtill more to view them perfectly.

Cleon. That you will do by and by; I only propoſe by theſe Specimens, that very ſmall Objects, when magnified 200 Times, are capable of being ſeen even with a Megalaſcope: ——— And were you to ſee a Fleſh-flie 200 Times as large as what you view with the naked Eye, they would command your Attention as much as a Crocodile from the River *Nile*, which is but a Lizard of a larger Bulk.

Euphroſ. Pray, of what Form or Size are thoſe Glaſſes which you make uſe of for greater Powers of magnifying?

Cleon. They are of the ſame Form with this Megalaſcope Glaſs, *viz.* a double Convex generally, but the Size very ſmall; for as they are intended to view ſmall Objects there is no need of a large Diameter, nor indeed will the Nature of the Glaſs admit of it: ——— As the Glaſſes are ſmall, ſo are their focal Diſtances, and in Proportion their magnifying Powers the greater; hence theſe Glaſſes are properly called MICROSCOPES, which denote only their Power of *magnifying very ſmall Objects:* But as theſe Glaſſes are ſo very ſmall, they cannot conveniently be applied to Objects without being adapted in a Frame, conſiſting of proper Parts for that Purpoſe, by which Means the Glaſs and the Object may be at any required Diſtance from each other, and from the Eye, and the Object viewed with all imaginable Eaſe, by holding them in the Hand againſt the Light, as you will eaſily ſee in the ſeveral Forms here before

you,

you, which indeed are but four, but they are the beſt and moſt convenient of all the numerous Inventions for this Purpoſe.

Euphroſ. Which of thoſe Microſcopes do you recommend as the moſt perfect and eligible?

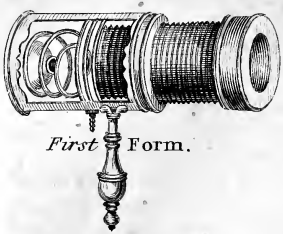
Cleon. It is difficult to ſay which is the beſt of all; they have ſeverally their peculiar Advantages ariſing from their particular Form, and the Apparatus proper to each. —— Some Gentlemen prefer one Form, ſome another, and I will point out the Properties of each ſeparately, that you may chuſe upon Occaſion which you pleaſe, for I ſhall make you a Preſent of them all.

Euphroſ. In this you will highly oblige me, indeed; but you muſt, in the firſt Place, make me acquainted with the Uſe of them, for there are ſo many ſmall Adjuncts in what you call the Apparatus, that unleſs I know the Uſe of each Particular, I ſhall not be perfect in the Application of the Inſtrument.

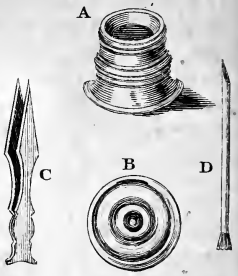
Cleon. It is very true, my *Euphroſyne*; I know it is incumbent upon me, in the firſt Place, to diſſect, as it were, each Microſcope, and ſhew the Uſe of the ſeveral Parts as they are variouſly applied for viewing different Objects. —— The firſt I ſhall begin with, is that which generally goes by the Name of WILSON'S MICROSCOPE, tho' the firſt Inventor of this Form is perhaps not known. This Microſcope conſiſts (1.) of an external and an internal Tube, the latter moving by a long Screw in the former; the external Tube being for the greateſt Part open on each Side: You obſerve (2.) two thin braſs Plates moving regularly in that Appurture by the Motion of that internal Tube or Screw; and to keep them together you ſee (3.) a ſpiral Wire bear upon them from the End on the Inſide of the outer Tube, the Intent of which is to preſs thoſe Plates firmly together. (4.) The ſeveral Ivory Sliders which you here ſee numbered 1, 2, 3, 4, *&c.* in which are contained the ſeveral ſmall Objects placed between two thin Plates of *Muſcovy* Glaſs, uſually called Talks; beſides theſe there is (5.) this long Braſs open Frame, to which is fitted an Ivory Slider, containing ſmall Concave Glaſſes, with a plain Slip of Glaſs placed over it for incloſing any Minute living Object without cruſhing it; this likewiſe, when uſed, is placed between the two thin Plates, below which is (6.) a third Plate or Piece of Braſs with a cylindric Hollow to receive (7.) the

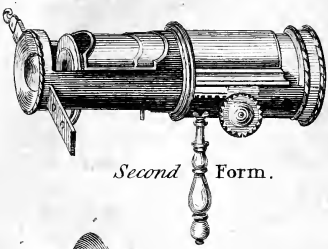
Different FORMS *of Single* MICROSCOPES.

Plate XLIII.

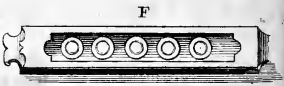


First Form.

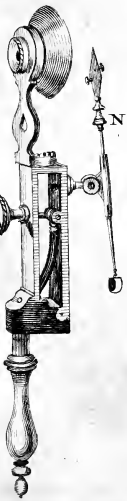


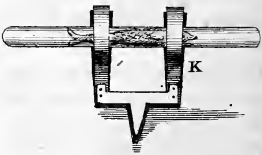


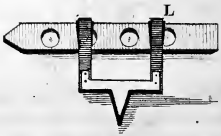
Second Form.



Third Form.







(7.) the ſeveral Glaſs Tubes, which you here ſee, three in a Sett, contained one within another, for holding any Fluids with Animalculæ, Tadpole, Water-Newt, ſmall Frog, *&c.* for ſhewing the Circulation of the Blood. (8.) At the End of the outer Tube is a Hole, with a Screw, to receive the ſeveral Plates of Braſs, or Buttons, which contain the ſmall magnifying Glaſſes. (9.) At the external End of the inmoſt Tube is a Plano Convex Lens, to throw Light upon the Object on the Sliders. (10.) Over this Glaſs are placed circular Pieces of Braſs, with Holes or Apertures of a different Size, for proportioning the requiſite Degree of Light. Theſe are the principal Parts to be uſed in viewing tranſparent Objects: But for thoſe that are Opake, you are ſupplied with the following Apparatus. (11.) A ſquare, flat Piece of Braſs, with a Bevel Edge on one Side, and pierced with a Hole through the Middle, with a ſmall Steel Spring to bear upon (12.) an Iron Wire, made ſharp at one End, and containing a Pair of Plyers on the other; this Piece of Braſs with the Plyers, being placed between the two thin Plates of the Microſcope, there is (13.) another Piece of Braſs with a Screw at one End, by which it is fixed on the object End of the Microſcope on one Part, and contains on the other a hollow Screw for receiving the ſeveral Magnifiers, which, in this Caſe, ſhew any Object held in the Plyers at one End, or fixed on the ſharp Point at the other; and to adapt every Glaſs for this Purpoſe, this Piece conſiſts of two Parts, with Motion ſeverally about a Center. (14.) On the ſharp End of the Wire there is ſcrewed on a ſmall circular Piece of Ivory, with one Surface Black and the other White, on which Objects of a different Colour are laid to be viewed. (15.) Inſtead of the ſmall Glaſſes, you may ſcrew on the Glaſs in this black Ivory Frame, which is called the Tun: This is deſigned for viewing larger Objects, like that which you have in your Pocket. (17.) A Pair of Nippers, Hair-bruſh, Box of Talk-wires for fixing them in the Sliders, *&c.* compleat the Apparatus of a *Wilſon*'s Microſcope, for viewing every Sort of Objects *.

* That the Reader may have a proper Idea of the four different Forms of ſingle Microſcopes, and the principal Parts of the Apparatus, we have thought proper to add a Figure of each Form drawn from the

Euphrof. You have run over a large Catalogue of Particulars indeed; one had need have a pretty good Memory to retain the particular Uſes of each: But I apprehend this will not be difficult after a little Practice.

Cleon. You will find it extremely eaſy to manage every Part with once uſing only; and when you know it in one Microſcope, it is nearly the ſame in all the reſt, which differ from each other principally in the different Manner of applying the ſeveral Parts of the ſame Apparatus.

Euphrof.

the Inſtruments themſelves, which need no particular Deſcription, as the Uſes of the ſeveral Parts may be eaſily underſtood by Inſpection. (See Plate XLIII.) The Particulars of the Apparatus are as follow:

A Is the Megalaſcope Glaſs, to be held in the Hand for viewing the larger Sort of ſmall Objects.

B The circular Piece of Braſs, in which the Microſcopic Glaſs is placed to be ſcrewed on at the End of *Wilſon*'s Microſcrope, or that of the firſt Form; of theſe there are 6 in Number.

C A Pair of Nippers for taking up ſmall Objects.

D A Quill with a Camel-Hair-bruſh at one End for cleaning Glaſs, and a Pen Point on the other for taking up a ſmall Quantity of a Fluid, *&c.*

E A Glaſs Tube for holding Fiſh, or other Animals, for ſhewing the Circulation of the Blood.

F A long Braſs Caſe for holding a Slider, with ſmall Concaves, and a plain Glaſs over them for confining ſmall living Animalculæ.

G A ſmall Box of Talk and Wires, for ſupplying the Ivory Sliders upon Occaſion.

H A Piece of Ivory with two Sides, the one Black and the other White, with two ſmall Steel Springs for holding Objects upon them.

I The Silver Speculum belonging to the Opake Microſcope, or that of the third Form, in the Center of which the ſmall Magnifier appears.

K A double Spring Frame for holding the Glaſs Tube.

L The ſame for an Ivory Slider.

M Two ſmall circular Pieces of Braſs, containing a Concave and a plain Glaſs, one moveable over the other for confining ſmall living Objects.

N The Plyers, in the Poſition they are applied for viewing Objects in the Opake Microſcope, to the Point of the End of which below are ſcrewed on the ſeveral Parts of the Apparatus, denoted by the ſeveral Letters H, I, K, L, and M.

There are other Particulars of an Apparatus belonging to theſe Microſcopes; but as they are ſeldom uſed, and the Manner of their Application not eaſily underſtood without viewing the Inſtruments themſelves, we have here omitted their Repreſentation.

Euphrof. You will pleaſe, in the next Place, to inform me of the different Power of magniſying belonging to each Glaſs of the Microſcope, that I may have a more adequate Notion of the Effects of this Inſtrument when I uſe it.

Cleon. This cannot be known without meaſuring very preciſely the focal Diſtance of each Glaſs: Thus, for Example, I find, by meaſuring, that the focal Diſtance of this Glaſs is *one Tenth* of an Inch: Now, you know that in 6 Inches there are 60 Tenths, and conſequently, when I view an Object thro' this Glaſs, it is then 60 Times nearer to my Eye than when I view it without the Glaſs, and therefore it will appear 60 Times larger in regard to Length and Breadth. Thus a Flea, or any ſmall Animal, will appear 60 Times longer and wider than it does to the naked Eye; and, becauſe a Flea is much about $\frac{1}{10}$ of an Inch long, it will appear through the Glaſs 6 Inches long.

Euphrof. What an hideous Figure muſt it make of that monſtrous Size!

Cleon. Eſpecially if you conſider that the whole Surface of the Body of the Flea will appear 60 Times 60, or 3600 Times larger than we view it with the naked Eye.

Euphrof. Heavens! why, at that Rate, it muſt appear as large as a Lobſter.

Cleon. I can aſſure you, the Compariſon is very *a propos*; for, when the Flea is thus magnified, it has very much the Appearance of that teſtacious Animal, as you will ſee by and by.—But add to this, that the whole Bulk of the Flea will be magnified 60 Times 3600, or upwards of two Hundred Thouſand Times, and ſo much larger it will appear through this Magnifier, than to the naked Eye *.

Euphrof. Prodigious, indeed! I muſt be ſtrangely delighted with ſuch unuſual and extraordinary Views. If ſmall Animals are magnified to that extreme Degree, how wonderful muſt it be to view the Mites, and other ſmall Animals, which appear in ſuch very great Numbers?

Cleon. They appear more numerous to the naked Eye, than through the Microſcope; for in Proportion as they are magni-

* At preſent we refer the Reader to the Print of the Flea. See *Magazine* for *April*, 1759, p.

fied more, the leſs in Number will be ſeen; and notwithſtanding this Glaſs which I have now mentioned has ſo very great a magnifying Power, there are others which ſtill much more exceed it, and other Methods of magnifying, beſides directly poring through the Glaſs, by which Means a Mite will be ſhewn as large as a Porcupine; and Animaculæ, when magnified Millions of Times, will appear ſcarce larger than phyſical Points; all which you will be ſatisfied about in a very little Time, by ocular Demonſtration.

Euphroſ. To tell you the Truth, I cannot help being in very great haſt to ſee them; therefore hope you will not detain me long from ſuch wonderful Speculations.

Cleon. As I have largely deſcribed to you the Apparatus belonging to Microſcopes in general, what remains, in regard to the particular Conſtruction, and Manner of Application, will be diſpatched in a few Words. In reſpect to the Manner of placing the Glaſſes, you obſerve, it is different in each of the three Forms; for, firſt, in *Wilſon*'s Microſcopes the Glaſſes are properly ſet in circular Pieces of Braſs, which are ſeparately ſcrewed on to the Body of the Microſcope, for viewing Objects, and they are adjuſted to a proper focal Diſtance by Means of a Screw.

But, ſecondly, the neweſt Invention for this Purpoſe, is to place all the Magnifiers in one long Piece of Braſs, by which Means it is eaſy to apply any Glaſs to the Object, inſtantly, without the Trouble of ſcrewing the Glaſſes on and off the Microſcope; alſo, the Focus is immediately adjuſted by the Contrivance of Teeth and Pinion, which you here obſerve on the Side of Microſcope of this ſecond Form.

Thirdly, in order to view Opake Bodies by the ſingle Microſcope, there has been lately contrived a Method of applying the Magnifier to a Hole made in the Middle of a reflecting Silver Speculum; which Speculum being ſcrewed on to the Inſtrument, the Opake Object in the Plyers is placed before the Magnifier, and the Light ſtrongly reflected upon it to render the ſuperficial Parts delightfully viſible. The Focus is adjuſted by a Braſs Piece, moveable by a Screw and Spring, as alſo by the Joint of the Plyers. In this Contrivance, all Kinds of Objects, both

both Transparent and Opake, are most advantageously viewed by Means of a single Magnifier.

The three Forms, now mentioned, are properly called *manual Microscopes*, as they are all of them held in the Hand, and turned to the Sky-light, or Candle, in viewing Objects.

But there is yet another, and (in some respects) a more commodious Form of a single Microscope, which is placed on a Foot or Pillar with a moveable Stage, on which the Object is placed; below which is placed a reflecting Speculum, moveable every Way to throw up the Light on the Object; and this we may call the Fourth, and last Form of a single Microscope.

Euphros. I think this appears to be the most convenient Method of them all, as I have nothing to do but only sit at the Table and look through the Glass at the Objects. —— But I see, that in this Sort of Microscope you have different Constructions; for I take it, that all these before me are Specimens of each particular Form.

Cleon. They are so; and I have procured them, in order to give you an Idea of the different Manner of applying, and viewing Objects in this Way. In all of them there is a Variety in the Frame in which the Glasses are placed, the Method of constructing the moveable Stage by adjusting Screws, *&c.* the Manner of fixing the reflecting Speculum, and many other Peculiarities, which you will easily become acquainted with in the separate Use of each. — Some of these are very expensive in regard of curious Workmanship: — Others, too much laboured and incumbered with too many Parts and Appendages: —— And others are as remarkable for their light, easy, and elegant Construction; one of this Sort I shall here recommend to you for your common Use, and it consists of the following Parts: (1.) A Piece of Brass properly formed for the Foot or Basis, with a circular Hole in the Middle, whose Use I shall mention hereafter. (2.) The Stem, which consists of two Parts: The 1st of which is a Pillar screwed into the Foot, and the 2d a square Piece of Brass screwed into the Capital of the Pillar. (3.) Two Pieces of Brass, moveable on the square Part of the Stem, the Lowermost of which is fixed by a Screw in the Side, while the other remains moveable by an adjusting Screw on the back Part. (4.) To the upper Piece, the Stage is adapted

dapted by a Dovetail Grove, in and upon which Objects are placed, as in the other Forms, to be viewed, and are adjusted to a proper Focus by the Screw behind. (5.) On the Top of the square Piece of Brass, or Stem, is fixed the Head of the Microscope, which has a flat Piece of Brass, properly formed, and placed horizontally and parallel to the Stage. (6.) On the under Part of this Plate is a circular Piece of Brass, containing 6 Glasses, disposed in a circular Manner near its Circumference: This Piece is moveable on a Screw-pin in its Center. (7.) On the upper Part of the Head-piece is another circular Piece of Brass, fixed at the End with a Screw on the Outside, and a small Hole in the Center, to which the Magnifiers are successively applied for shewing the Objects on the Stage below. (8.) The reflecting Speculum, screwed on to the Pillar, and moveable on a Joint, illuminates the Object to be viewed. —— From all which, you will readily see how easy and pleasant it must be to view Objects in this Construction of a Microscope. There are many other Ways and Methods of applying single Glasses, but none of them so well deserve your Notice, as the four different Forms I have now described to you: —— But I must take another Opportunity of explaining to you, the Difference between single and compound Microscopes; the different Construction of the latter, —— and, last of all, the Nature and Construction of the Solar Microscope, which must be the Subject of our ensuing Microscopic Speculations *.

DIALOGUE II.

Of the Nature, Construction, and Use of COMPOUND MICROSCOPES.

Euphrosyne.

AT our last Interview you entertained me with an Explication of the different Forms and Construction of single Microscopes, and promised me, in our next, the same Thing with regard to compound ones; and I see, by the Instruments before me, that you intend to be as good as your Word. — They are equally

* See Plate XLIV.

equally numerous, and much exceed them in Magnificence of Appearance; but, I fear at the ſame Time, ſince they are not ſo ſimple in their Nature as the former, their Conſtruction and Effects will not be ſo eaſy to be comprehended.

Cleon. When you ſee the Parts of which they are compoſed, you will not find them ſo very complicated as you imagine; and though they ſtrike the Eye with Grandeur and Sumptuoſity, yet the eſſential Parts, by which the Effects are produced, will be found to be very few, and thoſe eaſy to be underſtood.

Euphroſ. I hope I ſhall find it ſo; but, pray, is the Effect of a compound Microſcope above that of a ſingle One, in any Propoſition to its Magnitude? if it be, they muſt be wonderful Inſtruments indeed.

Cleon. In anſwer to that Query, my *Euphroſyne*, I need not inform you, that your Sex, as well as our own, are very apt to be affected with Grandeur and Magnificence, in every Shape; and the Microſcope, to many People, as much recommends itſelf by a pompous Appearance, as by its uſeful Effects: But as we are only at preſent concerned with the latter, I ſhall proceed to ſhew you the Difference between a ſingle and compound Microſcope, which conſiſts in the following Particulars: (1.) In the ſingle Microſcope one Glaſs only was neceſſary, becauſe the Object itſelf was viewed by that Glaſs; but (2.) in a compound Microſcope the Image of the Object is viewed by the Eye, and therefore two Glaſſes at leaſt are neceſſary in this Conſtruction, *viz.* one to form the Image of an Object, and the other to ſhew it magnified.

Euphroſ. Then I apprehend, by what you have ſaid, that only two Glaſſes are eſſential to a compound Microſcope: But beſides the two which you have now ſhewn me, I obſerve there are two others in the Inſtrument; pray, to what Purpoſe do they ſerve?

Cleon. They only ſerve to make Viſion more diſtinct and pleaſant, by properly attempering the Rays of Light, and enlarging the Field of View. The original Conſtruction was with the two Glaſſes only; then a 3d was added, for an Improvement of the Invention; and, at laſt, a 4th, to compleat that Improvement. ——— It requires a mathematical Skill in Optics, to conceive the *Rationale* of them all; but you will

eaſily

eaſily find, by Experiment, that they have each of them their peculiar Uſes, in producing the great Effect of a manifying Power in the beſt Manner poſſible.

Euphroſ. You will be ſo good as to point out to me the Uſes of each particular Glaſs, and illuſtrate the ſame by an Example.

Cleon. That I ſhall readily do, with an Object a little in your own Way, I mean, a Row of the ſmalleſt Minikin Pins, which you can give me; and you will be no leſs pleaſed with the Oddity of their Appearance, than you are with their Uſes in Dreſſing.

Euphroſ. This Experiment will be very *a propos*, indeed.—Here is a Row of the fine Pins you want.

Cleon. The Glaſſes of the compound Microſcope are all contained in one Part, which is called the Body of the Microſcope, the lower Part of which is a long Pipe, or Snout, as it is commonly called, on which is ſcrewed a Braſs Button, or Box, containing a ſmall magnifying Glaſs, which of itſelf has a conſiderable magnifying Power, as will appear by your applying the Row of Pins to the Focus of that Glaſs, which I have now taken off for that Purpoſe.

Euphroſ. Well; how oddly they appear, indeed!——they look as large as Corking Pins:—— Their Heads as large as Bullets, rough and uncouth.——There appears juſt five in the Field of View.

Cleon. By that you will know the Uſes of the other Glaſſes; for if now I ſcrew that on to its proper Place, at the End of the Pipe, and take off the Glaſſes on the upper Part, then, by placing the Body in the external Part, or Caſe of the Inſtrument, I move it gently down towards the Pins that are now laid upon the Stage, and by adjuſting the Glaſs to a little more than the focal Diſtance from the Object, the Image of the Pins are formed in the upper Part of the Body, as you will eaſily ſee by placing this Piece of oiled Paper in the Focus of the large Glaſs.

Euphroſ. I ſee the Image very plainly formed upon that Paper; and they appear this Way as large as in the other, or thro' the Glaſs itſelf.

Cleon.

Cleon. The Image (as you learn from the Principles of Optics which you read) is as much larger than the Object, as its Diſtance is greater; and ſince the Diſtance of the oiled Paper from the Glaſs is 6 Times as great as that of the Paper of Pins, therefore you ſee the Image of each Pin 6 Times in Diameter and Length greater than it appears to the naked Eye, from whence you underſtand that, by this ſingle Glaſs alone, the Object is magnified 6 Times: ——— Then, if this Image be viewed by another Glaſs, which you ſee here on the Top, of one Inch Focus, and therefore placed juſt one Inch above the oiled Paper, the ſaid Image will appear very diſtinctly to the Eye; and ſince, in this Caſe, it is at leaſt 6 Times nearer to the Eye than it can be ſeen without the Glaſs, therefore the Image will appear 6 Times larger, by Means of the upper Glaſs, than it does to the naked Eye; and, conſequently, the Object will appear 6 Times 6, or 36 Times magnified in Length and Breadth, and the Surface is magnified 36 Times 36, or 1296 Times, and in Solidity 36 Times 1296, or 46656 Times: And in that Degree you muſt underſtand the Heads of the Pins are magnified, as they are ſolid Bodies. ——— I will now put the Glaſs in its Place, and then you may ſee the Experiment.

Euphroſ. They are magnified to a prodigious Degree, I allow; but ſtill I cannot conceive they are magnified Forty-ſix thouſand Times.

Cleon. There are no Falacies like thoſe of Viſion, on the one Hand, nor any Truths ſo much ſuſpected on the other: We often ſee Things that are not, as if they were, and cannot eaſily be perſuaded to the Contrary; and no leſs frequently we look upon real Facts as the greateſt Improbabilities. ——— This ſhews, in general, how neceſſary the Knowledge of Geometry and natural Philoſophy is, to give People a juſt and adequate Idea of Things, and to free them from all Impoſition on their Senſes, as well from optical as all other Kinds of Illuſions. ——— Thus much for the magnifying Power of the two Glaſſes, which greatly exceeds that of the ſingle Glaſs alone.

Euphroſ. But another Thing I obſerve, *Cleonicus*, is, that though the Pins be much more magnified by the two Glaſſes, yet I obſerve not ſo many of them; for now, ſcarcely 3 appear inſtead of 5.

Cleon. This is only the common Conſequence of magnifying; for the more any Object is magnified, the leſs Number or Quantity of its Parts appear: And it is for this Reaſon, that this other larger Glaſs (called the *Body Glaſs*) is added, to inlarge the Field of View, by diminiſhing the magnifying Power of the two Glaſſes; for when I put this Glaſs in its Place, you will ſee the Image is contracted on the oiled Paper above it, and by that Means a larger Quantity of the Object will be depicted upon it, and conſequently a greater Number of Pins will appear, as you will find by trying the Experiment.

Euphroſ. This I clearly ſee;——but then one Queſtion will occur, which is this, you tell me, that one of thoſe Glaſſes on the upper Part is employed to magnify, and the other to diminiſh the Image formed by the ſmall object Glaſs; ſince this is the Caſe, is it not poſſible for one Glaſs to anſwer the End of both: That is to ſay, to magnify juſt ſo much of itſelf as they both do together?

Cleon. I anſwer in the Affirmative, one Glaſs will magnify juſt as much as the two; but there is another Purpoſe to be anſwered beſides the magnifying Power, and enlarging the Field of View, and that is, to correct the Errors of Refraction by a ſingle Lens, and to make the Field of View more perfect towards its extreme Parts, ſo that the Objects which lye round the Circumference appear leſs diſtorted and confuſed than in an equal Field by a ſingle Glaſs only: And moreover, the Rays of Light, paſſing through both Glaſſes, are ſo attempered, and, as it were, adjuſted, that the Cone of Rays entering the Eye, render the Viſion more eaſy, ſteady, and pleaſant*: All which you will eaſily find by obſerving the Object through both Glaſſes, and through one alone, when the magnifying Power is in both Caſes equal. And what I have obſerved now with reſpect to the Eye-glaſs, is equally applicable to the Object-glaſs below; and therefore, when refracting Microſcopes are conſtructed with four Glaſſes, they are then as perfect as the Nature of ſuch Inſtruments with admit of, and ſuch a one I have here put into your Hands.

Euphroſ.

* The *Theory*, or *Rationale* of this Doctrine of the Compoſition of Glaſſes, and of diſtinct and indiſtinct Viſion, is fully and particularly explained in my *new Principles of Optics*.

Euphrof. The Microſcope, which you have been now ſo kind as to make me a preſent of, is of a ſuperb and magnificent Form; and having ſo large a Bulk, I apprehend the Field of View, and conſequently the Uſe of the Inſtrument, will be ſo much the more perfect and pleaſant.

Cleon. In this you may, perhaps, be in ſome Degree miſtaken: It does not follow, that the Field of View is always proportioned to the Largeneſs of the Inſtrument, or Glaſſes; there is a Mean in all Things, or Limits, which, as your HORACE tells you, are the Bounds of Perfection, on either Side of which it is impoſſible any Thing ſhould be right. —— You will wonder, perhaps, when I tell you, that a compound Microſcope may be conſtructed not more than an Inch in Diameter, which will ſhew you moſt Sorts of Objects nearly as well as this large one of three Inches, and therefore is nearly thirty Times as big upon the Whole: And to convince you of this Truth, I have provided likewiſe a compound Microſcope of a portable, or pocket Form, that you may take with you into the Gardens, or Fields, for inſtantly viewing any Object that may preſent itſelf in your Walk.

Euphrof. You are very obliging, *Cleonicus*; it ſeems to be a pretty, neat Inſtrument for that Purpoſe. —— I obſerve, there is the ſame Number of Glaſſes in this as in the large One, and when I put the Row of Pins under, they appear, as you ſay, very nearly the ſame as in the larger Microſcope, and muſt conſequently afford me a Variety of optical Pleaſures from the Multiplicity of Objects which the Fields and Gardens afford: —— But, methinks, I ſhould be glad to know ſomewhat of the Reaſon, why thoſe ſmall Glaſſes perform ſo nearly as well as the large ones?

Cleon. The general Reaſon will appear from conſidering, that the Perfection of the Image in all the Variety of optical Inſtruments is regulated by the Aperture, or round Hole, by which the Light paſſes through the Glaſſes from the Object; on which Account we are obliged to have a ſtrict regard to this Aperture of the Object-glaſſes on two Accounts, —— the *firſt* is, becauſe the leſs the Aperture of the Glaſs is, the leſs will be the Error of Refraction, and conſequently the greater will be the Perfection of the Image formed of the Object. —— But, *ſecondly*, if the Hole be too ſmall, the Image will not be ſuffi-

ciently bright, and therefore the Aperture muſt be ſuch as will admit of a ſufficient Degree of Light, by which the Picture of Objects may be viewed to Advantage: Therefore the Perfection of the Inſtrument principally depends on the Aperture, and not on the Size of the Object-glaſſes, which you ſee is the ſame in the large and ſmall Microſcope.

Euphroſ. This, I obſerve, and am very well pleaſed that you have mentioned this Particular, which I might not otherwiſe have ſo well conſidered; as to what regards the Errors of Refraction, I muſt take that upon your Word: But I can readily apprehend, that if the Aperture of the Object-glaſs be too ſmall, or too large, there will certainly be too little, or too much Light for ſhewing the Object with a requiſite Diſtinctneſs and Perfection; and there is as little Pleaſure in viewing the Image, though well defined, in the Dark, as there is when confuſed with too much Luſtre. —— But tho' the Object-glaſſes are alike in the Parlour, and the Pocket-Microſcope, yet I ſee the Eye-glaſſes are widely different, being very large in the one, and ſmall in the other. ———

Cleon. 'Tis true, they are; yet the Effect is nearly the ſame in each: And to convince you of this, I ſhall ſhew you the Hole in that Piece of Wood which is uſually called the *Stop*, which is placed between the Eye-glaſſes, and which is but a Triſle bigger in the large, than in the ſmall Microſcope, as by ſcrewing off the upper Eye-glaſs you will diſcern very plainly.

Euphroſ. I ſee the Difference is but ſmall; but what is the Purport of theſe Holes?

Cleon. They are intended to limit the Field of View as far as it is perfect; and as they differ ſo very little from each other, it is plain, the Perfection of Viſion does not depend on the Size, or Magnitudes of the Eye-glaſſes. ——— Upon the Whole, therefore, you will find, that there is but very little Preference to be given to the largeſt Microſcope, on Account of the Bulk of the Frame or Glaſſes.

Euphroſ. Since this is the Caſe, pleaſe to let me know what are the peculiar Advantages of each Conſtruction.

Cleon. I will: And firſt, with regard to the Parlour-Microſcope, the Particulars which recommend it are as follow, (1.) I have obſerved to you before, that Grandeur pleaſes in every

Shape,

Shape, and we have naturally a high Opinion of any Thing conſtructed in a magnificent Taſte: The Palace is preferable, for its ſumptuous Appearance, to a Cottage; though you or I could ſleep, or enjoy Life equally well in either. (2.) The large Microſcope is fixed on a proper Baſis, and therefore Objects may be applied and viewed more readily, than when the Inſtrument is held in the Hand. (3.) There is in the Parlour-Microſcope, generally, a much larger and more expenſive Apparatus, that nothing may be wanting to render the Entertainments of this Inſtrument pleaſurable in the higheſt Degree. (4.) There is in this Inſtrument a larger Diſtance between the Object-glaſs and the Eye-glaſſes, and therefore, upon the Whole, the Scope or Power of magnifying will, in ſome Degree in this large Conſtruction, exceed that of the ſmall. ——— But then, on the other Hand, the ſmall one is recommended by the following Conſiderations, (1.) Being of a pocket Form, it may be carried any where, and, of Courſe, becomes more generally uſeful, than the large Microſcope. (2.) The Price is conſiderably leſs; and therefore ſuits the Generality of People much better. (3.) The ſmall Difference in the Effect, between a large, and ſmall Microſcope, together with the above Reaſons, incline many People to the Choice of the latter.

Euphroſ. As to the Form of the Microſcopes, I preſume, no great Matter depends on that; and farther, I ſuppoſe, the Two you have brought me, are of the neweſt Faſhion and Taſte. ——

Cleon. They are the lateſt Forms in which Microſcopes have been made. —— The three pillar'd Microſcope (as it is uſually called) is, indeed, an old Faſhion, but then they have always been made in the large Form, and the Braſs Legs, or Pillars, of a different Shape and Size from what you ſee in this Pocket-Microſcope. ——— But as for the Form of this Parlour-Microſcope, it is quite new, as none, that I know of, have ever been made of that Conſtruction before; for in this Form the Microſcope is placed in any Situation, either perpendicular, or parallel to the Horizon, or it may be placed in any oblique Poſition, as Occaſion may require; beſides this Advantage, there is yet another in the circular Stage that moves on a Center, and thereby ſhews all the different Parts of Objects in the moſt

com-

commodious Manner; these two Particulars, together with the Lightness, Air, and Elegance of the Form, render it, in my Opinion, most proper for a *Lady's Use*; to which may be added, it being contained in a neat *Shagreen* Case, with a complete Apparatus, renders it much more portable than those of the usual Forms kept in wooden Boxes.

Euphros. I think myself greatly obliged to you for the Trouble I have given you in so many Interrogatories about Microscopes, and for the Satisfaction you have given me in their Solution. At present, I think, it will be proper to desist from any farther Enquiries of this Kind, but shall be glad to embrace the next Opportunity for that Purpose.

DIALOGUE III.

On the Nature, Construction, and Use of the SOLAR MICROSCOPE.

Cleonicus.

I Have hitherto entertained you in the best Manner I am able, with an Account of microscopic Constructions of different Forms and Kinds; nor have I finished that Subject yet, as there remains one which far exceeds all the rest in its magnifying Power, or the astonishing Appearance it gives of the smallest Objects.

Euphros. This, I presume, is the Solar Microscope, which I have heard you speak of very often, on that Account, —— is not this the Instrument now before me on the Table?

Cleon. That is the Solar Microscope, whose Nature and Construction I shall now explain to you; and then, afterwards, entertain you with some Experiments of its Use.

Euphros. It is called the Solar Microscope, I suppose, from its being used with the Sun, or rather, that it is intirely useless without the Sun-beams; for I have heard you say, that it is applied to Use in a Room that it is darkened, and then only when the Sun shines. But the Method of its Application in the *Camera Obscura*, as you call it, is a Thing as yet I have little or no Idea of, and is what, I presume, you intend to instruct me in.

Cleon.

Cleon. This Morning is devoted to that Purpoſe. —— The Room is darkened and ready for Uſe, and the Sun will probably continue till I have diſpatched, in a few Words, the Deſcription and Uſe of the ſeveral Parts of the Microſcope. ——— You will therefore obſerve, this Inſtrument conſiſts of the following Parts; (1.) A long plain Glaſs in a Braſs Frame, which goes on the Outſide of the Window to receive the Sun-beams which fall obliquely thereon. (2.) The ſquare Plate, or Frame of Braſs, is, by a Couple of Screws, faſtened to a Window-ſhutter, containing a Hole for the Looking-glaſſes to paſs through. (3.) In the Middle of this Plate lies a Wheel with Teeth, concealed, with a circular Rim of Braſs placed over it, and is moveable by a Pinion which you obſerve in one Angle of the Plate. (4.) In the Central Hole of this Circular Wheel, or Piece of Braſs on the Outſide, toward the Looking-glaſs, is fixed a Convex Lens, whoſe focal Diſtance is about 8 or 10 Inches. (5.) In the Hole of the ſame Plate, on the Face of the Inſtrument, is ſcrewed the Tube or Body of the Microſcope with its Drawer or ſliding Part, as you there ſee. (6.) On the End of this Slider is ſcrewed a ſingle Microſcope of the firſt or ſecond Form, which I have before deſcribed to you, and thus you ſee all the compotent Parts of this curious Machine as they are put together.

Euphroſ. Well; but, methinks, I ſhould be glad to ſee the particular Uſe of each of theſe Parts, before we enter the dark Room, where I cannot ſo well ſee the Manner of their Application.

Cleon. This I can ſhew you juſt as well in a light, as in a dark Room, the Light is no Obſtruction to any Thing but forming a Picture of the Object; I have provided a Board with a Hole of the ſame Size with that in the Window-ſhutter, to which I ſhall apply the Machine in its ſeveral Parts ſucceſſively. And,

Firſt, I put the Looking-glaſs through the Hole of the Board, and then ſcrew the Plate firmly on to the ſame. This done, then,

Secondly, I turn the Pinion which moves the Wheel with the Looking-glaſs on it, towards the Sun, by which Means the Rays

Rays of the Sun are reflected from the Looking-glass, through the Convex Lens into the Room; as here you see by the Experiment.

Thirdly, It is necessary in the Use of this Instrument, that the Sun-beams should be made to go strait across the Room, or parallel to the Floor, and to fall Perpendicular on the opposite Wall or Side of the Room. Now there is but one Position of the Looking-glass that will reflect the Rays in that Manner, and therefore, you see here is a small Wheel, and endless Screw fixed on the other Part of the Plate, for moving the Looking-glass up and down, till it comes into the necessary Position, and then you observe,

Fourthly, The Beams of Light are refracted through the Convex Lens to its Focus, which, you plainly see, is at the Distance of about 10 Inches from the Glass.

Fifthly, From the focal Point you observe the Rays proceed diverging, and form a large Circle of Light on the opposite Side of the Room.

Sixthly, I screw on the Tube with the small Microscope, and place the Slider therein with the Objects intended to be magnified.

Seventhly, This done, I move the Drawer forward and backward, till I bring the Object in the Slider within a small Distance of the Focus of the Convex-glass, where you may observe it is very much illuminated in the denser Part of the Cone of Rays: Then,

Eightbly, and lastly, I apply the small Magnifiers to the single Microscope, and by the adjusting Screw, move them to such a Distance from the Object, as shall shew their Image very plain, and large, upon a Sheet hung on the opposite Side of the Room: And thus having shewn you how every Part is applied to use, I shall repair, with you, to the Room made dark, there fix the Instrument, and shew you its surprizing Effects.

Euphrof. I shall, with great Pleasure, attend you on this Occasion, to see how Darkness itself conduces to perfect these Experiments, which depend on the strongest Light.

Cleon. Here, my *Euphrosyne*, enter the Room, and place yourself in the Chair I have there set for you, you will there be near

ear me, to see the several Processes in the Application of the Instrument, and at a proper Distance to view the Image to the best Advantage.

Euphros. I am seated, as you direct. —— You may proceed to your Operation, as soon as you please.

Cleon. The first Object I shall put in the Microscope is, a transparent Scale of a Sole-fish —— observe its Image upon the Sheet.

Euphros. Its Image! ——— I see something prodigiously large, indeed; and you amaze me, when you say it is only the Scale of a Sole: ——— It appears at least 12 or 15 Feet long, and 6 or 8 Feet wide; ——— it fills almost the Side of the Room. ——— How thick set with long sharp Points at one End! its Substance transparent, and variegated with beautiful Undulations. ——— Were the whole Fish magnified in the same Proportion, it must surely be as big as a Whale.

Cleon. You might have said, my *Euphrosyne*, as big as a hundred Whales; since the Fish, magnified as much as its Scale, would appear very near half a Mile long. ——— By this Instance, you see how Nature has provided for the Defence of the Sole-fish, since the external Part of every Scale is armed with those sharp pointed Spines, or Thorns.

Euphros. I have often observed, that the Surface of those Fish were very rough to the Hand; but never knew the Reason of it before.* —— What is the next Object, *Cleonicus?*

Cleon. I have shewn you the magnified Scale of a Fish, and I will next shew the Scale of an Eel, magnified in the same Proportion.

Euphros. The Scale of an Eel, *Cleonicus*, that Expression seems to have a strange Sound: I am so great a *Virtuosa*, that I never before heard of, or knew there was any such Thing.

Cleon. That may be, and numberless others besides yourself are not only Ignorant of it, but will not believe it when it is told them: Nay, the *Jews* insist that it is contrary to the *Mosaic* Law, by which they are forbidden to eat of that delicious Dish, as they apprehend that Eels come under the Denomination of that Sort of Fish which have no Scales: —— But observe, on

* See a microscopic View of the Skin and Scales of a Soal-fish, in our Miscellany, Page 681, for *December* 1757.

the Sheet, the Picture of one in its full Dimensions and Perfection.

Euphrof. A prodigious Spectacle this, ——— it is nearly as large as the Scale of a Soal, but of a very different Form; ——— its Substance seems to be one continued Piece of Net-work, proceeding in long oval Rings, as it were, from a common Center: ——— I observe no Bristles, or Points, in this, nor can I tell on what Part it grows on the Body.

Cleon. These Scales, my *Euphrosyne*, differ from the Scales of common Fish, in the following Particulars: *First*, they lye not on the external Surface of the Eel, but are contained under one common Covering, or Skin. *Secondly*, they do not lye one over another, as the Scales of a common Fish; but are placed one by the other, as thick as they can lye, through the whole Skin of the Eel. *Thirdly*, their reticular Form, or Net-like Texture, is such as we observe in no other Sort of common Fish-Scales; beside many other Peculiarities which I shall observe to you at another Season. ——— You will next behold the wonderful Appearance of a certain Species of Eels themselves, real living Animals.

Euphrof. Living Animals, *Cleonicus*, ——— they have really so much Life and Motion, and monstrous Size withal, that I have scarce Courage enough to keep my Seat. Who could have thought to have seen, in a Moment's Time, that Sheet transformed into a Lake of Conger Eels? ——— They are vastly numerous, indeed, ——— and larger in Size than I have ever seen any Thing of the Kind; 5, 6, or 7 Feet long, and 3 or 4 Inches thick: ——— Their quick tortuous and serpentine Motion are really amazing and stupendious. ——— Pray, what are these Creatures in themselves, and how came you by them?

Cleon. These are really a Species of small Eels, or *Anguiculæ*; they are found very common in sour Paste, or stale Vinegar, and some other Fluids, of which I shall have the Pleasure to entertain you, one Day or other, with the common Microscope, when you will find that, notwithstanding the Appearance they now make by the solar Microscope, they are scarcely visible to the naked Eye; such Objects of Minuature are the mighty Serpents you now see.* *Euphrof.*

* See Figure 8, in the Plate of Microscopic Animalculæ. Page 161 in the Miscellany, *October* 1755.

Euphrof. They are every Way wonderful, I find. —— What do you intend to ſurprize me with next, *Cleonicus?*

Cleon. You will juſtly admire the wonderful Mechaniſm in the Eye of a Fly.

Euphrof. A glorious Object, indeed! —— the fineſt Piece of Lattice-work my Eyes have ever yet beheld: —— How grand and beautiful are the Works of Nature, and what great Variety in the Structure of the ſame Organ! —— In the Surface of this ſmall Eye, I obſerve Myriads of thoſe beautiful ſix-ſided Figures. —— Pray, *Cleonicus*, what Purpoſe do they ſerve, in this viſual Organ, in the Fly?

Cleon. We are not yet acquainted with the Deſign of Nature in every Part of her Operation: But I ſhall recommend you to read the Conjectures of ſome of the beſt Naturaliſts upon this particular Subject, rather than give you my own Opinion concerning it.* —— Every Part of a Fly is equally wonderful, as you will e're long be ſatisfied by the common Microſcope; but they are not all equally proper Subjects for the ſolar Microſcope: But the Wings of moſt Flies may be ſhewn to great Advantage in this Inſtrument, particularly thoſe that are membranous and tranſparent; nay, even the hard Wings of the Scarab Kind are ſome of them, in the ſmaller Species, moſt excellent Objects for this Purpoſe, —— ſee one of them fill the whole Side of the Room.

Euphrof. Is this, *Cleonicus*, the Wing of a ſmall, contemptible Scarab? —— This is a ſufficient Inſtance, to prove how neceſſary it is to apply the Inſtruments of Art for giving us right Notions, and juſt Ideas of the Works of Nature. —— I think this is the richeſt, and moſt glorious Spectacle I ever ſaw, and can ſcarce help looking upon it as the Height of Nature's Fancy, in Point of Grandeur; —— it ſeems all an embroidered Ground of Gold, emboſſed and ſtudded with Diamonds, in ſuch beautiful and regular Squares of Cheques and Compartments, as nothing but an actual View of ſuch a high finiſhed Piece could ever raiſe an Idea of. —— Pray, how large may the Animal be, that is thus ſo richly bedeck'd and adorn'd?

* See the magnified Head and Eyes of a Bee, in a large Copper-plate Print, with ſome Account of it, in the Miſcellany, Page 303, for *January* 1760.

Cleon. This small Beetle you may have often obſerved crawling about upon rotten Wood, old Walls, *&c.* of ſo diminutive a Size, as not to exceed one Tenth, or Two, of an Inch, and therefore eſcaped your Notice: But were theſe Minute Creatures to become magnified at once, *two thouſand* Times in Length and Breadth, as is the Caſe of the Wing you now ſee, what ſtupendous Admiration would they excite in all Mankind! —— The higheſt Wiſdom hath directed you to contemplate the Gaiety of the Lilly, and other fine Flowers of the Garden, with a Remark, at the ſame Time, that *Solomon*, in all his Glory, was not arrayed like one of theſe. But if, as I ſaid, thoſe Animals were to appear at large, we ſhould find Nature much more profuſe in the Richneſs of her Ornaments and Embelliſhments to them; and that the Robes they are inveſted with, do far ſurpaſs not only the Glory of *Solomon*, but all the Pomp and Grandeur that all the Courts in the World can afford in Works of Art.

Euphroſ. I ſhould never be tired with feaſting my Eyes with theſe delightful Scenes; but I muſt not detain you too long in Particulars. What is the next Object you intend ſhall gratify my Curioſity?

Cleon. It is what they call the *Exuviæ*, or caſt off Skin of a Spider. ——— See the wonderous Appearance on the Sheet.

Euphroſ. Prodigious! nay, even ſhocking: —— What a hideous Apparition is this! a Head three Feet long, —— with 8 Eyes as big as Saucers; —— 8 monſtrous hairy Legs, as big as Mill-poſts: —— What Appearance muſt ſuch a Spider as this make, with every Part magnified two thouſand Times in Length and Breadth, as I now ſee it, alive and in Motion.

Cleon. Your Sex are generally intimidated enough with this Animal in its natural Size and Appearance; but were a Spider, as large as you now ſee this, to drop from the Clouds in the Middle of *Smithfield*, on a Market-day, it would ſcare not only the Ladies, but the Butchers themſelves, and find Oxen to feed on inſtead of Flies.

Euphroſ. I don't know but that might be the Caſe, as I have known a Spider to have conquer'd an Ant, and devour it, tho' nearly

nearly as big as itſelf: But enough of this tremendous Creature. What does your Microſcope next diſplay upon the Sheet?

Cleon. A Spectacle that will fill you with equal Amazement and Delight. —— See Rivulets of fluid Particles running over all the Side of the Room.

Euphroſ. What can this mean? ——— I gueſs, by what I have heard you ſay, that this is the Circulation of the Blood in animal Veſſels. —— But what an incredible Number of Streams there are, and with what Velocity do they flow in every Direction through the Scene! ——— Pray, *Cleonicus*, what Part of the Animal is it that appears thus large and tranſparent, and in ſuch a wonderful Degree of Motion?

Cleon. It is the tranſparent Tail of a Water-Newt, which I judge to be the beſt Subject of all for this Purpoſe, and are found in every Pond of Water. The Tail of a Tad-pole will do nearly as well; as alſo the tranſparent Web and Toes in the Foot of a very ſmall Frog; the Tail of that Fiſh we call the Loach; and many other Subjects may be innocently applied for this Purpoſe, without thoſe cruel and inhuman Methods, practiſed by ſome who appear to have more the Form, than the Rationality of Men.*

Euphroſ. I abhor the Thoughts of Cruelty, in every Shape, and ſhould rather be thought to have no Curioſity, or Taſte at all, than a vicious One. ——— I am thoroughly ſenſible, by this Experiment, how the Blood flows through the Arteries to the extreme Parts, and from thence returns again by the Veins; I ſee the very Form and Size of the Particles of Blood: And therefore keep the Creature no longer in ſuch a Condition, which, tho' it may give me much Pleaſure, may be very uneaſy to itſelf. — I now wait your following Exhibition.

Cleon. Keep your Eye ſtedfaſt upon the Sheet, and you will ſoon ſee a common Animal appear in quite a new Light.

Euphroſ. This is a terrible Appearance, indeed: ——— What hideous Monſter do I ſee? ——— How large his Head, his jointed Horns, its bulbous Eyes, and monſtrous Legs and Claws, the Motions of which are very terrible in Appearance: —— I

* The barbarous Practice of *diſſecting a Frog alive*, to ſhew the Circulation of the Blood in the Meſentery, is here refer'd to.

—— I ſuſpect, by the Form, that this frightful Creature is the LOUSE. ——— But what is that red Spot I ſee in the Forepart of its Body, attended with an odd Kind of Motion?

Cleon. It is a living Louſe that you ſee, and the Spot which you mention ſhews the Place and Pulſation of the Heart; from which, you obſerve a Motion of a vital Fluid through the middle Part of the *Abdomen*, or large, hinder Part of the Body: But you ſee nothing like the Circulation of the Blood in other larger Animals, by diſtinct Arteries and Veins. How the Circulation of the Fluids are carried on in this, does not, even by this Inſtrument, appear.*

Euphroſ. Well; an uglier Thing I ſcarce ever ſaw, they are Objects of our Averſion in their natural Minute State; but what an horrible Aſpect they have now! ——— I have viewed this Monſter long enough. Pray, what Appearance does a Flea make?

Cleon. I have one at Hand to ſhew you. ——— There, you ſee it.

Euphroſ. I do, ſure enough: ——— It is as large as an Ox, —— it ſeems to be a Creature covered with a Coat of Mail or Tortoiſhell, ——— its Appearance is rather uncouth, than formidable, and a good deal in a Shape of a Lobſter, as you formerly told me: ——— What an amazing Head it has, with a large black Eye. ——— But what is moſt ſurprizing in the Structure of this Animal is, the peculiar and wonderful Form of its Legs, by which one may eaſily ſee how Nature has prepared it for moving in the Manner it does. —— I can likewiſe percieve, in the Body of this Animal, a Motion of the Fluids ſomewhat like that in the Louſe.† ——— But now for another Object, *Cleonicus*, if you pleaſe.

Cleon. I ſhall now entertain you with a few extraordinary Views of the vegetable Kind. —— Look at the Sheet, and tell me what you think you ſee there, my *Euphroſyne.*

Euphroſ. You have ſuddenly transformed the Scene to ſomething like a wonderful Sort of Stars, ——— ſome of which are Opake,

* See a Print and Deſcription of the Louſe, Page 893, of the Miſcellaneous, for *October* 1758.

† See a Print and Deſcription of the Flea, in the Miſcellany for *April*, 1759, Page 74.

Opake, others Tranſparent; ——— they are perfectly round, and large as cannon Balls: ——— They are vaſtly numerous, and make a delightful Appearance, truly. ——— Pray, what can it be, of a vegetable Nature, that I ſee?

Cleon. It is what the Botaniſts call the *Farina*, or that duſty Matter which grows on the Apices in the Middle of the Flowers, of which you ſee great Quantities in the Tulip, the Lilly, and many others: But that which I have in the Microſcope, is the Farina of a Holyhock, and is found in all of the Mallow Kind; for in every Plant of a different Species, thoſe Particles have a peculiar Size and Form, as you may obſerve at your Leiſure in the common Microſcope. —— Now caſt your Eye again on the Sheet, and you will ſee an Object that will give you Pleaſure to view it.

Eupuroſ. This is a curious Phænomenon, indeed: —— This has, in Truth, the Appearance of Vegetation itſelf: —— How beautifully coloured, and regularly branched and ramified in every Part! ——— Pray, what do you call this, *Cleonicus?*

Cleon. It is a Species of a very fine Sea Plant, or Coralline, of which there are innumerable Kinds, and all make the ſame beautiful Appearance you now ſee; for not only the Earth, but the Sea is productive of Vegetables, Plants, and Trees of various Kinds and Sizes; all which afford the moſt curious Objects for the Microſcope. ——— Again, you ſee the Scene is changed, and another Part of a Vegetable expoſed to your View.

Euphroſ. I think the Appearance of it very fine and delicate; but what it is, I cannot conjecture, as I never remember to have ſeen any Thing in a Plant of this curious Texture.

Cleon. It is a very thin tranſverſe Slice of the Pith of Elder, and tho' we know ſo little of the Uſe of that Part of the Plant, yet you may be aſſured that ſomething very conſiderable depends upon ſo elegant, and quite a geometrical Structure. —— The next Object has a ſimilar Appearance, but the Pores much ſmaller.

Euphroſ. Be this what it will, it is vaſtly beautiful; — the Pores, it is true, are much ſmaller, and more numerous, and therefore a more compact Subſtance than the Pith; but what Part of the Plant it can be, I am as much at a Loſs to gueſs as I was before.

Cleon.

Cleon. This is a very thin Piece of Cork, which, you know, is a vegetable Subſtance, as it is the outer Part of the Bark of a Cork-Tree; and tho' we cannot ſo well tell the Uſe of theſe Pores in Vegetation, yet, as they render Cork a ſoft and yielding Subſtance, they make it a very fit Medium for many Uſes in Life, particularly for corking of Bottles, and ſundry other Uſes for Fiſhermen, *&c.* —— Another Object well deſerves your Notice: Look upon the Sheet, and you will ſee it.

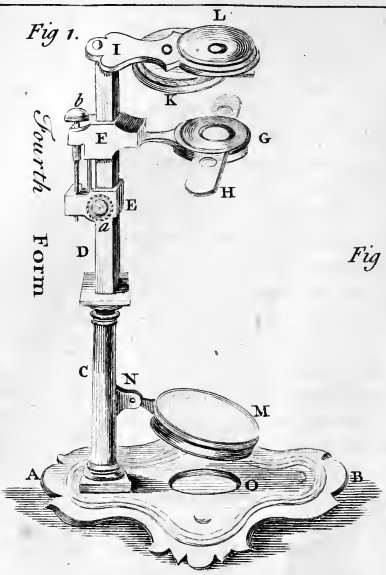
Euphroſ. I ſee ſomething in Appearance very regular, full of Holes of a larger and leſſer Size, and diſpoſed in a very beautiful Order: —— But this, like all other Objects in this new View, becomes quite unknown to me, however common it may be to the vulgar Sight.

Cleon. This, my *Euphroſyne*, is the eſſential Part of a Plant, it is a very thin Slice of Oak, cut tranſverſly, ſo as to render it quite Tranſparent; for, by this, it appears, that the Body of a Plant conſiſts almoſt entirely of long, hollow Tubes, or Veſſels, the Orifices of which, when cut aſunder, are what makes that variegated Appearance of Ringlets of different Sizes upon the Sheet. —— Thoſe of the largeſt Sort are the Orifices of Air-pipes which is that Syſtem of Veſſels which circulate the Air through the Body of a Plant; and though ſome of them appear now near a Foot in Diameter, yet, in themſelves, they are ſcarce viſible to the naked Eye. —— The other Order of ſmaller Orifices are thoſe of the Sap-Veſſels, which circulate the nutricious Juices of the Earth to all the Parts of the Plant; and it is theſe that make the very Subſtance of the Plant itſelf, and conſtitute thoſe cylindric Shells of Wood which appear in cutting the Tree aſunder, each of which is the Product of one Year's Growth: All which I ſhall more particularly diſcourſe of, to you, at another Time. —— At preſent, theſe Specimens muſt ſuffice for the Uſe of the ſolar Microſcope, and for giving you a juſt Idea and Eſteem for ſuch an excellent Invention, and which exceed all others of the optical Kind.

Euphroſ. I am much obliged to you for the Trouble I have given you, and for your Confinement ſo long in a dark Room; and I ſhall always look upon the Experiments of the Microſcope, and eſpecially of this Sort, as the moſt ſublime and rational Amuſements of my Life.

DIA-

Fig 1.



Fourth Form

Fig 2.

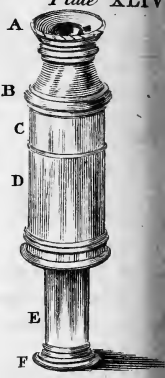
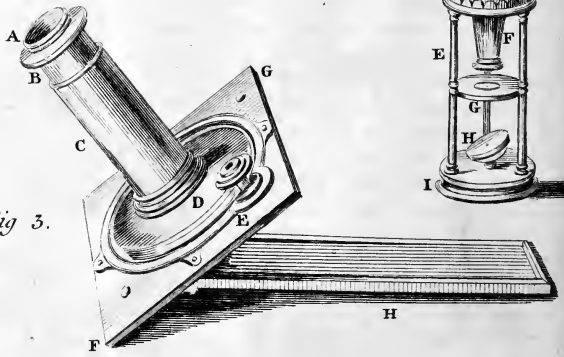
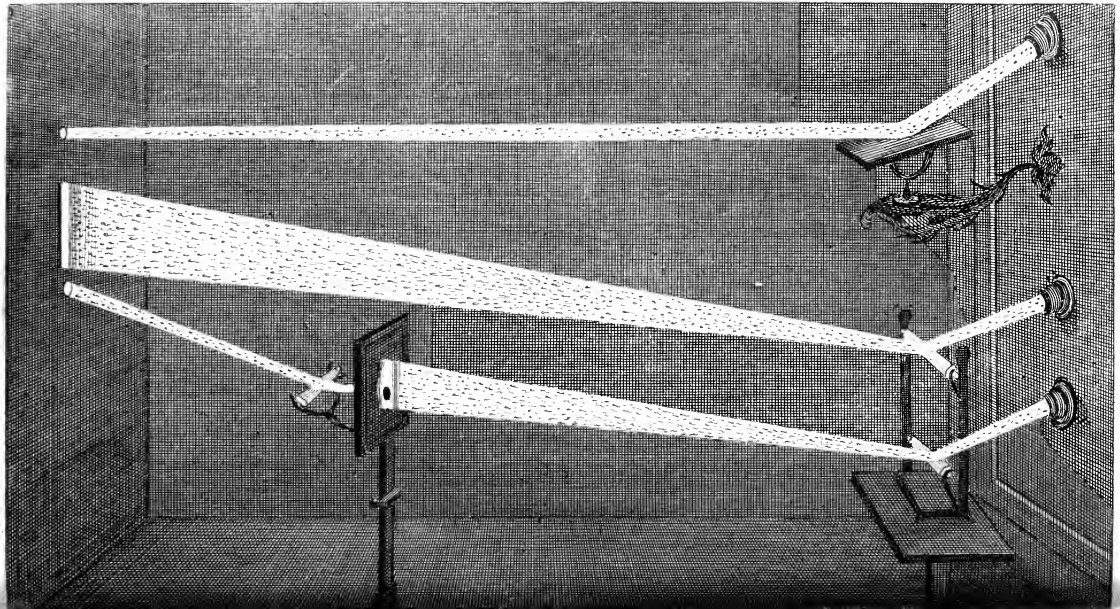


Fig 3.





DIALOGUE IV.

The Description of a MICROSCOPIC APPARATUS, *consisting of a* Single, Compound, *and* Solar MICROSCOPE *together.*

Cleonicus.

AS the Minds of Men are affected with a Variety of different Sentiments, in regard to the Manner and Form of Things designed to answer the same Purpose, so the Artist, in order to please, is obliged to contrive his Instruments of many different Forms and Structures; for his Mechanism must always vary with the Fancies of Mankind, and nothing appears to me a greater Instance of Providence, than that Variety and Mutability which we find in the Judgment and elective Faculties of the human Mind: For if all Men were to fancy the same Thing under the same Form, and constantly to persevere in their first Choice, there would be but little Business for Men to be employed in, and the World would become a dull Scene, in Comparison of what it now is. ——— I have already laid before you, the different Sorts of single, compound, and solar Microscopes, as they are usually constructed, and sold separately by themselves, for the Gratification of those who chuse to have them in that Manner: ——— But as some People are fond of single Structures, and like to have every Thing by itself, so they are pleased with Composition, and chuse to have as many Purposes as possibly can be answered by a Set of Instruments in the least Compass: And to oblige such Gentlemen, Opticians have found out a Method of combining the single, compound, and solar Microscope together, in such a Manner, that they are contained in much less Room, can be afforded at a less Price, and make a convenient microscopic Apparatus in one portable Case; and to give you a distinct View of the Instruments thus contrived, is proposed for the Employment of our present Hour.

Euphros. Notwithstanding you have been so kind as to furnish me with all the Instruments under the Denomination of Microscopes, yet I shall be obliged to you for a View of that

more compendious Form of an Apparatus you have now mentioned, and shall gladly receive your Instructions for the Use of it.

Cleon. You see, my *Euphrosyne*, they are all contained in this Shagreen-case, and are only the essential Parts of the three different Kinds of Microscopes, to be united as Occasion requires. ——— Thus, the single Microscope is that which you have of the fourth Form, (Plate 44. Fig. I.) on the upper Part of which (at L) you screw on the Body of the double Microscope, Fig. II. by the lower Part of the Snout (F:) Then, when the Objects are applied in the Ivory-slider (H) on the Stage (G,) they may be viewed by any one of the six Magnifiers contained in the circular Piece of Brass (K,) as they are successively moved and placed under the central Hole in the Part (L,) since the Stage (G) may be moved nearer to, or farther from the Part (L) by Means of the Sliding-apparatus (E F) and the two Screws (*a*, *b*.) The Objects are illuminated by the reflecting Mirror, (M) moveable on the Joint (N,) of a Piece of Brass fixed to the Pillar (C) of the Microscope. ——— And thus you see how easily and readily you form a compound Microscope at Pleasure.

Euphros. It is a great Satisfaction that I observe it, and which I shall frequently put in Practice; but, pray, *Cleonicus*, could not the magnifying Glasses be applied in a Slider, as they are in the second Form of single Microscopes? (Plate LXIII.)

Cleon. Undoubtedly, they may: ——— But each Way is so easy and convenient, that it is hard to say which is best: But, as you have the sliding Glasses already in the Microscope of the 2d Form, I have chose to give them you in the circular Plate in this.

Euphros. Very good, *Cleonicus*; but how do you proceed to apply this single Microscope to the Composition of a solar Microscope?

Cleon. This is done with a great deal of Ease; for you have only to observe, that on the external Part (A) of the Drawer (B) in the Tube (C) of the solar Microscope, there is a Screw, and also in the Foot (A B) of the single Microscope there is a central Hole (O,) with the Threads of a Screw cut in it, the same with those on the Part (A) in the solar Microscope, and consequently

quently the Drawer (A) may be readily ſcrewed into the Hole (O,) and thus the ſolar Microſcope is completed.

Euphroſ. I readily perceive it is; for, when the Plate (G F) is faſtened upon the Window-ſhut, the Diſpoſition of the ſingle Microſcope is horizontal; and when the Speculum (M) is turned down upon the Pillar (C,) then the Rays of Light reflected from the Looking-glaſs (H) without to the Convex Lens at (D) they will, by its Refraction, be converged in ſuch a Manner upon the Objects in the Slider (H) as to illuminate them very ſtrongly, ſo that their Images, formed by the Glaſſes in the Plate (K,) may be ſufficiently viſible in their various Degrees of Magnitude on the oppoſite Side of the Room. —— This is, indeed, a very ſimple, and, at the ſame Time, a very artful and elegant Compoſition of optical Inſtruments. Pray, can any Thing further be expected to aſſiſt us in viewing the *Minutiæ* of Nature, beſides the Inſtruments you have now deſcribed?

Cleon. I am greatly pleaſed to find you inquiſitive, many People of a leſs happy Diſpoſition would have thought I had harangued them full long enough on this Subject: —— But, as I have often told you, I am determined that nothing ſhall eſcape your Notice which is deſerving of it, and is, at the ſame Time, in my Power to lay before you; and therefore I ſhall hereafter ſupply you with other Ways and Means for viewing ſmall Objects: —— I mean, by thoſe Inſtruments we may properly call catoptric Microſcopes, or ſuch where the Viſion of Objects is effected by reflected Light; and you muſt know, and I doubt not but you will then find, by Experience, that this is the moſt exquiſite and perfect Kind of Viſion that Nature affords: For all the Microſcopes that we have hitherto been contemplating the Nature of, conſiſts of Lenſes only, and produce their Effects by refracted Light; therefore the Viſion of an Object will be imperfect upon two Accounts, the firſt is, becauſe the regular Refraction of Rays will be obſtructed by the Figure of the Glaſs; becauſe the Rays which go through one Part of the Glaſs are not refracted preciſely to the ſame Point with thoſe which paſs through another Part; and therefore every individual Point in the Object cannot be repreſented by a ſingle Point in the Image, but will be, as it were, dilated into a ſmall Space, and, conſe-

quently, the several Points of the Object will be confusedly blended together in the Image; therefore it must not be viewed by a Glass that Magnifies too much, lest it should discover the Imperfection of the Image, and render the View disagreeable.

Euphrof. You are now upon such a nice Subject, and what I have been so little used to think of, that I can but just comprehend your Meaning. —— I think, you intend I should understand, that unless every Point of the Object, which sends forth Rays to the Glass, could have all those Rays collected into a single Point, the Vision or Image of that Point cannot be distinct and perfect. —— Am I right, *Cleonicus?*

Cleon. It is the very Idea I endeavoured to convey; but that is not to be absolutely effected by Glasses: —— Besides this, there is another, and still greater Cause of imperfect Vision by refracted Light, and that is, the different Refrangibility of the Rays of common Light, that is to say, the Rays of Light, proceeding from the same Point of an Object to the same Part of the Lens, will some of them be refracted to one Point in the Axis, and some to another: Or, in other Words, some will be more, and others less refracted, and, consequently, the several Points of the Object will be very much dilated and confused, in the same Manner as I said before was occasioned by the Figure of the Glass; but in a much higher Degree: —— Nor is this the only Misfortune of refracted Vision arising from the Rays being differently refrangible; for each particular Sort of Rays that are contained in a Beam of common Light, will, at the same Time, act differently upon the optic Nerve, and produce different Ideas of Colour, according to its different Degree of Refrangibility; and therefore one and the same Point of an Object is not only, by Refraction, multiplied, as it were, into many Points; but is likewise diversely coloured in each of those Points in the Image, and, consequently, when the Image of any Object, formed by those Glasses, are viewed by a very deep Magnifier, they will appear not only very indistinct and distorted, but variously coloured at the same Time. —— Upon all which Accounts it is easy to observe, that we can arrive at greater Powers of magnifying small Objects by single Microscopes, than by compound Ones; because, in the former, we

view

view the Object itself, and in the latter its imperfect Image: ——— But as one of those Causes of the Imperfection of Vision is much less by reflected Light, and the other wholly avoided, it will, from thence, appear how much preferable a *Catoptric Microscope* is to a *Dioptric* One. ——— But, that you may be apprized more thoroughly of this important Subject, which is the Foundation of the Theory, or Doctrine of Colours; I must take another Opportunity of instructing you therein, by such Experiments as I make no doubt will afford you a very agreeable Entertainment, as well as give you a more accurate Insight into the Nature of Vision, and the Perfection of optical Instruments; especially that Part we call Telescopes, the Nature of which cannot be well understood without it.

DIALOGUE V.

Of the COLOURS *of natural* BODIES, *illustrated by Experiments of the* PRISM, &c.

Euphrosyne.

WHEN we last conversed together, you raised my Expectation in regard to the Theory of Colours. I think, you then told me, that the Doctrine of the different Refrangibility of Rays was the Cause of Colours in all the various Objects we view, and that the Proof of this was easy for me to understand, by Experiments: If this be so, *Cleonicus*, nothing will equal the Pleasure and Happiness which the present Hour will afford me.

Cleon. You will find every Thing I have said, relative to this Subject, to be true. ——— As the Pride, Gaiety, and Beauty of Nature appears more in the rich Variety of Colours, than in any one Thing beside, and seem as if intended in a particular Manner to pleasure and adorn your Sex, I know of nothing that can prove more *a propos* for a Lady's Study than the beautiful Doctrine of the Colours of Light, and which is more easily attainable by Experiments of the Prism.

Euphros.

Euphrof. I have partly experienced already the Truth of what you now say. ——— You remember very well, when we were Children, how often we diverted ourselves with the beautiful Colours that we observed in the Prism, that my Father had in his Study, and how often we delighted ourselves with viewing the exquisite Circles of coloured Light, which we always observed in those thin Bubbles which we blowed up out of Soap-water with the Shaft of a Tobacco-pipe. ——— I little thought then that these were Subjects of so curious and philosophical a Nature, as I now find they are. ——— The wonderful Colours of the celestial Bow, in like Manner, strike every one's Eye; but the Phænomena of Colours, beautiful as they are, are more generally the Subject of Sense, than of the Understanding in general.

Cleon. All the World, as well as you, might have said this before Sir *Isaac Newton*'s Time; they all admired the Variety of natural Tints and Colours, but never understood the Reason of it; though many of the Philosophers attempted to discover the Cause of Colours, and particularly to account for the Rain-bow, no one was so happy as to succeed in that Enquiry, before Sir *Isaac*; his great Sagacity in reasoning about natural Things, after he had observed the Effects of the Prism, and found that a Beam of Light was variously refracted through it, concluded, that this different Refrangibility of Rays was certainly the natural Cause of Colours, as I observed to you at our last Interview.

Euphrof. In what Manner did he proceed to confirm this Discovery?

Cleon. I will shew you some of his Experiments, in the darkened Room, with the Prism, and then you will be better able to judge of this Matter: —— For this Purpose, you have nothing to do but to put too the Window-shutters, admitting only a Beam of Light through the Hole, as the Sun now shines very favourably for that Purpose, and I have here an Apparatus to place the Prism properly in that Beam of Light.

Euphrof. The Windows are closed, as you directed, and the Beam of Light darts through the Hole to a great Distance on the Floor. ——— Where is now your Prism, *Cleonicus?*

Cleon. I place it in its proper Frame on the Table, to receive the Beam of Light, ——— and now you observe how beautifully

tifully that Beam is refracted into all its particular, and differently coloured Rays.

Euphrof. A very fine and wonderful Spectacle, indeed;—— I see the cylindric Beam of solar Light pass into the Prism:—— From thence, I observe it proceed dilated and variously coloured to the other Side of the Room, where they paint an amazing Spectrum of Colours.

Cleon. This is the coloured Image of the Sun, by Refraction, thrown into that oblong Form: ——— But it requires to be better defined, that you may view it more distinctly, and to give you a better Idea thereof, I shall make the Rays pass through a Lens, applied to the Hole of the Window-shut, and from thence, falling on a Looking-glass properly inclined on the Table, shall depict the Sun's Image on the opposite Side of the Wall.

Euphrof. I see; and an accurate beautiful Circle it is.

Cleon. I shall now remove the Looking-glass, and place the Prism in its Stead, and you see the circular Spot no longer continues, but is now transformed, by Refraction, into the party coloured Spectrum, and is now truly and nicely defined in the Focus of the Lens. ——— This Spectrum is still of the same Breadth with the Sun's circular Image; ——— it is only dilated in Length, and is circular at Top and at Bottom.

Euphrof. Those Particulars evidently appear, ——— I have been endeavouring to count the Number of different Colours, and think I can count five pretty distinctly; ——— for all the lower Part appears of a Red, gradually declining into a Yellow, —— to the Yellow succeeds an intense Green, ——— above that a bright and lovely Blue, and, on the upper Part of all, a soft, but glorious Mazarine, or violet Colour. —— I never saw Colours in such Perfection before.

Cleon. The Reason is, because you never see them in so simple a State as now; for the Rays of Light are generally blended, more or less, by Refraction and Reflection from natural Bodies, and therefore produce Colours less bright, less distinct and perfect, than what you now behold. ——— Sir *Isaac*, in his more accurate Experiments, could plainly discover seven different Sorts of Colours, *viz.* *red*, *orange*, *yellow*, *green*, *blue*, *indigo*, and *violet*, and that each Colour gradually degenerated into the

suc-

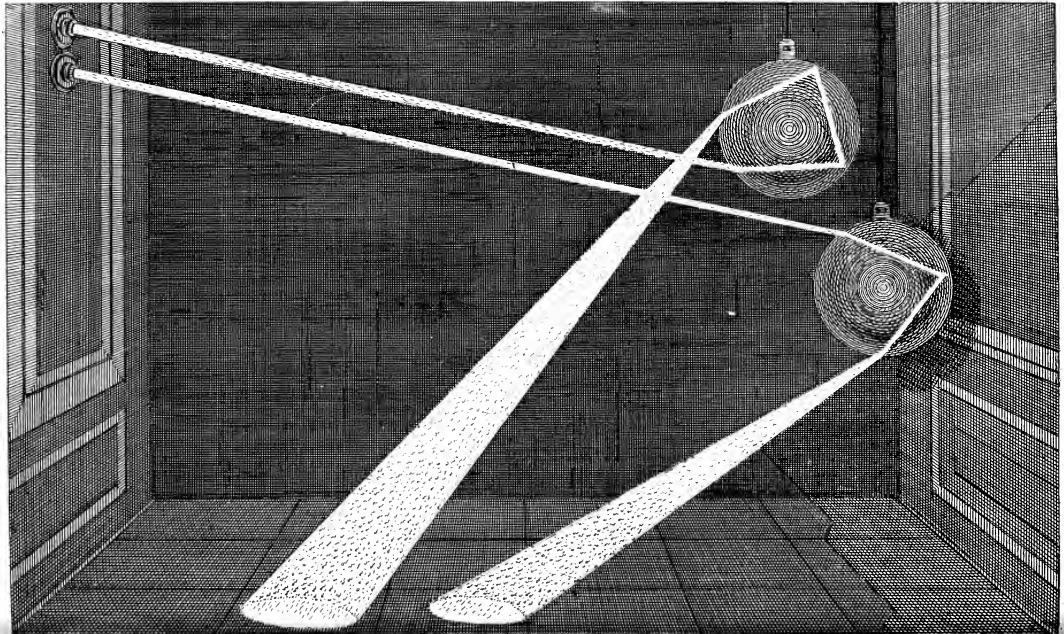
ſucceeding. ——— The Spaces which theſe Colours ſeverally occupied in the Image were nearly equal to the Intervals of a Monochord, when divided ſo as to ſound the ſeven natural Notes of Muſic; ——— and as there were plainly ſeven different Colours of Light, ſo he reckoned ſeven different Degrees in the Refrangibility of Rays.

Euphroſ. But what would be the Conſequence of receiving any Part of this coloured Light by another Priſm? Should we not obſerve that Light to be again differently refracted, and producing a new, and different Order of Colours, from what we now ſee by the firſt Refraction?

Cleon. One might imagine that it would be ſo, but we find the Contrary by Experiment; ——— for by a Lens of a ſhorter Focus, together with the Priſm, I will ſhew you the coloured Image, on a Skreen, placed in the Middle of the Room, ſufficiently large to receive the Whole, and in the Screen there is a round Hole, thro' which the Rays of any Colour may paſs, by moving the Screen up and down upon the Stand. ——— Thus, for Inſtance, I place the Hole againſt the blue-coloured Part of the Image, ſo that none but the blue Rays go through it,——— and then you obſerve, on the oppoſite Side of the Room, thoſe blue Rays, after they paſs the Priſm, make only a blue Image, ——— that they are refracted, is true, from the Direction of the incident Rays; but they are not dilated, or ſeparated into different Sorts, as by the firſt Priſm the common Beam of Light was: ——— The ſame will be the Caſe when I move the Hole of the Screen to the yellow Rays; ——— for now, you ſee thoſe Rays, falling on the ſecond Priſm, are refracted to the Side of the Room, and there make a yellow Spot only, of nearly a circular Form. ——— And this I might ſhew of all the reſt.

Euphroſ. Theſe Experiments ſeem to be curious, and exquiſitely deciſſive: I plainly learn from hence, that the Rays of the Sun's Light are the Grounds, or natural Cauſe of Colours, and that they are very differently refrangible: ——— But how comes it to paſs, *Cleonicus*, that we ſee Bodies variouſly coloured in Conſequence of this? By looking in a Priſm, we ſee all Bodies variouſly coloured; but in Glaſſes, or tranſparent Bodies of other Forms, we ſee them in their own proper Colours only.

Cleon.



Cleon. The Reaſon of this is founded in a Phiſico-mathematical Theory of Refraction,* reſulting from the two Sides of a Priſm being inclined to each other; but in any other tranſparent Body, whoſe Sides are parallel, or nearly ſo, whatever Alterations was made by Refraction at the firſt Surface, is reverſed by the Second, and conſequently, the refracted Rays are in the ſame State with the incident ones, and, therefore, make no Alteration in the Appearance of Bodies in any reſpect. —— But here we muſt except the Figure of a Globe; for the two oppoſite Sides of a Globe muſt be conſidered, not as parallel, but inclined, and therefore will produce a Refraction of Rays in the very ſame Manner with the Priſm. If Rays of Light falls on the Surface of a Glaſs Sphere filled with Water, they will be refracted to the other Side, and there ſhew a coloured Spot of refracted Light; from this Part the Rays will be reflected to another Part of the lower Surface, and there be refracted a ſecond Time into the Air, and dilated into all the different colour'd Rays; ſo that if a Perſon's Eye was placed under ſuch a Globe, to receive the Rays after a ſecond Refraction, he would obſerve all the different Colours appear in that Globe.

Euphroſ. I ſhould be glad, methinks, if not too much Trouble, *Cleonicus*, to ſee this illuſtrated by Experiment, for bare Deſcription conveys not ſo clear an Idea.

Cleon. I was fully aware of that, and therefore have provided, for you, a Globe filled with Water, and which I ſhall ſuſpend in a Sun-beam, at ſuch a Height that you may eaſily obſerve the Phænomenon that I mention. ——— See, there it hangs; —— and receiving the Light on the upper Part, refracts it from the Lower into all it's different coloured Rays, and thereby making a Circle of coloured Light on the Floor, very much reſembling the Rain-bow.

Euphroſ. There are, indeed, all the Colours of the Bow; and a glorious Phænomenon it is.

* Which ſee in our Inſtitutions of *Dioptrics*. —— And, for farther Illuſtration of this Subject, we have added a Copper-plate Print (*viz.* Plate XLV) in which the Experiments above mentioned are ſeverally repreſented, by Beams of Light entering the dark Room thro' optic Glaſſes, and refracted thro' Priſms, in the Manner as there deſcribed; ſo that, we apprehend, nothing farther is neceſſary for Explanation, but bare Inſpection.

Cleon. It will now be eaſy for you to obſerve, that if you place your ſelf in ſuch a Manner, reſpecting the Globe, that the Rays of Light, of different Colours, may ſucceſſively fall upon the Eye, then thoſe different Colours will all appear in the Globe, which before made the variegated Arch upon the Floor.

Euphroſ. I will place my ſelf as you direct. ——— And now, as I move my Eye, I ſee the ſeveral Colours ſucceed each other in the ſame Part of the Globe, agreeably to what you have ſaid. ——— I ſuppoſe it is from hence that you are able to explain the ſeveral Colours of the Rain-bow.

Cleon. By this Experiment you underſtand the Reaſon of that Part of the *Iris*, or Bow, which contains the Circle of ſtrongeſt Colours, and which we emphatically call the *Rain-bow*; for if this Globe of water was placed aloft in the Heavens, it is very evident that the Sun-beams would be there refracted thro' it, as they are here; and then, ſuppoſe your back was turned to the Sun, as it now is, then your Eye, remaining fixed, would perceive only one Colour, ſuppoſe that to be the firſt or red coloured Ray; ——— then, ſince the Orange is refracted a little above the Eye, if the Globe was to deſcend thro' a little Space it would cauſe that orange Ray to fall upon the Eye; ——— by deſcending a little lower, the yellow Ray comes upon the Eye; ——— and ſuppoſing the Globe to continue deſcending, the Green, the Blue, the Indico, and Violet will ſucceſſively paſs over the Eye, and conſequently you will obſerve, in the different Parts of the Heavens thro' which the Globe deſcends, the different Colours of it's ſeveral refracted Rays reſpectively; — and therefore, ſince in a Cloud, on which the Sun can ſhine, the Globules of Water will each of them refract the Light in the ſame Manner this larger Globe does, and conſequently ſome of thoſe Globules will be in that Poſition that will cauſe the red Rays to fall upon the Eye, ——— others, next to them below, will ſend forth orange coloured Rays to the Eye; ——— the Drops next to them will caſt a yellow Ray to the Eye, ——— and thoſe ſucceſſively in order below them will refract the blue, indico, and violet coloured Rays to the Eye; ——— and thus, in a certain Space in the Cloud, all the Colours will appear; — and ſince, under the ſame Angle, the ſame Phænomena will be

pro-

produced, therefore a Circle of this various coloured Light must necessarily be produced in the Cloud.

Euphros. I think, I pretty clearly apprehend you; for the *Rationale* of the brightest Bow; but there is one which we commonly call the *Water-Gall*, which is a fainter Circle of Colours in a superior Situation to the other. —— Can you give me any Idea, *Cleonicus*, how this comes to pass?

Cleon. I will endeavour at it, my *Euphrosyne*. —— In order to this, you must understand, that the Rays of the Sun in this Case falls upon the Globe in the lower Part, from whence they are refracted to a Part behind in the upper Hemisphere; —— from thence, after two Reflections, they are thrown to the fore Part of the Globe, at some Distance above the incident Rays; —— lastly, from this Part they are refracted out of the Globe in all their different coloured Species to the Eye; —— and this I shall shew you by Experiment; for now I will direct the Beam to the lower Part of the Globe; —— then you see plainly the coloured Spot behind, to which it is refracted, then casting your Eye on the upper Part you see the Point to which the Beam is reflected; —— from whence it is a second Time reflected to the fore Part of the Globe; —— and from thence, you see it a second Time refracted out of the Globe into the Air, and the Beam thereby dissipated into all its different coloured Rays: —— And now you plainly see, by the Colours on the Floor, as well as from the Reason of the Thing, that the several Rays in the Beam lie in a different Order from what they did when refracted from the Globe before; for there the upper Part was Violet and the under Part red; whereas, in the present Case, you observe the red Rays are the upper Part of the Beam, and those of the violet Colour in the lowest Part. —— Therefore, the two Bows in the Heavens must necessarily appear with their Colours inverted; —— and, lastly, you will understand, that as in the present Case there are two Reflections of Light in the Drop, and in the former Case but one Reflection, and that a considerable Quantity of Light is lost at each Reflection, therefore the refracted Beam will have less Light, and the Colours, of course, will be more dilute and faint, which you always observe to be the Case of the superior Bow.

Euphrof. I can partly ſee, from all that you have ſaid, the general Reaſon of both the *Iriſes*; —— and I could almoſt wiſh, that inſtead of ſo fine a Day it had happened to have been a ſtormy, or a rainy One, that I might have ſeen the Bows juſt now in the Heavens, while the Thing is freſh in my Mind. —— This Lecture is moſt proper in the Spring Seaſon, when *April* Showers ſo frequently preſent us with this Experiment, at large, in the ſable Clouds.

Cleon. You ſtill have your Wiſh, my *Euphroſyne*, in every Sunſhiny Day. —— For here you ſee a beautiful Inſtrument, which is called an *artificial* FOUNTAIN, with a various Apparatus for making different Kinds of *Jet d'Eaus*; amongſt which, one is particularly deſigned to throw up many fine Streams of Water to a great Height, which, as they ſpread very wide, mix and blend together in their upper Part, and form a beautiful Shower of artificial Rain; and, therefore, when I ſet this Fountain in the Sun, and let it play, if you put yourſelf in a proper Poſition you will ſee, in the deſcending Drops of the Shower, the ſame Appearance of refracted Light, and, conſequently, the two Bows formed in the ſame Manner as in a natural Shower.

Euphrof. Such an Experiment will give me great Entertainment; but you muſt tell me in what Situation I muſt put myſelf, in order to view it.

Cleon. This you will know by only conſidering, that the Rays go into, and come out of the Drop on that Part of it which is next the Sun, and therefore, that the immerging Rays may fall upon your Eye, your Face muſt be directed to the Shower, and, conſequently, your Back to the Sun. —— Therefore, when you ſee the Fountain playing you move one Way or other, 'till your Shadow points directly to it, and then you will obſerve the curious Appearance of the Bows. —— See, now the Fountain plays.

Euphrof. It makes a natural, and large Shower, indeed. —— My Shadow directs me to the proper Poſition: —— And now I truly ſee all that I could wiſh for —— The Colours of the Rainbow, very ſtrong and vivid —— thoſe of the Watergall, languid and faint —— The Colours of each in an inverted Order. —— But what ſuprizes me moſt of all, *Cleonicus*, is that when I know this artificial Shower is ſo near me, the Bows

appear,

appear, notwithſtanding that, as far off, and as large, as thoſe that we really ſee in the natural Showers of Rain.

Cleon. The Reaſon of this is, becauſe the Sky is the apparent Place of all Things that we obſerve in the Air; there the Moon appears as well as the Stars, and there the *Halo* appears about the Moon, tho' formed in the thick Fog of the Atmoſphere, near the Eye. —— By the Laws of Optics theſe Things muſt be ſo, and you ſee the two Bows, that are not above 30 Feet from you, and, in themſelves, very ſmall, extend to vaſt Dimenſions, and Diſtance in the Heavens.

Euphroſ. I don't know that I ever ſaw an Experiment which afforded me greater Pleaſure, and, in its own Nature, ſo curious and ſublime. —— What a wonderful Scenery of Nature is here diſplayed! Surely the Doctrine of Colours is highly worthy of every Perſon's Contemplation.

Cleon. And yet, when we conſider that tho' thoſe variegated Beauties of Nature are the common Objects of Viſion, how few there are that underſtand the Reaſon of them, and how much fewer ſtill are any Ways anxious about it; it muſt appear a wonderful Thing to every rational Man. —— Not only the Ladies, but Gentlemen love to ſee themſelves rendered conſpicuous by Garments and Habits of different Colours and Dyes; but if thoſe Colours are deemed ſo great an Ornament to the Perſon, how much more will the Knowledge of the natural Cauſes of them adorn and become the reaſonable Mind. —— If this be neglected, the *Peacock* has a much better Claim to Pride, from the Decorations of Nature, than any of the human Species, whoſe Colours are, at beſt, but mixt and imperfect, when compared with the genuine and ſimple Colours, intenſely heightened in the Plumage of that ſtately Bird.

Euphroſ. I muſt confeſs, tho' I have no Averſion to moderate Gaiety and Dreſs, yet the *Rationale* of the Colours I wear give me a Satisfaction and Pleaſure of a much higher Kind; for now, I not only put on a *red*, a *yellow*, or *blue Ribbon*, but they give me Occaſion, at the ſame Time, to reflect on the Reaſon why they are ſuch, and thereby double my Pleaſure in the Uſe of them. —— For I obſerved, while you were ſhewing me the Experiments of the Priſm in the dark Room, that whatever

ever Object was placed in the refracted Beam of coloured Light, appeared conſtantly of the Colour of thoſe Rays that fell upon it, becauſe thoſe Rays were alone reflected to the Eye; and, therefore, in regard to any Colours in Objects by Reflection or Refraction, I am taught, by theſe Experiments, to underſtand, that they proceed only from ſuch or ſuch particular Sort of Rays, as are reflected or refracted to the Eye.

Cleon. You apprehend this Affair very happily; the Thing you mention comprehends near the whole *Rationale* of the Doctrine of Colours, —— when Objects reflect or refract the Rays ſingly, they muſt neceſſarily appear of the Colour proper to thoſe Rays; —— but ſome Sorts of Matter will reflect one Sort of Rays and refract another; and, therefore appear of one Colour by Reflection, and another by Refraction; thus, for Inſtance, Leaf-gold reflects the yellow-making Rays, and, therefore YELLOW is its common Colour, but it tranſmits the green and the blue Rays, and therefore appears of an *azure Colour*, by refracted Light. —— Such Bodies as throw up all the Rays promiſcouſly muſt appear *white*, which is the natural Colour of the Sun's *Light*, where all the different coloured Rays are uniformly blended together: —— On the other Hand, ſuch Bodies as imbibe all the Light, and reflect little or none, appear of a dark, or black Colour, if I may ſo ſpeak, for in Strictneſs of Speech, Blackneſs is the Abſence of all Colour, rather than a Colour itſelf: —— Laſtly, as two or more different coloured Rays are reflected and refracted from Bodies they will exhibit a compound or motley Colour, and thus all Variety of Colours in Bodies may be readily accounted for by the different Refrangibility and Reflexibility of Light. —— But I muſt recommend to your Peruſal ſome eaſy Treatiſe on this Subject, which will farther enlarge your Ideas and Notion of the Doctrine of Light and Colours; the principal of which is Sir *Iſaac Newton*'s Treatiſe of Objects.*

Euphroſ.

* The Reader may alſo pleaſe to peruſe our *Inſtitutions* of DIOPTRICS, eſpecially the popular Part; alſo Chap. VII. on the Subject of priſmatic Colours, p. 140. —— And farther, for Illuſtration of the foregoing Doctrine of the Rain-bow, we have added a Copper-plate (Numb. XLVI.) to render viſible to the Eye the Manner in which the Beam of Light enters the Drop, is reflected in it, and refracted from

Euphroſ. Well; I have pretty well tired you for this Time; I ſhall peruſe that great Author's Book, and ſhall not be a little proud if there be any Thing in his Writings that I can pretend to underſtand. ——— Pray, *Cleonicus*, what is to be the Subject of our next philoſophical Conference?

Cleon. By the preſent Experiments and Diſcourſe, I have endeavoured to prepare you for underſtanding the Doctrine and *Rationale* of Teleſcopes, the different Forms, Conſtruction, and Uſes of which I ſhall diſcourſe of to you as Opportunity will permit, and which, I make no Doubt, will prove Subjects of agreeable Entertainment.

DIALOGUE VI.

On the Original of TELESCOPES; *and their general* NATURE, KINDS, *and* USES *explained.*

Euphroſyne.

WELL, *Cleonicus*, here is an illuſtrious Appearance of various Kinds of Inſtruments, moſt certainly; pray, are they all of that Kind you call Teleſcopes?

Cleon. They are, my *Euphroſyne*, but of different Kinds and Forms.

Euphroſ. Pray, what is properly imported by the Word Teleſcope? for I obſerve it is a general Name for Inſtruments of many different Sorts.

Cleon. The Word Teleſcope is of *Greek* Original and ſignifies an Inſtrument intended to *perfect* the *Sight*, that is to ſay, to improve and perfect the Sight of any Object, which the Eye alone is not fitted to diſcern; theſe I have obſerved to be ſuch as are exceeding ſmall, and others which are very remote; for the Limits of natural Viſion, are, on one Hand, the Diſtance of about ſix or ſeven Inches from the Eye; and, on the other, an

from it, in the Two Experiments for ſhewing the Colours of each Bow, reſpectively; and which, we ſuppoſe, can need no other Explanation than bare Inſpection.

an Angle of about one Minute of a Degree, unleſs diſtant Objects are ſeen under an Angle greater than that, they cannot be diſtinctly viewed by the Eye; and tho' the Word *Teleſcope* is general, and comprehends all Glaſſes that tend to improve Viſion, yet Cuſtom has reſtrained it to mean that particular Sort only, which relates to diſtant Objects; ſo that, by a TELESCOPE, is uſually ſignified an Inſtrument that perfects the View of diſtant Objects.

Euphroſ. Is the Invention of Teleſcopes of antient or modern Date?

Cleon. It is certain that it is not of very antient Date; the famous *Roger Bacon*, before the Year 1300, was the firſt that we find making any particular Mention of Inſtruments for magnifiing ſmall Objects, or making very remote Objects appear plainly to the View; and it is worth while for you to be acquainted with ſome of his Expreſſions, to this Purpoſe, which are as follow, ——— *for thus Lenſes and Speculums may be figured, that one Object may be multiplied into many,* ——— *that thoſe which are poſited at a great Diſtance may be made to appear very near;* ——— *that thoſe which are ſmall may be made to appear very large, and thoſe which are obſcure to appear very plain;* ——— *and we can make Stars to appear where we will.* ——— One would think, from ſuch kind of Expreſſions as theſe, and other Tracts which he wrote upon the Subject of Viſion, that this Author muſt have been well acquainted with the Nature, Conſtruction, and Uſe of Teleſcopes, and all the Glaſſes which compoſe them. But our modern Critics in Optics, deny him not only the Invention, but even the Knowledge of any ſuch Conſtruction as we at preſent call Teleſcopes.

Euphroſ. I cannot ſay but I ſhould at once have concluded that *Roger Bacon*, by his Manner of ſpeaking, had been an excellent Optician; but if he was not, can you tell me, *Cleonicus*, who was the Author of ſo uſeful an Invention?

Cleon. I do not wonder to find you ſo very particular in enquiring after the Inventor of ſo excellent an Inſtrument. ——— The great HUGENIUS ſays, *That in his Opinion, the Wit and Induſtry of Man has not produced any Thing ſo noble, and ſo worthy of his Faculties as this Sort of Knowledge,* (viz. *of the Teleſcope*); *inſomuch, that if any particular Perſon had been ſo diligent and*

ſagacious

ſagacious as to invent this Inſtrument from the Principles of Nature and Geometry, for my Part, I ſhould have thought his Abilities were more than Human; but the Caſe is ſo far from this, that the moſt learned Men have not yet been able ſufficiently to explain the Reaſon of the Effects of this caſual Invention. ——— This Author further adds, that though the Invention of this Inſtrument was certainly caſual, yet *James Mœtius*, a *Dutchman*, is ſuppoſed to be the firſt Inventor; but, ſaid he, to my certain Knowledge, Teleſcopes were made before his Time, *viz.* About the Year 1609, at *Middleburg*, in *Zealand*, either by * *John Lipperſheim*, or *Zachary Janſen*; notwithſtanding this, it is certain, that *Baptiſta Porta*, in his Book of natural Magic, ſeveral Years before, had delivered ſome Sketches of the Art of making Teleſcopes, but what he had done in that Way was merely accidental, and not the Effect of any Skill in Dioptrics. ——— After the Fame of the *Dutch* Teleſcopes began to ſpread Abroad, it ſoon reached the Ear of the famous *Galileo*, who being a conſiderable Mathematician, ſet about improving the rude Forms of the firſt Inventors, and ſoon made them in that Perfection that he, the firſt of Men, diſcovered the SATELLITES of JUPITER by One of his own making, and after that Time they became common, and ſoon made their Way into every Corner of the learned World.

Euphroſ. By the Accounts you have now given, whoever might, at firſt, caſually hit upon the Conſtruction of what you call Teleſcopes, yet it appears, that *Galileo* was the firſt who improved it into any of the Forms now in uſe. Pray, have you any Teleſcopes, of the original Conſtruction, by this famous *Italian?*

Cleon. We have one of the Form he firſt contrived, and it is the moſt ſimple, as well as the moſt diſtinct of all others, ——— and, to this Day, is called *Galileo*'s Teleſcope; of which I ſhall, by and by, give you a more particular Account of its ſeveral Parts: ——— But as this is ſuch an intereſting and curious Point, I cannot but think you will be pleaſed, if I give you an Account, in his own Words, of his Improvement of this Invention, which he publiſhed in his Book entitled, *Nuncius Sidereus*,

* There are two elegant Prints of theſe two Inventors of the Teleſcope, from the Paintings of BERCKMAN, in which their Names are ZACHARIAS JANSEN, and HANS LIPPERHEY.

in *March*, 1710, as follows: ——— "Near ten Months ago it was reported, that a certain *Dutchman* had made a Perſpective, through which many diſtant Objects appeared diſtinct as if they were near; ſeveral Experiments were reported of this wonderful Effect, which ſome believed, and others denied; but having had it confirmed to me a few Days after, by a Letter from the noble *James Badovere* at *Paris*, I applied myſelf to conſider the Reaſon of it, and by what Means I might contrive a like Inſtrument, which I attained to, ſoon after, by the Doctrine of Refractions; and, firſt, I prepared a leaden Tube, in whoſe Extremities I fitted two Spectacle-glaſſes, both of them plain on one Side, and on the other Side one of them ſpherically Convex, and the other Concave. Then, applying my Eye to the Concave, I ſaw Objects appear pretty large, and pretty near me; they appeared three Times nearer, and nine Times larger, in Surface, than to the naked Eye: And ſoon after, I made another, which repreſented Objects above ſixty Times larger; and, at laſt, having ſpared no Labour nor Expence, I made an Inſtrument ſo excellent as to ſhew Things almoſt a thouſand Times larger, and above thirty Times nearer, than to the naked Eye." ——— And in another Part of his Writings he tells us, that ——— "He was at *Venice* when he heard of the Effects of Prince *Maurice*'s Inſtrument, but nothing of its Conſtruction; that the firſt Night after he returned to *Padua* he ſolved the Problem, and made his Inſtrument the next Day; and, ſoon after, preſented it to the Doge at *Venice*, who, to do him Honour for his grand Invention, gave him the ducal Letters, which ſettled him, for Life, in his Lectureſhip at *Padua*, and doubled his Salary, which then became treble of what any of his Predeceſſors had enjoyed before."

Euphroſ. I do not wonder to find that this celebrated Man met with ſuch Honours and Preferments, from that great Patron of Learning, for his perfecting, and reducing to Practice ſo excellent a Diſcovery: ——— But I long to be informed of the Form and Structure of his Teleſcope.

Cleon. It will be neceſſary to begin with that; ſince, as I informed you before, it is the moſt ſimple Structure of this Kind of Inſtrument: ——— But, that you may be apprized of the *Rationale* of a Teleſcope in general, it muſt be conſidered, that the

the Design of such an Instrument is to inlarge the optic Angle, under which distant Objects appear; so that by that Means they might be rendered more perfectly visible, or distinct to the Eye. ——— This is done by forming the Image of a distant Object in the Focus of an optic Glass, ——— and then by viewing that Image by another single Glass, or Lens, of a short focal Distance.

Euphros. You will be a little more particular in explaining this Matter, before I can readily apprehend you.

Cleon. I intend so to be; for neither you, nor any one can be supposed to understand the Effect of a Telescope in a Word or two: ——— Therefore, you will recollect that in the Focus of any Convex Lens (from the Experiments I formerly shewed you) the Image of every Object is formed, ——— and that that Image subtends the same Angle at the Center of the Glass, as the Object itself does; that is to say, in other Words, the Object and its Image are both seen under the same, or equal Angles, by the Eye placed at the Center of the Glass. ——— In the next Place, you are to observe, that as the Image of an Object is in every respect an exact Picture, or Representative of that Object, it will follow, that the same Idea is formed in the Mind, of the Nature, Form, Magnitude, Colour, *&c.* of the Object, whether the Eye at the Center of the Glass views the Object itself, or the Image thereof in its Focus. —— Farther, you will remember, that any Object, placed in the Focus of a Glass, will appear very distinctly through it, as the Rays proceeding from the Object to the Glass are, by Refraction thro' it, rendered parallel to the Eye, which is a necessary Condition for distinct Vision. ——— Therefore, if an optic Lens of the Convex Form, and of a short focal Distance, be applied to view the Image before mentioned, you will easily understand, that then that Image will appear distinctly; and, consequently, the Object itself will be thereby shewn distinct in all its Parts; and so much the more so, as the Differences between the focal Distance of the two Lenses is greater, within a *limited* Degree. —— And therefore, lastly, as the same Image is nearer to one Lens than the other, it will of Course subtend a larger Angle at the nearest Lens, and therefore will, through it, be seen larger than through the other; and consequently the Image, and, of

Courſe, the Object will be thereby magnified in Proportion. Therefore the common Rule for eſtimating the magnifying Power of Teleſcopes conſtructed with two Lenſes, is *the Ratio of their focal Diſtances reſpectively.*

Euphroſ. I have a better Notion than I had of the Uſe and magnifying Power of a Teleſcope; but I am perſuaded, if you could exemplify what you have ſaid by an Experiment, it would ſtill render the Nature of that Inſtrument more eaſy to be conceived.

Cleon. That I can eaſily do, in the following Manner:—— Here is a Teleſcope with two Lenſes, that which is in the great End is called the *Object Lens*, as being next the Object when we view it; the other is called the *Eye-glaſs*, as being within a ſmall Diſtance of the End to which the Eye is applied in uſing the Teleſcope: ——— *The Object Lens I take out of the Teleſcope, and fix it in a *Scioptric Ball and Socket*, placed firmly over a Hole in the Window-ſhut, made for that Purpoſe, and then putting the Window-ſhutters together, the Room is made Dark, and you ſee nothing but what comes thro' the Glaſs by Rays of Light from without. —— A large, moveable Paper-ſcreen, upon a Stand, is provided, and which I now place at the focal Diſtance of the Glaſs from the Window, which is in this Glaſs but 3 Feet; — Upon this Screen you obſerve, there is inſtantly formed a beautiful Landſkip of all the diſtant Scenes of natural Objects without.

Euphroſ. Indeed, I do; and a finer Picture was ſurely never ſeen. ——— What wondrous Painting is this! ——— I ſee the diſtant Fields and Meadows, with the meandrous Windings of the River! ——— I view every Thing in Motion, the People walking, the Cattle grazing, and the Ships ſailing in the River.

* The Experiment of the SCIOPTRIC BALL *and Glaſſes* in the *Camera Obſcura*, is one of the moſt delightful in Optics, and thoſe who have ſeen it, will readily underſtand all that is here ſaid concerning the Nature and Effects of a Teleſcope: They who have not ſeen it, have it in their Power to purchaſe the Inſtrument at a ſmall Price, and to try the Experiments without any Trouble; but they who have not Curioſity enough to do this, are deſervedly excluded from participating in thoſe Pleaſures which are the moſt exquiſite that Nature affords, and place us at the greateſt Diſtance from the Brute-Creation.

ver. ——— The Objects all richly variegated with their natural Tints and Colours, ——— the Buildings all in Perspective, with a natural Relievo by Light and Shade! ——— I do not know that I was ever so delighted with a View of Nature at large, as I am with this Picture of it in Miniature; ——— and, upon the Whole, I cannot but observe how infinitely the beauteous Paintings from Nature's Pencil exceed the Imitations of those who Copy her; and when I hear of those incredible Sums of Money that have been given for such inferior Performances, and at how small a Price those Glasses are purchased which present us with the inimitable Original, I am quite at a Loss to conjecture at the unaccountable Fate of Things.

Cleon. Most Things of this Nature you will always find very difficult to account for; and in all Subjects of this Nature which depend on the Fancy, Humour, or Caprice of Mankind, you will generally observe a very great Disproportion betwixt the real Worth, or intrinsic Value of the Thing, and the Price that is paid for it. But to return to the Subject: —— You observe, in one Part of the Screen there is a round Hole, of about half an Inch in Diameter, upon which any Part of the Picture may be thrown at Pleasure: ——— On the other Side of the Screen is made to slide over the Hole, a small Cell, or Tube of Wood, containing a Convex Lens whose focal Distance is one Inch and a Half, that also is the Distance of the Glass from the Hole; the Distance of the said Glass from the other End of the Tube is about half an Inch, to which End, if the Eye be applied, it will, by Means of that Glass, view those Parts of the Picture which fall upon the Hole in the Screen, and perceive them very distinctly; and, in viewing these, you view the Objects, of Course, to which they belong. ——— You may, by placing yourself behind the Screen, try the Experiment immediately.

Euphros. I see perfectly well the Thing you mention. ——— I see the Man walking by the River-side: ——— I can easily distinguish the Colour of his Cloaths, his various Motions, and, what is very surprizing, he seems extremely near, and walks with his Heels upwards. ——— the same I observe of other Objects,

jects, when I move the Screen to bring them upon the Hole, as you have directed me.

Cleon. Your seeing the Object inverted, or upside-down is a necessary Consequence of your viewing it in its Picture; for the whole Landscape is in an inverted Position, as you see; and therefore every Part, when viewed by the Glass, must appear in the Position it really has, *viz.* upsidedown.

Euphros. This I plainly perceive must be the Case; and I farther suppose, that the Reason why it appears so very near is, also, because its Image, by which I view it, is so very near to the Glass.

Cleon. That is the true Reason which you have assigned; and the Image at that Distance from the Glass, subtending a much larger Angle, occasions your seeing every Part much more distinctly, than it could appear if viewed by the Eye at the Distance of the Glass in the Window; that is to say, it will appear as much larger, and more distinct in the former Case, than in the latter, as the Glass is there in Proportion nearer; for Instance, the Distance of the Eye-glass is but one Inch and a Half from the Image, but the Distance of the Object-glass in the Window-shut in 36 Inches. These two Distances are to each other as 1 to 24, and therefore the Image appears under an Angle 24 Times as large when viewed thro' the Eye-glass, as it does when viewed at the Distance of the Object-glass; and therefore it appears very plainly, from hence, that the Object will be seen under an Angle, when viewed in its Image, 24 Times larger than it appears to the naked Eye, or just so large as it would appear at one 24th Part of the Distance that it is from the Window.

Euphros. Then, if I understand you rightly, an Object at the Distance of 24 Rods, Furlongs, or Miles, will appear as plain in its Image, by Means of these two Glasses, as it would do to the naked Eye at the Distance of one Rod, Furlong, or Mile.

Cleon. That is the very Case: And from hence you will infer, that the Object is not improperly said to be magnified 24 Times. —— Now, from all that we have here done in this darkened Room, the Reason will appear, why those Glasses are put together at each End of a long Tube to render them useful in

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the Form of a Teleſcope, *viz.* becauſe the Space in which the Image of Objects are formed ought to be quite dark, or rather to have no other Light than that which enters the Glaſs and forms the Image of the Object. ——— This will appear by an Experiment; for if I open the other Window-ſhutters (letting that only remain ſhut which holds the Glaſs) then, becauſe the broad Day-light falls on the Screen, the Images of the Landſcape, which before were viewed ſtrong and diſtinct, are now, by this Profuſion of foreign Light, rendered faint, confuſed, and ſcarcely viſible; and when you apply your Eye to the Glaſs, as before, behind the Screen, you ſcarcely perceive the Object for the dazling Light which now overwhelms it.

Euphroſ. Well, let me try this Experiment. ——— I no ſooner apply my Eye to the Glaſs than I perceive the Truth of what you ſay: ——— The Object is loſt, in the Glare of Light, ſo far, that it can ſcarcely be ſaid to appear. ——— I am hereby thoroughly convinced how neceſſary it is to exclude, from the Place where the Images of Objects are formed, all Light, but that which proceeds from the Object itſelf, in order to ſhew it diſtinctly. ——— But one Thing occurs which ſuggeſts the following Query: Pray, if the Hole in the Screen was larger, could I not ſee more of an Object, or more Objects than one, with equal Diſtinctneſs? For I think the View is very much confined by ſo ſmall a Hole.

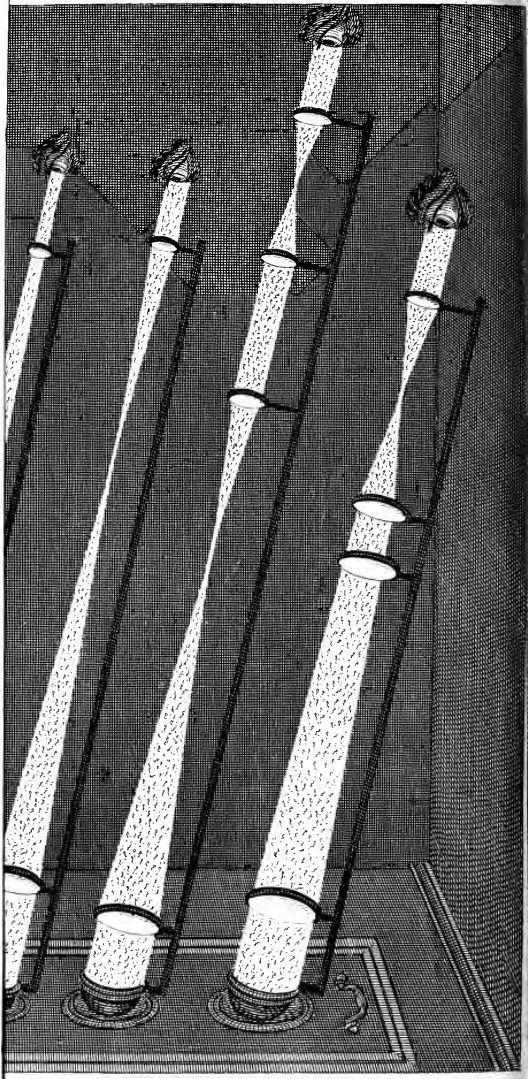
Cleon. Not with the ſame Eye-glaſs, my *Euphroſyne*; for, by Reaſon and Experiments, Opticians are taught to make the Diameter of the Hole about $\frac{2}{3}$ of that of the Eye-glaſs, in order that the Image may appear diſtinct. This Hole is generally called the *Field of View*; and therefore if the Field be enlarged, the Diameter of the Eye-glaſs muſt be enlarged likewiſe, and alſo its focal Diſtance, of Courſe; for if you enlarge the Diameter, or Aperture of the Glaſs itſelf, you may ſoon exeeed the Limit for diſtinct Viſion, ſince every Glaſs has a limited Aperture as well in Teleſcopes as in Microſcopes, as I have before obſerved to you.

Euphroſ. If this be the Caſe, what we gain by having a larger Field of View, we loſe in the Power of magnifying; for ſince the focal Diſtance of the Eye-glaſs muſt be larger, it will not be ſo often contained in that of the Object-glaſs, and conſequently the

the Object, not appearing under so large an Angle, will not be so much magnified as before.

Cleon. With the same two Glasses you cannot enlarge the Field of View, and at the same Time preserve equal Distinctness and magnifying Power: You may, indeed, chuse two other Glasses whose focal Distances are increased in Proportion; for Instance, if the focal Distance of the Object-glass be 6 Feet, or 72 Inches, and that of the Eye-glass 3 Inches, each of them double of what we now use, in this Case the Aperture of the Eye-glass, and of the Hole, may also be enlarged to twice the Dimensions; but then the magnifying Power still remains the same, as also the Field of View; for though the Hole be enlarged, yet, because the Image is enlarged in the same Proportion, no more can fall upon that Hole than falls on this, and consequently no more of the Object can be seen: And if the Aperture of the Object-glass be made twice as large also, then there will be the same Degree of Light, or Brightness in the Object. ——— But one Thing you would observe in that Case, *viz.* that the Object appears more distinctly in all its Parts, for a very small Image will not appear so distinctly as a large One, under the same Angle, and with the same Degree of Light; and therefore the Power of magnifying, by Means of Object-glasses of a larger focal Distance, may be encreased with sufficient Degrees of Brightness and Distinctness of Vision. Thus, for Experiment Sake, I will take that Glass from the Window-shut, and place another in its Room of double its focal Distance, *viz.* 72 Inches; then remove the Screen to the same Distance from the Window, where now you see the Landscape greatly enlarged, twice as much in Length and Breadth, and therefore 4 Times as large in Surface as before; and as the Diameter of the Aperture of this Object-glass is twice as much as that of the former, there will be same Quantity of Light in the Picture; so that each Image is now equally bright as before: ——— Then I apply a Glass of 3 Inch focal Distance behind, which will shew the Object under the same Angle as before, the Hole in the Screen being now twice as large. ——— Go, and apply your Eye to the Tube, my *Euphrosyne*, and tell me how it appears.

Euphros. I will. ——— By what you have said, Things ought to appear nearly the same as before. — But the Scene appears every

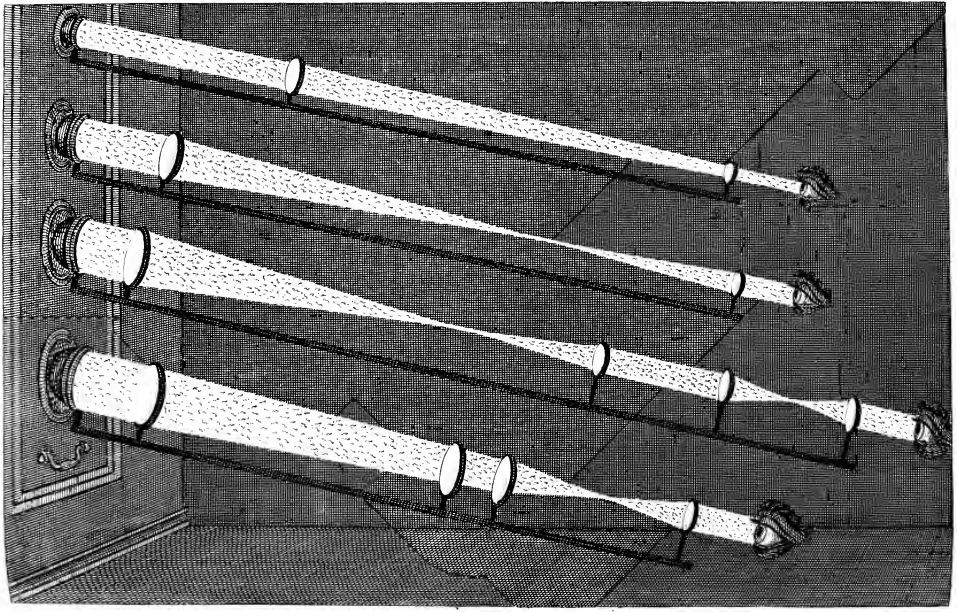


every Way more grand; and I cannot help thinking that the Objects severally appear not only more perfect, but also larger at the same Time.

Cleon. Your Observations are very just, except the last; the Objects are not in Reality magnified: This is a Deception of the Fancy; for we always imagine that the more illustrious any Thing appears, the larger it must be at the same Time.—— That the View of every Part is more perfect, I will allow; for which Reason I shall shew you, by another Experiment, that the magnifying Power of the Eye-glass may be increased, by changing that which is a new One of 3 Inches focal Distance, and substituting another in its Stead of 2 Inches only.——— This is done: Take a View as before.

Euphros. I do; and cannot but say, the Objects appear sufficiently distinct, though magnified much more than before: ——But they appear not altogether so lightsome, or bright.

Cleon. They are magnified now in Proportion as 2 to 72, or 1 to 36; and therefore the Power of magnifying now exceeds that in Proportion as 36 to 24.——— But, whereas you seem to think the Objects are now not bright enough, I must observe to you, that there is really more Light upon the Picture than is allowed of by the Laws of Optics or distinct Vision; for the Aperture of the Object-glass is now twice as large as before, whereas it ought to exceed the Aperture of the former Object-glass, but in the same Proportion as the focal Distance of the present Eye-glass exceeds that before used: That is to say, in the Ratio 3 to $1\frac{1}{2}$, or as 4 to 3. Consequently, it will appear, from all that has been said, that tho' there be an Increase in the Power of magnifying in refracting Telescopes, yet in equal Degrees of Distinctness, a less Proportion of the Apertures in the Object-glass, or of Light in the Picture, will be necessary; and thus we may proceed till, at Length, the Degree of Brightness will become so far diminished as to render the Telescope but of very little Use in viewing terrestrial Objects, whose Light, when they become magnified to a great Degree, will be found too little to shew them sufficiently plain, with those Apertures of Object-glasses which are necessary for distinct Vision.——— Having now explained at large, by these Experiments, the Nature of a refracting Telescope, and shewn that it is nothing more



every Way more grand; and I cannot help thinking that the Objects severally appear not only more perfect, but also larger at the same Time.

Cleon. Your Observations are very just, except the last; the Objects are not in Reality magnified: This is a Deception of the Fancy; for we always imagine that the more illustrious any Thing appears, the larger it must be at the same Time.—— That the View of every Part is more perfect, I will allow; for which Reason I shall shew you, by another Experiment, that the magnifying Power of the Eye-glass may be increased, by changing that which is a new One of 3 Inches focal Distance, and substituting another in its Stead of 2 Inches only.—— This is done: Take a View as before.

Euphros. I do; and cannot but say, the Objects appear sufficiently distinct, though magnified much more than before:—— But they appear not altogether so lightsome, or bright.

Cleon. They are magnified now in Proportion as 2 to 72, or 1 to 36; and therefore the Power of magnifying now exceeds that in Proportion as 36 to 24.—— But, whereas you seem to think the Objects are now not bright enough, I must observe to you, that there is really more Light upon the Picture than is allowed of by the Laws of Optics or distinct Vision; for the Aperture of the Object-glass is now twice as large as before, whereas it ought to exceed the Aperture of the former Object-glass, but in the same Proportion as the focal Distance of the present Eye-glass exceeds that before used: That is to say, in the Ratio 3 to $1\frac{1}{2}$, or as 4 to 3. Consequently, it will appear, from all that has been said, that tho' there be an Increase in the Power of magnifying in refracting Telescopes, yet in equal Degrees of Distinctness, a less Proportion of the Apertures in the Object-glass, or of Light in the Picture, will be necessary; and thus we may proceed till, at Length, the Degree of Brightness will become so far diminished as to render the Telescope but of very little Use in viewing terrestrial Objects, whose Light, when they become magnified to a great Degree, will be found too little to shew them sufficiently plain, with those Apertures of Object-glasses which are necessary for distinct Vision.—— Having now explained at large, by these Experiments, the Nature of a refracting Telescope, and shewn that it is nothing more

than a Sort of portable *Camera Obſcura* in Minuature, I ſhall defer what I have further to ſay, in Relation to the different Kinds and Conſtructions of this Inſtrument, to another Opportunity.

DIALOGUE VII.

On the various CONSTRUCTIONS *of refracting* TELESCOPES.

Euphroſyne.

YOUR laſt Leſſon on the *Nature* and *Rationale* of refracting Teleſcopes, illuſtrated by Experiments of the *Camera Obſcura*, gave me no ſmall Delight, as I am well ſatisfied I could have, by no other Means, acquired ſo good a Notion of this entertaing Inſtrument; ——— I ſee you have here many different Sorts and Sizes upon the Table: I ſuppoſe, *Cleonicus*, they are the various Forms in which refracting Teleſcopes are now made.

Cleon. They are ſo, my *Euphroſyne*; and, that you may have a more diſtinct Idea of them, I ſhall enumerate them according to the different Names they bear, reſulting from their different Structure and Uſes.

I. The leaſt Size of all is called an OPERA-GLASS, from its being principally uſed in the *Opera*, and Play-houſes.

II. The PERSPECTIVE GLASS, which is only the former Glaſs leſs in Diameter, but of a greater Length, and fitted for the Pocket: This is alſo, by Opticians, called *Galileo's Teleſcope*.

III. The *Aſtronomical* TELESCOPE, ſo called, as being chiefly appropriated to celeſtial Obſervations.

IV. The common TELESCOPE, adapted for viewing Land-Objects.

V. *Sea* TELESCOPES, conſtructed for viewing Objects at Sea moſt conveniently.

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There are, beſide theſe, other Conſtructions of this Inſtrument, which are called, *Helioſcopes*, *Polemoſcopes*, *&c.*

Euphroſ. I ſuppoſe the firſt that you mentioned, and called an *Opera-glaſs*, is this very ſhort one, with a broad Glaſs at the End; it ſeems very fit for the Purpoſes intended, as it may be eaſily held in the Hand and applied to the Eye.

Cleon. Yes, my *Euphroſyne*, that is the firſt Sort of proſpective Glaſs, and conſiſts only of two Lenſes, one of which is the broad Glaſs you ſpeak of at the End, called the Object-glaſs, and is a Plano-convex; the Glaſs at the other End is a Plano-concave, and is to be drawn out, or in, by Means of the ſliding Part, or Drawer; by this Means, the two Glaſſes are adjuſted to a proper Diſtance for viewing Objects.

Euphroſ. What are the particular Properties of this Sort of Teleſcope?

Cleon. Firſt, the Concave-glaſs is placed within the focal Diſtance of the Object-glaſs, by juſt ſo much as is equal to its own focal Diſtance; and when they are in this Poſition, the Rays, proceeding from the Object, will, by Refraction thro' this Inſtrument, be made to fall parallel to the Eye, and thereby a diſtinct Image will be formed on the optic Nerve, which is neceſſary for perfect Viſion. —— Secondly, the Object-glaſs at the End has generally a very large Aperture, to give ſufficient Light for viewing the Object, eſpecially as it is chiefly uſed by Candle-light: But for ſtrong Day-light, and viewing Objects enlightened by the Sun, the Aperture at the Object End ought not to be ſo large, as the Object, in ſuch Caſes, is liable to be very much coloured and leſs diſtinct. —— Thirdly, the Aperture of the Concave, next the Eye, is, or ought to be, always ſmall, *viz.* but a little bigger than the Pupil of the Eye. —— Fourthly, as the Eye-glaſs is placed within the Focus of the Object-glaſs, the Length is leſs, for the ſame Power of magnifying, than in any other Teleſcope. —— Fifthly, as there are but two Glaſſes in this Conſtruction, and each of them of the beſt Form, it renders Viſion in this Inſtrument moſt perfect; for that is always more ſo in Proportion, as the Number of Glaſſes are leſs, becauſe, by Refraction at every Glaſs, ſome Irregularities are produced which diſturb the Sight, or render the Image leſs perfect.

Euphrof. When I look through this Glaſs, I can ſcarcely imagine it magnifies at all.

Cleon. That is the Caſe with moſt People when they firſt uſe theſe Inſtruments, they often ſay as you do; nay, ſome of them will affirm, that they can ſee better without the Glaſs than with it: But theſe are all Miſtakes, or Deceptions of Viſion; for theſe Glaſſes, all of them, magnify Objects 3 or 4 Times, and there is no Form of the Eye but what may be aſſiſted by its Uſe, when it is properly applied. ——— The Proportion of magnifying is here the ſame as of the two Lenſes I uſed in the dark Room; for whether the Eye-glaſs be Concave, or Convex, it makes no Alteration in that Reſpect; for the Power of magnifying by any two Lenſes will be proportioned to their focal Diſtances. ——— Thus the Object-lens, here uſed, is 3 Inches focal Diſtance, and the Concave, next the Eye, has but one Inch focal Diſtance: Therefore this Opera-glaſs magnifies in Proportion as *three to one*, or *three Times*.

Euphrof. I muſt not pretend to contradict you; but, really, Objects do not appear to be ſo much magnified to me. Pray, *Cleonicus*, have you no Method by which you can ſatisfy me of the Truth of this by Experiment? ——— You will excuſe my being ſo troubleſome.

Cleon. It always gives me the greateſt Pleaſure to ſatisfy the ſcrupleous Curioſity of Ladies and Gentlemen in this Reſpect: ——— And the Method I take to convince them in general is, that which I have here provided for you; for I foreſaw you would make this Objection. ——— You ſee here, a Piece of white Paper, juſt 3 Inches long, and the Inches defined by two black Lines, ——— I ſtick it up on the oppoſite Side of the Room, for you to view it through the Glaſs, ——— and when you ſee the Paper diſtinctly in the Glaſs, open the other Eye and view it by that, without the Glaſs, and you will obſerve, that one Inch of the Paper, ſeen through the Glaſs, will appear juſt as long as the whole Length of the Paper appears to the naked Eye.

Euphrof. Let me try this Experiment forthwith, as it is ſo very eaſy. ——— I have adjuſted the Glaſs, and can plainly ſee the Paper through it. ——— Now I'll open my other Eye, and direct it to the Paper, ——— and, upon my Word, to my Surprize,

prize, I find the Thing you mention to be fact. ——— I actually see one Inch of the Paper, through the Glass, just covers the whole Length of the Paper as viewed by the naked Eye, and, of Course, the whole Paper appears 3 Times larger with, than without the Glass, which I could not have believed if I had not tried the Experiment. ——— I am, by this Instance, fully satisfied how much we are liable to be mistaken, and to form wrong Ideas of Things, for Want of proper Methods to inform the Judgment. ——— As you have been so obliging as to make me a Present of this curious Opera-glass, please to let me know if there are any Precautions to be given for the Use of it.

Cleon. It will be necessary to observe the following Particulars, ——— First, in adjusting the Glasses, you draw out the Tube to the black Circle which is drawn upon it, and then it is adjusted for Objects at a moderate Distance. ——— Secondly, but if Objects are very near, the Tube must be drawn a little farther out, and, on the Contrary, not quite so far as the Circle, for Objects at a great Distance; but you will never be perfect in the Use of this, or any other Telescope, till you can readily adjust it by moving the Tube forward and backward, while you are actually viewing the Object through it, and stop your Hand when you find the Object appear most perfect. ——— Thirdly, when you have Occasion to take the Glasses out to clean them, you will remember always, when you put them in again, to place the Object-glass with its Convex Part outward, and the Eye-glass with the Concave Part next the Eye, and then it will be always fit for Use.

Euphros. I am obliged to you for these Instructions. ——— But here is the other Glass you called *Galileo's Telescope*, pray, what are the Properties of that Construction, and how am I to proceed in its Use?

Cleon. This is in nothing materially different from the other, but in its *Length*, and *magnifying Power* in Consequence thereof; for as the Object-glass here has a longer focal Distance in Comparison of that of the Eye-glass, it will, of Course, have a *greater* Power of magnifying in Proportion. ——— This, which I here present you with, is a proper Size for the Pocket, and will magnify sufficiently for common Use. The Object-glass is 12 Inches

ches Focus, and magnifies the Object about ten Times: But there will always be an Inconvenience attend the great Length of an Inſtrument of this Kind, *viz.* the Smallneſs of the Field of View, which is here proportioned to the Area of the Pupil of the Eye, and therefore, when it magnifies much, the Field of View will be but ſmall, and render it more difficult to find the Object, and leſs pleaſant to view it: ——— Were it not for this Impediment, no Teleſcope would ſhew diſtant Objects ſo perfectly as this, on Account of there being but two Glaſſes in the Conſtruction. ——— But in Caſe the diſtant Objects be very ſmall, ſuch as the heavenly Bodies are in Appearance, then *Galileo*'s Teleſcope is applied oftentimes to very good Purpoſe; for, with that, the Sun, the Moon, and the Planets will be magnified very conſiderably in a Length of 18 Inches, or two Feet, even ſo far as to ſhew *Jupiter* and his four Moons, which cannot be done with other refracting Teleſcopes of leſs than twice that Length, but even in viewing the celeſtial Bodies, if we proceed to great Lengths in the *Galilean* Teleſcope, the Difficulty of finding the Object will fruſtrate our Deſigns, and oblige us to have Recourſe to the other Forms of Teleſcopes, next to be conſidered.

Euphroſ. I think the firſt of them you call the *aſtronomical Teleſcope*, as being deſigned for viewing the heavenly Bodies only?

Cleon. Yes: that is the firſt and moſt ſimple Conſtruction of Teleſcopes compoſed of convex Lenſes only, of which there are but two or three at moſt. ——— But, as in theſe Sort of Teleſcopes there is a real Image formed of a diſtant Object in the Focus of the firſt, or Object-glaſs, which Image is viewed by the Eye-glaſs in the Manner I ſhewed you in the darkened Room, it is evident, that this Inſtrument ſhews all Objects in an inverted Poſition, and therefore not fit for common Uſe, as I then obſerved to you; but the heavenly Bodies being of a round, or circular Form, the Inverſion of ſuch a Figure is no Diſadvantage to the View; and ſince the Appearance of an Object thro' two Glaſſes is moſt perfect, and the Moons of *Jupiter* and *Saturn* require the moſt perfect Conſtruction to ſhew them, this Teleſcope is preferable to all others on this Account, as the Field of View is large, and the Object found with Eaſe. ———

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In this Teleſcope one Object-glaſs is ſufficient, tho' in ſome Reſpects, two may do better. ——— There is alſo, generally ſpeaking, but one Eye-glaſs uſed; but it is certain, from the Laws of Optics, that two Glaſſes properly combined will ſhew the Image (and conſequently the Object) more perfectly than one alone.*

Euphroſ. I remember you told me the magnifying Power, by Means of theſe two Glaſſes, was in Proportion of their focal Diſtances: ——— But one Thing I am not quite ſo clear in, is, the Reaſon why the Images of Objects are inverted in the Focus of the Object-glaſs, and whether there be not any Method to prevent that diſadvantageous Effect?

Cleon. The Reaſon why the Image of an Object is inverted by a Glaſs you will readily perceive, when you conſider, that every Point of the Image is depicted by a Ray of Light coming from the Object in a right-lined Direction thro' the Centre of the Glaſs; from whence it will follow, that thoſe Rays of Light which come from the upper Part of an Object muſt, after paſſing thro' the Center of the Glaſs, go to the lower Part of the Screen, and there paint the Image of the upper Part of the Object. ——On the other Hand, the Rays which come from the lower Part of the Object, after paſſing thro' the Center of the Glaſs, go to the upper Part of the Screen, and there form an Image of the inferior Parts of the Object: ——— And, by the Laws of Refraction, all other Rays which proceed from the ſame Points in the upper, or lower Parts of the Object, to any Part of the Lens, will be refracted to the ſame Points of the lower, or upper Part of the Image, and there unite with thoſe Rays which paſs through the Center of the Glaſs; conſequently, the Image, by Means of the Rays croſſing each other in the Glaſs, muſt neceſſarily be formed in an inverted Poſition, and which, you remember, was univerſally the Caſe in all ſingle Lenſes you tried in the former Experiments.

Euphroſ. I remember this to be fact in every Inſtance I tried, and, as it is a great Imperfection in the Teleſcope, could it not be removed by applying another *Object-glaſs?*

Cleon. By no Means: Any Number of Object-glaſſes will form

* For the Demonſtration of this phyſical Problem in Optics, ſee my *New Elements of Optics*, p. 33, 34.

form an Image in the same Manner, as one alone: — But the Image will still be inverted, and only lessened in its Dimensions; so that no Redress for this Evil can be had from thence. ——— Yet are we not destitute of a Remedy, which is found in the Construction of the common Telescope, and is what I next propose to explain, after having proposed to you one Thing more, which is, the Reason why the Construction of the Telescope under Consideration, is also sometimes called the *Night Telescope*; for when the Aperture of the Object-glass is very large, and the Glass itself of a short focal Distance, as 8 or 10 Inches only, then the Field of View will be very large, and by Night, at Sea, there will be Light enough in the Atmosphere, and by Reflection from the salt Water, to enter through so large an Aperture as will be sufficient to shew Objects, on the Surface of the Sea, at a considerable Distance; at least, much better than they can be discerned by the naked Eye, and thereby such a Telescope becomes of general Use at Sea. ——— But when the focal Distance of an Object-glass is short, and so large an Aperture used, it becomes necessary to use two Object-glasses, that the Errors of Refraction, arising from the Convex Figure, may be in some Measure corrected, and Vision thereby rendered more distinct. ——— And in the largest Sort of Night Telescopes, where the Aperture is very large, no less than 3 Object-glasses are necessary to form the Image, on that Account.

Euphros. 'Tis easy to observe in this, as in many other Cases, that Necessity is the Mother of Invention; and had you not given me this *Rationale* of it, I should have thought you had jested with me, in talking about a Night Telescope, as it is well known, by Experiment, that every Telescope makes the Object appear less lightsome than it appears to the naked Eye, and therefore it should seem a Contradiction to have a Telescope for viewing opake Objects by Night. ——— I suppose, the Telescopes I here see of different Sizes are all *Day Telescopes* of the common Forms in Use?

Cleon. They are, my *Euphrosyne*; but some of them have more Glasses than others, and all of them shew the Object upright, or in its natural Position: But the least Number of Glasses, in any of them, is four. ——— You see, here is one at the Object

ject End, ——— and in the Drawer next the Eye, you obſerve this Tube with three Glaſſes is contained.

Euphroſ. So that in all the four-glaſs Teleſcopes I obſerve there are three Eye-glaſſes, and one Object-glaſs; but, pray, why are three placed next the Eye, *Cleonicus?*

Cleon. That you may have a clear Idea of this Matter you are to conſider,

(1.) That the firſt Image is formed in the common Focus of the Object-glaſs, and the firſt of the three Eye-glaſſes; and therefore,

(2.) The Rays which proceed from this Image to the firſt Eye-glaſs, are, after Refraction through it, rendered parallel among themſelves; and, conſequently, if they fall upon a ſecond Glaſs, placed at a Diſtance behind it towards the Eye, they will be all converged to a Point in the Focus of that Glaſs, and, for this Reaſon,

(3.) Rays thus proceeding from every Point in the firſt Image will, by Refraction through the two firſt Eye-glaſſes, form an Image at a proper Focus which will be every Way ſimilar to the firſt Image.

(4.) The two firſt Eye-glaſſes being placed at double their focal Diſtances from each other, will then have the moſt proper Poſition for producing the Effect; becauſe then the Rays that proceed from contrary Sides, in the firſt Image, through the firſt Eye-glaſs, will be ſo refracted as to croſs each other in its Focus, and conſequently fall upon the ſecond Eye-glaſs in a Manner juſt contrary to that in which they proceed from the firſt; and therefore the Image formed by Refraction through the ſecond, or middle Glaſs, will be in a contrary Poſition to the firſt Image, and therefore in the ſame Poſition with the Object itſelf. Hence,

(5.) An Image of the Object being now formed upright, that Image is ſo viewed by the third Eye-glaſs, or that next the Eye, which, for that Reaſon, muſt be placed at its focal Diſtance from it, that the Rays may proceed parallel to the Eye.

(6.) The three Eye-glaſſes are all of them of one and the ſame focal Diſtance, and therefore the Diſtance between each of them will be the ſame, as you ſee they are placed in this Tube.

(7.) Upon this Account it is evident, that the ſecond Image is viewed under the ſame Angle by the third Eye-glaſs as the firſt Image appears under when viewed by the firſt Eye-glaſs; and therefore the Power of magnifying is the ſame with three Eye-glaſſes as it was with one in the aſtronomical Teleſcope.

(8.) In the Place where the ſecond Image is formed is a Diaphragm, or round Hole in a Piece of Wood, or Braſs, of a Size ſomewhat leſs than the Area of the Eye-glaſſes, in order to ſhut out all the extraneous Rays, or to ſhew that Part of the Image only which is ſufficiently perfect for View.

(9.) And where great Nicety is required, there is alſo a Diaphragm with a ſmall Hole, of a proper Size, to be placed in the common Focus between the firſt and ſecond Eye-glaſſes; and if the firſt Image were circumſcribed by a proper Aperture in another Diaphragm, it would tend to render Viſion through a Teleſcope ſtill more perfect.

(10.) And laſtly, the Field of View in this Sort of Teleſcope is the whole Area, or Aperture of the Diaphragm next the Eye, and therefore as much larger than what you have in the *Galilean* Teleſcope, as the ſaid Aperture here is larger than the Pupil of the Eye. ——— And ſuch is the Conſtruction and *Rationale* of the common refracting Teleſcope, which you, nor no one elſe could properly comprehend without actually viewing the ſeveral Parts of the Inſtruments themſelves.

Euphroſ. I am thoroughly ſenſible of that; for it is here as with the Microſcopes, unleſs we ſee the Form and Poſition of the ſeveral Parts ſeparately, it is impoſſible to have an adequate Idea of the joint Effect of the Whole, in the Structure of Inſtruments. ——— And, after all, I find that this refracting Teleſcope does nothing more than the former, but *ſhew the Object upright*, which is certainly a very great Improvement upon the *Galilean* Teleſcope, in regard to the Amplification of the Field of View. ——— But at preſent I muſt deſiſt, to attend another Engagement, and will give you the Trouble to proſecute what remains, relative to this Subject, at our next Leiſure.*

DIA-

* *N. B.* The Teleſcopes deſcribed in the above Dialogue I have thought proper to illuſtrate by a Copper-plate, repreſenting the Sun-Beams

DIALOGUE VIII.

The NATURE *and* CONSTRUCTION *of refracting* TELESCOPES *continued.*

Euphrosyne.

I Am now ready to attend you, *Cleonicus*, in what you have further to say upon the Subject of refracting Telescopes. —— You have already described to me the four principal Forms, the last of which was one of four Glasses; but I remember you said, there were other Telescopes that had more than four Glasses; please to let me know what Purpose the additional Glasses answer?

Cleon. In some there are five, and in others there are six Glasses, which are principally intended to *enlarge the Field of View*, and to render the Image more perfect towards the extreme Parts: The Disposition of the Glasses is different in many of them; but, in general, it is the same as what you see in this, which I here put into your Hand: —— And that you may see the Difference between this, and a four-glass Telescope of the same Length, you have now an Opportunity of viewing the Cross, the Globe, or Ball, and the Dome of St. *Paul*'s, the Sun lying advantageously upon them.

Euphros. These Telescopes, I see, are about three Feet in Length, and I shall gladly experience their Difference. ——

Beams entering through Scioptric Balls into a darkened Room, and refracted through the Object-glasses of Telescopes fixed in circular Frames, perpendicularly, on long Pieces of Wood screwed on to the said Balls; and at the other End of the said Pieces of Wood are placed the Eye-glasses, at proper Distances from the Object-glasses, and from each other; by which it appears, that each Telescope produces the same Effect of refracting the Rays to proper Focuses, and, at last, rendering them parallel to the Eye, by which distinct Vision is produced. The first, or uppermost of these, represents the Glasses of the *Galilean* Telescope. —— The Second, the astronomical Telescope. —— The Third is the four-glass Telescope. —— The Fourth is the Night-Telescope. If the Glasses of any of these Telescopes were to be thus placed in a darkened Room, the Beam of the Sun's Light would pass through them in the same Manner as here repre-

Firſt, I will take the four-glaſs Teleſcope, —— with this I ſee the golden Croſs, curiouſly wrought, and very large and diſtinct. —— The Ball appears very grand, as well as globular, with curious Workmanſhip, —— and the Golden-gallery appears like what it is when we are upon it: I can eaſily diſtinguiſh Men and Women, their different Habits, Colour of their Cloths, ſome of them walking, and others leaning over the Palaſades. —— The Dome appears to be a glorious *Rotundo*, and every other Part, in Proportion, exhibits an agreeable Spectacle. —— I will now take the Teleſcope with ſix Glaſſes, —— and, in viewing the ſame Objects, I perceive a Difference in the Extent of the View, which is certainly here much larger and finer than before; but, at the ſame Time, I do not think the ſeveral Parts appear ſo very diſtinct as in the former, —— and, on that Account, I really do not know which of the two I ſhould chuſe.

Cleon. You need give yourſelf no Trouble about that, my *Euphroſyne*; for I ſhall make you a Preſent of them both: —— They have each their peculiar Advantages, and you never will find any one Inſtrument in which the different Perfections of various Forms can be all united.

Euphroſ. I readily believe what you ſay: But what are thoſe long Teleſcopes in Mahogany, and coloured Wood? —— Are they not what you call *Sea-Teleſcopes*, *Cleonicus?*

Cleon. Yes, my *Euphroſyne*, they are, and uſed chiefly by Maſters of Veſſels, and other Sea-faring People, for as they are all in one entire Length, they give them no Trouble, and require no Time in applying them to uſe: This renders them more fit for their Purpoſe, who oftentimes have not a Moment to ſpare, when their Uſe is required, for viewing a Ship, Headland, Lights, *&c.* at the firſt Appearance. Add to this, that Vellum, or Parchment Tubes, of which common Teleſcopes are made, will not bear the Action of a ſaline Atmoſphere, which ſoon diſcolours them, deſtroys their Texture, and renders them unfit for Uſe, unleſs they are taken very great Care of indeed, and kept in proper Caſes.

Euphroſ. But I ſee here a Teleſcope ſomewhat different from the former, eſpecially at the Object-end, the Braſs-work

of

of which I perceive to be of a square Form; to what Purpose does that serve, *Cleonicus?*

Cleon. That Object-end of the Sea-Telescope is made in the Form of a Dye, on Account of its holding two Glasses; either of which may be immediately applied, as an Object-glass, by turning the Piece round in which they are contained, which is done in an Instant, by a proper Mechanism in that Part; by this Means you have, as it were, a double Telescope in one Instrument; for the Glasses being of a different focal Distance, and the Brass Tube being made to draw out at the Object-end as well as the Eye-end, the Telescope may be lengthened, or shortened, at Pleasure, according to the Object-glass that is used: ——— But when we consider, that such a Telescope becomes, by this Construction, so expensive, as to equal the Price of three very good single Telescopes, at the same Time each of which may have a different Power of magnifying, it appears to me to be a very preposterous and an injudicious Contrivance, and, as such, deserves no further Notice.

Euphros. There is yet another Telescope which makes a considerable Appearance, concerning which you have not said any Thing. Pray, is the internal Structure of this different from any of the former, as I see nothing different in its external Form?

Cleon. This is a Patent Telescope, and different from others in having a double Object-glass, one Convex and the other Concave, placed contiguous to each other in the same Cell: The spherical Figure of which is different in each, and the Design of such a Combination of Glasses is, that one may correct the Errors of the other, in regard to the colorific Refraction of Light; for whereas you have been taught by prismatic Experiments, that Rays of Light have different Degrees of Refrangibility, and I have not long since observed to you, that this is one great Cause of the Imperfection of refracting Telescopes with a single Object-lens of a Convex Form, therefore this Concave is added to correct this Aberration of Rays, and to render the Image of external Objects more perfect and uniform.

Euphros. And do those two Glasses answer such a Purpose in a most sensible Degree?

Cleon.

Cleon. You will have no Occaſion to take my Word, or Opinion, about this Matter, becauſe you may try the Experiment yourſelf, and ſee the Difference betwixt this and another of the ſame Length and magnifying Power. ——— I have here contrived to place them both in a Poſition, to view the ſame diſtant Object, which happens very *apropos* to be the Croſs on the Top of St. *Paul*'s in a direct View.

Euphroſ. The Croſs makes a very curious Spectacle; and I obſerve, very plainly, that there is a Difference, but not ſo great as I ſhould have imagined, from the very great Difference which you mention in the Price of theſe two Teleſcopes. ——— There is *(je ne ſcai quoi)* ſomething which I cannot well expreſs, in the Effect of this Teleſcope. ——— I ſee the Croſs and its Parts more perfectly in one reſpect, yet not ſo much ſo in another. ——— But there ſeems to be ſo much of Ambiguity in the different Effects of theſe Teleſcopes, that I muſt be longer exerciſed in the Compariſon of them before I can pretend to form any adequate Notion of their reſpective Merits, or how much one is preferable to the other.

Cleon. Moſt People, who have uſed this Teleſcope, are of the ſame Sentiments with yourſelf; and the Reaſon why the Effect of preventing the colorific Refraction is not ſo great as one might expect, is, as far as I can judge, owing to an unlucky Accident in this Compoſition of Glaſſes; for at the ſame Time as the Concave-glaſs corrects this Error in the Refraction of the Convex one, it increaſes another which reſults from the Figure of the Glaſſes. ——— Beſides, you will obſerve, that, in the Structure of each of theſe Teleſcopes, there is the ſame Tube of five Glaſſes next the Eye; from whence it is evident, that the Rays of Light, coming from the compound Object-glaſs, will be incident on the firſt of theſe Glaſſes, before they arrive at a Focus, and are refracted by it to a new Focus; and by this ſecond Refraction it muſt neceſſarily follow, that there will be, in ſome Degree, a Diſſipation of the Rays, and a proportional Imperfection of the Image which is formed in the Focus, common to all the *three Glaſſes*, and not to *two alone*, as People in general think. ——— In the laſt Place, you, or any one may judge, what the Perfection of that

that Vision of Objects must be that is effected by *Seven* Glasses, when you have been so clearly convinced that Objects always appear more distinct as the Number of Glasses is *less*, by which they are shewn.

Euphros. I am fully satisfied in that Particular; ——— but, pray, what is that particular Construction of a Telescope you call a *Polemoscope?*

Cleon. By that Term is meant, a Telescope, at the Object-end of which is fitted a very curious reflecting plain Speculum at half a Right-angle to the Axis of the Telescope, which is directed to the middle Point of the said Speculum, as you observe in this Part which I screw off and on.

Euphros. But what is implied in the particular Etymology of the Word?

Cleon. The Name implies an Instrument of the Telescopic-kind, for the Uses *of War*; that is to say, such as the Generals, or Officers concerned in Sieges, Fortifications, *&c.* have often Occasion to use: For, in many Cases, besides a direct View strait forward, they have often Occasion to see what is doing by Persons on either Side, above, or below the Place where they stand, and which, with this Contrivance, they can easily command a View of; for, as you turn the Glass in your Hand, you take in all Objects in a lateral Situation, or such as are placed Side-ways, and cannot be seen by a common Telescope. ——— If you turn the Speculum downward, you see all below; ——— if you turn it upwards, the Top of the Buildings, and the People there, are exposed to your View: And thus the Actions of the adverse Party may be reconnoitred, while they think themselves quite secure from your Notice.

Euphros. Why, after all your learned Terms, I find that this high-sounding Instrument is nothing more than the common Opera-glass, which a Lady of my Acquaintance shewed me the other Day, having a Hole on each Side, in which there appears a plain Looking-glass adapted to each End, and by which she could take a View of any Person she pleased without his having the least Suspicion of it, as the Glass was directed quite another Way. I cannot say but I was very much pleased with the Effect, and wished for such a one of my own.

Cleon.

Cleon. Then here you have your Wiſh, my *Euphroſyne*; for I have deſignedly procured ſuch a ſmall colateral Opera-glaſs on Purpoſe to exemplify the Uſe of the other more at large, ſince Side-views may oftentimes be agreeable and uſeful to the Fair-Sex, as well as neceſſary to military Officers. Thus, both the one and the other you have in your Poſſeſſion, to uſe at your Pleaſure.

Euphroſ. You will greatly enrich me with an Apparatus of ſuch curious Inſtruments. —— But I remember, in the laſt Place, you mentioned another Sort of optical Inſtruments, you called HELIOSCOPES, pray, what are they?

Cleon. They are ſtill of the Teleſcope Kind, and are ſo contrived as to give a very pleaſant and inoffenſive View of the Sun, whoſe ardent Luſtre is much to great to admit him an Object of the common Teleſcope. —— It is neceſſary, one Way or other, to weaken, or obſcure his Rays, that our Eyes may behold the moſt illuſtrious Object of Nature; —— there are many Ways of doing this, the moſt common is, to hold one of the Eye-glaſſes of a common four-glaſs Teleſcope over the Flame of a Candle till it is thereby rendered ſufficiently black, to view the Diſk of the Sun without hurting the Eyes, which will do pretty well for common Uſe: —— Another Method is, by placing a Piece of ſtained Glaſs, of a very deep, dark Colour, in the Braſs Cell next the Eye, which will anſwer the ſame End and with leſs Trouble: —— But the beſt, and moſt perfect Method of making a Helioſcope is, to weaken the Rays of the Sun by many Reflections, forward and backward, from Surface to Surface of a proper Number of plain, poliſhed Speculums, till, at laſt, they are rendered ſo faint, that the Eye may ſuſtain their Effect without any Trouble or Inconvenience, and the Face of the Sun will appear, in this Way, ſo very ſerene and diſtinct in every Part, that the *Maculæ*, and *Fæculæ*, *i. e.* the dark Spots, and the brighter Parts above them, will, this Way, appear to the greateſt Perfection: This is one of the many celebrated Inventions of the late Dr. *Hooke*.

Euphroſ. The Subject of Teleſcopes, I find, is very extenſive, and admits of great Variety —— Are there any other Forms or Denominations of this Inſtrument which remain to be conſidered?

Cleon.

Cleon. Yes; one very material one, called the *ſolar Teleſcope*, and which will afford you no ſmall Amuſement at your leiſure Hours, in a darkened Room. ——— This Inſtrument is no other than a *Galilean* Teleſcope, ſcrewed into a ſcioptric Ball, moveable in its Socket, faſtened to the Window-ſhut. ——— Walk but into the little Parlour, which is already darkened, and there you will ſee its delightful Effects.

Euphroſ. And what am I to ſee now I am here, *Cleonicus?* At preſent I obſerve only a Beam of the Sun's Light coming thro' the Inſtrument.

Cleon. That Beam of Light is to paſs through this ſmall proſpective Glaſs, when ſcrewed into the Hole of the Ball, and in ſuch a Manner, that when they Rays proceed from it they will form a very large and beautiful Image upon the Screen, which you there ſee placed on purpoſe to receive it. ——— I have now ſcrewed it on, and you obſerve the Effect of it as a Helioſcope; for this is one of thoſe Helioſcopes which Dr. *Hook*, in his Treatiſe on this Subject, recommends, and it is, in his Opinion, the beſt Method of forming the Sun's Image.

Euphroſ. I cannot but admire the Effect of it, in producing ſo curious a Picture of the Sun: ——— How large and well defined a Circle it makes, ——— in its own native and pure white Light! ——— The Spots, how plain and diſtinct they appear! ——— and the Clouds, how quick and how natural they are in Motion, upon the Sun's Diſk! ——— I think this is every whit as perfect as that which I ſaw by the reflecting Teleſcope ſome Time ago, which you purpoſely contrived to oblige me with an artificial View of the Tranſit of *Venus*: ——— But now the Time is at Hand, when we are to view that glorious Phænomenon in Reality, will not this Experiment, by *Galileo*'s Teleſcope, be ſufficient to anſwer that Purpoſe?

Cleon. If not the moſt perfect and ready Way of exhibiting that Phænomenon, it ſeems to have been this very Method that Mr. HORROX himſelf made uſe of, to obſerve the Tranſit of *Venus* in 1639; *for he tells us, he obſerved the Planet* Venus *on the Face of the Sun, by Means of his Teleſcope, in his darkened Chamber.* Now, there could be no Neceſſity for his darkening the Room for obſerving the Sun, by a Teleſcope, any other Way than

this; nor is it in any Degree neceſſary even here, but only for greater Diſtinctneſs; for, at the Time of the Tranſit, the Planet will be ſeen ſufficiently plain, as you may judge by the Appearance which the Spots of the Sun now make when I open the Window-ſhutters and let the Light into the Room. ——— I have now opened the Window, that you may ſee the Experiment both Ways, *viz.* in the darkened and enlightened Room, at once.

Euphroſ. I am fully convinced, by this Experiment, that ſcarce any thing more is neceſſary to ſhew the Spots upon the Sun, than only ſome Contrivance to keep off the Sun-beams, and the direct Light from falling upon the Screen, in any Sort of Teleſcope or Helioſcope whatſoever. ——— Would not this be a very good Way, *Cleonicus*, to obſerve a ſolar Eclipſe?

Cleon. The laſt conſiderable Eclipſe of the Sun I ſhewed this Way, to a great Number of Spectators, who were all greatly pleaſed in viewing it in ſo advantageous, and, at the ſame Time, ſo inoffenſive a Manner: And thus, alſo, you may view the approaching great Eclipſe in 1764. ——— But for my own Part, when I want to ſatisfy my Curioſity with a View of the ſolar Spots, &c. I give myſelf no trouble in darkening of a Room, but do it either by the reflecting Teleſcope, in the Manner I formerly ſhewed you, or elſe by this ſmall Teleſcope, in a Ball and Socket, fixed to a Board, which I place near the Side of a Table on a proper ſtand, and, as it darkens the Screen, gives me an Opportunity of viewing the ſolar Diſk, Spots, and Clouds, juſt as you now obſerve.

Euphroſ. I ſee you have many Inventions to gratify the few who have any Taſte for natural Curioſities, or think it worth while to obſerve the Wonders of Nature.

Cleon. You have as yet ſeen but one Part of thoſe optical Inſtruments, we call Teleſcopes; but there is another Sort yet, more perfect than theſe, which we call reflecting Teleſcopes, the external Form of which you are no Stranger to; but the Nature and Structure of this Inſtrument being very peculiar and delicate, I ſhall endeavour to give you an Idea of it the next

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Opportunity we have to converſe upon theſe Subjects, together with ſome Account of their Origin and Invention.

DIALOGUE IX.

Of the NATURE, ORIGIN, CONSTRUCTION, *and* USE *of reflecting* TELESCOPES.

Cleonicus.

IN our former Converſation, I have obſerved to you a very material Defect in the Nature of refracting Teleſcopes, *viz.* that they refract not all the Rays of Light to a ſingle Point, as they ought to do, for the Perfection of Viſion, both on Account of the Figure of the Lenſes, and of the different Refrangibility of the Rays of Light; and, in the very great magnifying Powers required for celeſtial Obſervations, their great Length renders them unweildy, and conſequently very inconvenient for Uſe: And this proved the general Reaſon for the Invention of Teleſcopes by Reflection, which are, generally ſpeaking, called CATOPTRIC TELESCOPES.

Euphroſ. I remember you have often mentioned this Affair: But let me aſk you one Queſtion concerning long Refractors. Pray, have not all the Skill and Ingenuity of Opticians been able to contrive a Contraction of their immoderate Length, ſo as to render them more eaſy to be uſed?

Cleon. Many Attempts of this Kind have been made; but the moſt remarkable were thoſe invented by Dr. *Hook*, under the Name of HELIOSCOPES, which he effected by various Reflections, from plain Speculums which he placed in a long ſquare Tube; ſo that if theſe Reflections were made from End to End, he ſhews (to uſe his own Words) how $\frac{4}{5}$ of the Length of the common Tubes may be taken away by four Reflections. —— But we do not find that this ingenious Invention of the Doctor's ever obtained ſo far as to be of general Uſe: It is probable it might be owing to the imperfect Manner of making and po-

liſhing the Speculums 100 Years ago; and that if the ſame Method were to be now revived, it might be attended with better Succeſs: But this only by-the-bye. ——— Reflecting Teleſcopes are undoubtedly the beſt *Succedaneum* to Refractors.

Euphroſ. Pray, who was the firſt Inventor of Teleſcopes by Reflection?

Cleon. The firſt who has given us any direct Account of this excellent Invention was, Dr. *James Gregory*, in his Book entitled *Optica Promota*, which was printed in the Year 1663. He has there (Page 94,) given us a Figure of the ſaid Teleſcope, very much the ſame Form with thoſe we have now in Uſe, *viz.* conſiſting of one large, and one ſmall reflecting concave Speculum, and one Lens in a Piece at the End, whence it will appear with how much Propriety this Form is called, the *Gregorian* Teleſcope. But with Regard to the great Speculum in this original Teleſcope, it ſeems to have been made of Glaſs, and was of a *parabolical* Figure. The ſmall Speculum, he tells us, was *elliptical*; but afterwards he allows, that, conſidering the Difference of acquiring theſe Figures mechanically, Speculums of a ſpherical Form will do very well.

Euphroſ. I always had a Notion, that Sir *Iſaac Newton* was the Inventor of the reflecting Teleſcope: Pray, is not this the common Opinion?

Cleon. Moſt People have ſuch a Notion; but it rather proceeds from his Improvement, or the Method which he took to bring them into common Uſe: For that great Man did, for a long Time, labour with his own Hands, both in grinding Mirrors, in Metal and Glaſs, of a ſpherical Form, and conſtructed a Teleſcope with Speculums of his own Working; and, laſtly, gave a general *Rationale* of the Whole: From whence the World was firſt taught the Nature of Viſion by Reflection, and how much it is preferable to that by Refraction; and therefore the THEORY of the Inſtrument, eſpecially the comparative Part, we owe to Sir ISAAC NEWTON.

Euphroſ. Pray, wherein does the great Excellency of a reflecting Teleſcope conſiſt?

Cleon. In this one Particular, that ſince (as I heretofore ſhewed you) the Angles of the incident and reflected Ray are ever equal,

equal, therefore Rays of every different Sort falling upon a Speculum, very near to its Axis, will all be reflected to one Point therein, at leaſt ſo nearly, that the Difference is not ſenſible in any Experiments of Viſion; and therefore all that Imperfection ariſing from the colorific Quality of Rays, in refracting Teleſcopes, has here no Place; nor is the Error, from the Figure of the Speculum, any Thing like ſo great as that from the Figure of Lenſes: Theſe Teleſcopes, therefore, are as perfect in their Nature as any Thing of this Kind can be.

Euphroſ. Methinks I ſhould be very glad to have an Idea of the particular Manner in which Viſion is produced, or the Object formed in a reflecting Teleſcope.

Cleon. I will give you as particular Account thereof as poſſibly I can, and illuſtrate each Part by an Experiment.

Firſt, with reſpect to reflected parallel Rays, you muſt know that their Focus, or Point, where the Image is formed, is juſt a fourth Part of the Diameter of a Sphere, of which the great Speculum is a Segment. Thus, for Inſtance, you ſee a metaline Speculum, which I take out of this Reflector, and holding it in the Sun-beams, they are all reflected to a Focus, at 9 Inches from the Speculum, as you ſee meaſured by the common Foot-rule; and therefore the Diameter of the concave Sphere, of which this Speculum is a ſmall Portion, is 4 Times 9, or 36 Inches in Diameter.

Euphroſ. All this I perceive very plainly; and the Image of Objects formed by ſuch a Speculum is, I ſuppoſe, equal to that made by a Lens of 9 Inches focal Diſtance.

Cleon. It is ſo; and ſince the Image and Object both appear under the ſame Angle from the Vertex of the Mirrour, we may reckon the magnifying Power, by the firſt Reflection, to be 9 Times: Which may be demonſtrated after the ſame Manner as I formerly ſhewed by Lenſes, which I ſhall likewiſe now ſhew you by Experiment. For the ſmall Speculum, which you obſerve at the other End of the Tube, has its focal Diſtance juſt one Inch, and therefore if placed juſt 10 Inches from the great Speculum, by Means of the Wire-ſcrew at the Side of the Teleſcope, then will the Image be in the common Focus of both the Speculums; the Rays therefore which proceed from the

Image

Image to the ſmall Speculum will be reflected by it, parallel among themſelves, through the Hole of the large one; and therefore, if your Eye be placed in thoſe parallel Rays, you will ſee the Object moſt perfectly in the ſmall Speculum, and magnified in Proportion to the focal Diſtances of the two Metals, that is to ſay, as 9 to 1. ——— I will take off the Eye-piece, then apply your Eye to the Hole, and turn the Screw till you ſee the Object plain.

Euphroſ. Let me try this Experiment; ——— I do as you direct me; ——— at length I ſee the Object very diſtinct, very perfectly, indeed: ——— But I ſee no more than what is in the Face of the ſmall Metal, and therefore the Field of View is very ſmall: ——— I alſo obſerve it is magnified; but I ſhould not have thought it was 9 Times larger than the Object. ——— I likewiſe ſee every Thing upſide down. ——— On all which Accounts, this ſeems not to be the beſt Method of viewing Objects.

Cleon. You are ſo far right, my *Euphroſyne*; the Field of View muſt neceſſarily be ſmall, as the Eye muſt be placed ſo far from the ſmall Speculum; ——— the Image muſt neceſſarily be inverted, as the Rays croſs each other in the common Focus of the Mirrors: ——— But your imagining the Object not to be ſo much magnified, is one of the moſt uſual Fallacies of Viſion; for the Objects muſt ever be magnified in the Proportion of the focal Diſtances of the Mirrours. ——— The two Metals, as they are thus combined, are exactly analagous to the aſtronomical Refractor, except, that in the latter, your Eye may be placed near the ſmall Lens, and by that Means you have an amplified Field of View.

Euphroſ. The ſmall Braſs Tube that you ſcrewed off, and which you called the Eye-piece, ſeems neceſſary to render this Inſtrument compleat; but in what Reſpect it is ſerviceable to this End, you will pleaſe to let me know, *Cleonicus?*

Cleon. I will: ——— This brings me to conſider the ſecond Part, or Effect of this optical Machine, which, you are to know, is intirely of the Microſcopic-kind: For the ſmall Image, formed by the great Speculum, is ſo perfect by Reflection, that it will bear to be magnified a ſecond Time by the ſmall Speculum,

lum, and therefore may now be conſidered as a *Microſcopic Object:* Beyond which, if the ſmall Speculum be placed (by Means of the Wire-ſcrew) a little more than its proper focal Diſtance, then the Rays, which fall on it from the firſt Image, will not now be reflected *parallel*, as before, but *converging* to a Focus in the Axis of the Teleſcope produced; for which Purpoſe, you ſee it is neceſſary there ſhould be a Hole in the great Mirrour for thoſe reflected Rays to paſs through. —— In the Point where the Rays are united, there will be a ſecond Image formed from the Firſt, and as much exceeding the Firſt in its Dimenſions of Length and Breadth as it exceeds it in Diſtance from the ſmall Speculum; and therefore you will eaſily obſerve, that the Effect of the Teleſcope in this Part is quite analogous to the compound Microſcope, whoſe Conſtruction I heretofore explained to you.

Euphroſ. I think, in a general Way, I conceive the Reaſon of all you ſay very well; but ſhould be glad if you could familiarize it to me by Experiment.

Cleon. That I can very eaſily do. —— I place the Tube of the Teleſcope in the Direction of the Sun-beams, and then I have made a little Door to open on the Side of the Tube, by which you may look in and ſee the Rays reflected, thro' a large Speculum, to a Focus juſt at 9 Inches Diſtance: —— The Image of the Sun is there nicely formed, as you will obſerve, by my holding this ſmall Slip of poliſhed black Ivory there to receive it; which Image, you obſerve, is perfectly round, and nearly $\frac{1}{10}$ of an Inch in Diameter.

Euphroſ. This is a very curious Experiment, indeed; the Image of the Sun on the black Ivory is very eaſy and plain to the Eye, —— it appears to be very perfect, indeed, and is, I ſuppoſe, now to be conſidered as a Microſcopic Object to the ſmall Speculum.

Cleon. It is ſo; and you will ſee a ſecond Image will be formed, by ſcrewing the ſmall Speculum backward, at any Diſtance from it, by Rays reflected through the Hole of the large One, the Eye-piece being taken away: —— Thus, if I hold a piece of Writing-paper juſt behind the great Speculum, and keep moving the ſmall Speculum, you at Length ſee the Image

Image formed very distinct, and large, in Proportion to the first; for the Distances of the two Images from the small Speculum are nearly at 10 to 1; and therefore this secondary Image is nearly 10 Times as large as the first, or about $\frac{9}{10}$ of an Inch in Diameter. ——— I now place the Paper at the Distance of 18 Inches from the small Speculum, and, as I move the Speculum still farther back, it gives a perfect Image on the Paper in this Position, which is larger than before in Proportion of the increased Distance. ——— Once more; I place the Paper at the Distance of two Feet from the little Mirrour, and then you see, by removing the small Speculum still farther from the first, how a second Image is formed twice as large as the first in Diameter, and yet very perfect.

Euphrof. So very perfect, *Cleonicus*, that I really see the Spots on the Sun's Disk. ——— Why, this seems to me to be an excellent Way of viewing an Eclipse, the Spots in the Sun, or a Transit, *&c.* without more ado.

Cleon. It is the most perfect Way, of any, of representing those Phænomena, as they are formed by two Reflections only, and they cannot be shewn by less; and if the great Metal has a large Focus, the Experiment of exhibiting the solar Disk this Way is most delightful, indeed, ——— as for Instance, suppose it was 3 or 4 Feet focal Distance, the Image of the Sun's Image might be thereby easily made 5 or 6 Inches in Diameter, which will be large enough for all the before-mentioned Purposes. ——— But to return; this second Image is that which we view by the Eye-glass of the Telescope, in the same Manner as the large Image is viewed by the Eye-glass in the upper Part of the compound Microscope: ——— From all which it appears, that a reflecting Telescope is a compound Instrument, *consisting of a* TELESCOPE *and a* MICROSCOPE; and if the Metals are such as are beforemention, whose focal Distance are as 9 to 1, then, as a Telescope, it will magnify 9 Times, and in the Microscope Part it will magnify 10 Times; therefore, upon the Whole, it will magnify 9 Times 10, or 90 Times, and all this in a Length of Tube not greater than 14 Inches.

Euphrof. By this compound Power of magnifying I readily discern the Reason, why a reflecting Telescope is so very short, com-

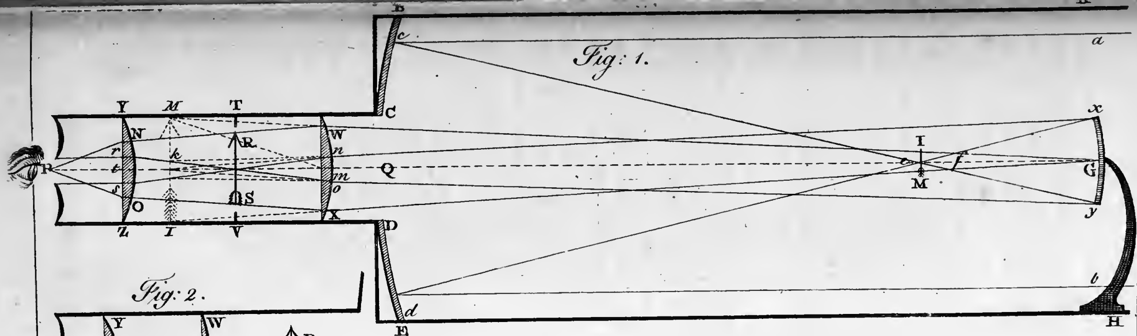


Fig: 1.

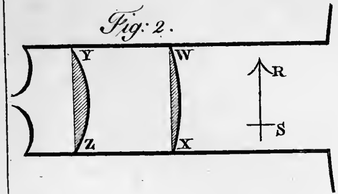


Fig: 2.

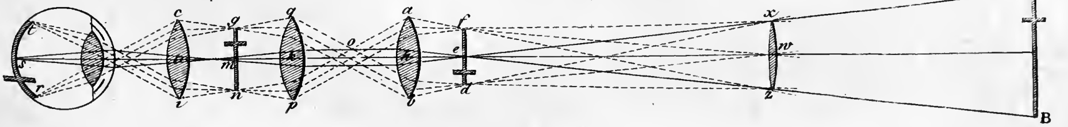


Fig: 3.

compared with a Refractor of the same Power, and consequently how much more convenient they are for Use, as they are easily applied to a proper Stand or Pedestal, and are capable of a Motion every Way, which not only facilitates its Use, but renders it vastly more pleasant and agreeable. ——— But one Thing I must remind you of, *Cleonicus*; I remember, some Time ago, I asked you what was the magnifying Power of this Telescope, and I remember you told me, it was about 50 Times, or somewhat more: How, then, does that agree with the magnifying Power you now mention of 90 Times?

Cleon. I will soon satisfy you in that Particular. I have at present supposed, for your more easy Comprehension, that the focal Distance of the small Speculum is only one Inch; but that is found, by Experience, to be too small, or the Power of magnifying too great, to admit of a sufficient Degree of Distinctness and Brightness in viewing common Objects, and therefore it is customary now to make the small Mirrors about an Inch and half focal Distance, and then it will magnify, as a Telescope, six Times, and, as a Microscope, about eight Times and an half; and therefore the Power of magnifying will be, upon the Whole, about 51 Times, because six Times eight and an half is 51.

Euphros. I apprehend you very clearly, and cannot but admire the wonderful Art employed in the Structure, and the noble Effects of this curious Machine. ——— But one Thing occurs as a Query, which is this: Since the primary Image in the Telescope is magnified in the small Mirror in the Nature of a common Microscope, pray, *Cleonicus*, would not any small Object, substituted in the Place of that Image, be magnified by this little Mirror in the same Manner, and thereby this Telescope be made to answer the common Use of the compound Microscope?

Cleon. I must compliment you, my *Euphrosyne*, on this happy Thought of yours; for tho' this Telescope is now of near 100 Years standing, the Use you have now mentioned of it has never been considered 'till very lately, nor do you find any Author who has given Directions for this Part of the Use of the Telescope: ——— But, to say the Truth, there is no Microscope can give so perfect a View of an Object as you have this Way; and I can assure you, that this was the Sentiment of a

NOBLEMAN of the first Rank (for whom the Muses are now in the deepest Mourning:) And whoever has Dexterity enough to apply Objects this Way, will find their Curiosity highly rewarded with the most exquisite Views of Nature's high finished Pieces in Miniature, and that nothing of this Kind in Nature or Art may escape your Notice, I have contrived to make this Method of applying Objects very easy for your Use, *viz.* in the Telescope at large, by a Door opening on the Side against the common focus of the two Mirrors; where a Pair of Plyers are easily fixed for holding any small Object before the small Speculum in a proper Manner, and then, whether transparent or opake, it may be viewed by procuring a proper Focus by turning the Screw at the Side.

Euphros. I was just wondering what that Opening, or Door at the Side of the Tube should mean; but now I see how perfectly it suits the Design: ——— You'll however oblige me with a View of some small Objects in this Method.

Cleon. With the utmost Pleasure I shall do it, having provided several fit Objects for that Purpose. ——— In the first Place, the Ends of the Plyers itself, which are placed to hold the Object, will give you full Satisfaction in this Point. ——— I put the Cover on at the End, to keep all Dark about the small Speculum when opake Objects are designed to be viewed, then turning the Telescope about, so that the Sun-beams may fall on the Side of the Knippers next the said Speculum, you may View the same magnified in a very agreeable Manner by looking through the Instrument in the common Way.

Euphros. It makes a very delicate Object, indeed, and shews wonderfully well the microscopic Power of magnifying in this Instrument: ——— I cannot but admire the fine Colours which appear, how intense the Blue, and strong the Mazarine! ——— your Plyers seem to the naked Eye, a pretty polished Thing; but in this Instrument it appears very Coarse, and furrowed with the Teeth of the File. But now let me view some other Object.

Cleon. The Skin of a Sole-fish is what you have seen in other Microscopes, and is what I shall now put in the Plyers for you to view, and form a Judgment of its Appearance in the two different

rent Inſtruments. ——— It is now placed in a proper Light: Look at it.

Euphroſ. I do remember ſeeing the ſame Object before; but I muſt acknowledge I never ſaw it in that Perfection, and ſo diſtinctly, as now: ——— I cannot ſee how it is poſſible for any Thing to exceed the Delicacy of ſuch a microſcopic View. ——— Pray, how do tranſparent Objects appear?

Cleon. That you will likewiſe eaſily find by viewing one ſingle Scale of this Kind in the Plyers: ——— I have choſen a large one for this Purpoſe, which you may now obſerve, the End of the Teleſcope being now opened for the Sky-light.

Euphroſ. I view it with great Satisfaction, — and by moving the Teleſcope a little one Way, and the other, I find that Light which ſhews it to the beſt Advantage. ———

Cleon. I next preſent to your View a ſmall Piece of a Leaf anatomized, ſuch a one as you here ſee diveſted of its Skin, and all the green Part, which the botanical Anatomiſt call the *Parenchyma.*

Euphroſ. Why this Leaf, *Cleonicus*, is one of the fineſt Objects I ever ſaw, without being magnified at all; but as its Texture appears ſo delicate, it certainly requires a magnifying Glaſs to ſhew it to its utmoſt Advantage: A ſmall Piece of that muſt certainly make a fine microſcopic Object.

Cleon. A Piece of an *Aſpen-leaf* is now in the Plyers, to gratify your Curioſity.

Euphroſ. And a great Curioſity, indeed, it is to view it; what wondrous fine Branchery, and Ramification thro' all the Parts, appear! ——— How amazing are all the Works of Nature, in theſe artificial Views!

Cleon. Theſe Inſtances ſufficiently ſhews how excellent a Part of the Teleſcope has hitherto paſſed unnoticed by the Public, and how very incurious they have been about the Improvement of ſo noble an Invention: ——— But a farther Proof of this we have in the deficient Structure thereof, by all the Opticians hitherto, who, from Father to Son, have gone on in one common Track of limiting our View of all Objects to the Diſtance of 60, 80, or 100 Feet, according to the different Sizes of the Inſtrument; ſo confined and indelicate were their

Notions in the Mechaniſm of this Inſtrument, that they never conſider it as capable of improving the Sight for near Objects; ——— they left us to the dull Satisfaction of diſtinguiſhing a *Fly* from a *Bee*, a *Waſp* from a *Hornet*, or an *Anemony* from a *Jonquill*, *&c.* by the natural Sight, as if the general Form and Appearance of Objects were all that we were to be ſollicitous about: ——— But they who know the Pleaſure of the more improved and refined Views even of common Objects, cannot but look upon the uſual Structure of our reflecting Teleſcopes as very imperfect; every Object about us we view with a naked Eye, appears ſo ſtrangely altered by the Teleſcope, that you ſcarce know what you look at. I could engage to ſhew you many of them, without your being able to gueſs at the Subject, though ever ſo well known in a vulgar View. ——— I ſhall now try you with an Object you are well acquainted with; but had I ſaid nothing to you, I am well aſſured you would not have had the leaſt Idea of it, even from the moſt perfect View; ——— for this Purpoſe, turn your Back for a Moment, and be upon Honour not to look upon any Thing but through the Teleſcope, when I ſpeak. ——— There it is; tell me what you ſee.

Euphroſ. I do not know that I can preſently, ——— it is ſomething vaſtly large, with a great Elliptic opening at one End, cloſed in a ſpherical Form at the other, ——— over all which are a Number of large deep Holes in proper Arrangement, each one big enough to hold a Bullet; ——— the whole ſeems of a hugh cylindric Form, and I do really think, had you not been ſpeaking of this Sort of Deception, I ſhould have formed no Idea of the Thing at all; but as the Caſe ſtands, I judge it muſt very much reſemble a *Thimble*, which *Gulliver* might have ſeen on the Finger of the *Brobdingnag* Woman at Work with a Needle.

Cleon. The Conceit is very juſt; for the Appearance would have been much the ſame as your ſmall Thimble thus magnified, by the *Megalaſcope*: For now this Inſtrument leaves the Name of a Teleſcope, which denotes its ſhewing *diſtinct Objects only*; but when we come to apply it for viewing Objects that are very near, it is called an ENGYSCOPE; and on Account of its ſhewing all the larger Sort of Objects, ſtill much larger than they

they appear to the naked Eye, it is called a MEGALASCOPE.

Euphrof. It is on this Account, I ſuppoſe, that the ſmaller Sort of reflecting Teleſcopes are made with a Drawer, or Tube, to ſlide out by Means of Teeth and Pinion on the Side.

Cleon. You are right, my *Euphroſyne*, that is the Deſign of this Conſtruction; for by that Means you may lengthen the Teleſcope as you hold it in your Hands for viewing any Object in the Room where you ſit, or any where about you to the Diſtance of within 2 or 3 Feet; for let the Object be placed where it will, you need only direct your Teleſcope to it, and, turning the Screw once or twice round, you will be preſented with a new and delightful View of the ſame: ——— Here, take this Inſtrument and look at any Thing you pleaſe about the Room.

Euphrof. I will: ——— And firſt let me look at the Carpet. How very coarſe the Texture and Colours appear, an odd Figure it makes, indeed. ——— Next, I view the Blind in the Window, which looks as coarſe as Wire-lattice, inſtead of Linen-cloth. ——— I now turn the Tube to the Horſe-hair Bottom of the Chair; and theſe I ſhould never have known had I not firſt ſeen them with a naked Eye: They look more like Hurdles of poliſhed Whalebone. —— I next direct it to the ſilvered Plate of the Barometer, where the Glaſs-tube, with the Silver in it, appears as big as your Walking-cane, and I can plainly ſee the Index ſtand at *Fair*. —— I ſhall next remove it to the Fruit-piece, and there I obſerve the Diſh of Nectarins, Grapes, and Philberts, as natural as on the Table itſelf. ——— I view my Grandfather's Picture, and it gives Life and Relievo to the Face of the old Gentleman; his Face, his Noſe, and Lips all project in ſuch Manner, as if coming out of the Canvas.

Cleon. Theſe Objects may afford you a fine Entertaintment within Doors; but now throw up the Saſh, and view the glorious Scenes of Nature over all the Garden before you, and this I ſhall propoſe for your Amuſement while I withdraw, at preſent, to make good an Appointment.

DIALOGUE X.

Of the genuine Conſtruction of REFLECTING TELESCOPES, *and alſo of a* new proportional CAMERA OBSCURA.

Cleonicus.

IN our former Converſation on the Subject of reflecting Teleſcopes I obſerved to you, its general Nature in aſſiſting the Sight to diſcern moſt perfectly all Kind of Objects, great or ſmall, remote or near at Hand: I have likewiſe farther obſerved, that the Errors of Viſion, by Reflection, are incomparably leſs than thoſe by Refraction, and that therefore the reflecting Teleſcope is juſtly eſteemed the moſt Perfect of all optical Inſtruments; and then, with regard to the Conſtruction, I have ſhewn you how that is to be improved for a more general Application and Uſe of it. But there is ſtill one Thing remaining, which, I think, you ought to be apprized of, and that is, that the reflecting Teleſcope, in its preſent Form and Conſtruction, is not made to anſwer that Character truly, or it is not, properly ſpeaking, a *pure reflecting Teleſcope*; but its Effect is produced partly by Reflection, and partly by Refraction, and therefore called, by Opticians, a *Catadioptric* Teleſcope: Whereas, that which produces Viſion wholly by Reflection is properly called a *Catoptric* Teleſcope.

Euphroſ. How do you propoſe to explain to me the Difference of theſe two Conſtructions?

Cleon. By ſhewing you the different Poſitions of the Speculums and Glaſſes in each, and, at the ſame Time, ſhewing how the Images are formed, by a Diagram. I have already ſhewed you how the Metals and Glaſſes are placed in a common Teleſcope, which are ſuch as are expreſſed in this Figure (See Fig. 1.) where A B E H is the Tube of the Teleſcope, and C P D the Eye-piece at the End, B E the great Metal with the Hole C D in the Middle, G H is a Stem or Foot on the other End, which ſupports the little Speculum *x y*; in the Eye-piece, W X is the

firſt

first Glass, or that which is next to the great Metal; Y Z is the second Glass, or that next the Eye at P.

Euphros. This I know is the Disposition of the Glasses in the Telescope I have seen; but now, how the Image is formed by Reflection and Refraction both, you will please to explain.

Cleon. I will: In order to which, let *a c* and *b d* represent two Rays proceeding from a Point, of a very distant Object, placed in the Axis of the Telescope; they will, after Reflection from the Point *c d* in the large Metal, be converged to a Point *e* in the said Axis: And, in like Manner, Rays proceeding from all other Points of that Object will, by the great Speculum, be converged to so many other Points at the Distance Q *e*, where they will altogether form the Image of that Object I M.

Euphros. This I well remember you shewed me, in explaining the Nature of Concave Mirrors of Glass; and moreover, that the Position of the Image I M is contrary to that of the Object, or inverted. Lastly, I observed that this Image I M is formed wholly by reflected Light: ——— But, pray, *Cleonicus*, let me ask you one Question, how comes it to pass that the Image is perfect and intire, when there is so large a Hole in the Center or Middle of the Speculum? I should have thought that Hole would have occasioned some Deficiency in the middle Part of the Image.

Cleon. Not at all, my *Euphrosyne*; for you will easily perceive that any small Part of the Speculum alone may be considered as an entire Speculum of itself, and will form the Image, or Appearance of any Object, as well as the Whole, only the Picture will be less luminous in Proportion as the Surface is less; and this is the Reason why, when a Speculum is broke into ever so many Pieces, every Piece, great or small, forms the same Image of a given Object, in every Respect but that of Brightness; and therefore the Hole in the Middle of the Metal avails no more than it would do to stick a large black Patch any where on the Surface of an entire Concave Glass, which you would find would make no Difference at all in the Appearance of an Image, or perspective Picture, formed thereby.

Euphros. I apprehend you very well, and shall interrupt you no farther in this Matter. ——— What do you next observe in the Structure of this Instrument? *Cleon.*

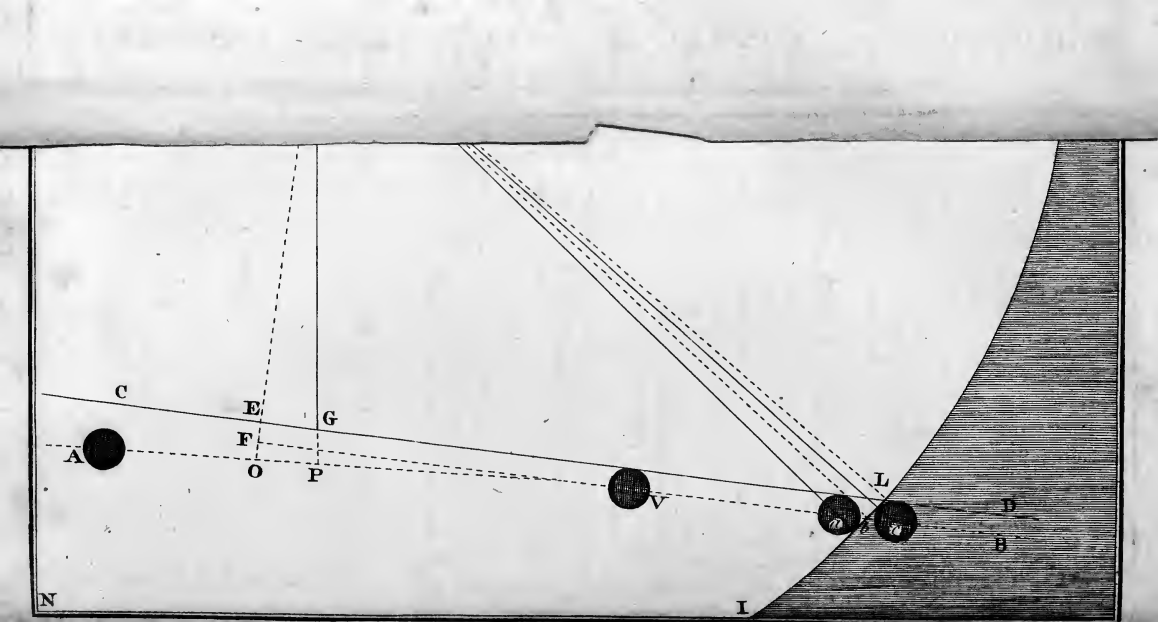
Cleon. You are to take Notice, that the Point f is the ſolar Focus of the ſmall Speculum *x y*, and therefore by moving this Speculum to the Diſtance G *e*, greater than its focal Diſtance G *f*, the Rays *e y* and *e x*, diverging from the middle Point *e* of the Image, will, after Reflection at *y*, *x*, be made to converge to ſome diſtant Point in the Axis at *k*; but, in their Paſſage at *n o*, are intercepted by the firſt Glaſs W X, and by it are refracted to a Point nearer to the Glaſs at K, in the Axis of the Tube; alſo, two other Rays, I G and M G, proceeding from two extreme Parts of the Image I M to the Center G of the ſmall Speculum, are from thence mutually and alternately reflected on contrary Sides in the ſame Direction towards the diſtant Points *M I*; but in their Way are intercepted by the firſt Eye-glaſs in the Points W X, and from thence refracted to the Points R S; and therefore the ſecond Image is R K S, and is formed partly by Reflection from the little Metal *x y*, and partly by Refraction thro' the Glaſs W X: And hence it is, that the Inſtrument, in this Form, partakes of the Nature of a reflecting, and of a refracting Teleſcope, and is of a middle Kind between both.

Euphroſ. And therefore, of Courſe, it muſt likewiſe partake of the Advantages and Diſadvantages of both thoſe Sorts of Teleſcopes: The principal Imperfection, I ſuppoſe, is that ariſing from Refraction through the Glaſs W X.

Cleon. You obſerve rightly, my *Euphroſyne*, that is an Objection that a Catadioptric Teleſcope is liable to; the ſecond Image cannot be formed without a *colorific* Refraction, and therefore cannot be ſo perfect as one that is formed wholly by reflected Light.

Euphroſ. In what Manner then are the Glaſſes to be placed, ſo that they ſhall be no Way concerned in forming the Image?

Cleon. For this Purpoſe you need only conſider, that the Image may be formed by the two Metals alone, and then that Image may be viewed by two Glaſſes, as repreſented in the Eye-piece (Fig. 2.) where R S is the Image now formed intirely by reflected Light, and is ſhewn by the two Glaſſes W X and Y Z placed at a proper Diſtance, and in this Caſe we view the Images of Objects to the greateſt Advantage poſſible; and this is the true Form of a *reflecting*, or *catoptric Teleſcope*, which has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has all the Advantages that any Inſtrument of this Kind can have, and ſeveral more than are found in the common Sort, as I ſhall take an Opportunity hereafter to ſhew you more particularly; * and, at preſent, I have another optical Inſtrument to deſcribe, which I fancy will give you equal Pleaſure with many of the foregoing, eſpecially as it contains, in a ſmall Compaſs, a general Praxis of optical Experiments: The Inſtrument I mean is a *new proportional Camera Obſcura*.

Euphroſ. Its a pretty Inſtrument, I allow; but how does this differ from the common *Camera Obſcura?*

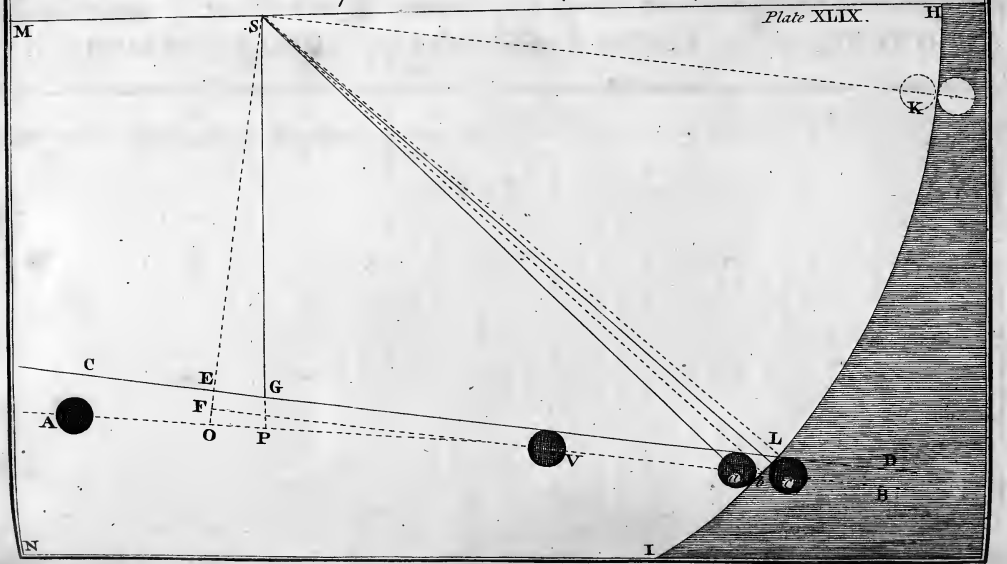
Cleon. In three reſpects: Firſt, in the Form; but this is the leaſt of all material. ——— Secondly, it forms an Image in any aſſignable Proportion to the Object, in all Degrees below Equality. ——— Thirdly, *Wilſon*'s Microſcope is adapted to it, for exhibiting a large Image of any very ſmall Object.

Euphroſ. By what you have ſaid, *Cleonicus*, I ſuppoſe the Uſe of this *Camera* is principally for *Drawing*.

Cleon. That is the chief Deſign of it: As the Arts of Deſign and Drawing are very innocent, inſtructive, and uſeful, they ought to be conſidered as a Part of the polite Education of every young Lady and Gentleman of Genius; and therefore all Helps ſhould be furniſhed for rendering them eaſy in Practice: And as every Art proceeds at firſt from Imitation, ſo do thoſe more eſpecially which are relative to Drawing and Painting, and the better the Originals are, the more exact and exquiſite will be the Improvements that are acquired by copying of them; and it is

* *N. B.* We have thought neceſſary to illuſtrate the Doctrine of reflecting Teleſcopes by Figure I. II. of Plate 48, as it will greatly aſſiſt the Imagination in repreſenting the Courſe of the Rays of Light, by right Lines drawn in the Manner as the Rays are reflected by the Speculums, and refracted through the Glaſſes, as we could not ſo well give a Repreſentation of the Sun-beams paſſing through this Inſtrument in a darkened Room, as we did for the ſeveral Sorts of refracting Teleſcopes in Plate 47; alſo in Figure III. we have ſhewn how the ſeveral Pencils of Rays proceeding from the Points of a diſtant Object O B are refracted by the Glaſſes of a common Teleſcope, *viz.* the Object-glaſs *x z*, and the 3 Eye-glaſſes *a b*, *p q*, *c i*, ſo as to produce diſtinct Viſion upon the optic Nerve in the Eye in the inverted Picture *r s p*; by obſerving the Courſe of thoſe Rays, or Lines, the Reader will have a better Idea of what was delivered on this Subject in a former Dialogue.

The BEGINING & END of the EGRESS of VENUS from the SOLAR DISK



has all the Advantages that any Inſtrument of this Kind can have, and ſeveral more than are found in the common Sort, as I ſhall take an Opportunity hereafter to ſhew you more particularly; * and, at preſent, I have another optical Inſtrument to deſcribe, which I fancy will give you equal Pleaſure with many of the foregoing, eſpecially as it contains, in a ſmall Compaſs, a general Praxis of optical Experiments: The Inſtrument I mean is a *new proportional Camera Obſcura.*

Euphroſ. Its a pretty Inſtrument, I allow; but how does this differ from the common *Camera Obſcura?*

Cleon. In three reſpects: Firſt, in the Form; but this is the leaſt of all material. ——— Secondly, it forms an Image in any aſſignable Proportion to the Object, in all Degrees below Equality. ——— Thirdly, *Wilſon's* Microſcope is adapted to it, for exhibiting a large Image of any very ſmall Object.

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Cleon. That is the chief Deſign of it: As the Arts of Deſign and Drawing are very innocent, inſtructive, and uſeful, they ought to be conſidered as a Part of the polite Education of every young Lady and Gentleman of Genius; and therefore all Helps ſhould be furniſhed for rendering them eaſy in Practice: And as every Art proceeds at firſt from Imitation, ſo do thoſe more eſpecially which are relative to Drawing and Painting, and the better the Originals are, the more exact and exquiſite will be the Improvements that are acquired by copying of them; and it is

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well known, that Nature's Drawings, Perſpective, and Painting, are in themſelves moſt perfect, and therefore ought to be propoſed in the firſt Place for Imitation. They who do not draw, or deſign, from Nature, in effect do nothing, as neither Spirit nor Sublimity can be found in any other Compoſitions: But in order to qualify a Perſon to copy Nature with Art and Judgment, he ought firſt to be acquainted with the Nature and Rules of Perſpective; for Nature, it is well known, is all Perſpective to the Eye. If we take a Survey of Fields, Gardens, diſtant Towns, *&c.* they all appear to the Eye as if repreſented on a tranſparent Plain, placed perpendicular to the Horizon at a ſmall Diſtance from you.

Euphroſ. If then I take you right, *Cleonicus*, you mean, as yonder Fields and Meadows appear on the Glaſſes of this Saſh-window to my Eye, viewing them here in the Room?

Cleon. Exactly in the ſame Manner, my *Euphroſyne*, ——— all the Ground beyond the Window, which you ſee, riſes on the Glaſs-plain, and, by Degrees, the Parts leſſen to the View as they are more remote, till they become very indiſtinct, and gradually diſappear in the moſt diſtant Part which you ſee, and is called the perſpective Horizon on the Window.

Euphroſ. In what you have now ſaid, you ſeem to have deſcribed a viſual Landſcape on the Window.

Cleon. The common Landſcape is only the ſame Thing in Oil-colours on the Canvas, if executed by the Rules of Art. ——— I only take this Opportunity to convince you, that all pictureſque Repreſentations of Nature are ſtrictly limited by perſpective Rules; and they who do not therefore obſerve them in their Drawings, and Deſigns, muſt never expect any Praiſe for their Performances. ——— Now as all thoſe Imitations of Nature is a Sort of Minuature-painting (for the largeſt Landſcape is only a perſpective Repreſentation of a large Field of View in a ſmall Compaſs) therefore, in order to facilitate ſuch a Practice, Art ſupplies manifold Helps to that End. — A Perſon the moſt ſkilful in Perſpective, and in the Art of Deſigning, ſucceeds but ill in Landſcape-painting without long Practice in the common Way, or otherwiſe by having Recourſe to their Aſſiſtance. ——— What I mean regards that Variety of artificial Pictures

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and Landſcapes that are made by different Sorts of Glaſſes; for you very well know, that no poliſhed Mirrour can be expoſed to a Building, or diſtant View, but there immediately reſults an extemporaneous Picture of the ſame in true Perſpective, if the Glaſs be of a proper Size.

Euphroſ. This I have oftentimes, with the higheſt Pleaſure, obſerved, and I think nothing can compare with the Beauty and Perfection of thoſe Landſcapes that I have ſeen formed by large Convex Speculums. ——— Thoſe Pictures which you ſhewed me in the darkened Room, ſome Time ago, are of the ſame Kind, but inverted. ——— In ſhort, I often amuſe myſelf with the pictureſque Appearance of Objects, by Reflection of almoſt every Kind of Glaſs that comes in my Way.

Cleon. As thoſe Glaſſes gives ſo juſt and artificial a Repreſentation of any particular View of Nature, they have been much uſed in thoſe Sorts of Inſtruments called portable *Camera Obſcuras*, becauſe in them the Artiſt can eaſily obſerve the true Diſpoſition of all the Parts of the Piece he intends to draw, the Contours or Out-lines of the Figures, the perſpective Diminution, the *Claroſcuro*, or the Light and Shades, with every other Circumſtance neceſſary to be obſerved in forming the perfect Picture. ——— But after all, this Inſtrument is not perfect in a principal Particular which I mentioned to you before, and that is, the Artiſt, by a common *Camera*, cannot draw any particular Building or other Object in a given Proportion of Magnitude, as is often required; and therefore I have contrived this, which you here ſee, to ſupply that Defect.

Euphroſ. By what Means is this effected? I ſhould be glad to find myſelf capable of underſtanding the Reaſon of it.

Cleon. That I will endeavour to ſhew you by Experiment. ——— When Objects are at a very great Diſtance, or ſo remote, that the focal Diſtance of the Glaſs bears no Compariſon to their Diſtance, then the Image or Pictures of thoſe Objects are formed in the Focus of the Glaſs, and bear no ſenſible Proportion of Magnitude to the Objects: ——— But in Caſe of Objects near at Hand, their Pictures become larger, and will bear a ſenſible Compariſon with the Object, *viz.* the Propor-

tion of their Diſtances from the Glaſs, all which I have formerly obſerved to you, and ſhewed you by Experiment.

Euphroſ. I remember you did; and I can eaſily underſtand, that as the Object approaches the Convex Lens, the Image will recede from it; for as the Diſtance of the former decreaſes, ſo that of the latter will increaſe, and the Size of the Image will alſo increaſe along with it: And according to this Doctrine I can eaſily conclude, that the Diſtances of the Object and the Image may at Length become equal, and that conſequently they themſelves will become equal alſo; but what the Ratio of theſe Diſtances is, for any given Proportion of the Object to the Image, I preſume the Learned only can know.

Cleon. I can eaſily ſupply you with a Rule for determining the ſame; but as it will be different for every different Sort of Glaſs, I ſhall not pretend to trouble you with it, having put it in your Power, by means of this Inſtrument, to form the Image for any Object equal in Magnitude to the Object itſelf, or in any Proportion leſs, at Pleaſure, from one to 100 Times. ——— One Thing, however, I think is a Matter of ſome Curioſity, and therefore proper you ſhould know, *viz.* that when an Image and Object are equal, their Diſtance from the Glaſs being alſo equal, will be juſt double the focal Diſtance of the Glaſs. ——— Thus, ſuppoſing the focal Diſtance of a Glaſs was 9 Feet in a ſcioptric Ball and Socket placed in the Window-ſhut of a dark Room, then if you were to place yourſelf before the Window, at the Diſtance of 18 Feet, a Perſon in the Room would ſee your Face of the ſame Magnitude as it really is, on the Screen at the Diſtance of 18 Feet from the Window.——— In the ſame Manner, if the Glaſs were but 10 Inches focal Diſtance, any Object placed before it, at the Diſtance of 20 Inches, would have the Image formed on the Screen at the Diſtance of 20 Inches from the Window; and this is the Caſe of one of theſe Glaſſes which belongs to this proportional *Camera Obſcura*, which being ſcrewed on in the Front of the Box, and being then drawn out to the Diſtance of 20 Inches, marked on a proper Scale, whatever Object is placed before this Glaſs, at the Diſtance of 20 Inches, will have its Image formed on the Glaſs of an equal Size with the Object.

Euphroſ.

Euphrof. Let me try that Experiment with my Snuff-box, which I will place in an advantageous Light: ——— Now let me draw out the Glaſs to the Diſtance of 20 Inches, ——— and then I move it forward and backward till I ſee the Image perfect; ——— and then, as you obſerve, I ſee the white enamelled Lid, and the whole Box juſt of an equal Size.

Cleon. Then there let it reſt, till I meaſure the Diſtance with this Rule, ——— which, you obſerve, is juſt 20 Inches from the Glaſs to the Box, the ſame as the Diſtance of the Image. ——— And hence you ſee how eaſy it is to draw any Object, not larger than the Glaſs, of an equal Bulk.

Euphrof. On the Right-hand Part of the Copper-plate Paper, on the Drawer, is a double Row of Figures appoſitely placed by the Scale of Inches, pray, what do they denote?

Cleon. They ſhew the Proportion of Magnitude between the Object and the Image when formed on the Glaſs, when the Drawer is moved or ſet to any of thoſe particular Numbers: Thus, for Inſtance, if I move it to the Numbers 15 or 10, then is the Glaſs 16 Inches and $\frac{6}{10}$ from the End; and whenever an Image in that Situation is formed in the Glaſs, its Size, or Dimenſion of Length and Breadth, will be to thoſe of the Object as 10 to 15.

Euphrof. After the ſame Manner, I ſuppoſe, if I move the Drawer to 15 Inches on the Scale, the Out-lines of the Image then formed on the Glaſs will be thoſe of the Object in Proportion as 10 to 20, or juſt half as big.

Cleon. That is the very Thing; you there repreſent the Object of half its natural linear Dimenſions.

Euphrof. But I obſerve in that Scale, the Proportions go no farther than of 30 to 10.

Cleon. It is true; when the Drawer is moved quite home to the Numbers you mention, the Length and Breadth of every Image on the Glaſs is juſt $\frac{1}{3}$ Part of that of the Object, ——— and this is as far as we can conveniently go with a Glaſs of 10 Inches focal Diſtance: ——— But now, if we take that out, and place in another Glaſs of 15 Inches focal Diſtance, then with that we can form an Image in any Proportion leſs than the Object, from that of $\frac{1}{3}$ to $\frac{1}{100}$ Part.

Euphrof.

Euphrof. For this I obſerve you have a Scale on the Left-hand Side of the Paper, ——— and that when the Drawer is moved quite out to 20 Inches, the Proportion is then as 1 to 3. ——— If I move it to 18 Inches, the Proportion is that of 1 to 5. ——— Again, 16 Inches and $\frac{1}{2}$ gives the Proportion of 1 to 10; and thus, I obſerve, by moving it to the ſeveral Numbers ſucceſſively on this and the other Scale, I can form an Image at any aſſigned Proportion leſs than the Object, by uſing the proper Glaſſes, which, on many Occaſions, muſt be very convenient.

Cleon. The young Artiſt will always find Occaſion for drawing of Objects leſs than the Life, and oftentimes of a given Size, which he may do by this *Camera* as well as by any other, and have the Pleaſure of ſeeing at the ſame Time the Proportion between the Image and the Object: But of this I have ſaid enough to give you a clear Idea of the Nature and Deſign of the Inſtrument, and ſhall now leave it with you to render the Uſe of it more familiar, by Practice, and to make it a Part of your Amuſement at leiſure Hours. ‡

DIALOGUE XI.

Concerning the TRANSIT *of the Planet* VENUS, *and its* EGRESS *from the* SOLAR DISK, *on* June *the 6th in the Morning; together with ſome* CALCULATIONS *relative to the* ELEMENTS *of her* THEORY. *Alſo of the* SATELLITE *ſuppoſed to attend her.*

Euphroſyne.

AT Length, the long expected Morning came, and the univerſal Phænomenon viewed to greater Perfection, than could be expected from the Weather for many preceding Days. ——— Well,

‡ I thought it not neceſſary here to ſay any Thing of the Uſe of the *Solar Microſcope*, ſince that will not be difficult to any one acquainted with that Inſtrument already ſo fully deſcribed.

——— Well, I cannot but say, I viewed the glorious Spectacle with more exquisite Pleasure and Satisfaction, than ever I beheld any other Object in the whole Circle of the Creation; and to other admiring Mortals, as well as myself, I make no Doubt but she appeared more desirable and eligible in her sable Dress, than when arrayed with all the Splendor of the Morning. ——— *Phosphorus* and *Hesperus* are indeed most glorious Contrasts of what she appeared this Day upon the Sun: ——— Divested of all her usual Radiance, she shewed herself in the natural Simplicity of a dark, or opake Planet, ——— so large, so black, so perfectly round, and uniform in her Motion, that she answered perfectly to all the Ideas of Expectations that had been formed from every Prediction of this great Event. ——— And since I have had the Pleasure of observing this Phænomenon, I must desire you to give me some Account of the same, and how you apply it to the Uses you formerly mentioned to me.

Cleon. The Morning, upon the Whole, proved very favourable; the rising Sun would have been an acceptible Sight; but this was not permitted to us at *London*, though, in many Parts of *England*, they had the Satisfaction of viewing it the whole Time. —— However, we had, as if for the Purpose, a clear Sky, for observing the critical Moment, which was that of her Egress, or Emersion from the Sun's Disk: Which gave us a fair Opportunity of observing, to nearly a Second of Time, the Moment when she touched the Limb of the Sun internally and externally, and thereby to determine the Space which she passed in her visible Path during the Time of her Egress: Which Space, were it accurately ascertained, would be of the greatest Consequence for settling the principal *Elements* in the THEORY of this Planet's Motions.

Euphros. I do not then wonder that you and several other Gentlemen were so very attentive to that Particular, and that you were so very busy with your Watches in observing those Moments of Time. ——— But were you sure that your Watches were perfectly right, or that they shewed the Time of those Incidents truly?

Cleon. They were adjusted by Regulators the Night before; but whether they were exact as to what the Astronomers call the

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mean Time, was not so much the Question here; the principal Thing, in regard to the Time, was the Division of it into *Seconds*; for by this Means we could observe, nearly to a *Second* of Time, the Moment that the Planet touched the Sun's Disk internally, and also the external Contact, within very a few Seconds. Now, if you remember, I told you that *Venus* at this Time very accurately described *four Minutes* of a Degree in an *Hour*; or 60 Minutes of Time, and therefore one Minute, or 60 Seconds of Motion in each Quarter of an Hour, or 15 Minutes of Time; which is at the Rate of four Seconds of a Degree for a Minute, that is, 4‴ for every Second of Time; from whence you must observe, that a few Seconds of Time in the Duration of the Emersion will produce no sensible Error in the Space described by the Planet in that Time.

Euphros. I farther observe, that you were not a little anxious about the Size or Dimensions of the planetary Spot, and that you took Notice in particular how far it fell short of the Number of Seconds which Dr. *Halley* gave it in his Dissertation.

Cleon. This is another Point of no small Importance towards perfecting the Theory of this Planet, as without it no great Use could be made in Calculations depending upon the exact Time, or Space described in the Emersion, as I shall illustrate to you more particularly in a very large Diagram by and by, which shall be a Representation of the Sun's Disk 8 Feet in Diameter, and that of the Planet 3 Inches, by which every Thing relating to those Particulars will be evident by Inspection. —— Dr. *Halley* made the Diameter of this Planet 75″, whereas she appeared by our Measurements not to be 60″. I had prepared an Instrument for measuring the Diameter of the Planet with the greatest Exactness, but found it was impossible to apply it in a public Company.

Euphros. By these Observations you can ascertain the Ratio of the Diameter of the Planet to that of the Sun?

Cleon. Yes, pretty nicely; for Dr. *Halley* gives 31′ 51″ or 951″ for the Diameter of the Sun: But by measuring it very accurately by the Micrometer, a few Days after the Transit, I could not make it less than 32′ or 960″; and supposing that of the

the Planet was nearly one Minute, their apparent Diameters were to each other as 32 to 1. —— By this Experiment of the Tranſit, we find how much more accurately the Planets are to be meaſured when diveſted of their Luſtre or Radiance.

Euphroſ. I remember you told me heretofore, that this Planet was near as big as the Earth; but ſince you have now found her Diameter leſs than was uſually eſtimated, I ſuppoſe ſhe will ſhrink to a leſs Bulk, and we ſhall now have a greater Superiority over that Planet in regard to Magnitude, than was heretofore ſuppoſed.

Cleon. Yes, ſhe now dwindles very much indeed; the Magnitudes of all Bodies, viewed at the ſame Diſtance, being in Proportion to the Cubes of the Diameters: Now the Cube of 75 to that of 60, is as 412 to 216, and therefore the Planet is, by this Obſervation, reduced to nearly one half of its former ſuppoſed Magnitude, or to little more than half that of the Earth, and muſt now be reckoned the leaſt of all in the Heavens but one, *viz. Mercury*; whereas, heretofore the Planet *Mars* was thought to be ſo. —— However, her Magnitude is ſo very conſiderable, that, in regard to her Vicinity to the Sun, ſhe makes the moſt reſplendent Appearance, and has always been regarded as the moſt beautiful of all the planetary Syſtem, inſomuch, that the GODDESS of BEAUTY herſelf was honoured with her Name.

Euphroſ. This Phænomenon of the Tranſit of *Venus* is looked upon as a great Curioſity, I ſuppoſe, on Account of its happening ſo very rarely; but what may be the natural Reaſon, or Cauſe of this, I ſhould be glad to know, *Cleonicus.*

Cleon. You will eaſily perceive the Reaſon of it, when you recollect what I have ſaid concerning the Limits of ſolar and lunar Eclipſes, and eſpecially if, with that, we conſider the Smallneſs of *Venus*'s Diameter compared to that of the Sun, and the long Intervals between the Conjunctions of this Planet which produce a Tranſit, and, laſtly, the great Proportion which the Velocity of the Earth bears to that of *Venus* in her Orbit. —— But to be more particular: You are to conſider, (1.) That if *Venus* was to move in an Orbit quite parallel to the Ecliptic, ſhe would then appear to paſs over the Face of

the Sun in every inferior Conjunction, which would be in the Space of one Year and 8 Months nearly. (2.) But the Orbit of *Venus* does really make an Angle with the Ecliptic of nearly three Degrees and a Half, and therefore the Orb of the Planet cannot possibly be seen on the Sun, unless she happens to be within a certain Distance of the Node at those Conjunctions; and though the Inclination of the Planes of the Ecliptic and her Orbit be so small, yet, on the Account of the Smallness of her Diameter, the ecliptic Limit on either Side the Node would be somewhat more than four Degrees, if she were to be viewed at those Conjunctions from the Earth at rest. (3.) But the Earth and Planet being both in Motion, and since *Venus* moves at the Rate of four Minutes in an Hour, and the Earth 2′ 28″ *per* Hour, their Velocities will be in Proportion as 240 to 148, the Difference of which is 92″: And on this Account the angular Motion of *Venus* from the Ecliptic (as viewed from the Earth in Motion) will be increased in the Proportion of 240 to 92; and therefore will amount to near eight Degrees and a Half: Hence, as her visible Path makes so great an Angle with the Ecliptic, the Limits of the Transit will be greatly contracted, or will not amount to more than one Degree and three Quarters on each Side the Node, instead of 4 Degrees and $\frac{1}{4}$, as before. From hence it will appear, that *Venus* and the Sun must be very near the Node at the inferior Conjunction, for any Transit to happen: And of Course, since (4thly) the Intervals of these Conjunctions are so great, the Chance of the Sun's being within the Transit-Limit when *Venus* comes round to the Node, is consequently very great also; and therefore it will appear, upon all these Accounts, that *Venus* can be very seldom seen upon the Face of the Sun. But I shall take Occasion to illustrate these Things, by a large Diagram, at another Opportunity.

Euphros. You will by that much oblige me, though I can very easily apprehend the general Reason of all that you have now said, from the astronomical Principles which I have heretofore received from your Instructions. ——— But now, *Cleonicus*, let me know what kind of Uses you intend to make of your Observation on the Transit.

Cleon.

Cleon. As the Beginning of the Tranſit could not be obſerved in *England*, the great or general Deſign, *viz.* of making a proper Eſtimation of the *Parallax of the Sun* could not be pretended to, this muſt be left to a Compariſon of many Obſervations that are made in very different and diſtant Places, where the Parallaxes of Longitude and Latitude favour that Deſign in the greateſt Degree; and this will be a Work of ſome Time. But when all the Obſervations that have been made here, with proper Degrees of Accuracy, are compared, the Poſition of *Venus*'s viſible Path upon the Sun will be nearly aſcertained: Alſo her viſible Latitude at the Conjunction, and Place of the Node, will be deducible from thence, which are Points of the utmoſt Conſideration to be ſettled in the Theory of this Planet's Motion. I have prepared a Diagram that may ſerve to give you ſome Idea of what I mean, relating to theſe Subjects: That Part of the Sun on which the Planet appeared to us, let us ſuppoſe to be repreſented by H L I M N,* the Center of the Sun S, M H a Part of the Ecliptic, and C D the true Path of the Planet as viewed from the Center of the Earth, parallel to which is the Line S K, making an Angle with the Ecliptic H S K of 8 Degrees and 28 Minutes, the Angle of *Venus*'s apparent Motion, which I juſt now mentioned unto you; and let A P V B repreſent the Curve-line Path of *Venus*'s viſible Motion on the Sun's Diſk.

Euphroſ. I ſhould be glad, *Cleonicus*, if you would tell me why the viſible Path is not a ſtrait Line, as well as the true Path C D.

Cleon. The Reaſon of that you will underſtand as ſoon as you conſider, that the Difference between the true and apparent Place of the Planet is occaſioned by its Parallax, as I have formerly ſhewn you, and which Parallax depreſſes the Planet below its true Place, and more ſo in Proportion as the Planet is farther from the Zenith, or nearer to the Horizon; and conſequently when the Planet appeared in the Horizon at A at Sunriſing, it was then depreſſed below the true Path at C by the whole Quantity of the horizontal Parallax, which is more than 40″: But as the Planet advanced on the ſolar Diſk, and the Sun grew higher above the Horizon, the Quantity of the Parallax

* Plate XXXVIII.

rallax in Altitude did conſtantly decreaſe, and therefore the Planet's apparent Diſtance from its true Path muſt be always decreaſing likewiſe as it paſſes from A to D, and that in ſuch a Manner as to occaſion the viſible Path to be in ſome Degree a Curve-line; ſo that when it came to touch the Sun's Limb internally at (*a*) when the Diſtance of the Sun from the Zenith was about 41°, then the Parallax in Altitude was but about 30″, and therefore the apparent Diſtance from the true Path at the Egreſs was more than one fourth Part leſs than at Sun-riſing.

Euphroſ. You have ſatisfied me in this Particular; and I think in your Diagram the Planet makes the very ſame Appearance as ſhe did on the real Diſk of the Sun.

Cleon. It is drawn pretty nearly in the ſame Proportion as you then ſaw it on the paſt-board Screen; you obſerve, the Planet is here placed ſo as to touch the Sun's Limb internally and externally at (*a*) and (*c*).

Euphroſ. This, I preſume, I can conjecture the Reaſon of; for I well remember, you were often ſpeaking about the Method of determining the Poſition of *Venus*'s Orbit, from an Obſervation of the Time in which ſhe paſſed from (*a*) to (*c*), or the Time of the entire Egreſs or Emerſion from the ſolar Diſk.

Cleon. It is true, my *Euphroſyne*, this was what induced me to be more than uſually curious, and anxious in nicely obſerving the Moment of Time for each of the two Contacts; becauſe that Time, if it could be accurately defined, would give the Length of the Space or Line (*ac*), then if we draw the Line S*a* and S*c* there will be formed an oblique Triangle *a*S*c*, in which all the three Sides are known, ſuppoſing the Diameter of the Sun and Planet to be exactly determined by a Micrometer. If then we continue the Line *ca* to F, where it meets the Perpendicular S F, from the Sun's Center, the Diſtance of the Point F from *a* to *c* will be known, from Principles of plain Trigonometry, therefore alſo the Diſtance of F *b*, which is juſt half the Length of the Chord, or parallatic Path of *Venus* upon the Sun: Hence, therefore, the Time of deſcribing that Chord would be known; alſo from hence the viſible Conjunction S P will be likewiſe known, and alſo the Point of the Ecliptic to which the Line B F tends, or place of the Node will likewiſe be-

become known: And when, from Obſervations made abroad, it ſhall be known what the true Quantity of *Venus*'s horizontal Parallax is, then E F will be alſo known, which is the Difference of the true Path from the viſible One, and therefore its Poſition will be known alſo. ——— But it muſt be confeſſed, that Matters of ſuch great Nicety and Importance ought not to be truſted to, or made to depend upon one ſingle Obſervation, but ought to be deduced from all that are made of the Planet while it was ſeen on the Diſk, but principally thoſe which relate to the Time of the Egreſs, and the perpendicular Diſtance of the Planet from the Limb of the Sun, at different Inſtants of Time, during the Tranſit. ——— Therefore, at preſent, we muſt be ſatisfied to have only a general Notion of theſe Matters, and muſt poſtpone the farther Conſideration of them to a future Opportunity, that may furniſh us with freſh Materials for proſecuting this Subject in a more extenſive Degree.

Euphroſ. But what is your Opinion, *Cleonicus*, concerning a Satellite's attending this Planet, which has been of late ſo much the Subject of Converſation, and which ſome of the Gentlemen preſent apprehended they ſaw on the ſolar Diſk?

Cleon. A Man's Opinion in ſuch Caſes avails little or nothing; but this I know, that what the Gentlemen took for a Satellite in the Sun was only a ſolar Spot, and it is certain that what was publiſhed in the common News-papers was the ſame Kind of Miſtake; for the Satellite having a ſimilar Appearance with that of the Planet, *viz.* perfectly *black* and *circular*, and withal ſo large as to equal the fourth Part of the Planet's Diameter, muſt neceſſarily have been very eaſily ſeen on the Sun's Diſk, had any ſuch Thing been there; and farther, as the Diſtance of this Satellite is ſuppoſed not to exceed 50 Semi-diameters of its Primary, it is very certain, as it has been obſerved to move in a Circle directly before the Eye, it muſt neceſſarily have been obſerved on the Face of the Sun, unleſs it happened to be in the lower or ſouthern Part of its Orbit. ——— From the Accounts of Mr. *Caſſini*, Mr. *Short*, and now of theſe *French* Philoſophers, it is very certain there is ſomething that muſt have appeared about the Planet in their Teleſcopes; but whether it be a Satellite of the ſame Nature and Kind with

thoſe

thoſe which belong to the *Earth*, *Jupiter*, and *Saturn*, is ſomewhat of a Queſtion, becauſe of the unuſual Poſition of its Orbit, and of its very ſeldom and precarious Appearance. Were it only an opake Body like another common Satellite, it would, like them, appear at all Times in a uniform Manner, more or leſs enlightened, but generally in the Form of a Creſcent like the primary Planet itſelf; and as *Venus* is ſo near to the Earth, at her inferior Conjunctions eſpecially, it would be impoſſible not to have a frequent View of a common Satellite that attended her. ——— You muſt, therefore, in regard to this Phænomenon, wait far farther Information to ariſe from repeated and accurate Obſervations, and, according to thoſe which have been already made, the Time for ſettling the Theory of this Satellite ſeems not to be very near: But if ever it comes to paſs, it will conduce not a little to the Advancement of Aſtronomy and natural Philoſophy; for, in the firſt Place, the Aſtronomy of the Secondary Planets will then receive its laſt Perfection, for no Satellite is ever to be expected about *Mars* or *Mercury*. And, Secondly, the Power of Gravity in the Planet *Venus* can then be known and compared with that in the *Sun*, *Saturn*, *Jupiter*, and the *Earth*; for the Quantities of Matter in any two Planets are in a certain Ratio of the periodical Times and Diſtances of the Satellites which revolve about them, and conſequently the Forces of Gravity which are proportional thereto; and that this Planet, in her lower Conjunction, approaches ſo near the Earth, her Force of Gravity and its Influence on the Motions of the *Earth* and *Moon* may be looked upon as not very inconſiderable, and conſequently the Share it has with the perturbating Forces of the other Planets and Comets, introducing Irregularities in the Motions of the *Earth* and the *Moon*, may then be eſtimated, and conſequently the Theory of theſe Planets (the moſt conſiderable in the Syſtem) will be thereby greatly improved.

Euphroſ. Since ſuch great Events depend on a Diſcovery of a Satellite about *Venus*, it is not to be feared, I ſuppoſe, that the Vigilance of Aſtronomers will one Day or other put that Matter out of all Doubt, and ſatisfy Poſterity whether it be a real Satellite, or a mere *Ignis Fatuus* that now amuſes them and perplexes

plexes their Curiosity. ——— But what is this Preparation, or Apparatus of Globes, Orreries, and other Things which I see here upon the Table?

Cleon. These, my *Euphrosyne*, are intended to entertain you with an *artificial Transit*, and not only that, but likewise to explain, at the same Time, the *Rationale* of so curious a Phænomenon as far as I can do it by Instruments. — It is a great Satisfaction and Pleasure which the real Transit has afforded so many thousand *Virtuosi*, but, I think, that is not enough for you; for it has ever been my chiefest Care to enliven your Ideas with the *Rationale* of them, and then you have the highest Entertainment that the Nature of Things afford. ——— You here observe three Instruments placed on a Right-line, by each other, on the Table; that in the Middle, you will recollect, is the artificial *horological* Globe which I made use of to explain the Nature and Reason of Eclipses.

Euphros. I see it is the very same Globe; but the Apparatus is not the same as you then made use of.

Cleon. It was necessary here to make an Alteration in that Respect; for now this Globe is be connected with the Orrery, which you see on the right-hand Side, and with the Transit Instrument on the Left.

Euphros. But the Orrery is the same which you formerly used in explaining to me the solar System, at least, so far as I can perceive.

Cleon. There is one material Difference, my *Euphrosyne*, in the Structure of those Orreries; ——— that which I then used, moved with Clock-work, this, which you here see, is put in Motion only with a Winch, when used by itself, by which Means it is easily connected with, and put in Motion by the Globe, by Means of that String which you see go round the Pulley.

Euphros. The same String, or silken Cord, I observe goes on the other Side to the Transit Instrument, as you call it, which, as it consists of a Board with a black Ground and a large silvered circular Plate in the Middle, is, I suppose, intended to represent the Sun in the dark Field of View in the Telescope;

I likewiſe ſee the ſilken Line go over that Part of the ſilvered Plate which *Venus* traverſed on the real Sun; and ſo, I preſume, repreſents the viſible Path of *Venus* on the ſolar Diſk. But where is the Planet itſelf, *Cleonicus?*

Cleon. That you will ſee by and by: ——— You will firſt take Notice that, in general, the Motion of the *Earth* will neceſſarily give Motion to the Orrery on one Hand, and to the Line over the artificial Sun on the other; and that, by this Means, the Planet *Venus* will appear in the periodical Revolutions about the Sun on one Side, and exhibit the natural Cauſe of her retrograde Motion and Conjunction with the Sun, in the Orrery, at the ſame Time that ſhe is ſeen to paſs over the ſolar Diſk, in the Tranſit Inſtrument on the other ſide. — And, laſtly, the Motion of the *Earth*, the relative Poſitions of its Inhabitants, and the ſeveral Moments of Time for the reſpective Phaſes and Circumſtances of the Tranſit are all ſhewn by the Globe.

Euphroſ. But if you intend I ſhould have a clear and diſtinct Idea of the complex Effect of this Apparatus, you muſt be particular in explaining what I am to ſee, and have a direct regard to, in each particular Part of it.

Cleon. This I will do: And, firſt, with reſpect to the Orrery, I will place all the Planets in ſuch Parts of the Ecliptic, as they appeared in on the firſt Day of *January*, or the Beginning of the preſent Year, and, when the Machinery is in Motion, you will have a particular Regard to the Motions and Poſition, of *Venus* and the *Earth*; and, on the 6th of *June* on the Plate of the Orrery, the Planet will come exactly between the *Earth* and the *Sun*, and from thence the Manner how the real Tranſit is occaſioned will be eaſily conceived.

Euphroſ. That I ſhall attend to; but what am I to obſerve in the *Earth?*

Cleon. The following Things, (1.) In order to adjuſt the *Earth* to its proper Poſition for that Time, I bring the Index, at one End, to point to the 6th of *June*, which will bring the North-pole of the Earth to its proper Situation in the enlightened Hemiſphere. (2.) As the *Sun* is then over the middle Point of that Hemiſphere, I turn the Globe till the Meridian of *London* paſſes through the *Sun* in that Point, and there holding

ing it faſt, I turn the Dial-plate till the other End of the Index points to XII at Noon. (3) Then I revolve the Globe backward, 'till the Index points to about a Quarter after II in the Morning, which was nearly the Time of the Beginning of the Tranſit at *London*. (4.) Then the Iſland of *Great-Britain*, and all other Places have their reſpective Situations for that Phaſe of the Tranſit.

Euphroſ. I ſuppoſe you mean that any particular Place, as it is ſituate in the light or dark Hemiſphere, will be able to view, or not to view the Beginning of the Tranſit. Thus, for Inſtance, *London* appears at that Time far within the darkened Surface of the Globe, and St. *Helena* ſtill more remote from the Circle of Illumination, whilſt, on the other Hand, I ſee *Bencoolen* in *Sumatra*, and all the Eaſtern Part of the Globe in the illumined Hemiſphere, viewing the Planet entering the ſolar Diſk, in various Altitudes above the Horizon.

Cleon. If now, in the laſt Place, you caſt your Eye on the black Ground of the upright Board, you may obſerve, on the Left-hand Side of the ſilvered *Sun*, a large black round Patch juſt ready to enter, and ſhew itſelf on the Limb of the Solar Orb.

Euphroſ. Yes; I ſee it now you direct my Eye; but before it was ſo much of the Colour of the Board, or rather no Colour at all, that I did not perceive it at this Diſtance. ——— By the braſs Screws on the Side of the Board, I ſuppoſe you can adjuſt the Path of *Venus* to any Part of the *Sun*, or ſo as to cut the Ecliptic in any given Point, as the Poſition of the Nodes require; and the Limb of the *Sun* being divided into Degrees, the Quantity of the Arch at the Ingreſs and Egreſs of the Planet from the Ecliptic Diameter of the *Sun* is eaſily repreſented.

Cleon. You ſeem now to have a juſt Apprehenſion of the Uſes and Deſigns of the ſeveral Parts; it remains, therefore, now to put the whole in Motion, which, as it is very ſlow, will afford you an Opportunity of viewing very minutely all the Peculiarities of the Tranſit in each ſeparate Machine. ——— I wind up the Spring, and now obſerve the diurnal Motion of the Earth, ——— the planetary Motions about the Sun, ———

and the artificial Planet or Patch just entering the eastern Limb of his Disk.

Euphros. The several Phænomena you mention in the respective Machines are now very obvious: —— In the Orrery, I see all the Planets moving in their proper Orbits from the Beginning of the Year; and tho' the *Earth* be at that Time before the Planet *Venus*, yet, as that Planet follows with a quicker Motion, she is every Moment advancing nearer and nearer to a Conjunction, 'till at Length I perceive them both in a right Line with the *Sun*, on the 6th Day of *June*, on which Account, as she is then so near the Node, she is there seen to pass over the Face of the *Sun*; and as she is then describing that Part of her Orbit between the *Earth* and the *Sun*, she must necessarily appear to have a retrograde Motion, and enter the *Sun*'s Disk on the eastern Side, as, I well remember, you shewed me in a former Lesson on these Subjects: all which gives me a clear Idea of the astronomical *Rationale* of this famous Transit. —— Then, with Regard to the *Earth*, I perceive it moving with a diurnal Motion analogous to that of the real *Earth*. —— At the Beginning of this Motion, the Index points to II o'Clock in the Morning, and the Island of *Great-Britain* then is in the darkened Hemisphere; and I have the Satisfaction of seeing, in one View, how all the Parts of the *Earth* are situated in the enlightened and dark Hemispheres, which gives me a clear Idea of the Times in which the Beginning of the Transit will happen to all the Parts of the *Earth* where it will be visible, and of all other Parts of the Globe where it will not be seen.

Cleon. Here I must interrupt you for a Moment, —— you remember that some Mathematicians were sent abroad to observe the Transit in distant Parts of the World, their Destinations were originally to the Isle of St. *Helena*, and to that of *Sumatra*: the first of which you observe near 16° of South Latitude, and about 6° 30′ West of the Meridian of *London*, and therefore far from the enlightened Hemisphere at the Beginning of the Transit, insomuch, that they only arrive to it just Time enough to observe the End of the Transit in the Morning: nor had they any other View originally, in their Deputation to St. *Helena*, than of viewing the End of the Transit near the Horizon, that they

they might have the greateſt Parallax of Altitude, which in that Caſe would be nearly equal to the horizontal Parallax of the Planet. —— But with Reſpect to the Iſle of *Sumatra*, or *Bencoolen*, the Deſign was there to obſerve the Times of the *Beginning* and *End* of the Tranſit both, and conſequently the Duration of the whole, in order to compare it with the real Time of Duration as obſerved from the Centre of the *Earth*; and for this Purpoſe you ſee this Iſland is ſituated moſt advantageouſly in the enlightened Hemiſphere; —— but, by a Paragraph in the late News Papers, we underſtand this great Deſign is fruſtrated; for, by that we learn, that thoſe who went out in the *Sea-horſe* for that Department were obliged, by ill-fated Incidents, to put in at the *Cape of good Hope*, whoſe Situation, as you ſee on the Globe, at the Time of the Beginning of the Tranſit, is far within the darkened Hemiſphere; and conſequently the moſt intereſting and important Part of the Phænomenon, and which was their particular Buſineſs to obſerve, was wholly inviſible to them. For as the *Cape of Good Hope* has a greater South Latitude than St. *Helena*, and a leſs Diſtance from the enlightened Hemiſphere, the Parallax both of Altitude and Longitude will be much leſs there, and conſequently the Obſervations made at the *Cape* will be of much leſs Conſequence than thoſe at St. *Helena*, and therefore anſwer no Purpoſe at all: So that the Share which *England* is likely to have in the Diſcovery of the Parallax of the *Sun* is not likely to be great, unleſs any of our Nation at the Factories in the *Indies*, for the Honour of their Country, or their own Curioſity, ſhould be excited to make their Obſervations at the Beginning and End of the Tranſit very nicely.

Euphroſ. This will be a very ungrateful Piece of News to the curious Part of the Public, eſpecially to thoſe who could wiſh to ſee *England* as renowned for the Improvement of aſtronomical Science, as by the Succeſs of its Arms. —— By this Time I ſee the *Britiſh* Iſle is juſt upon entering the illumined Hemiſphere, and the Index now points to about $\frac{3}{4}$ after II: —— But the *Cape of Good Hope* is ſtill in the dark. —— And juſt now I perceive the artificial Planet, or Patch, juſt riſing above the Horizon, and ſo far advanced on the Solar Diſk as it appeared to thoſe who had the Pleaſure of viewing that Part of

the Phænomenon. —— As the Motion of the *Earth* continues, the Parts of the Surface are ſucceſſively brought into, and carried out of the enlightened Hemiſphere, and *England*, amongſt the reſt, gradually proceeds towards the Middle Part of its diurnal Arch. —— In the mean Time, the Planet regularly advances on the *Sun*'s Diſk, —— and is nearly in the Middle of her Path when the Index of the Globe points at VI. —— The *Cape* now enters the Sun-beams, and obſerves the Tranſit more than half over, while the *Sun* is not yet riſen to St. *Helena*. —— The *Earth* keeps revolving uniformly upon its Axis, and, at length, brings St. *Helena* to enter the enlightened Hemiſphere, and ſoon after views the End of the Tranſit at a ſmall Altitude of the *Sun* above the Horizon. —— I obſerve the artificial Planet to be now much about that Poſition of the *Sun*'s Diſk as when I firſt ſaw it thro' the Teleſcope, *viz.* about ſeven o'Clock in the Morning of that memorable Day. —— The Motion here of the Planet, I plainly ſee, is every Way ſimilar to that of the real Planet on the *Sun*'s Diſk. The Motion of the Planet and the *Earth* being perfectly correſpondent to each other, at length the Patch arrives at the weſtern Limb of the *Sun*, and ſhews the internal Contact of the Planet at the Time the Index points to a few Minutes after VIII in the Morning. —— And it is very curious now to obſerve the *artificial Egreſs*, which ſeems in every Reſpect to bear a proper Reſemblance to that of the natural one. —— The artificial Tranſit is juſt now at an End, for the Patch is now in external Contact with the Limb of the *Sun*. The Index of the Globe now points to nearly half an Hour after IX, ſo that I obſerve the Time the Egreſs here is about 18 Minutes, which is the ſame as was obſerved of the real one. —— In the laſt Place, I ſee the Poſition which our Iſland had on the enlightened Hemiſphere at the Time of the total Egreſs, and alſo the relative Situation of all other Places where that Phænomenon could be ſeen. —— And now, *Cleonicus*, I muſt acknowlege that you have, by this Means or Contrivance, conveyed to my Mind as perfect a Knowlege of the geographical and optical Principles of the Tranſit as I could poſſibly have from any artificial Machinery, and, for

your

your Care and Trouble herein, ſhall ever think myſelf highly indebted.

Cleon. It ever was, and will be my Study to repreſent the various Phænomena of Nature in ſuch a Manner as may moſt exactly correſpond with the Operations of Nature itſelf, and nothing will more felicitate my Succeſs than the Pleaſure and Inſtruction that may thence redound to one who is ſo dear to me as yourſelf. —— I fear I have, by this Time, proved tedious; but you will remember, it is upon a Subject that, like the *ſecular Games*, happens but *once in an Age*.

DIALOGUE XII.

Concerning the NATURE *and* USE *of* BINOCULAR TELESCOPES.

Cleonicus.

OUR laſt Converſation was a Digreſſion from our Speculations on the *Nature and Uſe of optical Inſtruments*. But it happened very opportunely to a moſt ſignal Inſtance of the latter, as I then obſerved to you. —— I ſhall now return to the former Subject, which I ſhall re-aſſume with the Conſideration of *the Nature and Uſe of Binocular Teleſcopes*. —— We have already largely enough deſcanted on all the common Conſtructions of this Inſtrument; but as the Binocular Teleſcope is of a different Form, and has a very peculiar Property, I thought it might be worth while to ſpeculate on the Nature of it for an Hour. —— A *French* Author, formerly, *(P. Cherubin)* had ſo high an Opinion of this Inſtrument, that he wrote a large Volume in Folio almoſt wholly upon the Subject; and, indeed, ever ſince their firſt Invention their Effects have been greatly admired by all who delight in Optics.

Euphroſ. If I can judge from the ſound of the Word, this Inſtrument imploys *both the Eyes*; —— and as I preſume the Inſtruments you ſpeak of, are thoſe before us, they appear to me

me to be a *double Teleſcope*, one of the refracting, and the other of the reflecting Kind.

Cleon. You obſerve very rightly in each Reſpect; the Binocular Teleſcope conſiſts only of the Glaſſes of two common Teleſcopes, properly adjuſted, to ſhew the ſame Object to both Eyes. —— You will readily conceive the Deſign and Utility of this Conſtruction by conſidering how great the Advantage of common Viſion by two Eyes, is, in Compariſon of that by one only: It hath been uſually made an Argument of a moſt obvious Providence, that Animals are in general furniſhed with two Eyes, that they might not be dark with the Loſs of one; but we may add to this, the great Pleaſure and Perfection of viewing Objects with two Organs of Sight inſtead of one: Nor is this at all difficult to be experimented, as I make no Doubt you have oftentimes had the Curioſity to try.

Euphroſ. I have many a Time tried that Experiment, and found the Difference very ſenſibly: —— The Field of View is not only more confined by ſhutting one Eye, but the Objects are leſs vivid and bright, and ſeem, as it were, diminiſhed and contracted to the View.

Cleon. It is all very true that you ſay; but 'tis very obſervable, that the Difference is nothing like ſo great to the naked Eye as by the Teleſcope, where, as we may ſay, this very difference is magnified in Proportion with the Objects themſelves; and this is that very wonderful Effect that I juſt now mentioned, and which ſo wonderfully recommends this Inſtrument to all the Curious.

Euphroſ. But how are the two Teleſcopes adapted to exhibit one Idea of the Object only: One would think, that, by two Teleſcopes, we ſhould have two different Views of the ſame Object?

Cleon. The natural Reaſon of this is the ſame as that by which an Object appears but one and the ſame to two naked Eyes, notwithſtanding there are two Images formed, one in the Bottom of each Eye. For by the wonderful Diſpoſition of the nervous Syſtem, the two optic Nerves are united in the ſame Part of the Brain, where the Senſations of each Image, or the Ideas which they occaſion, are united in one, and ſo preſent

preſent it to the common Senſory of the Mind; and you will eaſily conceive that the Teleſcope, ſingle or double, does not multiply the Image, but magnifies it only. The Image in each Eye is ſtill the ſame, but only larger; and therefore two Teleſcopes only produce two larger Images to the Eyes, inſtead of two ſmall ones, and conſequently the Mind has ſtill the *ſingle Idea* of the Object, but enlarged.

Euphroſ. I preſume, this is pretty much a parallel Caſe with thoſe who uſe Spectacles; for they, with two Glaſſes, ſee the Object enlarged, but ſingle at the ſame Time.

Cleon. Your Compariſon will hold, provided the Spectacles you ſpeak of are diſpoſed as they ought to be, (but thoſe of the common Make are not,) *viz.* when the Axis of the Glaſſes are both directed to the Object that we view, and there interſect each other: And this is the Caſe of the two Teleſcopes which compoſe this Inſtrument, the Axis of each are ſo directed, by adjuſting Screws, as to point to, and terminate in the Object we look at; for, in that Caſe, each Teleſcope preſents the ſame View, enlarged, as we have in ſmall, by the naked Eye: Thus, two Teleſcopes, in that Reſpect, has the Effect of one, with this important Addition, that the Field of View in the Binocular Teleſcope, tho' really the ſame as in the ſingle one, is yet ſeemingly vaſtly enlarged, at a greater Diſtance, ſhewing the Objects more ſtrong, bright, and perfect, than they uſually appear; which is one of the moſt agreeable and noble Deceptions that can be found in any optical Inſtrument, of which I ſhall now gratify you with an Experiment, having firſt obſerved to you, that while we look thro' the Inſtrument it is neceſſary to turn two Sets of Screws, to adjuſt it to the Eye, one which moves the Object-glaſſes, and the other the Eye-glaſſes, nearer to, or farther from each other, 'till the Axes of each Teleſcope coincide with thoſe of the Eye and nicely meet in the Object. ——— In this Manner I have now adjuſted the Refracting Binocular, and now, if you take my Place, you will ſee yonder Houſe in the moſt agreeable View you ever beheld it.

Euphroſ. I do, ſure enough. ——— I find every Thing juſt as you have deſcribed it: ——— With both my Eyes I ſee the

the Field of View, in Appearance, wonderfully enlarged: The Appearance of the Houſe more natural, eaſy, and vivid. ——— But when I ſhut one Eye, then I ſee the very great Difference you ſpeak of, the Field, as it were, ſeems contracted as well as the Objects; and every Thing has a poor and unpleaſant Aſpect in Compariſon of the former. ——— To tell you the Truth, *Cleonicus*, you will, by this Experiment, put me out of Conceit with the common Teleſcopes. ——— I can ſcarcely think I ſhould reaſon well if I uſed a ſingle Teleſcope inſtead of a double one, any more than I ſhould, if I preferred viewing Objects with one Eye inſtead of two. ——— Pray, is the Effect nearly the ſame in the Binocular Reflectors?

Cleon. It is there in Proportion heightened, as they magnify more than the Refractors: ——— I have fitted them for your View: ——— Look now at the ſame Object through them.

Euphroſ. Well, this is wonderful indeed: —— I may truly ſay I never knew what it was to view Objects thro' a Teleſcope before. I have ſeen them indeed magnified, and thought that was a wonderous Effect; but I ſcarcely know how to expreſs the different Senſations which ariſe from a Proſpect of the ſame Objects in this compounded View: —— Here is truly (*je ne ſçay quoi*) ſomething inexpreſſibly delicate, grand and delightful in the Effect of this Inſtrument! —— It is amazing to me, that every Lady or Gentleman of Fortune and Curioſity has not one of theſe Binoculars in their Poſſeſſion.

Cleon. You might be in an eternal Amazement if ſuch Things were to excite it; the Caſe is ſo far otherwiſe, that you ſeldom obſerve the Purchaſe of any Inſtruments is in Proportion to their Merit and Uſes: Things in common Vogue, that give us no Trouble to underſtand their Uſe, and which have been made Time immemorial, are moſtly the Subject of common Demand; few inquire after new, or more perfect Improvements. —— But yet, I cannot help wondering a little, with you, that there are not more of thoſe curious Perſons than we find; ſo very few there are, that I never ſaw but one of thoſe Binocular Reflectors, yet, in any Gentleman's Collection of *optical Inſtruments*, and yet there is nothing in the Price

that

Plate L.

Fig. I.

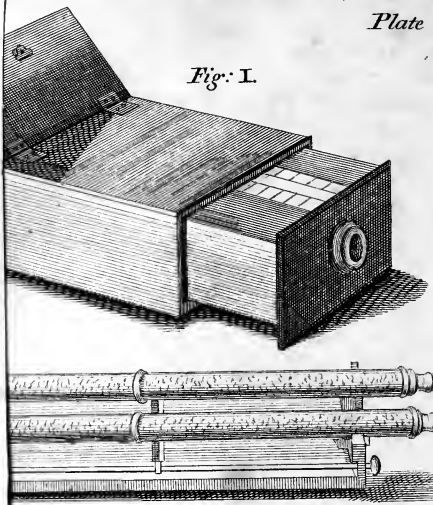
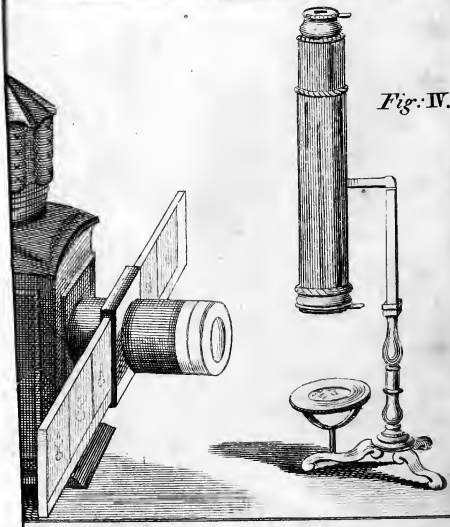


Fig. IV.



that is so very extraordinary, or difficult in its Use, that might deter People from having them. Especially as to the Refracting Binoculars, whose Expence and Use are both very reasonable and easy. Of these there were no less than three or four of different and very curious Construction in the Museum of his Grace the late Duke of *Argyle*.

Euphros. And was I a Duchess, I would have as many, and every Instrument of every Form and Construction that could afford me any different Pleasure and Instruction; and I should always look upon those Instruments as the principal Furniture of the choicest Apartments of my House.

Cleon. There is yet another optical Instrument, which, at our next future Leisure, I shall describe to you, and tho' it has no magnifying Power for distant Objects, is not without a Variety of Uses adapted to the Amusement of Ladies and Gentlemen, and with which, I dare say, you will be very well pleased.

DIALOGUE XIII.

The DESCRIPTION *and* USE *of an* OPTICAL INSTRUMENT *for measuring the* ANGLE *of* VISION, *the apparent* MAGNITUDES, *and* DISTANCES *of Objects; for viewing perspective* PRINTS, PICTURES, *Intaglio's, &c.*

Cleonicus.

I Shall now present you, my *Euphrosyne*, with a small optical Instrument that is not only designed for Amusement, but many considerable Uses.

Euphros. It makes but a small Appearance, 'tis true; but the Value and Uses of Things, in general, depend very little on their Bulk. —— Pray, what are the Peculiarities of this Instrument?

Cleon. I shall relate them to you in Order, and exemplify them by Experiment: One Thing, however, I shall premise

Plate I.

Fig: I.

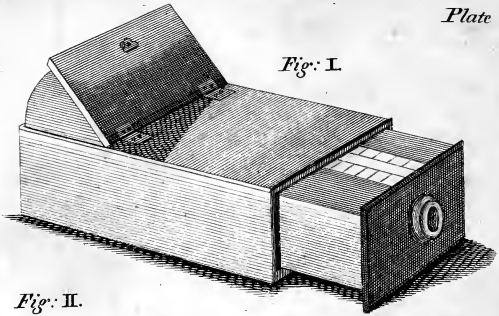


Fig: II.

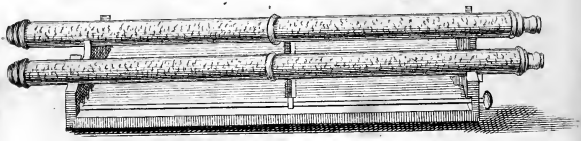


Fig: III.

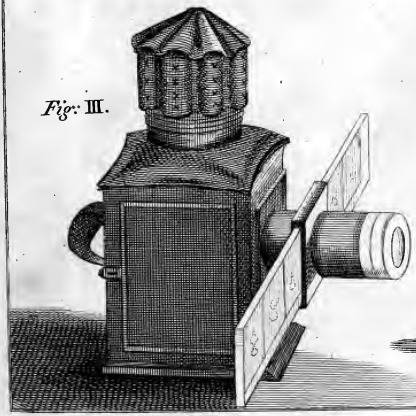
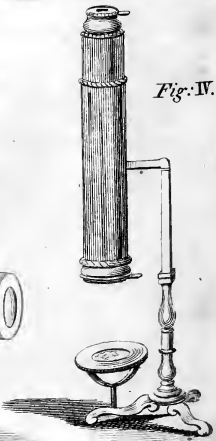


Fig: IV.



that is so very extraordinary, or difficult in its Use, that might deter People from having them. Especially as to the Refracting Binoculars, whose Expence and Use are both very reasonable and easy. Of these there were no less than three or four of different and very curious Construction in the Musæum of his Grace the late Duke of *Argyle*.

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DIALOGUE XIII.

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Cleonicus.

I Shall now present you, my *Euphrosyne*, with a small optical Instrument that is not only designed for Amusement, but many considerable Uses.

Euphros. It makes but a small Appearance, 'tis true; but the Value and Uses of Things, in general, depend very little on their Bulk. —— Pray, what are the Peculiarities of this Instrument?

Cleon. I shall relate them to you in Order, and exemplify them by Experiment: One Thing, however, I shall premise

with respect to the Nature and Construction thereof, as it is a Property quite peculiar to this Instrument, and that is this, *viz. that it gives you a clear View of distant Objects, without magnifying them at all, and, at the same Time, it presents you with a magnified View of Objects near at Hand*, by a proper Change of Glasses.

Euphros. Pray, what, and how many Glasses have you in this Instrument?

Cleon. There are essentially no more than two required, and those both of the same Form, or Figure, and consequently of the same focal Distance:——And, as to the Position, they are placed, as you see, one at each End of the Instrument, and from this Construction you will easily understand the Nature of the Instrument, from what I have formerly said of a Telescope with two Glasses; for in such a one, you remember, I told you that the magnifying Power was in Proportion of the focal Distance of the Object-glass to the focal Distance of the Eye-glass. Now, in this Instrument one Glass is to be considered as the Object-glass, by which an Image is formed; the other, as an Eye-glass, by which it is viewed; but since these Glasses have an equal focal Distance, the Image will be equally distant from either Glass, and consequently there can be no magnifying Power at all with respect to distant Objects: For the Image will appear under the same Angle to one Eye applied to the Glass, as the Object does to the other naked Eye, and therefore they must appear equal, as you will find by Experiment.

Euphros. Pray, let me try that Experiment.——I will place myself on this Side of the Room, and look on the Sash-window on the other Side, and see how the Quarrels appear, in the Manner you formerly directed me by viewing it with one Eye applied to the Glass, and the other without it.——And now I perceive the Truth of all you say,——each Quarrel in the Window is of the same Bigness in the Instrument as to the naked Eye, and, by properly removing it, I make the whole Frame in the Image exactly coincide with the Appearance of the Window itself to the naked Eye: Which, therefore, fully proves that the Image and the Object are equal to each other.

Cleon.

Cleon. You will farther obſerve, that in the Conſtruction of this Inſtrument there is a Screw and Cell in the middle Part, for another Glaſs; which is to be of the ſame focal Diſtance with the other Two, whoſe Uſe is to render the Field of View more perfect towards the extreme Part; by which Means the Eye may be applied nearer, and view the Object to much greater Advantage. ——— You will ſatisfy yourſelf by the Experiment: For I have now put in the third Glaſs.

Euphroſ. It is really fact: The Images of all Objects that I view, appear in an enlarged, and a much more perfect Field, even to the extreme Circumference; this Glaſs is a great Addition to the Diſtinctneſs and Perfection of the Inſtrument. ——— But it is ſomething of a Paradox to me, that a Glaſs, which, in itſelf, has ſo conſiderable a magnifying Power, ſhould yet, when placed in the Inſtrument, appear to have no Effect of that Kind.

Cleon. Optical Glaſſes, applied in different Circumſtances, will have different Effects; it's Diſpoſition in the Middle of the Inſtrument gives it no Power of magnifying, but only of perfecting the Field of View.

Euphroſ. The Image I obſerve is inverted; but that, I preſume, is no Obſtruction to the Uſes you would make of this Inſtrument: ——— But, as it neither magnifies nor diminiſhes, I ſhall be glad to know wherein the Uſes of it conſiſt.

Cleon. That I ſhall now particularize to you. It is therefore to be obſerved, that ſince the Object and the Image appear under the ſame viſual Angle, that Angle may be eaſily eſtimated, or meaſured by this Inſtrument, by adapting a MICROMETER to the middle Part, where the Image is formed in the common Focus of both the Glaſſes, which Micrometer may be made of many different Forms, *viz.* (1.) With a Screw having very fine Threads, or (2.) by Means of parallel or equadiſtant Lines drawn on a circular Piece of plain Glaſs very near to each other; or, (3d) by two Hairs moving parallel to each other in a ſmall braſs Frame placed in the middle Part of the Inſtrument.

Euphroſ. How, by Means of theſe Micrometers, you meaſure a viſual Angle, be pleaſed in the next Place to explain to

me; for, as yet, I am not acquainted with these Instruments of Measure.

Cleon. A MICROMETER is an Instrument of great Use in the nicer Computations of Astronomy, which concerns the Magnitudes and Distances of the heavenly Bodies: But, in the Use of this Instrument, great Exactness is not required; and therefore a Micrometer made of a Screw will answer this general Purpose as well as any, and will be more simple and least expensive of all others; and a Screw that has *forty Threads in an Inch* will be sufficient for this Purpose. Then, if the focal Distance of the Glasses be *one Inch*, the Angle, which is subtended by the Interval between two of those Threads, will be 1° 26′, and two will subtend an Angle of 2° 52′, and 3 Threads will subtend an Angle of 4° 18′, and so on; the Angles and their Subtenses being very nearly proportional, when very small, and therefore, by observing how many of those Threads of the Screws the Image of any Object occupies, it will be known from thence what the Quantity of the optic Angle is under which it appears: ——— And if a Screw has a greater Number of Threads to an Inch, as suppose 60 or 80, the Accuracy of the Instrument in measuring the optic Angle will be in such Proportion greater. ——— But though this Use of the Instrument may the least concern you, yet it may be oftentimes of great Importance to those who are concerned in measuring the Angle under which distant Objects appear, which are generally very small, in order to form a Calculation, or an Idea of their Distance, by previously knowing the Dimensions of the Object. Thus, for Instance, by knowing the Number of Feet in the Length of the Cross on the Top of St. *Paul*'s, and observing, by this Instrument, what Angle it subtends to the Eye, a Person will immediately find, by the Rules of Trigonometry, what Distance he is from that Object.

Euphros. This is an Affair of too mathematical a Nature for me; there are others, I presume, more adapted to my Understanding, which may afford me some Degree of Pleasure and Curiosity.

Cleon. There are, most certainly; the next I shall mention is one of them, which is, that by Means of this Instrument we may easily judge of the comparative, or apparent Magnitude

nitude of Bodies: For when you would compare the apparent Magnitude of any two Objects, you only move the Inſtrument in ſuch a Manner, as ſhall bring the Image in each Object ſucceſſively upon the Threads of the Screw, and then obſerving how many of thoſe Threads are occupied by each. Thus, for Example, if the Image of one Object was equal to the Diſtance of two Threads of the Screw, and another meaſured three Threads; then their apparent Linear Dimenſions would be in Proportion as 2 to 3, and their Surfaces in Proportion to the Squares of thoſe Numbers, *viz.* 4 to 9, and their Solidities as the Cubes, or as 8 to 27: And thus the *comparative apparent Magnitude* of all diſtant Bodies may be eaſily eſtimated.

Euphroſ. This, I allow, is a very pretty and inſtructive Uſe of the Inſtrument, as nothing is more common than to hear People aſk, How large do ſuch or ſuch Objects appear? whereas, it is impoſſible to give any Anſwer to ſuch Queſtions, without a Method of comparing their Magnitude with that of ſome other Object that we know; which, by what you have now ſaid, I find is very eaſy to be done by ſuch a *Micrometer*.

Cleon. Another Uſe of this Inſtrument, equally curious and amuſing, is, to meaſure the Diſtance of any Object without any Skill in Geometry, or the leaſt Degree of Difficulty: Thus ſuppoſe you obſerve the apparent Image of any Object upon the Threads of the Screw, then, if you walk ſo far backward 'till the Image of the ſame Object occupies but half the Number of Threads, or if you go forward 'till the ſaid Image meaſures twice the Number as at firſt, in either Caſe you walk juſt ſo far as is equal to the Diſtance of the Object from your firſt Station; for you well know, the apparent Magnitude of Bodies increaſe or decreaſe very nearly with their Diſtances inverſly, or, that at twice the Diſtance, they appear twice as ſmall; and, at half the Diſtance, they appear twice as large.

Euphroſ. I believe I pretty nearly comprehend your Meaning: For, ſuppoſe I was on the Bank of a River, and I took, with this Inſtrument, the apparent Magnitude of the Body of a Tree on the other Side, and then Retreat from the River, ſo far, 'till I obſerve the Image of the Tree occupy but one Half the Number of Threads as before; then the Diſtance I have

gone

gone back from the Bank will be juſt equal to the Width of the River, which by this eaſy Experiment becomes known.

Cleon. That is juſt the Thing that I mean; and, in like Manner, you may apply it to meaſure the Diſtance of many other inacceſſible Objects.——Again, another Uſe of this Inſtrument is to view the Height of an Object, when you know the Diſtance from it: For, by knowing the Number of Threads in the Screw which go to an Inch, you, by that Means, know the Proportion of the Image of any Object to the focal Length of the Glaſs; and this is the very ſame as that of the Height of the Object to the Diſtance you are from it; and therefore you may only ſay, as the Number of Threads contained in the focal Length of the Glaſs is to the Number of Threads which meaſure the Image, ſo is the Diſtance of the Object to the Height of it; which therefore becomes known without any farther Trouble.

Euphroſ. This Application of the Inſtrument appears not the leaſt conſiderable, to thoſe who underſtand the *Rule of Three.* But you were mentioning ſome other Uſes which would be ſtill more intereſting than theſe, *viz.* ſuch as relate to viewing Prints, Pictures, *&c.*

Cleon. Theſe Uſes require a Change of Glaſſes in the Inſtrument; for as one principal Deſign hereof is to view diſtant and perſpective Prints, one of the equal Glaſſes at the End muſt be chang'd, for another whoſe focal Diſtance is longer; for then that will add a magnifying Power to the Inſtrument: but this is upon Suppoſition, that the Print or Picture that you view, is at a Diſtance from you, and in itſelf not very large, or greater than the uſual Size of Family Pictures.—— But if the Picture, or Print, be in itſelf very large, and near at Hand, as, for Inſtance, upon the Table before you, then will the Inſtrument, without any Change of Glaſſes, do; for in this Caſe a magnifying Power is not required, the Image filling the whole Field of View, without it; and, indeed, that is the only Rule to be obſerved in all Caſes whatſoever, that ſuch a Glaſs be applied as will cauſe the Image of the Object to appear as large as the Field of View will admit of, and then the beautiful Effects of the Inſtrument will appear, *viz.* a moſt natural and fine *Relievo*

of

of all the Parts: This will be better ſeen by Experiment, than expreſſed by Words. ——— Here, view the perſpective Print before you on the Table, without changing the Glaſſes.

Euphroſ. It is a fine View of St. *Paul*'s Cathedral, I ſee at once: ——— The auguſt Pile riſes to the View, and its majeſtic Dome and Croſs appear ſublime in the Air: ——— The Pillars all in proper Arrangement and Diſtance, and the whole Architecture appears in the natural and glorious Conſtruction of the Weſt Front: The ſpacious Area, or Court before, appears expanded and in the ſame natural Perſpective as if I was viewing it from the adjacent Corner-ſhop in *Ludgate-ſtreet:* ——The Pedeſtals are all erect, and her Majeſty, with the other emblematical Statues, appear as natural and vivid as on the Spot. ——— Upon the Whole, I think this a ſufficient Proof of the excellent Uſe of this Inſtrument in viewing perſpective Prints.

Cleon. But you will be eaſily convinced that the ſame Glaſſes will not ſuffice for viewing Prints hanging at the oppoſite Side of the Room, as the Image will be there too ſmall for all its Parts to appear diſtinctly: For your Satisfaction, I will place the ſame View of St. *Paul*'s, with a good Light, at that Diſtance, and then you may view it with the ſame Glaſs.

Euphroſ. I do as you inſtruct me; ——— I view it, indeed, but not with the ſame Satisfaction as before: ——— it is in Perſpective, I confeſs, but the Appearance ſo diminutive and indiſtinct as convinces me, that ſome Degree of magnifying is now neceſſary.

Cleon. I will change the Glaſſes, and apply one proper for the Purpoſe, and then you will obſerve the ſame Effect nearly as before.

Euphroſ. It is very true; the ſumptuous Pile has now the ſame Appearance of Grandeur as to the naked Eye. ——— But now let me view a Landſcape, or ſome ſuch large Perſpective Painting.

Cleon. I will go and invert two or three for this Purpoſe, without letting you know what they are 'till you view them. ——— There is one now ready, can you tell me what Part of *England* you ſee?

Euphroſ.

Euphrof. Yes, that I can without Hesitation: ——— I must necessarily consider myself as on the Summit of *Richmond Hill*, and there surveying the beautiful Scenes of the distant Country and *Villa*'s all below: ——— The perspective Diminution and tortuous Irregularity of the noble Stream; ——— the Forest, Fields, and Lawns, all attract the wondering Eye: —— But what a Change have you suddenly made, from so delightful a Scene to one so shocking to human Nature! —— Cathedrals, Palaces, and the most beautiful Ranges of Houses, all in one confused and ruinous View! —— Methinks, I see a City all in Commotion, and falling by the tremendous Shocks of an Earthquake! This, therefore, I am satisfied, is a View of the terrible State in which *Lisbon* has lately, and often appeared, from its most inauspicious Situation. —— The Scene is again most wonderfully changed; the River of a fine and flourishing City now regales my View, and the glorious Appearance of a Bridge, constructed with one Arch, makes me fancy myself at *Venice* viewing the *Rialto*, so famed throughout the World. —— These Instances of perspective Views are sufficient. Let me next see what is the Effect in viewing Portraits and family Pictures.

Cleon. I must take one down, and put it in an inverted Position, for the Reasons I have heretofore mentioned: It shall be that venerable old Face of your Grandfather, of which you have often expressed so high a Value; for, by this Instrument, you will see how properly, and with how much Reason you do it: ——— Take a View of it.

Euphrof. Upon my Word, it almost reinstates him in Life: ——— The Face, as it were, starts from the Canvas, and the poor old Gentleman seems to regard me with so natural a Smile, as if he knew me in the near Relation, ——— his Eyes seem lively, and percipient, —— they sink very naturally under his Brow, —— his Nose properly projects from the Face: in short, his whole Mein, or Countenance is such as plainly bespeaks him a Man of that Sedateness and contemplative Disposition for which he was so remarkable when living. —— By these Experiments, I am satisfied how useful this little Instrument is for this Kind of Views. ——— What other Uses yet Remain?

Cleon. Several: one of which will not a little delight you, I am well assured. ——— For now, if to the two equal Glasses

I add

I add a third of the same focal Distance with them, and the Intervals of the Glasses be respectively equal to twice their focal Distances, then is it fitted for viewing, in a peculiar Manner, all Intaglios, or deep cut Figures in precious Stones, Seals, *&c.* for then they appear just contrary to what they are; *viz.* as *Cameo's*, or with a Bass Relief, as you will easily observe by viewing the Head excavated in this Seal.

Euphros. This is something very odd, indeed; that the Head, which I know to consist of a hollow Cavity in the Seal, should now appear with so perfect a *Relievo* above it; I see every Part of the Head, Hair, Face, and whole Bust, just as plain as the *Cameo*, or Impression on the Wax: ——— And from the Picture and Bust, which I have often seen of Sir *Isaac Newton*, I guess this to be a Representation, in Miniature, of that celebrated Personage.

Cleon. It is, indeed, that venerable Man: ——— But the Excellency of the Instrument, in this Respect, consists not so much in the Conversion of a Figure, as to enable you to examine the Perfection of Work of this Kind; for the Glass will, much better than the Wax, shew you the Care and Skill of the Artist in the Execution: Nor can you, any other Way, be so thoroughly satisfied of the Value of his Performance, or the Estimation which it really deserves. These Glasses, therefore, are of the utmost Service to Engravers, Jewellers, *&c.* as well as to Ladies and Gentlemen of Curiosity and Fortune.

Euphros. But before we drop this Subject of *Intaglios*, I shall be glad to be informed of the Reason of so odd, or rather contrary Appearance of the Object.

Cleon. This is one of the most celebrated optical Paradoxes, and is equally curious and inexplicable; there is scarce any Thing in the optical Science so directly contrary to the known Laws of Optics as this very Phænomenon: For it is most certain, that the Image formed of the hollow Object is still a deeper Cavity than the Object itself, and therefore one would naturally expect to see the *Intaglio* Concave in a higher Degree; whereas, on the Contrary, it is so much more a *Cameo*, or the *Relievo* in Proportion higher. ——— In Perspective, a Semicircle, being drawn on a proper Ground, may be made to appear as a convex or concave Hemisphere, at Pleasure; by a

proper *Claroſcuro*, or Diſpoſition of Light and Shade; but here, without any Aſſiſtance of Art, a more wonderful Effect of the ſame Kind is produced, not a plain Circle, but a concave Hemiſphere is in any Sort of Light raiſed into a perfect convex One. ——— The true phyſical Reaſon is as yet dubious among the learned in Optics, and it would prove an unentertaining Diſquiſition to trouble you with it at this Time.

Euphroſ. Are there any farther Uſes to which this Inſtrument may be applied?

Cleon. Yes, of very conſiderable Importance; no Inſtrument being better adapted for ſhewing, to the greateſt Advantage, all Kinds of Foſſils, Minerals, Oars, Earths, *&c.* either with a Magnifier that is now on, or others that might be placed in its Room: ——— See the Ore which I have now placed under the Glaſs.

Euphroſ. I do, indeed, view a fine beſpangled Surface of ſomething; but had you not ſaid it had been an Ore, I ſhould not have known what it had been: ——— I ſee the Metaline Particles curiouſly interſperſed, and incorporated with the ſtony Matter of the Ore. ——— I could not have thought the Metal had been ſo diſtinctly viſible in its natural State as I now perceive it to be. ——— By the Colour I gueſs it to be Silver, as it appears not in the leaſt diſguiſed in the Stone: ——— But what gratifies my Eye in the higheſt Degree is, to obſerve the moſt curious Vegetation of the metalic Matter, ——— it evidently ſhoots into various Sprigs and forms, in many Places, a like Kind of Ramification; and, in others, the Repreſentation of a beautiful Foliage. ——— Surely, *Cleonicus*, this is a very rich Piece of Ore, as I ſee it ſo very replete with ſilver Particles, over all the Surface expoſed to View.

Cleon. It is ſo rich, my *Euphroſyne*, that one Pound of this Ore contains near four Ounces of Silver. ——— But now I will place under the Glaſs another Sort of Ore, ——— ſee, if you can tell me what it is.

Euphroſ. By the fine Appearance it makes, of a rich gold Colour, I judge it to be a Piece of gold Ore.

Cleon. I thought you would be miſtaken, on that Account; and you ſee, from thence, how eaſy it is to be deceived by Appearances: ——— The Ore which you now view is not Gold, but

but Copper Ore; and what you see in such brilliant golden Colours is neither Gold nor Copper, but what the Miners call *Mundick*, a Matter of little Value in itself, and only remarkable for its falacious Mimickry of Gold. ——— In like Manner you may, at your Leisure, view all other Species of Ores and terrestrial Substances, which will afford you a most instructive Amusement.

Euphros. I shall be sure to embrace every Opportunity for that Purpose. What is the next Use of this Instrument?

Cleon. By screwing on another Glass at the Bottom, in the Room of that which is now there, it is converted into a common Microscope for viewing any Sort of small Objects; but, as this will afford you nothing new, it need not be further insisted upon. ——— You will observe, upon the whole, that this one Instrument is capable of being applied to almost all optical Purposes: ——— I have placed it on a proper Foot, or Stand, by which it may be very readily applied to any proposed Object, and, as such, shall desire your Acceptance of it. There remains yet one Instrument more, that shall be the Subject of our next Discourse.

DIALOGUE XIV.

The CONSTRUCTION *and* USE *of the* LANTERNA MEGALOGRAPHICA, *vulgerly called, The* MAGIC LANTHORN.

Euphrosyne.

PRAY, *Cleonicus*, what Compliment do you intend to make me by this Instrument, which I see is a Magic Lanthorn, whose principal Use, as I understand, is to divert Children with the Appearance of ludicrous Objects?

Cleon. The Compliment I shall make you is no other than the Knowlege of the Construction, and proper Uses that might be made, of a noble optical Instrument, whose Nature and Use have been but little considered, and those applied to serve

the loweſt Purpoſes, by which Means this Inſtrument has been brought into Diſgrace, and acquired the vile Name of *Magic Lanthorn:* ——— But the Abuſe of Things, by the Ignorant, does not alter their Nature; and becauſe this Inſtrument is capable of exhibiting a large and ſurprizing View of any odd, ridiculous, or monſtrous tranſparent Picture, and thereby occaſion Wonder and Surprize to an inconſiderate Populace, it does not by any Means follow that Ladies and Gentlemen, nay Scholars, and Sages themſelves may not be very rationally amuſed with the curious and noble Effects which ſuch an Inſtrument can produce with proper Objects applied to it. A precious Stone is not of leſs Value for being worn on the Finger of a Show-man, and there is nothing in the Magic Lanthorn that is ſcandalous, but the Name itſelf, ſo deſire you will not think yourſelf affronted by having this Inſtrument ſet before you.

Euphroſ. I only joke with you, *Cleonicus*, as I know the Reputation this Inſtrument is in: ——— But, pray, how comes it to be called the *Magic* Lanthorn?

Cleon. From the wonderful Effects which it was obſerved to produce, by the ſtupid and ſuperſtitious Part of Mankind, and the Villany of Cheats and Impoſtors. For, on the firſt Invention of this and ſuch like Inſtruments, it was well known how the Minds of the ignorant Populace would be influenced by ſuch amazing Effects; and as it was eaſy to conceal the Cauſe, the Conjuror had it by this Means in his Power to work Miracles, and multiply the Experiments of his Magic Art; and it is not to be doubted, the Tribe of Miracle-Mongers found their Cauſe of Impoſture to be as much promoted, by this Inſtrument, among their credulous Votaries, as by any one Inſtrument that ever fell into their Hands: ——— But after all, nothing more has been done with the Magic Lanthorn, to anſwer the execrable Views of Sorcerers, than is daily practiſed with the Bible itſelf, by the Profeſſors of pious Frauds, in almoſt every Age and Country: and it is moſt certain, that if there were no Fools, there could be no Pretenders to the Magic Art; nor ſhould we ever have heard of any ſuch Thing as a *Magic* Lanthorn. ——— We ſhall therefore diſcard the infamous Appellation of *Magic*, and ſubſtitute in its Room the true and deſerved Epithet of *Me-*

galographic

galographic Lanthorn, by which the Nature of the Inſtrument is, as it were, deciphered and explained, as ſignifying nothing more than the *producing a very large and magnified Picture of a ſmall Object.*

Euphroſ. This Inſtrument, then, I ſuppoſe is to be uſed by Candle-Light, as you have choſen the Evening to diſcourſe of it, and from thence I conclude, that it has ſome Affinity to the Solar *Megalaſcope*, which you ſome Time ago explained the Uſe of to me.

Cleon. It is in Effect almoſt the ſame Inſtrument; it differs, it is true, in Form, and requires the Candle-light, as the other does that of the Sun: But as a ſmall Quantity of the Sun-beams will ſuffice in a Megalaſcope, and in the Megalographic Lanthorn a very great Quantity of Candle-light is neceſſary, therefore the Lanthorn muſt neceſſarily exceed the Megalaſcope in Bulk, as it muſt contain the Candle itſelf and a large Speculum, or Lens, by which the Light may be collected ſufficient to illuminate the Objects that are magnified: and hence ariſes a two-fold Conſtruction of this Inſtrument, *viz.* with a Speculum and Lens conjointly, and the other with Lenſes only.

Euphroſ. This, I ſuppoſe, is the Reaſon why I ſee two Lanthorns here before me, one of a large, and the other of a ſmaller Size.

Cleon. It is ſo: The large one, as you will ſee on my opening the Door, has a large Speculum placed on the Back-part, or Left-hand, which collects the Light of the Candle placed in the Middle of the Lanthorn, and then reflects it to the tranſparent Images on the Glaſs to illuminate them ſtrongly, and then the ſaid Object is magnified by a glaſs Lens in a ſliding Tube, which adjuſts it to a proper focal Diſtance; and becauſe the Speculum is large, and the focal Diſtance 12 or 15 Inches, therefore the Lanthorn of this Conſtruction muſt neceſſarily be of a very conſiderable Bulk. ——— But in the other Lanthorn, upon opening the Door, you ſee only a large, thick Lens (almoſt a Hemiſphere) of Glaſs placed between the Candle and the Objects; and tho' in this Caſe the Surface of the Lens be not near ſo large as that of the Speculum, yet, on Account of its much ſhorter focal Diſtance, the Rays of Light will be ſufficiently ſtrong for a requiſite Illumination of the Object.

Euphroſ.

Euphrof. I think, if I remember right, the Objects made use of in these Lanthorns are all painted in square Panes of Glass, and in transparent Colours, which are disposed together in a wooden Frame to be applied for Use.

Cleon. They are so; for it is necessary the Colours should be transparent to render them vivid and lively in their Images magnified as large as the Life: —— As the Objects themselves are some of them two or three Inches long, therefore a large Lens will be necessary to be used; for the Lens and its Apperture must be proportioned to the Size of the Object in this, as well as in all other optical Instruments; and then it will be easy to know what Distance the Lanthorn must be placed from the Wall, in order that the Portrait of a Person two Inches long may form on the Wall an Image of six Feet high; for if the Lens which magnifies it has its Focus at about six Inches Distance, then it will be as two Inches to six Inches, so is six Feet to eighteen Feet; therefore, if the Room be 18 Feet wide, the small Pictures of Men and Women will be formed on the Wall just as large as the Life; and therefore, when those painted Objects are properly chosen, this Instrument may afford as agreeable an Entertainment, and excite as much rational Laughter, as any one that I know of. And here I must observe to you, that among the old dull Classes of Schoolmen, *Risibility* was esteemed no inconsiderable Faculty of human Nature, and, in their Logics and Metaphysics, they often considered it as peculiar to, and a distinguishing Characteristic of Man; and surely such Faculties were never bestowed upon us in vain: and therefore the Amusement of the Megalographic Lanthorn, if they were considered in no other Light than that of Recreation, are worthy of rational Beings, and, consequently, far from being impertinent.

Euphrof. As you put so good a Gloss upon the Matter, you have excited my Curiosity to see a few Experiments at this Time, tho' I cannot help thinking, after all you have said, they will look like Puerilities, or Entertainments fit for Boys and Girls only.

Cleon. We may see the Force of Prejudice against Things taken up in a general Way, in this one Instance of your almost invincible Indifferency to this poor, degraded Instrument: For

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my own Part, I could heartily wish we had no Opportunities to observe our valuable Moments of Time spent on Subjects of Amusement more puerile, or trifling than these: However, I must entertain you with something of this Kind, and, because the Subject shall not be low, I have procured an Artist, well skilled in this Miniature Painting, to draw on two or three Slips of Glass the whole PROCEEDING of the late CORONATION, which, when you observe in Motion on the Wall, you will certainly have a different Idea, than what you have hitherto entertained of these Subjects. ——— See, I put the Slips in, one after another, and will move them in a proper Manner, while you take a cursory View of them as they pass in the regal Procession.

Euphros. This will be an elevated Subject, indeed: ——— Good Heavens! The Herb-Woman appears at a greater Advantage than when I saw her on the Plat-form at the Time. The Painter has certainly complimented her six Maid: ——— The Flowers lie as naturally on the Carpet as I then saw them: ——— A delightful Appearance, indeed; the various Orders and Degrees of Gentry and Nobility, with their proper Habits, Robes, and regal Investments, bring to my Mind so naturally the Thing itself, that I really judge this View, by Candle-light, much to exceed that by Day-light, if it may be so called when they returned from the Abbey. ——— The Canopies, under which our Sovereigns walk, are very elegant and highly improved by the Painter's Hand: ——— The King and his Royal Consort appear with all the Pomp of solemn Majesty. ——— Upon the whole, it is a most exquisite, grand, and beautiful Scene; and were such Subjects as these to be used for this Lanthorn, I cannot say but I should be as much entertained with its Effects as any of my Sex.

Cleon. But this is still in the Way of Entertainment only, nor has the Instrument as yet been ever applied to any other Purpose, tho' it be very capable of it. ——— I shall give you some particular Instances of the superior Use of this Instrument. ——— In the first Place, observe the Object which now passes over the Sheet upon the Wall.

Euphros. I know the Object at its first Appearance, having seen it before in the *Megalascope* of the *Camera Obscura*: ——— It is a Leaf dissected, or anatomised, and all its curious Ramifications

fications and Contexture exhibit a delightful and inſtructive Spectacle to the Eye. ——— What other Objects of this Kind can you put into the Lanthorn?

Cleon. In the general Collection of marine Vegetables, or Sea Plants, with which you were ſome Time ago preſented by an eminent Virtuoſo, I obſerved you was not a little delighted in recounting their various Species, and obſerving and reflecting on their peculiar Nature and great Variety of beauteous Forms; you have likewiſe employed many Hours in ſorting them out, expanding them on Paper, and diſpoſing of them in proper Frames, which you now look upon as the moſt ornamental Part of your Study: ——— You have likewiſe farther obſerved, that moſt of thoſe Marine Plants are tranſparent, and variegated with Colours the moſt delicate to be found in Nature: Theſe Qualities, therefore, render them a proper Subject for the Megalographic Lanthorn. ——— Accordingly, I have ſelected a Specimen or two of that Kind, and placed them on Glaſs in a Frame of the uſual Form, that you may ſee them, one after the other, upon the oppoſite Wall.

Euphroſ. They are, indeed, as fine a Spectacle as Eyes can behold. ——— I thought they made a glorious View in my Frames; but how infinitely ſhort does that fall of the Glory and Grandeur with which they now appear! ——— They ſeem to be each of them a new Species of large, or full grown Trees, with Limbs and Branches reſembling tranſparent Coral, of all the Variety of exquiſite Colours: ——— The Form, the Texture, and Subſtance of theſe Plants, I really think, could not be ſhewn in any other Way to ſo great an Advantage.

Cleon. There is no other Inſtrument that has yet been made for ſhewing an Object ſo large in the Sun's Light: the common Megalaſcope takes in an Object of little more than an Inch in Diameter, which is too ſmall for ſhewing theſe curious Plants, or any other large Objects, to the greateſt Advantage; tho' ſuch might be made, and applied to the ſame Purpoſe, in the *Camera Obſcura*, as you have now ſeen by Candle-light; but the Glaſſes for this Purpoſe muſt be large, and the Inſtrument of Courſe more expenſive than the common Solar Microſcope; and it is very probable, that I ſhall have it in my Power, e're long, to entertain you with one of this Kind. ——— But to return to

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our Subject: ——— There are yet other Uſes to be made of this *Megalographic* Inſtrument, ſince every Subject that is tranſparent immediately becomes applicable to it, and, though ſmall in itſelf, yet, being hereby rendered extremely large, becomes in Proportion more agreeable to the View: Thus, for Inſtance, ſuppoſing you have Glaſs Medals, or Glaſs Pictures of perſpective Views, theſe, illuminated and magnified in this Inſtrument, would have a very noble and fine Effect to the Eye, if properly ornamented and tinged with natural Colours.

Euphroſ. I ſuppoſe, by your Manner of ſpeaking, that you have ſome ſuch like Curioſities to entertain me with; and I cannot ſay but, from the Nature of the Thing, they muſt, when this Way applied, yield a very delightful Spectacle.

Cleon. You have conjectured right: For though I have not real Glaſs Medals, yet I have procured ſuch as will anſwer the ſame Purpoſe, and in a much better Manner, and which, I am well aſſured, will give you no ſmall Pleaſure when you are perfectly inſtructed in the Method of manufacturing them for your Uſe. ——— What I mean is, a Collection of very curious Impreſſions, clear and tranſparent as Glaſs itſelf, and yet without that unlucky Property of its Brittleneſs; and ſo they are never in any Danger of being broke. ——— Another valuable Property is, that they are thinner than any Wafer, and 100 of them may be put in a *Frank* and tranſmitted, by the Poſt, from one Part of the World to another. ——— The Nature of theſe medalic Impreſſions diſpoſes them to receive, and repreſent the fineſt Strokes that can be drawn by the Hand of the Engraver, and therefore will appear a more ſharp or perfect Repreſentation of the Medal, than can be expected from Plaiſter of *Paris*, or any ſuch earthy Matter. ——— Again, their Colour greatly favours a View of the Impreſſion; for you can ſcarcely find any Colour ground that will ſhew them to a greater Advantage than their own natural Colour: ——— But, if you chuſe it, you may tinge them with any Colour you pleaſe, by mixing proper Dyes or Tints with the Subſtance of which they are made. ——— See here, a great Variety of different Sorts, Sizes, and Impreſſions.

Euphroſ. A rich and beautiful Variety, indeed; to my Knowledge, I never ſaw any Thing of a more curious and delightful

Appearance: ——— They repreſent the Buſts of Men and Women in *Relievo*, as naturally as the Medal itſelf: ——— The curious Portraits, perſpective Deſigns, and Landſcapes, in Minuature, are taken off in a moſt elegant Manner, and muſt have a noble Effect when magnified in this optical Machine. ——— I obſerve, among others, the Impreſſions of their preſent Majeſties, which, I ſuppoſe, you have made from the Coronation Medals: ——— There is all the Majeſty and graceful Mien of the King, by which he is ſo eaſily diſtinguiſhed and known; and a greater Likeneſs in the Side-view of his Conſort Queen, than has yet appeared, in my Opinion, in any print. ——— I ſhall be greatly delighted to ſee them repreſented at large, by the magnifying Power of the Lanthorn.

Cleon. I have them already diſpoſed in proper Frames for the Purpoſe; ——— and now, upon the Wall, you ſee their Majeſties almoſt as large as the Life, and by this Method alone can they be repreſented ſo in any Perfection; for if theſe Figures be compared with thoſe painted ones you ſee before you, the Perfection of theſe Repreſentations will as much exceed the others, as the fine Art of Engraving exceeds the common tawdry Painting of Water-colours. ——— Here you ſee Nature itſelf heightened with all the Majeſty of ornamental Decorations and Attitudes, as far as the Skill of the Artiſt can perform, and all exhibited in full Perfection in theſe magnificent Views: ——— But, behold! a City now riſes to the View.

Euphroſ. Surely, it makes a very grand and natural Appearance. What does it repreſent, *Cleonicus?*

Cleon. It is an Impreſſion taken from a Medal of a perſpective View of the City of *London* before the Fire, where you now ſee the antient State of this great Metropolis as large as in a four-ſheet Print: ——— But I ſhall change the Scene, and preſent you with ſomething that will be ſtill more agreeable. ——— It is a variegated Piece of Perſpective, with many emblematical Scenes on a Landſcape Ground: It is the Reverſe of a Medal ſtamped on ſome extraordinary Occaſion, tho' I cannot recollect particularly the Deſign.

Euphroſ. Be that as it will, it makes a noble Picture on the Side of the Room; and if theſe pelucid Pieces of minuature Drawings are capable of ſuch high Improvement by the optical Science,

Science, it is hoped our *Engliſh* Artiſts will think of providing proper Subjects for our Entertainment this Way, in greater Plenty than we have hitherto had; ſince every curious Deſign of a pictureſque Nature cannot fail of having that Effect. —— But what do I now ſee! a wonderful Variety of mathematical Figures, Triangles, Circles, *&c.* in one Scene, and a Variety of figured Solids in the other: Pray, what is the Meaning of all this, *Cleonicus?*

Cleon. Theſe were intended, my *Euphroſyne*, (not as a Subject of Entertainment this Way, but) as an artificial Help to the Memory of the young Mathematician; for on one Side of the Medal you have engraved, the Repreſentation of the principal fundamental Theorems in Geometry, in a Variety of plain Surfaces: —— On the other Side the Medal are, finely engraved, a perſpective View of the five *Platonic*, or regular Bodies; but as I intend theſe only to ſhew what may be done in every Way where tranſparent Objects can be applied, even without the Aſſiſtance of Colours, I ſhall conclude, at preſent, with one Scene more, to ſhew how much theſe medalic Impreſſions may be improved and heightened by the Application of Colours. —— Obſerve the ſplendid Appearance on the Wall.

Euphroſ. A glorious Sight, indeed; the King's Arms all richly blazoned and coloured, as the Laws of Heraldry direct. —— I am, by this Time, thoroughly ſatisfied of the delightful Effects of this Inſtrument; and I am impatient to know how theſe Impreſſions are made, as it will be the higheſt Subject of Amuſement for ſome of my leiſure Time.

Cleon. It is a Solution of *Iſing-glaſs* in Spirits properly prepared, which is not worth your while to attempt: I have provided for you a 4 Ounce Phial of this Subſtance, which you ſee has the Appearance of a fine white Glew, and will ſerve you not only for taking medalic Impreſſions, but alſo for many other uſeful and valuable Purpoſes.

Euphroſ. You will be ſo good as to let me ſee your practical Method of taking off Impreſſions firſt, and then I make no Doubt but I ſhall be able to do it myſelf.

Cleon. In the firſt Place, the Medal is ſuppoſed to be very clean; then, having diſſolved the Glew by placing the Phial at a ſmall Diſtance from the Fire, and placed the Medal very level

on the Table, I pour the Glew on the Surface till it has covered the whole, and with the point of a Pin carry it nicely round upon the Edges of the Medal: I there let it ſtand to dry, or to evaporate the humid Part; the Remainder, which will be the pure Iſinglaſs, will be ſo tranſparent as not to be ſeen on the Face of the Medal, and will, of itſelf, come off without giving you any Trouble in that Reſpect: and thus they appear, like thoſe which you here ſee, of the Colour and Tranſparency of Glaſs.

Euphroſ. But how do you gild them with Gold and Silver, in that beautiful Manner of many of thoſe Specimens before me.

Cleon. For that Purpoſe, I lay a Leaf of Gold or Silver on the Face of the Medal, and then pour the fluid Glew upon it: ——— Or elſe, you may firſt pour on the Glew, and then let an expanded Leaf of Gold or Silver gently fall upon it, and thus the Impreſſion will be gilt on the Concave or Convex Part: or you may put the Leaf of Gold on both Sides, and ſo gild it thoroughly: And thus they look like Gold or Silver Medals. ——— And I here preſent you with a Frame of ſuch Gold Impreſſions, of all the Kings and Queens of *England* ſince the Conqueſt; together with the curious Devices on the Reverſe of each particular Medal.

Euphroſ. I am infinitely obliged to you for theſe Inſtructions: I now can take what Variety of Impreſſions I pleaſe, and thereby enlarge and enrich my *Muſæum* of Curioſities at Pleaſure. ——— But you was mentioning ſome other Uſes that were to be made of this Solution, Pray, what are they?

Cleon. They are of a more ſervile and inferior Nature, but ſtill the beſt of their Kind; I mean, that of a gelatinous Subſtance, or Glew; for it is applicable not only where common Glew is, to cauſe a Coheſion in the higheſt Degree between Pieces of Wood; but in moſt other Subſtances that are liable to be broke, particularly thoſe valuable Pieces of Furniture, Glaſs and China, when broken, will, by this Glew, be cemented ſo firmly together, that the Juncture of the Pieces will be hardly viſible, and the Strength of it almoſt equal to that before it was broke.

Euphroſ. Theſe are important Uſes of the Glew, indeed; but, pray, how is it applied to produce the ſtrongeſt Effect this Way?

Cleon.

Cleon. You must proceed thus: As soon as the Glass or China is broke, let each Part be placed by the Fire and made very hot, as also the Phial of Glew; then, with a Camel's Hair-brush, take a little of the Glew and strike over the fractured Surface of each Part, then carefully putting the Piece, or Pieces, into their proper Place, and gently pressing them together, let them stand till they are cold, and it will do admirably well for show, and, in many Cases, for real Use, as you will be thoroughly convinced of by every Experiment you try of this Kind.*

DIALOGUE XV.

The Description and Rationale of the optical OCTANT, *and* Helioſtata, *or* optical CLOCK.

Euphrosyne.

IT seems, *Cleonicus*, by the Apparatus you have prepared for my Entertainment at this Time, that you are going to quit the delightful Subject of Optics, for something in the mechanical Way; for what else can be the Meaning of the Quadrant, Clock, and other mechanical Preparations I here see?

Cleon. The Subject of Optics is not so soon exhausted as you may imagine: This most delightful of all philosophical Sciences affords

* It was thought necessary here to give a Representation of the several Instruments that have been described in some of the last Dialogues, that the Reader might have a more compleat and satisfactory Idea of each of them: therefore, in Plate L.

Fig. I. Represents the portable and proportionable *Camera Obscura*, described at large in the 10th Dialogue of this Part, Page 249.

Fig. II. Is the refracting binocular Telescope, described in Dialogue 12. Page 269.

Fig. III. Is the optical Instrument, described in Dialogue 15. P. 273. It is here represented as placed on a Foot, or a Stand, for more convenient Use; but it will do very well without.

Fig. IV. Is the megalographic Lanthorn, above described.

As the several Parts of these Instruments have been particularly described, nothing more need be said of them here.

affords you such an extensive Field, that you will find that, as yet, we have little more than traversed it half over, and that the remaining Part is all upon a delightful rising Ground. The Objects of this Science are connected with, and depend, in many Respects, on the Principles of many others, particularly the most useful Science of Mechanics; but I shall not propose any Thing for your Information that shall give you any Diffidence about understanding.

Euphros. I shall never be tired in my Progress through these delightful Scenes: but I cannot say that I ever expected to meet with a Quadrant, or a Clock, in my Way among optical Subjects.

Cleon. Perhaps you might not; but it does not follow from thence, but that Quadrants, Clocks, and many other curious Inventions may owe their essential Properties and Uses solely to the Principles of Optics, and yet never be the Subject of common Knowledge, or heard of by you or the Bulk of Mankind. ——— You will wonder, perhaps, if I tell you, that this very Quadrant, (or, more properly, *Octant*,) has always been esteemed by those who are judges as the most exquisite and useful of all the noble Inventions in Optics, which we owe to the great Sir *Isaac Newton:* And therefore, as such, I think it is very necessary that a Person of your delicate and general Taste for Science should be made acquainted with it. ——— I have often observed to you, that Science has no Relation to Sex, and therefore a Lady may as well be taught the Nature and Theory of *Hadley*'s Quadrant, as that a Gentleman should be at the Pains of studying the Theory and Mechanism of a *Spinning-wheel.**

Euphros. Whatever is of an optical Nature I am sure will please me, and therefore I shall very readily attend to all you have to say on that Instrument. ——— I see it is furnished with several Glasses, and therefore must be entitled to this Class: —— I likewise observe a Speculum and a Telescope pertaining to your Clock, and therefore I consider it as a Compound optical Machine.

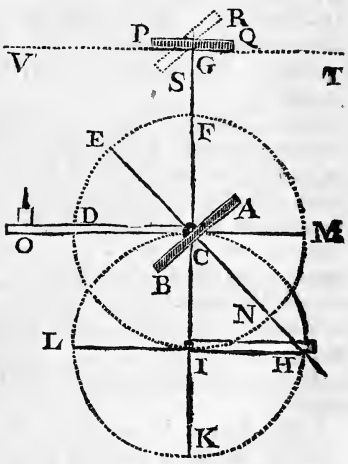
Cleon.

* See this domestic Machine explained, among others, in Mr. *Emerson*'s *Mechanics.*

Cleon. They are both of them ſtrictly ſo, and the higheſt of the catoptrical Claſs; for all their Effects are purely by reflected Light, and the Principle on which they depend is of Courſe extremely eaſy, being only this, *viz. that the Angle of Incidence is ever equal to the Angle of Reflection.* ——— This Principle you have long ſince been taught the Truth of, by Experiment, and therefore muſt, at preſent, be taken for granted; and in this the whole Theory of theſe curious Inſtruments conſiſt.

Euphroſ. If nothing more than that be required as a preliminary Qualification, I ſhall find myſelf very capable of underſtanding their *Rationale*, for there is not an Operation of Nature more familiar or eaſy of Demonſtration, than the Principle you have now mentioned; and therefore you may proceed, as ſoon as you pleaſe, to its Application in the Conſtruction of thoſe Inſtruments.

Cleon. Preparatory to that, I have provided a little Machine to illuſtrate this Matter by Experiment: This conſiſts, as you obſerve, of the following Parts, *viz.* (1.) A reflecting Speculum, or plain Glaſs, A B, moveable on a central Point C, thro' which paſſes a Wire, H E; and therefore at right Angles to the Plane of the Speculum. (2.) The Wire H C is connected with an Arm H I, moveable about a Center I, ſo that, by the Motion of the Arm I H, the Wire HE, and conſequently the Glaſs A B, is moveable at Pleaſure. (3.) On the Center I, with the Radius I C, you obſerve a Circle C H K I, is deſcribed; and (4.) on the Center C, with the ſame Radius,



is

is described the Circle D F M I. (5.) You farther observe, that the Diameters D M and L H are perpendicular to the Diameters F I and C K. (6.) In the Diameter D M, produced towards D, I place a luminous Object, *viz.* the Flame of a Candle, so that the Rays which come from it, and fall upon the Glass A B, will be reflected from thence in the Direction C F, making the Angle of Incidence D C E, equal to the Angle of Reflection E C F. ——— In all this, I presume, you understand me, *Euphrosyne?*

Euphros. With the utmost Ease, I can assure you. If there be nothing more difficult than this, you may proceed successfully.

Cleon. The next Thing you are to take Notice of is, that if the moveable Arm I H be placed at right Angles to C K, then will the Wire C H divide the Quadrant M I into two equal Parts in the Point N, and, consequently, the Perpendicular C E will bisect the opposite Part of the Circle D F in the Point E; in which Case the Angles of Incidence and Reflection, D C E and E C F, will be each equal to 45 Degrees. ——— This, likewise, I suppose, you very readily understand.

Euphros. Yes, surely, or I must be very dull indeed. Pray, proceed.

Cleon. Another Thing that you must take particular Notice of is this, that while the Arm I H describes the Quadrant H K, or 90 Degrees, the Wire E H will describe only half a Quadrant, *viz.* N I on one Part, and E F on the other; and that therefore the angular Motion of the Wire E H is but *half so much* as that of the Arm I H. ——— You moreover observe, that since the Glass A B moves equally with the Wire E C, its angular Motion will be also the same, and just half that of the Arm I H. ——— In this, likewise, I hope you will see no Difficulty.

Euphros. Not in the least, as I wish nothing to be more obvious.

Cleon. By the Mechanism of this Instrument, upon the Center C there is a moveable Arm C O, carrying the radiant Object, fixed upon it at O; and this Arm C O has the same Motion with the Arm I H, that is, when I turn the Winch you see the Arm I H move from H to K in the same Time that the Arm

Arm C O moves from D to F, and that the Glaſs and its Wire E H moves through half a Quadrant in the ſame Time.

Euphroſ. All this I obſerve with Pleaſure, and underſtand with Eaſe. What follows next?

Cleon. I turn the Winch backward, and bring the Arms I H and C O to their former Situation, perpendicular to F K; and you are then to take Notice, that a Ray of Light coming from the Candle at O, and from the Glaſs reflected to G, will there ſhew the Image of the Candle in another Looking-glaſs P Q, placed perpendicular to the Right-line F K. Now the great Point to be conſidered is, how, or in what Manner, the reflected Beam of Light C G is to be rendered permanent, or immoveable, while the Object at O is moveable upon the Arm C O, over the Arch D F; for if that can be done, the Candle in the Glaſs at G will, all that Time, remain Quieſcent, or be ſeen in the ſame Place; now this effected by the Mechaniſm of this Inſtrument: becauſe the Glaſs A B, and its Perpendicular E C, have but half the angular Motion of the Arm C O: And thus it happens, that while E C moves over any Space towards F, the Angle E C F will be diminiſhed by that Space, and the Angle E C D be juſt ſo much increaſed, and, conſequently, that the Angle E C F may be always equal to the Angle E C D, the Arm C O muſt move juſt twice as faſt as the Perpendicular C E, or the Wire C H, and then will the reflected Ray of Light always continue in the ſame Poſition, or ſhew the Image at reſt in the Glaſs P Q, while the Object or Candle is any where ſituated on the Arch D F. ——— For Example: If the Perpendicular move from its Situation at 45 Degrees E to 50°, then will the Angle E C F be only 40 Degrees, and the Angle E C D 50, which is 10 Degrees more than the other: Therefore, if while the Point E deſcribes 5 Degrees towards F, the Arm C O paſſes over 10 Degrees, it will all the while keep the Angles of Incidence and Reflection equal; and therefore the reflected Ray C G will be invariable, and ſhew the Image without any Motion in the Glaſs P Q. ——— The Truth of this you obſerve by Experiment, while I continue the Machine in Motion.

Euphroſ. It is very true; I ſee the Candle conſtantly moving over the Arch D F, while its Image appears perfectly at reſt in

the Glaſs P Q: A very curious Effect indeed, and ſuch as I could not have thought produceable from ſo eaſy a Principle.

Cleon. The next Thing you are to obſerve is, that ſince the Ray C G is, by this Means, fixed, it will be rendered ſo if reflected into any other Poſition: As, ſuppoſe G T parallel to O M, by moving the Glaſs P Q, on its Center G, into the Poſition R S, which is preciſely parallel to that of the Glaſs A B, and then an Eye, placed at T, will ſee the Image of the Candle in the Glaſs R S at reſt, as before, while the Candle moves over the Quadrant of a Circle from D to F. ——— I turn the Glaſs P Q into the Poſition R S, and you ſee, by Experiment, its Image continues immoveable in the horizontal Line T V.

Euphroſ. All this is very evident, by Inſpection. ——— I ſuppoſe I ſhall ſee the Uſe of it exemplified in the Conſtruction of theſe Machines.

Cleon. You will, in many uſeful Inſtances: ——— But you are yet farther to obſerve that, for the ſame Reaſon, the reflected Ray is fixed, when the incident Ray is moveable. So, on the contrary, when the incident Ray is fixed, the reflected Ray will be moveable; for, if the Ray O C be ſuppoſed to continue the ſame, while the Glaſs A B and its Perpendicular A C be moved about the Center C, the Angle of Incidence E C D will be conſtantly altering, and ſince the Angle E C F muſt be always equal to it, therefore the reflected Ray C G muſt be conſtantly in Motion with a Velocity twice as great as that of the Perpendicular E C, or the Index C H, for the Reaſons beforementioned. Therefore the Image will, in this Caſe, appear to be moveable, and which you ſee in every common Looking-glaſs, which, if you move them one Way or other, will always ſhew a Motion in the Images of Objects by Reflection.

Euphroſ. I never ſit down to the Toilet without being obliged to obſerve this Phænomenon; but I never adverted to the Celerity of the Motion in thoſe Images, or knew that it was twice as great as that of the Glaſs itſelf, which, by what you have now ſaid, I clearly apprehend it to be.

Cleon. In the laſt Place you will obſerve, that when both the Glaſſes are equally moved together, the Perpendiculars to each Glaſs, as E C, G C, will conſtantly make the ſame Angle with each other; and therefore, alſo, the Angle of Incidence being

ever

ever equal to the Angle of Reflection, it will follow, that the incident Ray O C, and the second reflected Ray G T, will ever be parallel to each other; and, consequently, the Image at V always appearing in the Line T V, parallel to O C, must necessarily be Quiescent, or Motionless all the Time the two Glasses are in Motion: And this you will see by the Experiment. ——— For observe, I move both the Glasses in the Instrument round the Center C, without altering their Positions to each other, and the Image of the Object at rest in O will appear to be at rest in the Glass P Q, to your Eye placed at K. ——— Again, I turn the Glass P Q into the Position R S, parallel to A B, and then moving them both equally about the Center C, you will observe the Image, by the reflected Ray G T, at rest, in the same Manner as before.

Euphros. Your Instrument is very prettily adapted to shew these curious Particulars very naturally: But how is all this applicable to the Sea Quadrant, which, it seems, I must understand before I can pretend to be an expert female Navigator?

Cleon. When the Reason of a Thing is understood, the Practice can never be difficult: ——— This Quadrant, you see, which I take in my Hand, has the same two Glasses with those in this little Machine, the largest of which answers to the Glass A B, and is fixed upon an Index analogous to C H in the Machine; the other Glass, on the Side of the Quadrant, is to be considered as fixed while the Quadrant is in use, and answers to the Glass R S: ——— Therefore, the Use of this Quadrant being to take the Height of the Sun at Sea, in a Ship continually in Motion (which would render the common Methods at Land impracticable there) this End is extremely well answered by the peculiar Property of this Octant; for, if I hold it up towards the Sun, the Rays reflected from the Index Glass to the other, will, upon moving the Index, shew a Motion of the Sun's Image in that other Glass: And, as one half only is silvered, the solar Image will in that be seen; and, in the unsilvered Part, the Horizon, or Edge of the Sea, will appear: And consequently, while you move the Index forward on the Limb of the Quadrant, you will observe the Image of the Sun to descend in the Glass, till, at Length, it touches, with its lowest Limb, the horizontal Edge of the Sea: And when I have got it there,

it will appear at reſt, notwithſtanding the Quadrant, or Glaſſes are moveable by the Motion of the Ship. The Navigator, therefore, has it in his Power to make this Contact as nicely as he pleaſes; and from what I ſhewed you before, the angular Motion of the Image of the Sun is twice as great as that of the Index of the Quadrant: And therefore I need only obſerve, that that Angle is expreſſed in the proper Degrees on the Limb, by reckoning every half Degree a whole one; for you obſerve, the Limb of the Quadrant is divided into 90 Degrees, whereas it is in Reality but 45, or the 8th Part of a Circle (for which Reaſon it is properly an *Octant* and not a *Quadrant*:) And thus the Arch of the Sun's Altitude is, at any Time, very eaſily taken on the unſteady Baſis of a Ship.

Euphroſ. I make no doubt but you can exemplify the Uſe of this Inſtrument by Moon-light, as well as that of the Sun: If ſo, there is now as delightful a clear Moon as you could wiſh.

Cleon. There is ſo: And I ſhall command the Queen of Night to deſcend, in Complaiſance to you, from her lofty ætherial Seat, and be perched upon the Top of yonder Chimney, without any Power to move: or, to be ſerious, I will inſtantly meaſure her Height above that Chimney, which ſhe ſeems to be perpendicular over. —— Here, take the Quadrant, and hold it juſt in the Poſition as you ſee me do, and, looking through the ſmall Hole in the Braſs-ſight, you will perceive the Moon depreſſed to the Edge of the Chimney; and moving the Quadrant any how, you will obſerve the Image of the Moon to be as immovable as the Chimney itſelf.

Euphroſ. I do, indeed; and ſo curious a Sight I never before beheld: For, notwithſtanding I move the Quadrant, or Glaſſes, the Moon appears as abſolutely ſteady as if nailed on to the Top of the Chimney. —— Now let me ſee the Number of Degrees on the Limb, —— it cuts 27° 30′ that, I perſume, is what you call the Height of the Moon above the Top of the Chimney?

Cleon. It is: And after the ſame Manner you will find the Degrees contained in an Arch of the Heavens between the Moon and any particular Star, which is called the Diſtance of the Moon from the Star. Thus you obſerve yonder bright Star, called *Regulus*, or the Lion's Heart; the Diſtance of that Star from

from the Moon I eaſily find, by putting the Quadrant into a proper Poſition for bringing the Reflection of the Star upon the quickſilvered Part of the ſmall Glaſs, and then I move the Index till I bring the Image of the Star to touch the Limb of the Moon next to it, and then you will obſerve the curious Appearance they make both together: —— Here, take the Quadrant, and put it into the ſame Poſition for your own Eye.

Euphroſ. This I will do as ſoon as I can: —— I find it requires a little Practice to be ready at this Matter: —— I have juſt now brought it to bear, and ſee the Star nicely touch the Edge of the Moon next to it. —— This is a very pretty Phænomenon, indeed.

Cleon. On the Limb, you obſerve, the Index has moved over 23 Diviſions, which is therefore the Number of Degrees contained in the Arch of a great Circle, between the Moon and the Star: And to meaſure this Diſtance of a Star from the Moon is a principal, and moſt uſeful Problem in Navigation, and was the original grand Deſign of this Invention, by Sir *Iſaac Newton.*

Euphroſ. You have thoroughly convinced me of the important Uſes of this valuable optical Inſtrument: —— But I imagine, ſince you can ſo readily meaſure the Arch of Diſtance between any two Objects, it muſt be of Uſe in many Caſes on Land, as well as at Sea: Is it not, *Cleonicus?*

Cleon. You may think it very ſtrange, that a Perſon ſhould be able, by any Inſtrument whatever, to take the Height of the Sun, or any other Object, in a Ship rolling on the Waves of the Sea, more certainly, than on the firmeſt footing by Land: But you will ſoon recollect, that at Sea there is generally a clear and evident HORIZON, from which we can meaſure the Height of the Sun, Moon, or Star; but, on Land, ſuch an Horizon is wanting, and therefore this excellent Inſtrument is but of little uſe in the common Conſtruction: But it is yet capable of an *artificial Horizon* being adapted to it, and thereby the Altitude of the Sun may be obſerved, not only by Land, but likewiſe at Sea in foggy Weather, when the Sun, but no Horizon can be ſeen: By this Means alſo, it may be rendered of very great Uſe in *Surveying*, and in all Caſes where a *Theodolite*, *Circumferentor*, or common *Quadrants* are applicable.

This

This new Conſtruction of a Quadrant I ſhall take ſome other Opportunity of giving you a farther Inſight into, having ſaid, at preſent, as much as I thought neceſſary, to give you a general Idea of this noble Invention, as it pertains to the Claſs of *optical Inſtruments.**

DIALOGUE XVI.

The Deſcription and Uſe of the HELIOSTATA, *or the* ſolſtitial *and* planetary CLOCK, *on a new Conſtruction, for fixing the* SUN, MOON, *and* PLANETS *in* aſtronomical OBSERVATIONS.

Cleonicus.

I Have reſerved this Opportunity as the moſt convenient, for inſtructing you in the Knowledge of the Nature and Uſe of an Inſtrument, whoſe Theory is the moſt Sublime of all in Philoſophy. This grand Invention, like all others, has arrived at its preſent Perfection by ſeveral Gradations: Its firſt Principle is founded in Optics, and its general Nature is derived from optical, mechanical, and aſtronomical Principles; and this you will eaſily conceive when I tell you, that it is a Clock of ſuch a peculiar Nature, as to fix the Rays of Light from any radiant Object, and thereby to render the Sun Beams of Uſe in the *Camera Obſcura* more perfectly than any Inſtrument has hitherto done; and alſo, what is ſtill of much greater Conſequence, the Aſtronomer can hereby detain the Sun, Moon, or Planet, in his Teleſcope, in a quieſcent State; by which Means they become the proper Subjects of his Obſervation, and that for any Time propoſed. This hath been hitherto the *Deſideratum* of Aſtronomy; for as often as the Aſtronomer has been intent upon determining the Eclipſes of the Sun and Moon, upon delineating their *Maculæ*, or Spots, or meaſuring their apparent Dia-

* It was not judged neceſſary to exhibit, in a Plate, any Thing relating to the Structure or Uſes of the Quadrant, as that is fully done in a ſmall Treatiſe, which is given with every Inſtrument of this Kind that I ſell.

Diameters with a Micrometer, ſo often he could wiſh to ſay, *Sun, ſtand thou ſtill*; and *thou, Moon, proceed no farther in thy Path:* Since the conſtant Motion of thoſe Luminaries, in the Teleſcope, does every Moment elude his utmoſt Efforts to accompliſh the abovementioned Deſigns.

Euphroſ. Well, and are thoſe great Points effected now by this new Clock, which I here obſerve in ſo elegant a Conſtruction?

Cleon. They are, in a Degree ſuperior to any Thing that could be expected in ſo complicated a Machine, and fully ſufficient to anſwer all the Intentions of the moſt accurate Aſtronomer. ——— It may ſeem very ſtrange, that though it be wholly impoſſible to ſtop the Sun in its Courſe, yet that it ſhould be ſo eaſy to fix, as it were, his Rays, and thereby render him apparently Motionleſs: But nothing has been ſo arduous and paradoxical, which Philoſophers have not, at one Time or other, endeavoured to effect, and often have found, to their great Satisfaction and to the Perfection of the Sciences, that they are far leſs ſo in Fact than in Appearance. ——— The firſt Step toward the Diſcovery of this univerſal, optical, and aſtronomical Clock, was the Invention of Sir *Iſaac Newton*, in regard to fixing the Image of the Sun, by two Reflections from two Speculums in *Hadley*'s Quadrant, as I explained to you in the laſt Converſation; and ſince it appeared, from the Experiment in the ſmall Machine you then ſaw, that the Beam of Light from a moveable Object was rendered ſtable by one Reflection, and of Conſequence the Image was thereby rendered quieſcent, or at reſt, by a Reflection of that fixed Ray, it was eaſy to conclude, that if Rays, thus fixed by a firſt Reflection, could be thrown upon the Object-glaſs of a Teleſcope, by Reflection from a ſecond Speculum, then might the Image of the Object be made to appear at Reſt through ſuch a Teleſcope, and this was ſoon found to be practicable, by Experiment: But then they found a conſtant manual Operation was neceſſary, to keep the firſt Speculum moving, ſo as always to keep the reflected Rays in one and the ſame Poſition in the Teleſcope. ——— Thus far went the illuſtrious Inventor himſelf here in *England*, and the celebrated *Farrenheit* and *Boffat*, Abroad.

Euphroſ.

Euphrof. This ſeems to be a large Step taken at once; but, pray, what was the next Enterpriſe, to render this Machine more perfect?

Cleon. The next Improvement was an Addition of *Clock-work*, by the late learned S' *Graveſande*, who, in a moſt ſuperb Manner, conſtructed one of theſe Machines, by which the ſolar Beams, reflected from a ſingle Speculum, were rendered permanent, and conſequently fit for all Experiments of the *Camera Obſcura*, and all the Purpoſes of teleſcopic and aſtronomical Obſervation.

Euphrof. No doubt but ſuch an Atchievement in the Sciences was received with great Eagerneſs and Applauſe: I ſuppoſe, thoſe who had Occaſion for trying Experiments on Priſms, the ſolar Microſcope, *&c.* took the firſt Opportunity of availing themſelves of this Invention, and that no public or private Obſervatory would be without ſuch a teleſcopic Clock.

Cleon. Alas! my *Euphroſyne*, it is much to be wiſhed, the Fate of the Sciences were not ſo much like that of Virtue itſelf, *viz. to languiſh under univerſal Applauſe:* For notwithſtanding the Philoſopher had, by this Means, rendered the Sun obedient to all their Wills, and fixed him for their View for every Kind of Obſervation, yet have I never heard of a Purchaſer of one of thoſe noble Machines, nor have I converſed with any Gentlemen who had ever ſo much as ſeen them. I thought it would reflect great Diſhonour for ſuch an Invention not to be found in any *Engliſh* Author, and therefore procured a Copper-plate of it to be engraved and publiſhed, to gratify ſuch *Engliſh* Artiſts who might be willing to enquire into its Nature and Uſes; and this, as far as I can learn, is the only Appearance it has ever made in *England.**

Euphrof. But I ſee you have now proceeded farther, and conſtructed ſuch a Clock in Reality: Pray, is this the ſame as you mentioned before, of S' *Graveſande*, or is it with any additional Improvement ſince?

Cleon. It has received ſeveral Additions from the celebrated Philoſopher and Mechanic C. G. KRATZENSTEIN at *Petersburg*, who has rendered its Conſtruction more univerſal, by adapting it

* The Plate here referred to is to be ſeen in the *Philoſophia Britannica*, at the End of the Lecture on Optics.

it to the Motion of the Planets, as well as that of the Sun, to which S' *Graveſande* was confined, together with ſome other Alterations and Improvements, which render the Uſe of it more ſimple and eaſy: But even the Accounts which this Gentleman has given of the Machine, in the Commentaries of the *imperial Academy of Sciences*, is ſuch as left ſufficient Room for many Alterations to be made even in his new Conſtruction. Theſe I have attempted in the beſt Manner I could think of, and which makes the Appearance of the Clock as here exhibited to your View; and I can think of nothing more that can be altered, or added to it, to render it more fit for uſe.

Euphroſ. As this Machine promiſes ſo much Eaſe, with Exactneſs, in aſtronomical Obſervations, I ſuppoſe thoſe Machines that have been heretofore uſed for ſuch Purpoſes will now be laid aſide, unleſs the Expence ſhould be any Objection to this new Improvement.

Cleon. The Expence is ſo far from being an Objection againſt it, that it is a very great Circumſtance in its Favour; it is deſigned to ſucceed what is uſually called the *equatorial Teleſcope*, which, by a large and complicated Syſtem of Wheel-work, puts it in our Power to find out the heavenly Bodies very readily, and to continue them in the Field of the Teleſcope, by a conſtant Application of the Hand to the ſeveral Screws; by this Means, the Aſtronomer can make a ſhift to keep the Planet in View, but not to fix it there, which was the great Point wanting, and effected only by this new aſtronomical Clock: And yet, after all, the equatorial Teleſcope will coſt more than double the Price of this Machine.

Euphroſ. If the Advantages of this be ſo much greater, and the Expence ſo conſiderably leſs, I ſhould think there can be no Queſtion made of its being readily received, and greatly encouraged here. ——— I ſuppoſe, by what you ſay, that which I here ſee is the firſt that has been made in *England?*

Cleon. It is; and an *Automaton* of this Kind is a new Phænomenon in the King of *Great-Britain*'s Dominion. The Ingenuity of Clock-makers has hitherto principally appeared in ſhewing, beſides the Hour of the Day, the Age and Phaſes of the Moon, the Day of the Month, the Equation of Time, and

ſome other Particulars of that Sort, which were judged to be uſeful or neceſſary in domeſtic Affairs: But, in regard to the Sciences, very little has hitherto been effected by Clock-work, the great Point endeavoured by the principal Mechanics in this Way is an *equable Motion*, which is almoſt as impoſſible in its own Nature as a *perpetual Motion*, both on Account of the Nature of the Materials of which ſuch Machinery muſt conſiſt, and alſo from the Principles of Mechaniſm themſelves. However great Sums of Money have been expended for improving Machines only to aproximate thereto, it would be incredible were I to mention the exorbitant Sums that have been paid for Clocks and Pendulums on this Account, and yet, after all, we find no ſuch Thing as an equable Motion in any tolerable Degree. Thoſe Pieces called Regulators, as the Machinery is the moſt ſimple, ſo their Motions are moſt equable; but even thoſe very Automata themſelves require to be regulated by ſydereal Obſervations, and every Clock hitherto propoſed is confined to the *mean ſolar Time*: But the Clock we are now to diſcourſe of is of an univerſal Nature, and ſhews, as well the *Lunar* and *Planetary* Day as that of the Sun, by the Contrivance of a Pendulum proper for ſuch a Deſign.

Euphroſ. I have not a clear Idea of what you mean by a Lunar, or planetary Day: Pray, *Cleonicus*, explain that Matter to me, that I may underſtand the Uſe of your Machine in its full Extent?

Cleon. That I will do, as ſuch a Phraſeology is not as yet very common; and, for this Purpoſe, I ſhall diſtinguiſh Days into four Kinds, (1.) A *ſidereal Day* is that Space of Time which is taken up in one compleat Revolution of the Earth upon its Axis, or, in other Words, the Time that paſſes from the Moment in which any particular Star is on the Meridian, to the Moment it returns to that Meridian again. (2.) A *ſolar Day* is the Time that paſſes from the Sun's leaving the Meridian, to its return thither again: This Day we uſually divide in 24 Hours. (3.) The *lunar Day* is the Time which intervenes between the Moon's Departure from the Meridian, and her Appulſe to it again. (4.) A *planetary Day* is the Time which the Planets ſeverally take in departing from, and returning

ing to the ſame Meridian. ——— Theſe ſeveral Sorts of Days are of a very different Length from each other, and the three laſt conſtantly variable among themſelves; eſpecially thoſe of the Moon and Planets: And as the Deſign of this Clock is to ſtop the apparent Motion of theſe Luminaries, it is neceſſary the Index of the Clock ſhould be adapted to a Motion analogous to thoſe of the heavenly Bodies themſelves, which is effected by a Pendulum of a different Structure from any that has yet been made, as none of the common Sort would commodiouſly anſwer this End.

Euphroſ. Then, if I apprehend you right, when you purpoſe to obſerve the Sun, you adapt the Pendulum for moving the Index in ſuch a Manner as to ſhew *ſolar Time*, or the 24 Hours of the common Day. ——— But how do you proceed with regard to the *Moon* and *Planets?*

Cleon. As the lunar Days are almoſt an Hour longer than the ſolar Day, the Pendulum muſt be made to vibrate ſlower, ſo that the Index, or Hand of the Clock may be made to go once round in about 25, inſtead of 24 Hours; for the longer the Time is of the diurnal Revolution, the ſlower the Pendulum muſt beat of Courſe, that the Hand of the Clock may correſpond to the Motion of the Planet. Thus, for Inſtance, the longeſt lunar Day is almoſt exactly 25 Hours, and therefore, if I make the Vibration of the Pendulum ſlower, in the Proportion of 25 to 24, the Index of the Clock will keep Time with the Moon for that Day, in ſuch Manner, that were you to obſerve the Moon through the Teleſcope, by the Rays of Light reflected into it from the Speculum of the Clock, ſhe would appear fixed, or immoveable in the Field of View, and you would have the utmoſt Pleaſure of viewing her variegated Face without any Interruption from her Motion; of which ſignal Curioſity, I ſhall give you a remarkable Inſtance, by and by, by Way of Experiment, after we have refreſhed ourſelves at the Tea-table. ——— But as for the Planets, their Motions are, ſome ſlower, and others quicker than that of the Sun; their Days will therefore be, in Proportion, ſhorter or longer than the *ſolar Day*. Thus, for Example, ſuppoſe *Saturn* upon the Meridian, together with the Sun, this Day at Noon, then, as the Motion of *Saturn* is

ſlower than that of the Earth, in its Orbit, or Sun in the Heavens, the Earth, in revolving upon its Axis, will ſooner bring the ſame Meridian to *Saturn*, than to the Sun; and, therefore, when I ſhew you that Planet through the Teleſcope of this Machine, in order that he may remain quieſcent in the View, it will be neceſſary for me to accelerate the Motion of the Pendulum in Proportion, as the *Saturnian* Day is ſhorter than that of the *Solar* One. On the other Hand, if it be propoſed to view the Planet *Mercury*, as his diurnal Motion in his Orbit exceeds that of the Sun, then, if I retard the Motion of the Pendulum in ſuch Proportion as the *mercurial Day* exceeds the Length of the *ſolar Day*, will you have a View of this Planet fixed, or permanent as if really Motionleſs in the Heavens. And this Proceedure is the ſame with regard to any of the other Planets; and this is called, *rectifying the Machine for planetary Obſervations.*

Euphroſ. I ſuppoſe it will alſo require to be rectified for the Latitude of the Place, ſince I perceive your Clock is not in a perpendicular Poſition, like other Clocks; but inclined to the Horizon in a certain Angle.

Cleon. It is true; the Face or Plane of the Clock muſt ever be parallel to that of the Equator, and therefore inclined, in the ſame Angle, to the Horizon; and conſequently the Clock muſt be rectified to the Latitude of the Place where it is uſed; on which Account, the Fulciment, or Supporter at the End of the Hour-index, which carries and directs the Index of the Speculum, muſt alſo be longer, or ſhorter, in Proportion, as the Latitude is greater or leſs; for, otherwiſe, if this be not ſcrupulouſly obſerved, the Luminary will not appear fixed in the Teleſcope.

Euphroſ. I farther imagine, by another Part of your Aparatus for the Speculum, that that alſo muſt be rectified, or adjuſted to the Sun's Declination at different Times of the Year.

Cleon. In this you alſo conjecture right; for, according to the different Declination of the Sun, North or South of the Equator, ſo the Speculum muſt conſequently have its Height above, and Diſtance from the Clock properly altered: To which End, you obſerve, a due Proviſion is made by Sliding-bars, which are adjuſted, by Screws, to a great Exactneſs in each of theſe

these Respects; and because the Declination of the Moon and Planets, from the Equator, never exceed 30° 0′, it was not necessary to provide for viewing any Objects beyond that.

Euphrof. Do you not likewise find it necessary to adjust the Machine, in regard to the Meridian and Horizon?

Cleon. Yes: These are also Articles to be nicely observed; and in order thereto, you take Notice of a curious *magnetical* NEEDLE and COMPASS placed in a proper Part of the Machine, by which it is placed due *North* and *South*: —— And then, with Regard to his horizontal Position, you see there are two Spirit-levels placed at Right-angles to each other, by Means of which, and four adjusting Screws, the Machine in all its Parts is truly placed in a horizontal Position. These Things are all of them easy to be performed for any given Time, as is evident by Inspection.

Euphrof. But, as the Speculum has its Height constantly varying above the Base of the Machine, it seems necessary that the Telescope should always keep Pace with it, or be elevated, or depressed, exactly in the same Degree: To which Purpose, I see the same Contrivance applied by Sliding-plates and adjusting Screws, for fixing it in the required Position. —— If there be any farther Particulars relating to its Rectification, you will be kind enough to mention them, as I am impatient to see the Effects of so exquisite and uncommon a Machine.

Cleon. Nothing remains now but to rectify the Machine, and shew you the Use of it, which, at present, must be confined to the Sun: We have just now half an Hour for that Purpose. —— To this End, it will be only necessary to put to the Window-shutters; and let a Beam of the Light come through a Hole, made in one of them of a sufficient Width, that it may, for sometime together, fall upon the reflecting Speculum. —— This you see is done, and the Sun-beam is reflected in a Position parallel to the Floor, and falls on the Side of the Room, which reflected Beam you will observe continues immoveable, or always retains the same Position or Direction.

Euphrof. To prove this, I must make a Mark with my Pencil in the Side of the luminous Spot, and then I can easily observe if it moves or not. —— A sufficient Time has passed to have

have obſerved the Motion, if there was any: ——— By this Time I am fully convinced that the reflected Beam is perfectly quieſcent: ——— It is not without ſome Degree of Surprize, and equal Pleaſure, that I obſerve this new and very extraordinary Phænomenon, *a Beam of Light fixed and motionleſs.*

Cleon. It muſt afford the higheſt Satisfaction to every *Virtuoſo* in Optics, to have the ſolar Beam tranſmitted into his Room, and there, by this Means, rendered conſtant and immoveable, for Hours together, without the leaſt Trouble to himſelf, while he may ſit down, and, at his Pleaſure, apply his Priſms in all the Variety of Experiments relative to the different Refrangibility, Reflexibility, and Colours of Light: Alſo, his ſolar Microſcope, for magnifying ſmall Objects, may here be applied without that expenſive Apparatus that uſually attends them, the *Wilſon*'s Part only being here ſufficient for all ſuch Purpoſes; eſpecially if, inſtead of the plain Speculum which you now ſee applied to the Clock, one conſiderably Concave was placed in its Stead; for then would the Rays of Light be reflected converging to a Focus, and in this converging State *Wilſon*'s Microſcope might eaſily be applied, on a proper Foot or Stand, and all Experiments thereby performed with the utmoſt Eaſe.

Euphroſ. This I plainly perceive; and many other Uſes I make no doubt but ſuch a permanent Beam of Light, in its various Forms of parallel, diverging, and converging Rays, may be made to anſwer, by thoſe who are curious in this Science. ——— But I want to have a View of the Sun through the Teleſcope, which I obſerve you have taken off from the Machine.

Cleon. I will replace it, and adjuſt it, that you may ſay, for once, you have ſeen the Sun without Motion, —— There, look through it.

Euphroſ. I behold the glorious Orb, which nearly fills the Field of View: ——— And there I ſee it remains without the leaſt Tendency to Motion: ——— With how much Pleaſure, now, I view the Spots on the ſeveral Parts of his Diſk, and their relative Poſitions: ——— I have now an undiſturbed View of every Part of that wonderous Body, which I never beheld in any

any such Perfection before: ——— It gives me great Pleasure and Delight, to see the *Sun stand still* by such a plain and simple Contrivance of Art: ——— One would wonder, that a Thing so very curious in its Nature, and yet so very plain and easy in itself, should not long 'ere now have been found out.

Cleon. There seems to be, for the continual Entertainment of Mankind, a gradual Discovery both in the Works of Nature and Art. It is not consistent with the Notions we ought to form of a wise Providence, that it should at once open all the Scenes of Knowledge to the Views of Mankind: This would rather confound and perplex, than instruct and amuse them; and it appears, by Experience, that every Age, before it can be thoroughly instructed in the Doctrines of former Times, has a great Variety of Novelty to excite and exercise the Ingenuity of Men. ——— But to return: You have seen the Sun itself quiescent through the Telescope; you will, in the next Place, be no less pleased to see the Image of this great Luminary transmitted thro' the Telescope on the Side of the Room, as soon as you remove from your Place. ——— I move the Screw on the Side of the Telescope but a little, and you see the solar Disk, with all its Spots, depicted on the Side of the Room, as motionless as a Picture in a Frame: You may there draw the Circle and delineate all the Spots, and thus make a Map of the Sun with Ease and Pleasure.

Euphros. This is a most curious Effect indeed, and one of the most sublime Experiments I have hitherto seen: ——— The Sun itself, the Beam, the Image, the Spots, are all, by this Means, permanent and fixed, and, consequently, must thereby give the highest Satisfaction to all curious Enquiries of Nature, and answer the utmost Expectations of Astronomers. ——— But now let us adjourn to Tea: I am persuaded, by this Time, you stand in need of some Refreshment. ———

Cleon. I promised you, as soon as it became Dark, to entertain you with a View of the Moon and the Planet *Jupiter*, through this horological Telescope, and we have now a most delightful Opportunity for that Purpose: ——— The Evening

is

is very clear and mild, and the Moon and Planet present themselves fairly to the View.

Euphrof. We could not have wished for an Evening more serene: ——— But your Machine, I presume, will want adjusting before I can have the Pleasure of any lunar Aspects through it. You told me the lunar Day was longer than that of the Sun, and that therefore the Pendulum must vibrate slower to adjust the Clock to lunar Time.

Cleon. This is previously necessary to be done; for, by the Nature of this Pendulum, the Clock may be adjusted to any Sort of Time without altering its Length, or the Use of any secondary Bob, or Ball to be screwed up and down, as in common Pendulums: ——— I have set it now to the Time of the present lunar Day: ——— I find, by the *Ephemeris*, that the Moon will culminate this Night, or be upon the Meridian at three Minutes after XI, therefore I move the Hour-circle about till such Time the common XII o'Clock Line cuts that Hour and Minute: Thus is the Hour-circle adjusted for the Moon. ——— Then I place the Hour-index to the present Moment of Time, which is half an Hour after VII. ——— Lastly, I adjust the Speculum to the Moon's Declination, and placing the Machine due North and South, you will find the lunar Rays, reflected from the Speculum into the Telescope, will present you with the Phases of that nocturnal Luminary without any Interruption from its Motion.——You may now replace yourself in your Chair and view them.

Euphrof. 'Tis delightful, thus to set at my Ease and view the bespangled Face of the Moon as long as I chuse:——I have now nothing to do but to feast my Eyes with that wonderful Variety which there appears: I have often viewed her dark and brighter Spots, but never had so clear an Idea of all together as now presents itself in this steady and uninterrupted View.——It seems all one, as if I viewed a real Map of the Moon drawn with infinite Art and Perfection.———As I understand, pretty well, the Rules of Drawing, I could find no Difficulty in making an exact Copy of this celestial Prototype:———Which brings to my Mind, how often I have wished that such a Thing as this could be rendered feasable, that we might have the Pleasure of viewing

ing the Moon in an adequate Repreſentation, or a Natural Map thereof, as, I am fully convinced nothing of that Kind, of ſeven or eight that I have hitherto ſeen, can any how deſerve that Title, or be eſteemed a tolerable Copy of the Moon.

Cleon. What you obſerve is with too much Reaſon; the World abounds with Maps of the Moon, and ſome of the Sun; but they who made the Latter, one would naturally think were born blind; at leaſt, it could never be ſuppoſed they had ever ſeen the Face of the Sun thro' a Teleſcope, as there cannot well be a greater Difference between the uniformly ſmooth and glowing Face of the Sun, decorated only with a few ſmall Spots, and that ſhocking Repreſentation thereof by Father *Kircher*, full of Flames and Vulcanos. ——— It is too eaſy a Matter to view the Face of the Moon in a common Teleſcope, not to be able to make ſome Reſemblance of her; but ſtill it is evident, from all the Maps of the Moon I have hitherto ſeen, that Reſemblance is ſo diſtant, and ſo imperfect, as to be ſcarcely allowed to be called a Portrait of the Lineaments and native Beauties of her Face. ——— In ſhort, our *Selenography* is the moſt imperfect Part of all our Aſtronomy; but you ſee, by this Machine, how eaſy it is to make an exact Draught of the Moon, even juſt as eaſy as to take a Copy of any Family Piece placed on the Eaſel before you. Nay, even thoſe who have no Skill in drawing, by Means of a proper Lattice of Squares placed in the Focus of this Teleſcope, might, in this Manner, be able to make an accurate Map of the Moon.

Euphroſ. This noble Invention makes all the Difficulty of conſtructing a juſt Map of the Moon vaniſh, as here is nothing to divert or interrupt his Pencil or his Fancy. ——— But I ſhall be too tedious, therefore haſten to ſhew me the Planet; for I conſider that you have done, as it were, double Duty this Day, and that you will not be a little fatigued.

Cleon. Never fear me, my *Euphroſyne:* Why ſhould not I be able to talk two Hours, as well as ſome of your Sex a whole Day together. ——— But now for the Planet: the Scene muſt be altered, the *Jovian* Day is ſhorter than that of the Sun, and therefore the Pendulum muſt now be adjuſted to beat Time to *Jupiter:* ——— Alſo, the Speculum muſt be adapted to its

Declination from the Equator; and as he was upon the Meridian at VII o'Clock this Evening, and it is now juſt turned of VIII, therefore I bring the Hour of VII to the Meridian Line of the Clock, and place the Hour-hand to the preſent Minute after VIII, and thus is the whole Machine, in all its Parts, adjuſted to view the Planet, undiſturbed by the Motion of the Earth about its Axis, or his own real Motion in his Orbit: ——— As ſuch you may now view it.

Euphroſ. I view him in perfect Serenity and reſt: ——— A charming View of his ſpacious Diſk regales my Sight: ——— I ſee three of his Moons with great Diſtinctneſs; but one of them is either eclipſed or ſuffers an Occultation. ——— He continues ſtill in the ſame Part of the Field. ——— This, muſt, ſurely, give a fair Opportunity for obſerving the Eclipſes and Occultations of theſe Satellites, and conſequently for diſcovering the Longitude, which, I have often heard you ſay, is more feaſible by this Method than by any other.

Cleon. Your Obſervation is very juſt: This Clock will be of ſingular Benefit to Mankind in that Particular; ſince, in whatever Part of the World it is uſed, the Longitude of that Place will be hereby diſcovered with the utmoſt Eaſe and Certainty. ——— In ſhort, from the Nature of the Thing, it is moſt evident, that no aſtronomical Obſervations can be made with Eaſe and Exactneſs by any other Means than this, which will be ſufficient to recommend it to all the Studious in natural Science, as an Object of the greateſt Curioſity and Utility to Mankind. ——— Having thus given you a particular Account of all the uſeful Conſtructions of optical Inſtruments, I ſhall endeavour to prepare you, at the next Opportuity, for perceiving the infinite Wiſdom in the Conſtruction of the Organ of Sight, or Viſion, in the natural Mechaniſm of the Eye, by a few previous Speculations on the Nature and Effects of ſingle Glaſſes or Lenſes.

DIALOGUE

DIALOGUE XVII.

On the NATURE *and* USES *of* SINGLE LENSES, *both Convex and Concave, applied as* READING-GLASSES, VISUAL GLASSES *and* BURNING GLASSES.

Euphrosyne.

IT gives me the greatest Pleasure to find we are approaching towards an Enquiry into the natural Constitution and Mechanism of the Eye, which you propose to explain to me, by a Dissection of the same, and a particular Account in what Manner every Part is conducive to so noble an End: ——— But you tell me, I must be previously acquainted with the Use of single Glasses, the better to comprehend the same; and accordingly I see you have a great Variety of Convex and Concave Lenses, Spectacles, *&c.* spread before me on the Table.

Cleon. I have provided such an Assortment only as will be necessary for you to know the Uses of, as Reading-glasses, or such as assist the Sight by a single Application of them to the Eye. ——— But here I do not suppose you are ignorant of the Nature of a Convex Glass in general, or of its Uses in the Construction of optical Instruments, which I have exemplied to you in so many Cases. ——— You very well know, that if an Object be placed on one Side of such a Lens, at more than its focal Distance from it, the Rays, proceeding from every Point, diverging upon the Glass will be refracted thro' it, converging to so many Points on the other Side, which form the Image thereof. ——— You have also been taught, that when an Object is placed just at the focal Distance of the Lens, the Rays will then be refracted parallel to each other, and thereby fitted to produce distinct Vision of such an Object: This you had an Instance of in those very small Lenses which are used in single Microscopes: ——— But there is one Case yet remaining, in which both Convex and Concave Lenses become extremely useful to Mankind, which has not yet been explained: And

that is, when the Object is placed between the focal Point and the Glaſs itſelf.

Euphroſ. This Caſe is indeed new to me, and I ſhould be very much pleaſed to know in what Manner theſe Glaſſes are rendered ſerviceable to us in this Reſpect. ——— When an Image is formed of an Object, by a Lens, I can eaſily conceive how that Object may be contemplated in its Image; ——— alſo, I know, that when an Object is placed in the Focus of a Lens, it becomes in itſelf thereby viſible; ——— but when it is placed nearer to the Glaſs than its Focus, I have no Idea which Way the Object becomes magnified to the Sight.

Cleon. Yet this you muſt underſtand before you can be properly ſaid to know the Theory, or *Rationale* of a common Reading-glaſs, which, you know by Experience, has a magnifying Power, and may be as properly called a *Megalaſcope* for magnifying large Objects, as very ſmall Lenſes are called *Microſcopes* for magnifying ſmall ones. Thus, the Page of a ſmall printed Book may, in itſelf, be conſidered as a large Object, while the Words and Letters are too ſmall to be eaſily read by a good Eye, and not at all by one whoſe Sight is rendered in any Degree deficient by Age, or other Accidents: But when a large Convex Glaſs, in this Caſe, is applied between the Book and the Eye, the Page becomes greatly dilated to the View, and the ſmall Characters appear as a large and eaſily legible Print.

Euphroſ. All this I know very well, as I am oftentimes obliged, in Caſe of ſuch very ſmall Prints, to make Uſe of a Reading-glaſs myſelf; but how this magnifying Power is produced, I am ſtill at a Loſs to apprehend, and muſt beg of you to explain.

Cleon. This I will do in the beſt Manner I can; but it muſt be by a Diagram, as no real Image of an Object is, in this Caſe, formed any where but in the Eye: To this End, therefore, let E C D be ſuch a Reading-glaſs, or Convex Lens, and let F be the Focus in the Axis F N; on C the Center of the Lens, with the Diſtance C F, deſcribe the Arch of a Circle Q F P, draw the right Lines Q C and P C, making any Angle with the Axis F C on either Side; then, in the Line Q C, let any Point, A, be taken, and from that Point let the Line

Line A E, and A D be drawn, to repreſent two diverging Rays iſſuing from that Point on the Convex Glaſs. Now, you know, it is the Property of a Convex Lens to bring diverging Rays, which fall upon it, nearer together after Refraction, and therefore the Rays A D and A E, inſtead of purſuing their firſt Directions to I and L, will, by the Lens, be refracted nearer together, *viz.* into the Direction D K and E M: ——— If then theſe Lines D K and E M, as they are inclined to each other, be continued out, they will meet in a Point G in the Line Q C. All this, I ſuppoſe, is very plain from the Figure, my *Euphroſyne.*

Euphroſ. So very plain, that it can admit of no farther Explication. But what am I to infer from thence?

Cleon. This much, that the Point A, being not far from the focal Diſtance Q, will cauſe the diverging Rays A I and A L, after Refraction into D K and E M, to be not much different from parallel Rays, and therefore will produce diſtinct Viſion of the ſaid Point A: ——— But then the apparent Place of the Point A will be much altered; for ſince the two refracted Parts D K and E M enter the Eye, as if they came from the Point G, they will there repreſent the Point A; ſo that the apparent Diſtance of that Point will be much greater than the real Diſtance C A. This, I ſuppoſe, you can likewiſe ſee from the Diagram?

Euphroſ. Nothing is more evident; and at the ſame Time I obſerve, from your Drawing, that on the other Side of the Axis the Rays proceeding from the Point B will, after Refraction, repreſent that Point at H.

Cleon. Your Inference is juſt; and I ſee, by that, you have a clear Idea in what Manner the Points A and B are removed to the Diſtances G and H reſpectively from the Glaſs; and that therefore all the Space contained between A and B will be expanded into the Length, or Space contained between G and H; and conſequently any Objects contained between A and B will be enlarged in Appearance, in the Proportion of the Diſtance between A B to the Diſtance between G H, that is, in the *Ratio* of A C to G C: and, conſequently, if the Page of a ſmall printed Book be placed at the Diſtance of A C from the Glaſs, and

parallel

parallel to it, the Words, or Print of that Page will appear enlarged in the same Proportion as G C is larger than A C, with respect to their Diameters or lineal Dimensions: But the whole Area, or Surface of the Page, will be enlarged or magnified in Proportion as the Square of A C is to the Square of G C.

Euphrof. This I see very plainly illustrated by the Words, *God save the King*, in small Print between A B, and in much larger Characters between G H.——Pray *Cleonicus*, is there any general Rule to be observed, for holding the Reading-Glass, with Respect to the Eye and the Print?

Cleon. There is, my *Euphrosyne*:——For by the Mathematical Theory we learn this Rule, *the Distance of the Object* A C *and that of its magnified Appearance* G C, *is always in the Proportion of the Distance of the Object from the Focus* A Q, *to the Distance* Q C *of that Focus from the Glass*; and, consequently, from hence you will observe, the less A Q is, or the nearer the Object is held to the Focus of the Glass, the more it will be magnified; and since the Rays passing thro' the Glass differ but little from parallel Rays, it will give a distinct view of the Object so magnified; and by moving the Glass one Way or the other ever so little, you will immediately find the Position of the Object, and the Glass where the Field of View and magnifying Power will best suit the Eye. But this is a Point which we are directed to by Nature, without any Rules of Art. And this, I think, is as much as I can say with regard to the Nature and Use of a READING GLASSES.

Euphrof. Is there nothing particular with respect to the Size, or focal Length of those Glasses, by which we may be directed in the Choice of them?

Cleon. Yes, most certainly; for if it be proposed to read with both the Eyes, then, in such a Case, the Glass must be sufficiently large, to transmit the Rays from the Object to both the Eyes, and, consequently, ought not to be less than three Inches in Diameter:——The elliptic Form is also preferable to a round one, in a Reading-glass:——and, lastly, the longer the focal Distance, the less irksome is the Effect to the Eye. But in this Respect, the Eye must be consulted, and the magnifying Power of the Glass must be such as is required.

Euphrof.

Euphrof. What is the Difference between theſe large Reading-glaſſes and Spectacles, or *Viſual Glaſſes*, as you call them.

Cleon. The Nature and Effect of both are much the ſame, only the Viſual Glaſſes, being diſpoſed in a proper Frame, may be, in different Ways, applied to the Eye, without being held in the Hand; and, therefore, having both Hands at Liberty, they are much better ſuited to all Occaſions of Reading, Writing, Working, *&c.* than a manual Glaſs can be. ——— Beſides, the Viſion is more diſtinct and perfect thro' two Glaſſes, than by one alone; becauſe the Axis of each Glaſs, when they are properly fixed in their Frames, may be made to coincide with the Axis of each Eye reſpectively; and therefore the Rays of every Viſual Pencil will be much more naturally refracted to the Eye, than they can be through a ſingle Glaſs, where only the collateral Rays of ſuch Pencils can enter the Eye, by which the Viſion can be neither ſo eaſy or perfect as in the former Caſe.

Euphrof. But what is the Reaſon of this black Circle or Ring of Horn about the Glaſs?

Cleon. There is more Reaſon for this than many Perſons are aware of: the Pupil of the Eye is but ſmall, and no more Light can be of Service to Viſion, than what enters that Pupil: a Spectacle-glaſs, therefore, but little bigger than the Pupil of the Eye, would be ſufficient for converging a Pencil of Rays to the Eye as large as that which now enters it from the wideſt Glaſs; therefore, all that Part of a Pencil, ſo very large, as falls on ſuch a Wide Glaſs, muſt, by far the greateſt Part, be loſt upon the Eye: but that is not the worſt Conſequence of a broad Glaſs; the great Quantity of Light which falls upon the Ball of the Eye cannot fail, by ſuch a conſtant Suffuſion, to diſturb, and render Viſion indiſtinct, by that which really enters the Eye: not only ſo, but the conſtant Action of Light upon the Ball of the Eye muſt have a ſenſible Effect, in Time, in weakening the ſame, and produce, gradually, thoſe Changes and Alterations in its Texture as muſt be attended with Uneaſineſs to the Perſon, and Injurious to all the Purpoſes of Viſion: ——— Therefore, to prevent, as much as poſſible, ſuch bad Effects, the circular Zone, or Ring of Horn is applied on the Out-ſide of the Glaſs, to cut off

ſo

ſo much of the collateral Rays, or hurtful Part of Light: And were this Rim broader, and of Courſe the Glaſs narrower, it would ſtill conduce more to the Perfection of Viſion: But as there is no Convenience without an Inconvenience, the making the Glaſs narrower would be apt to contract the Field of View too much; the Diameter, therefore, of the Glaſs muſt be left ſo large as will admit of a ſufficient Extent of View, for all the Purpoſes required; and all that is more, is detrimental, and ought to be excluded.

Euphroſ. I have no Occaſion, as yet, to experiment the Truths you have been now advancing; but I judge of their Reaſonableneſs from the Structure of optical Inſtruments, and from the Make of the Eye itſelf; for in all Microſcopes, Teleſcopes, *&c.* I obſerve a Diaphragm, or Stop is placed in the Focus of the Eye-glaſs, to circumſcribe the View within proper Limits: And alſo, the Apertures of Object Lenſes adjuſted to a peculiar and determinate Size, for Admiſſion of one requiſite Degree of Light, in order to produce diſtinct Viſion in thoſe Inſtruments: And I make no Doubt that the ſame Reaſon holds, for the ſmall Size of the Aperture, or Pupil of the Eye itſelf: — But as I ſhall, at other Times, diſcourſe with you farther on this Subject, you will give me Leave to aſk one Queſtion concerning *Concave Lenſes:* How they become ſo uſeful to ſhort-ſighted People, as I find they are uſeful to them only?

Cleon. The Nature and Uſe of thoſe Lenſes will be better underſtood, after you have ſeen a Diſſection of the Eye; and then the Uſes of theſe, and alſo of Convex Glaſſes will be exemplified with Experiments of an *artificial Eye.*

Euphroſ. Are there any other conſiderable Uſes to be made of Convex, or Concave Lenſes?

Cleon. There is one of a very extraordinary Nature, *viz.* the *Power* of BURNING, which is the Effect of very large Convex Lenſes, and Concave Speculums; this they perform by converging the Sun's Rays into a very ſmall Space, or into what we may properly call the Solar Spot, or Image of the Sua: And it is well known, the ſmaller the Space is into which a given Quantity of Rays can be collected, the more Denſe they will be, and conſequently the more powerfully they will act or burn.

Euphroſ.

Euphrof. I have heard much concerning the wonderful Effects of Glaſſes of this Kind, with Reſpect to their burning Power; but have ſeen little or nothing of it more than the common Experiment of lighting a Pipe, or making a Piece of Wood ſmoak with a common Burning-glaſs.

Cleon. Theſe are trifling Effects to what are produceable by theſe Kinds of Glaſſes. But as I know you will not be ſatisfied with the mere Relation of Facts, though of ever ſo wonderful a Nature, without ſome previous Ideas of the Reaſon and Cauſe of them, and, as in this Caſe, it is not very difficult to be underſtood, I ſhall give you the following conciſe *Rationale* thereof: ——— You have ſeen that every Object has its Image formed by a Convex Lens, and Concave Mirror, in its Focus; accordingly, the Sun itſelf will have its Image produced of a ſenſible Magnitude, becauſe, as I have formerly told you, the Object and its Image ſubtend equal Angles at the Glaſſes; and therefore, becauſe the Angle under which the Diameter of the Sun appears is full half a Degree, therefore, alſo, the Image of the Sun will ſubtend an Angle of half a Degree at the Glaſs: ——— Had the Sun been at an infinite Diſtance, it could have ſubtended no ſenſible Angle at all, and its Image would have been a Point in the Focus of the Glaſs; but that is not the Caſe; for, in the Focus of all Glaſſes, the ſolar Spot, or Image, is of a ſenſible Magnitude, and may be meaſured and compared with the Area of the Glaſs itſelf.

Euphrof. If I underſtand you right, all the Rays which fall upon the Surface of the Glaſs are collected into that circular, and very luminous Spot, which we call its Focus, and then the Rays of Light will be denſer in that Spot, in Proportion, as the Surface of the ſaid Spot is leſs than the Surface of the Glaſs; and, conſequently, their Diſpoſition to burning. ———But what will be the moſt convenient Method of meaſuring this ſolar Spot?

Cleon. You may very readily hold a Box-ruler, divided into Inches and Tenths, and thereby eſtimate the Diameter of the ſolar Spot in Tenths of an Inch: But this Method will not do in all Caſes, I ſhall therefore propoſe one that will. ——— It happens very luckily that, with the Radius or Diſtance of ſix Inches, one Degree is very nearly equal to $\frac{1}{10}$ of an Inch;

therefore, at the focal Distance of 12 Inches, half a Degree will be equal to $\frac{1}{10}$ of an Inch, or that will be the Diameter of the solar Spot of a Lens whose focal Distance is 12 Inches. —— Now this Spot in a Lens of twice, or three Times that focal Distance, will be twice or three Times as large; so that in a Lens of four foot Focus, it will be $\frac{4}{10}$ of an Inch, and so on for other Lengths in Proportion.

Euphros. This I clearly apprehend; but what is your Inference from hence?

Cleon. When the Diameters of the Glass and solar Spot are known, then also the Proportion of their Surfaces are known, being always in Proportion as the Squares of those Diameters. Thus, for Instance, if a Lens be four Inches in Diameter, and its focal Distance 12 Inches, then will the Diameter of the Spot be $\frac{1}{10}$ of an Inch, as I said before: But in the Diameter of the Glass there are $\frac{40}{10}$ of an Inch, therefore the Area of the solar Spot will be the Area, or Surface of the Glass, as the Square of one to the Square of 40; that is, as one to 1600: Therefore the Density of the Sun-beams, in the solar Focus, will be 1600 Times greater than that of the solar Rays falling upon the Glass: And hence you may plainly perceive the Reason, why a Lens no more than 4 Inches in Diameter will yet prove so powerful a Burning-glass, as you observed it in the Instances you just now mentioned.

Euphros. I now begin to see plainly, the Reason of the Effects of Lenses and Mirrors, in regard to burning; and I also apprehend, that this Power of burning will increase in Proportion to the Square of the Diameter of the Glass, while the focal Distance remains the same.

Cleon. It will so: Thus, suppose the forementioned Glass of 12 Inches focal Distance were 6 Inches, or $\frac{60}{10}$ of an Inch, in Diameter, then will its Power of burning be to the former as 3600 to 1600, or more than twice as great, because more than twice the Quantity of Rays fall upon this larger Glass.

Euphros. But supposing the Surface of the Glass continue the same, but has a less focal Distance, then will the solar Spot be likewise less, and, consequently, the same Quantity of Rays, being collected into a smaller Space, will act, or burn more ve-

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hemently: Therefore, alſo, the Power of burning muſt be greater in Proportion as the Area of the ſolar Spot is leſs. Is not this right, *Cleonicus?*

Cleon. Extremely ſo: You reaſon like a Mathematician. ——— The true *Ratio* is, the Diameter of the ſolar Spot being always as the focal Diſtance, the Area thereof will be as the Square of its Diameter, and, conſequently, as the Square of the focal Diſtance of the Glaſs: Therefore we collect this general Rule, *the Power of burning in any Lens is proportioned to the Square of its Diameter directly, and the Square of its focal Diſtance inverſly*: And from hence it will be very eaſy to compare the burning Powers of any Lenſes whoſe Diameters and ſocal Diſtances differ.

Euphroſ. Pray, what are the largeſt ſize Lenſes uſually made for this Purpoſe?

Cleon. They ſeldom exceed 7 or 8 Inches in Diameter; and are from 3 to 4 Feet Focus; and ſuch a one you here ſee: The Diameter of this is 8 Inches, and the Focus 3 Feet, therefore the ſolar Image will be $\frac{3}{120}$ of an Inch Diameter: And, as there are $\frac{80}{120}$ of an Inch in the Diameter of the Glaſs, it will condenſe the Rays in Proportion, as the Square of 80 to the Square of 3, that is, as 6400 to 9, which is little more than 700 to 1. Whereas I obſerved to you before, that the Power of a common Burning-glaſs, no more than half this in Diameter, and whoſe focal Diſtance but $\frac{1}{3}$, had a Power of burning as 1600 to 1, which is more than twice as great as this very large Lens is capable of, which Inſtance I give to ſatisfy you, that as much may be done by ſhortening the Focus of the Lens as by increaſing its Diameter or Surface. ——— But, becauſe when the Diameter of the Lens is very large, it will require a very extraordinary Thickneſs of Glaſs for grinding them to a ſhort focal Diſtance ſufficient to render them Burning-glaſſes in any conſiderable Degree.

Euphroſ. But, pray, *Cleonicus*, is there no Method of combining two of theſe Lenſes together, to increaſe their Power of burning?

Cleon. Yes, my *Euphroſyne*, there is; for if a Lens 6 Inches Diameter and one Foot focal Diſtance, and another Glaſs 4 In-

ches Diameter and 6 Inches focal Diſtance, were put together at a proper Diſtance, the Rays of the Sun, collected to a Focus by them, would be more denſe and burn more powerfully than they could be made to do by any ſingle Lens: ——— But there is nothing of this Kind that can compare with a Concave Mirror in this Reſpect; for, in theſe Mirrors, the ſolar focal Diſtance is never more than half the Radius of Concavity; and what ſtill adds to the Intenſity of their burning is, that the Aberration of the Rays, in the Focus, ariſing from the Figure of the Glaſs, is not near ſo great as in the Focus of a Lens of the ſame focal Diſtance in Diameter.

Euphroſ. Since Concave Speculums are in their own Nature ſo well fitted for Burning-glaſſes, I preſume, the Ingenuity of Philoſophers muſt have been exerciſed in various Wiſe, to render this Invention as extenſive and powerful in their Effects as they poſſibly could.

Cleon. No Pains has been ſpared, by ingenious Artiſts in the optical Way, for conſtructing theſe burning Speculums of different Kinds, of which I ſhall mention to you four of the principal Forms. The (1.) is an entire Concave Glaſs, but of very large Diameter, and as ſhort a focal Diſtance as poſſible. (2.) A very large ſpherically Concave Frame, in which are placed ſeveral leſſer Concave Speculums, of the ſame Radius with that of the Frame: Theſe, truly fixed, will have all their Focuſes thrown upon one common Focus in the Axis of the Frame, which, of Courſe, muſt burn to a prodigious Degree. (3.) In ſuch a large Frame, they have alſo contrived to fix plain Glaſs Speculums, which, being duly adjuſted by Screws, will throw all the Sun's Rays which fall upon them into one common Part of the Axis of the Concave Frame, which, there making a Sort of Focus, will burn very intenſely. (4.) Any large Concave Frame, as before has been deſcribed, with a ſmooth polliſhed Surface of ſuch Matter as will ſtrongly reflect the Rays of Light, and has been found to anſwer extremely well.

Euphroſ. Have you ſeen thoſe ſeveral Kinds of Speculums which you now mention?

Cleon. I have ſeen of the firſt and ſecond Sort; but never any of the third and fourth: ——— But of the firſt Sort, I have never

ver ſeen any ſo large as to deſerve particular Mention at this Time: Thoſe of 2 Feet, or 2 Feet and ½ in Diameter, are the largeſt that are commonly made, and are much more uſed for optical Purpoſes than for Burning-glaſſes, as their focal Diſtances are not ſhort enough to anſwer the Purpoſe of burning ſo much as might be expected from ſo large a Surface: However, all of this Kind, that are in any Degree large, burn very intenſely, eſpecially with a Summer Sun.

Euphroſ. And what have you known of the ſecond Form of Speculums, which you mention; which, I think, may be called compound Burning-glaſſes?

Cleon. They are very properly ſuch; but all that I know of them is, that they have been made of a very large Size, one of which, in particular, contained about 30 very large ſquare Concave Speculums, not leſs than 20 by 24 Inches, if I remember right: This very large Concave Speculum was placed at the Top of a Houſe, *viz.* at the great Toy-ſhop the Corner of St. *Paul's Church-yard*, moveable upon an Axis, to render it of more convenient Uſe: But as to its Effects, though they muſt have been incredibly great, I do not remember to have had any particular Account of them, any more than in one Inſtance, *viz.* that a large Bar of Iron would inſtantly be melted aſunder in its Focus.

Euphroſ. That was a prodigious Effect, indeed; and I wonder very much, that the World has not been more apprized of the ſtupendous Effects of a Concave burning Speculum of ſuch an amazing Structure. ——— Pray, what do you know of the third Sort you mentioned, compounded of plain Speculums inſtead of Concave ones?

Cleon. This is but a late Invention; the principal Inſtrument of this Sort was made by Mr. *Buffon*, which was 6 Feet in Diameter, and contained 168 ſmall Mirrors, or flat Pieces of Looking-glaſs, with proper Movements for adjuſting them to a common Focus: They were each of them 6 Inches ſquare. ——— But what is peculiar to this Contrivance is, that we have it in our Power to make the focal Diſtance greater or leſs, and, conſequently, while the Frame remains in the ſame Place the Glaſſes

may

may be so adjusted and disposed as to throw their common Focus upon the Object intended for Accension.

Euphros. This must be a curious Artifice most certainly; but I suppose the Difficulty and Expence of such an Apparatus, for this Purpose, is not inconsiderable: ——— But, pray, has it been brought to any great Perfection, or has any very considerable Experiments been made with it?

Cleon. It is said, that Mr. *Buffon*, in the Month of *March*, set on Fire Boards of Beach-wood, at the Distance of 150 Feet: At another Time, he burnt Wood at the Distance of 200 Feet: He also melted Tin and Lead, at the Distance of 120 Feet; and Silver, at 50. ——— But, as you rightly judge, the Expence of such a compound Speculum must be very great, since each small Speculum had no less than three adjusting Screws to give it a proper Inclination, for directing the solar Rays to any given Point, and the whole Machine is moveable by a Swivel-like Contrivance; so that one may burn horizontally, upwards or downwards, and that almost at any Distance one pleases.

Euphros. One would think such an Instrument as this should prove dangerous, especially near the Sea-side, where Ships in the Harbour might be liable to be set on Fire by it.

Cleon. Your Observation is so far rational, that, if such a Machine could be conveniently made, it would certainly be of Use to every Town liable to a Siege, whether by Sea or Land, especially if the Time for adjusting the Lenses were not very tedious. It is related by several Historians, that ARCHIMEDES did actually set Fire to the *Roman* Fleet, at the Siege of *Syracuse*, by a Burning-glass; and that the Navy besieging *Byzantium* was, by a Burning-glass under the Direction of PROCLUS, reduced to Ashes. But what Sort of Glasses the Antients made Use of for this Purpose, Historians do not inform us; but, very probably, they were not Speculums, but either Lenses or burning Spheres.

Euphros. Then you really think that Burning-glasses, of some Sort or other, were in Use among the Antients? Pray, what Account do you find of them among the Writers of Antiquity?

Cleon.

Cleon. I can say but little on that Head: *Pliny* mentions what he calls Balls, or Globes of Glass and Crystal, which were made Use of by Surgeons, who collected the Sun-beams with them in order to cauterize their Patients: And *Lactantius* tells us, that a Glass Globe, filled with Water and held up to the Sun, would kindle a Fire even in very cold Weather: But, to pass by other Instances, there is one very remarkable in the first Scene of the second Act of *Aristophanes*'s Play, called, *The Clouds*, which the famous Mr. *De la Hire* makes no Doubt is a full and convincing Proof of the Use of Lenses, as Burning-glasses, among the Antients; and, because the Passage is not long, I shall read it to you out of that Author: —— *Strepsiades*, an old stupid Fellow, tells *Socrates*, he had found out an excellent Contrivance against paying his Debts; and is introduced speaking after this Manner:

STREPSIADES. *Have you never seen, at the Apothecaries, that fine transparent Stone with which they kindle Fire?*

SOCRATES. *Do you mean that Glass?*

STREPSIADES. *Yes.*

SOCRATES. *Bring it; what then?*

STREPSIADES. *When the Attorney hath written an Action against me, I will take this Glass, and, standing at a Distance in this Manner against the Sun, I will melt down the Letters of my Action.*

SOCRATES. *Cunningly done, by the Graces.* The Scholiast, upon this Place says, this Glass was a *Trochoide*, which implies, that it was *round like a Wheel*, and, therefore, I think very plainly indicates its being lenticular, and not of a spherical Form.

Euphros. Well, this has pretty well gratified my historical Curiosity: —— Tell me next, what you know of the fourth Kind of Burning-glasses.

Cleon. With respect to the Power of Burning, they are the most celebrated of any, concerning which, we have several curious Anecdotes; for Mr. *Boyle* made one of these, of black Marble, of a very large Size; but, though well polished, yet, being of a black Colour, it would not set Fire even to Wood, though exposed a long Time in its Focus; which plainly shews

how

how ſmall a Quantity of Light is reflected from black Subſtances. ——— On the other Hand, we read of a Burning-glaſs (if we may ſo call it) that was made only of a ſmooth Concave Surface, and overleaved, or finneered, as it were, with white Straw, made by an *Italian* Artiſt, which had a prodigious Effect in burning from the Light reflected from ſo large a Surface and natural poliſh of Straw. ——— But the moſt remarkble of all theſe Sorts of Mirrors was that of the celebrated Mr. *Villette*, which was 3 Feet 11 Inches in Diameter, and its focal Diſtance was 3 Feet and 2 Inches: It was a Compoſition of Tin, Copper, and Biſmuth, ſomewhat like the Metals we now make for reflecting Teleſcopes; it was a white Metal, and bore a very fine Poliſh, and therefore, from ſo large a Surface and ſo ſhort a focal Diſtance, it is no Wonder if we find its Power of burning, melting, calcining, and vitrifying Bodies very extraordinary indeed.

Euphroſ. I wiſh I could get Information what ſome of thoſe Effects might be, for I have a great Inclination to be ſatisfied about every Thing in regard to the *Wonderful*.

Cleon. In this you are not particular, my *Euphroſyne*; it is a Kind of univerſal Paſſion that, more or leſs, affects all Mankind; Things of an uncommon and extraordinary Nature never fail to ſtrike us with agreeable Pleaſure and Surprize: And as Burning is in itſelf one of the moſt exquiſite Actions of Nature, the following Experiments, made in Relation thereto, cannot but give you the higheſt Satisfaction: A Catalogue of ſuch as are moſt remarkable I ſhall here rehearſe to you.

1. A red Piece of *Roman Patera* (or Tile) began to melt in 3″, and was ready to drop in 100″.

2. Another black Piece melted at 4″, and was ready to drop at 64″.

3. Chalk taken out of an *Echinus Spartagus* fled away in 33″.

4. A Foſſile-ſhell calcined in 7″.

5. A Piece of *Pompey*'s Pillar at *Alexandria* vitrified in the black Part in 50″, and in the white Part in 54″.

6. Copper Ore vitrified in 8″.

7. Slag,


Fig. 4
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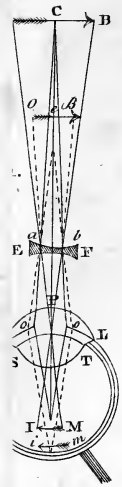

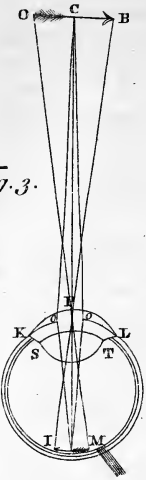

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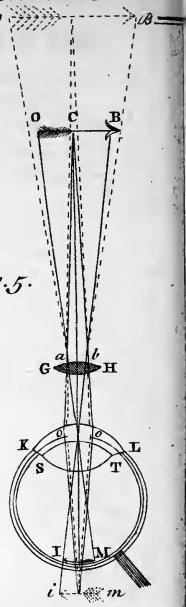


Fig. 5.

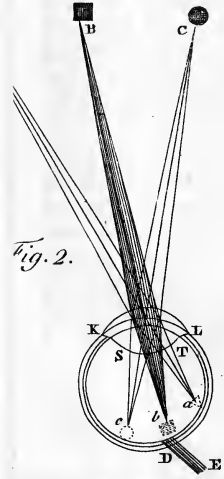


Fig. 2.

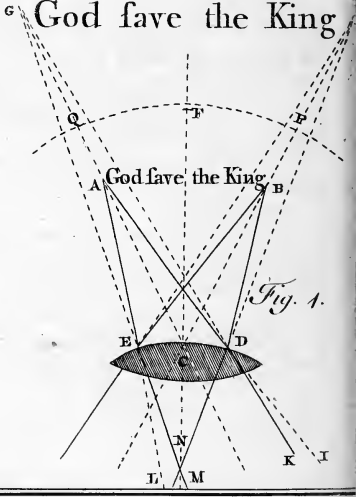


Fig. 1.

7. Slag, or Cinder, of antient Iron-work, ready to run in 29 $\frac{1}{2}$″.

8. Iron Ore fled at firſt, but melted in 24″.

9. Tale began to calcine at 40″, and held in the Focus 64″.

10. *Calculus humanus* was calcined in 2″, and only dropped off in 60″.

11. A great Fiſh's Tooth melted in 32 $\frac{1}{2}$″.

12. The Aſbeſtos ſeemed a little condenſed in 28″, and Mr. *Villette* ſays, the Glaſs uſually calcines it.

13. Marcaſite of Gold broke to Pieces, and began to melt in about 30″.

14. A Silver Sixpence melted in 7 $\frac{1}{2}$″.

15. A Copper Halfpenny (of King *William*'s) melted in 20″, and ran with a Hole in 30″.

16. A King *George*'s Ditto, melted in 16″, and ran in 34″.

17. Tin melted in 3″.

18. Caſt-Iron melted in 16″.

19. Slate melted in 3″, and had a Hole in 6″.

20. Thin Tile melted in 4″, had a Hole, and was vitrified in 80″.

21. Bone calcined in 4″, and was vitrified in 33″.

22. A Diamond, weighing 4 Grains, loſt $\frac{7}{8}$ of its Weight.

Euphroſ. Theſe are wonderful Effects indeed, to think that the *Aſbeſtos* itſelf, which no common Fire can injure, ſhould yield to the calcining Force of this Burning-glaſs. —— I ſuppoſe you have the ſame Method of computing the Force of this Glaſs, as before of the Lenſes?

Cleon. The very ſame; and by Computation it appears, that the ſolar Beams are condenſed by this Speculum upwards of 17,000 Times, and that the Heat in the Focus of this Glaſs will burn with Intenſity 433 Times greater than that of common Fire; and therefore nothing is an *Aſbeſtos*, *Amianthus*, or *incombuſtible* Subſtance in the Focus of ſuch a Speculum. —— It may be in my Power one Time or other, to repeat theſe Experiments and verify them by ocular Demonſtration; but, at preſent, you muſt be content with a mere Narration of Facts.

Plate LI.

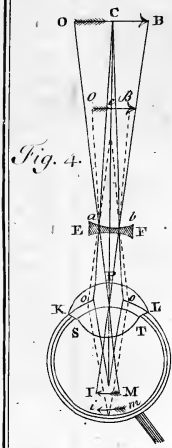


Fig. 4.

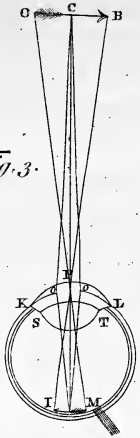


Fig. 3.

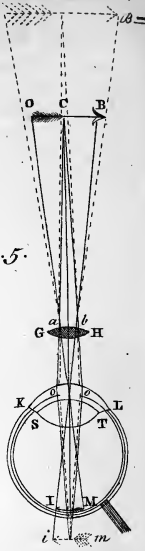


Fig. 5.

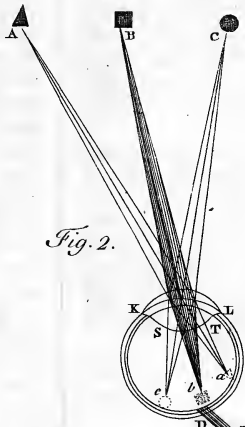
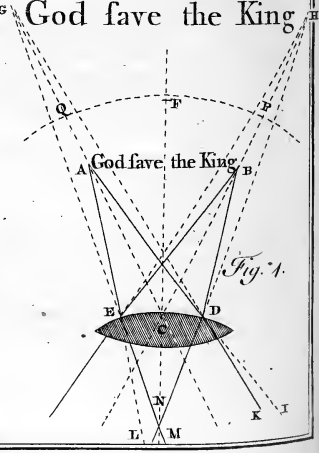


Fig. 2.



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DIALOGUE XVIII.

The NATURE *and* STRUCTURE *of the* EYE *explained, with regard to perfect* VISION, *by an* anatomical DISSECTION *thereof.*

Cleonicus.

OF all our Senſations, thoſe of Viſion have been ever eſteemed of the firſt Order: It will therefore be no unpleaſing Speculation to my *Euphroſyne*, to be entertained with a ſhort Narrative and Explication of the natural Mechaniſm of the wonderful ORGAN of SIGHT, and what the proper Office of each conſtituent Part is, or how far it conduces to perfect this moſt exquiſite of all our Senſes.

Euphroſ. I am tranſported with the Thoughts of being in any Degree capable of underſtanding the Principles upon which the Structure of ſo noble an Organ depends; the component Parts of the Eye, I preſume, you intend to exhibit, by a Diſſection of thoſe Eyes which I ſee you have here prepared; and, as I have never yet ſeen any Thing of this Kind, the Inſtructions I ſhall receive will be both novel and improving in the higheſt Degree.

Cleon. I do not propoſe to trouble you with an anatomical Account of the great and wonderful Apparatus of Muſcles, wherewith the Eye is furniſhed for all neceſſary and convenient Motions; this being only a collateral Conſideration, or Circumſtance of the principal Object we are at preſent intent upon, which is the Faculty of natural Viſion: For though the Eyes of many ſmaller Kinds of Animals, as in moſt of the inſect Tribes, are fixed, yet they are ſo diſpoſed, that Motion in them is rendered unneceſſary, as they can ſee all around them without: But as the Eyes of moſt Animals, and particularly our own Species, are both in Front, and we could look only directly before us, provided there was no muſcular Motion, it became neceſſary to conſtruct the Eye with a Variety of Muſcles to give it Motion,

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in all Directions, in the visible Hemisphere before us; and one Thing I must not omit to observe, that as it is sometimes necessary to have an oblique Motion of the Eye towards the Nose, and there being no Room on that Side for Muscles, as on every other Part, provident Nature (which is never at a Loss for Means to accomplish her Designs) has contrived a small Bone on the Side of the Nose, with a small Perforation, or Hole, to serve as a Pulley through which the Tendon of a Muscle passes to a convenient Insertion, and thereby such an oblique Motion is given to the Eye, which would have been otherwise impossible.

Euphros. One would think it was impossible that any Person who considers this, or any such Instances of the most apparent Design and wise Disposition of Parts, could ever be an Atheist.

Cleon. What you observe is very just; they who consider such Things are sufficiently convinced of the Existence and Providence of a Deity; and perhaps there is not a more fertile Field of irrefragable Proofs of those wise Designs and Artifices, which Nature makes Use of to answer her proposed Ends, than *anatomical Dissections*. Every Part in the Structure of animal Bodies fills us with Wonder and Amazement, not more at the Almighty Power, which is visible, in making, but at the infinite Wisdom which is so manifestly employed for answering, in the best Manner, all the Purposes of the animal Oeconomy. ——— But now to the Point: You see, here are two Bullock's Eyes, which I have provided on purpose to dissect, that you may see how far the several Parts are concerned in producing the sublime Faculty of Sight: ——— But, before we begin the Dissection, it will be worth your while to consider a few Particulars, respecting the external Disposition, or Form of the Eye: And first of all, you observe a long white cylindrical Body of nervous Fibres, which enters the Eye on the hinder Part or Bottom of the Eye, and which the Anatomist usually call the OPTIC NERVE.

Euphros. The Part you now mention has engaged my Attention ever since I have been in the Room; but before we proceed farther, pray, let me know what you mean by a NERVE.

Cleon. A Nerve is that moſt diſtinguiſhed Part of animal Bodies which Naturaliſts tell us is the univerſal Organ of Senſation. A Vegetable is an organized Body, and has Variety of Veſſels for circulating Fluids, analagous to thoſe we find in animal Bodies called Arteries, Veins, *&c.* but, as it has no Senſation, there is no Occaſion for this Part which is called the *Nerve*, and therefore we find none in the *vegetable* SYSTEM.

Euphroſ. But, pray, *Cleonicus*, how is this Part, you call a Nerve, the Organ of Senſation?

Cleon. I can give you but a partial and imperfect Anſwer to ſuch a Queſtion.——The Nerve, which you ſee, is a Continuation of the medullary Subſtance of the Brain, contained in proper Coats, or Integuments; the Fibres of this Nerve, having paſſed through the Coats of the Eye, are there ſpread into a moſt exquiſite fine Membrane, which covers all the interior Parts of the Eye, except that which is open before: This Membrane the Anatomiſts call the *Retina*, and is, beyond all Diſpute, the immediate Inſtrument of Viſion:——For the Rays of Light which enter through the fore Part of the Eye, being refracted to this nervous Membrane, will ſo affect, by their various Impulſe, the Fibres thereof, which are in immediate Connection with the Brain, as to convey to the common Senſory thereof the Species of Things without us, from whence they proceed; and by this Means they excite in the Mind the Ideas of thoſe Objects under all their Circumſtances of Form, Magnitude, Diſtance, Colour, and all their other Affections.——But how, by this natural Agency of one Sort of Matter upon another, thoſe mental Ideas are formed, and the Operations of the Mind directed and influenced, is a Subject far beyond the Reach of the human Underſtanding.

Euphroſ. I know the inſcrutable Secrets of Nature do not belong to us: I think myſelf very happy that I have the Faculty of Viſion, though I can never adequately know the wonderful Manner in which it is effected; its enough for me, that I can be acquainted with the Ways and Means which the Author of Nature makes uſe of to effect it.——But I obſerve, *Cleonicus*, that the optic Nerve enters the Eye on one Side, and not directly

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in the Middle of the Bottom of the Eye; pray, do you assign any Reason for that?

Cleon. Yes, my *Euphrosyne*, and a very good one too, *viz.* because the Rays of Light, which fall on that Part of the Eye where the Nerve enters it, are thereby rendered of no Effect, or become useless in that Point, where all the Fibres of the optic Nerve are divided one from the other, and no one in particular can be acted upon by those Rays: ——— By this Means you will easily understand, that those Rays which come from Objects quite on one Side of the Hemisphere of View can be lost; but those Rays which are lost in one Eye, are always effectual in the other: So that with both the Eyes, it is in our Power to see every Object wherever posited in the natural Extent of View. —— Hence another Instance offers of wise Contrivance, as also a Reason, among many others, why two Eyes are naturally of more Advantage than one.

Euphros. By what you have said, one would conclude, that an Object could not be seen by Rays which fall on that Part of the Eye where the Nerve enters it: Pray, is there any Experiment by which this can be confirmed?

Cleon. Yes, there is, and which you shall immediately try, for your own Conviction. ——— I will stick three Pieces of Paper (A, B, C)* upon the Side of the Room, about 15 Inches apart, and then I will place you at such a Distance from, and directly before the middle Paper, that, if you shut one Eye, and then turn the other obliquely towards that outside Paper which is on the Side of the enclosed Eye, the Rays coming from the middle Paper (B) will enter the Eye, and fall upon the Insertion of the optic Nerve, by which Means the said Paper will immediately vanish from the Sight, while the two extreme Papers continue visible.

Euphros. This is such an optical Paradox, that I long to be satisfied of the Truth of it by Experiment. ——— I see you have placed the Papers on an advantageous Ground to be viewed: ——— But now, whereabout must I stand to view this odd, or rather *Non Phænomenon?*

Cleon.

* See Fig. 2. Plate LI.

Cleon. As the Papers are about 15 Inches aſunder, you muſt place yourſelf directly before the middle Paper, at the Diſtance of about 6 Feet and a Half, and take Care that your Head be not in the leaſt turned on one Side: ——— Then ſhut the left Eye, and turn the right Eye obliquely to view the Left-hand Paper (A), and the middle Paper (B) will inſtantly diſappear at the ſame Time as the other extreme Paper (C) is viſible.

Euphroſ. Well, I think I am very near the Spot you point to, and that my Face is quite parallel with the Side of the Room: ——— I ſhut my left Eye, and direct my Right to the Left-hand Paper, without moving my Head: ——— And, ſure enough, the middle Paper is gone; it diſappears as if by Enchantment, —— and the other Paper beyond is ſtill in my View. ——— I think this Experiment equally curious and wonderful. ——— But now, let me try with the other Eye. ——— I find it the very ſame as before; therefore to each Eye, in this Situation, the middle Paper becomes inviſible, though ſo large as an Inch Square.

Cleon. Nor is there only that particular Spot on which you ſtand, where this will happen: But if you remove yourſelf thro' the Space of 10 Inches back, in a Right-line, you will obſerve the ſame Thing, or the Paper will continue unſeen through all that Space; for ſo long will the Image (*b*) of that middle Paper be paſſing over the Place where the Nerve (D E) enters the Eye, while the Images (*a* and *c*) of the two extreme Papers are at a conſiderable Diſtance from that Point, and therefore conſtantly viſible to either Eye.

Euphroſ. This is a ſtriking Inſtance of Contrivance, indeed: But, pray, what have you farther to obſerve in Relation to the exterior Parts of the Eye?

Cleon. The Form of the Eye on the poſterior Part deſerves your Notice: It is neither plain, nor ſpherically round, as I have heretofore obſerved to you that neither of theſe Surfaces will admit of a perfect Repreſentation of the Images of Objects, portrayed in the Focus of a Glaſs: But it is really of that Form which the Laws of Optics require for a perfect Deliniation of the Images of Objects, as well in an oblique, as a direct View, on the Expanſion of the optic Nerve, or *Retina* in the Eye.

Euphroſ.

Euphrof. This a curious Circumſtance, moſt certainly, and is very obvious with the ſlighteſt Inſpection. ——— I ſee all the back Part of the Eye is opake, and the fore Part only is tranſparent.

Cleon. This will convince you of the Truth of that which I have often obſerved to you, *viz.* that the Eye is nothing more than a moſt perfect *Camera Obſcura* in Miniature, in which the whole Buſineſs of Viſion is tranſacted; for which Purpoſe you ſee, on the fore Part, a very tranſparent and convex Covering, which is called the *Cornea*, or *horny* Coat of the Eye (L P K, Fig. 3.)

Euphrof. I think I can ſee the Reaſon why it is both Tranſparent and Convex; for the Tranſparency is neceſſary to a free Admiſſion and Refraction of Light, and the Convexity of it is neceſſary for converging the Rays of Light to a Focus, at the Bottom of the Eye, for the Formation of Images there: ——— And one Thing farther I can hence obſerve, and that is, the proper Degree of Convexity in the Eye, which muſt ever correſpond to the Diameter or Bulk of the Eye; ſince the optic Nerve, in the Bottom of the Eye, muſt neceſſarily be in the Focus of the Convex *Cornea*, as you call it. But, pray, how is the Convexity of this Part ſupported, and conſtantly kept up?

Cleon. By a fine limpid Humour, which lies immediately under it, and, being in Appearance like *Water*, is called the *Aqueous*, or watery Humour of the Eye. ——— This you will be immediately ſenſible of; for I pierce the *Cornea* with the Launcet, and you ſee it run out upon the white Paper. ——— Pray, what do you think of it?

Euphrof. Why, truly, it ſo much emulates Water, in Appearance, that I ſhould not have known it had been any other Fluid, if I had not ſeen how, and from whence it came there: ——— But, upon letting it out, you have quite defaced the beautiful Appearance of the Eye; for now the *Cornea* loſes its Convexity, and ſubſides in Wrinkles, which gives a ghaſtly Appearance to the Eye.

Cleon. I will ſoon relieve you from that diſagreeable Sight. ——— With theſe anatomical Sciſſars, I ſever the *Cornea* from the opake Coat called the *Sclerotica*, and then you behold the next

Part,

Part, which is deſtined for the Service of Viſion: This, the Anatomiſts call the *Uvea*, (K o L) it is, in our Eyes, of a circular Form, and quite Opake, and, being of different Colours in different Eyes, it is vulgarly called the *Iris*. —— In the middle Part thereof, you obſerve an oblong Perforation, which in human Eyes is perfectly round, and called the *Pupil*, (*o*, *o*.)

Euphroſ. The Inſtructions you have already given me in Optics, enables me to judge of the Uſe of this Part, at firſt Sight. The Pupil of the Eye anſwers to the Aperture in the object End of a Teleſcope, which muſt be of a determinate Size for a proper Degree of Light to illuminate the Image in the Bottom of the Eye. This Doctrine you frequently inculcated in your Deſcription of optical Inſtruments, and particularly the *Camera Obſcura*.

Cleon. What you ſay is true, in general, in artificial Optics: But when we conſider the natural Structure of this Part, it will appear very admirable; for this natural Aperture, or Pupil in the Eye, is capable of various Dimenſions, by a double Syſtem of muſcular Fibres of which it is compoſed, *viz.* one on the external Part which is of a circular Form, and by whoſe Action the Pupil of the Eye is contracted: The other Syſtem, on the interior Part, has its Fibres diſpoſed like Rays iſſuing from the Center of the Pupil, and when I take it off they will be very conſpicuous. —— You ſee I paſs my Sciſſars round, and it is ſeparated from the interior Coat of the Eye; and now the radial Syſtem of Fibres appear.

Euphroſ. I ſee them very plainly, and cannot but wonder at ſuch divine Mechaniſm in this ſmall and uſually ſuppoſed inconſiderable Part of the Eye: —That when the Light of an Object is too glaring, we have the Faculty by one Syſtem of Muſcles to contract the Pupil, and thereby to exclude all the offenſive and ſuperfluous Light: And on the other Hand, for diſtant and obſcure Objects which require to be viewed with all the Light poſſible, we can, by the Action of the radial Fibres, dilate the Pupil, and thereby give Admiſſion to a greater Quantity of Light.

Cleon. I have ſometimes been curious enough to meaſure the Diameter of the Pupil in each Caſe, when a Candle has been held

held very near to the Eye of a Child, I have found the Pupil not much to exceed the $\frac{1}{8}$ of an Inch; but in the Twylight of the Day I have found the Diameter of the Pupil near twice as large, and therefore the Area of that Pupil near 4 times as great as before: ——— The *Uvea* being removed, you behold another Part, in a great Measure, resembling a Lens of Glass placed just in the Middle of the Eye behind the Pupil.

Euphrof. A very curious Part, indeed; pray, what do you call it?

Cleon. It is called, the Crystalline-humour; for it is, as yet, contained in an exceeding fine transparent Capsule called, the *Arachnoides*, on the upper Surface of which you see a circular Zone of Fibres; these, also, are in form of Rays issuing from the Center, and are of a black Colour.

Euphrof. They are very conspicuous, indeed; I should be glad to know their Use, and by what Name they are called.

Cleon. This black *Annulus*, or Ring of muscular Fibres, is called, the *Ciliary Ligament*, as resembling the Hairs of the Eyes-lids: — The Use of this Part, being affixed to the delicate Tunick of the Crystalline-humour, is to give a proper Motion to the same, and as some think, to alter the Figure of this Humour in some small Degree, as will be farther evident when, by making a fine Incision in the Capsule, the Crystalline-humour immediately slips out, which I take on this printed Paper that you may see how the Letters are magnifyed thro' it, as in a common Glass Lens.

Euphrof. Amazingly fine, indeed: ———In my Life, I never beheld any Thing so transparent: ——— It seems a perfect Glass Lens, but more pollished than Glass, infinitely: —— It may very well be called the *Crystalline*-humour, I see, for no CRYSTAL can ever emulate this Part in Regard to clearness. ——— I observe one Thing very remarkable, and that is, tho' it be apparently, and, (I suppose,) really, of a spherical Surface on both Sides, yet, that one is considerably more convex than the other: Pray, what is the Meaning of this, *Cleonicus?*

Cleon. As this Part is undoubtedly destined, by Nature, to correct and adjust the common Refraction of Light, thro' the Eye, to a proper Focus on the *Retina* at the Bottom, the

convex Surfaces may, in ſome Degree, contribute thereto, as the Denſity of the Cryſtalline-humour is a ſmall Matter greater than that of the other Humours, in which it is contained; and, by the Action of the *Ciliary* Ligament, the Degree of Convexity in each Surface may poſſibly be a very ſmall Matter altered; but Reaſon, more than Experience, directs us in theſe Conjectures. ——However, it muſt neceſſarily follow, from the Nature of a muſcular Ligament, that, by its Contraction and Relaxation, the Poſition of the Cryſtalline-humour muſt be ſubject to Alteration, and this is neceſſary in the Nature of Viſion; for, when Objects are near to us, their focal Diſtance becomes greater than when they are placed afar off, and therefore the Fibres of this Ligament, by contracting, removes the Cryſtalline-humour a ſmall Matter farther from the *Retina*, and thereby procures a due focal Diſtance for nigh Objects: But, by their Relaxation, this Humour ſinks lower, and ſhortens the focal Diſtance for thoſe that are farther off: and thus the Eye is provided with a Power of procuring Viſion for Objects in all Variety of Diſtances.

Euphroſ. There is no End to the Admiration of the Wiſdom we obſerve in the Works of Nature, and the moſt evident Marks of Deſign and Contrivance in every particular Part. —— But what is that large Quantity of Humour that fills the whole Body of the Eye, in Appearance like the white of an Egg?

Cleon. It is commonly called the *Vitreous*, or *Glaſſy humour:* But for what Reaſon I know not, unleſs for that one Quality of Glaſs, its *Tranſparency:* ——It is in a very large Quantity, in Reſpect of the other two Humours, on purpoſe to fill out the Body of the Eye, and to render it Globous and Roomy: —— For, before I take this Humour out of the Eye, it is worth your while to obſerve how very perſpicuouſly it ſhews the optic Nerve, expanded over all the interior Part of the Eye, together with the Arteries and Veins which enter with it, and are moſt delicately ramified thro' all its Texture: —— For the Blood Veſſels ever accompany the Nerves thro' every Part of the Body, for they circulate the Fluid of *Life*, as the other does that of *Senſation*.

Euphroſ.

Euphrof. A Phænomenon equally curious and wonderful: It is impoſſible a finer Sight ſhould greet the Eye. I ſee the whole Expanſion of that noble Organ in its natural Poſition, the Idea of which will ever be indelible in my Mind!

Cleon. I ſhall ſhew you the ſame Thing, by and by, in a different View. That curious viſual Membrane is every where connected with the fore Part of the Eye, immediately under the Ciliary Ligament, as you will eaſily perceive when I turn the Eye inſide out, upon the Surface of the Water in this Glaſs, which ſupports the deſcending Humour, and the *Retina*, till, with the Knife, I have ſeparated them both from the anterior Part of the inner Membrane of the Eye, called the *Choroides*, which lies immediately under the *Retina*, and is beautifully coloured in *Quadrupedes*.

Euphrof. I ſee the Separation manifeſtly: —— as your Knife proceeds, the Glaſſy-humour ſubſides and becomes inviſible in the Water; but the optic Nerve remains behind, upon that fine coloured Coat you mentioned.

Cleon. Tho' the Glaſſy-humour is not ſeen in the Water, I ſhall take it out on the blade of my Knife, —— and you ſee how very large and tranſparent a Subſtance it is.

Euphrof. Pray, of what does this Humour conſiſt, there ſeems to be a great Quantity of aqueous Matter, as I ſee it continually keeps dripping a clear limpid Fluid like Water?

Cleon. It from thence appears to be compoſed of a Syſtem of infinitely fine Veſſels, which contain and continually diſtill the fine Lymph you ſee; and ſo inconceivably fine are thoſe Veſſels, that, when they have diſcharged all their aqueous Contents, they ſcarcely amount to the Weight a ſingle Grain. —— But now obſerve, I paſs my Knife round the extreme Part of the *Choroides*, and the *Retina*, being by that Means ſeparated, ſubſides into, and floats upon the Water, 'till at Length, the whole being ſevered, it totally ſinks and collapſes into a Body almoſt in Appearance like the external Nerve. —— I now cut away all the Coat of the Eye from the Nerve, and then it appears moſt evidently, that the *Retina* is only a Continuation of the Nerve. ——Laſtly, with my Sciſſars I ſeparate the *Retina* at the Nerve, and let it fall into a Glaſs of clean Water; then, with the Point of my

Knife, I expand it, and you see how fine an Appearance it makes.

Euphros. It is, indeed, beyond all Expression, fine: —— it resembles now a Piece of fine white Linen, of a curious Texture, and interwoven with a great Variety of Blood-vessels, in a beautiful Ramification, gradually eluding the Sight by infinite Degrees of Miniature; —— But I observe this wonderful Part, this Organ, or Seat of the visive Faculty is, in itself, not Transparent, but almost Opake.

Cleon. Opacity, or Transparency, are both indifferent to the Cause of Vision, which consists wholly in the peculiar Action and Modification of the Rays of the Light on the Filaments of the optic Nerve:——But its being in so great a Degree Opake, shews how far some Men may be carried from the most evident and obvious Truths, to support a new Hypothesis which has no Foundation either in Nature or Reason; but Truth will ever confront and prevail over Error, tho' supported with all the Powers of Rhetoric and Novelty. The optic Nerve, which immediately receives the Rays of Light, and sustains their first and whole Impulse, will ever be acknowledged the natural Organ of Vision by every modest and judicious Philosopher; and the *Choroides* must in vain pretend to rival it in that Honour, to which the Rays of Light can have no Admittance through the *Opacous* Substance of the *Retina*, and must be content with the more humble Office assigned to it by Nature. ——Thus much for the Description of the *Natural Eye*. At our next Interview I shall entertain you with an Account of the Deficiencies in the Structure of the Eye, and how they are rectified by the Application of Glasses, and illustrate the whole by an *artificial Eye*.

DIALOGUE

DIALOGUE XIX.

Of the preternatural CONFORMATION *of the* EYE; *the* DEFECTS *of* VISION *arising from thence; and the Means of remedying them by* OPTIC GLASSES. *The whole illustrated by an* ARTIFICIAL EYE.

Cleonicus.

I Took an Opportunity, very lately, to let you see how accurately every Part in the natural Eye is contrived to answer the Purposes of Vision; that no Part could be wanting without a Deficiency in the Structure and Uses of that most noble of all Organs: On the other Hand, it appears, that no Part was redundant, or superfluous: And again, with respect to the Position and Figure of each Part, that it was altogether such as the Nature of Vision required: Upon the whole, the Eye is naturally of so just a Conformation that it stands in no Need of the Assistance of the Science of Optics, but in Regard to Telescopes and Microscopes, concerning which I have very largely discoursed to you heretofore.

Euphrof. But how, *Cleonicus*, shall we then understand the Reason of so many defective Eyes, which we daily observe in all Ranks and Degrees of People, from the youngest to the oldest; for nothing is more common to observe, than that both Old and Young apply Glasses, concave or convex, to their Eyes, to mend their natural Sight?

Cleon. Your Animadversion is founded on a general Experience, I allow; but it must be considered, that all those who use the convex Sort of Glasses do it in the Course of Nature; for the Eye, like all other Members of the Body, is subject to Decay, and in our declining Years require Assistance equal with every other Part, and consequently this can be reckoned no preternatural Affection of the Eye: But with regard to young People, if they are obliged to use Glasses, it is from a real preternatural Conformation of the Eye; in them, the Eye is of a Figure too

too convex for making a perfect Image of Objects on the *Retina* in the Bottom of the Eye: but if we consider how very few there are of this Class, compared with the Bulk of Mankind, we must reckon them only particular Exceptions to Nature's perfect and Handy-work.

Euphrof. I have also heard of another Reason for the Use of concave Glasses, *viz.* that because some People in higher Life have been obliged, from a natural Necessity, to use them, others in lower Spheres (whose corporeal Eyes stood in much less Need of mending than those of their Mind) thought it became them to imitate their Superiors in this Respect; and so the Application of Concaves became improved into a Fashion.

Cleon. People are not only excessively fond of being in the Fashion, in setting off the real Beauties and Excellencies of their Persons with all the Extravagance imaginable, in regard to dressing, painting, *&c.* but they are so prepostrous, as even to blemish and eclipse their natural Perfections to gratify this absurd Passion; witness, in your Sex, the *Patches*, (which at first were only designed to hide Pimples) and in ours, the affected Practice of *Myopism*, or the Application of Concaves where none are wanting,

Euphrof. Why is such a Person who uses a Concave called, a *Myops*.

Cleon. The Word *Myops* is of *Greek* Etymology, and signifies, in plain *English*, *Mouse-Eyed*; because a Mouse has a very round Eye, or the whole of it is almost a Spherule, or small Globe, as you may easily satisfy yourself when you see that Animal in a Trap, or which is nearly the same Thing, you see such an Eye every Day in the beautiful little Squirrel you keep.

Euphrof. You have satisfied me in that Particular. —— By the Instructions you have heretofore given me, I believe, I am able to see the Nature of this Deficience in the Eye, which you call *Myopism*, for it is, if I mistake not, an Eye with too short a focal Distance, occasioned by too great a Degree of Convexity in the *Cornea*, or anterior Part of the Eye.

Cleon. That is the very Case, my *Euphrosyne*, and that you may the better see and compare an Eye of a just Conformation with the two Sorts that are not so, I have provided three Diagrams,

grams, to shew their different Structures respectively. In one of these (Fig. 3. Plate LI.) an Object O B is placed at a proper reading Distance before the Eye, whose *Cornea* K P L, the Pupil *o o*, and Crystalline Humour S T, with every other Part, are of a just Conformation to make the Image I M perfect on the optic Nerve at the Bottom of the Eye.

Euphros. This is all very evident in the Figure, where the focal Distance of the Eye is just equal to its Diameter: ——— But what is the proper reading Distance C P, at which the Object O B is to be held for viewing it in the best Manner?

Cleon. When we want to read, or view a Thing in the most perfect Manner, Nature, without our Attention, stretches out the Hand to about 14 or 16 Inches, according to the Difference of Eyes, which is seldom more or less; and therefore, by Experience, that is confirmed to be the Distance for viewing Objects with the natural Eye. ——— But if the *Cornea* happens not to have this natural Degree of Convexity, as in the other Diagram (Fig. 4,) which you here see, where K P L, the *Cornea*, has a greater Degree of Convexity than what is just, the Rays which come from any Point C, in an Object at the Distance C P as before, will here be united, and represent that Point C, short of the *Retina*; and so all other Points in the Object O B, and consequently the image thereof, will be formed and represented at I M, some Distance from the Bottom of the Eye. ——— As this is the Case, we find a near-sighted Person obliged to hold the Object much nearer to his Eye, *viz.* at *O B* in order to lengthen the focal Distance, and make the Rays reach the Bottom of the Eye before they unite; and as they, in that Case, represent the Image perfect on the *Retina* at *i m*, they procure distinct Vision of the Object in that near Distance *c* P.

Euphros. As the *Myops* has it in his Power to rectify his natural Defect of Vision for any Objects near him, or such as he holds in his Hand, by lessening the Distance between the Object and the Eye, till the focal Distance is thereby adjusted upon the *Retina:* So a concave Glass cannot be necessary on that Account. ——— It must therefore be only for viewing remote Objects, where the Distance is unalterable, at least cannot be diminished so much as is necessary for a just Prolongation of the Focus of the

the Eye, and where, of courſe, a concave Glaſs muſt be applied to perform that Office.

Cleon. You ſeem to have very juſt Ideas of this Matter; for the concave Glaſs E F being applied before the Eye, diverges every Pencil of Rays *a* C *b* in ſuch Manner as to make them fall upon the Pupil *o o*, as if they came from the Point *c* at a much leſs Diſtance from the Glaſs E F; and when the Concavity of this Glaſs is ſuch as the near-ſighted Eye requires, then will the Image *i m* be duly formed on the *Retina*, of the diſtant Object O B.

Euphroſ. This I apprehend very clearly, and, with Regard to a *Myops*, I obſerve, that any Object O B appears leſs to him, as *O B*, and alſo at much nearer Diſtance than to a well formed Eye. ——— Hence likewiſe it muſt follow, that as there may be various Degrees of Convexity in the Eye beyond that which is juſt, ſo there muſt be a great Variety of concave Glaſſes neceſſarily correſponding thereto, and to be uſed as Remedies for the ſame.

Cleon. After the ſame Manner you will underſtand, by the third Diagram, (Fig. 5.) that for *Preſbytæ* (which is a *Greek* Word for *elderly People)* the *Cornea* K P L has too ſmall a Degree of Convexity to converge a Pencil of Rays *a* C *b* coming from a Point C (in any Object O B at the natural reading Diſtance (as in Fig. 3.) to its proper focal Diſtance at the Bottom of the Eye; but they will proceed to a point beyond the Eye, where, if they were not intercepted, they would form the Image (*i m*). Now tho' ſuch a long-ſighted Perſon might remove a Book, or other Object, to ſuch a Diſtance from the Eye, that he ſhall be able, by that Means, to ſhorten the focal Diſtance of the Rays, and read without a Glaſs, yet this would be attended with great Inconvenience, in general, and the reading at ſo great a Diſtance would be aukward and unſightly, as well as unnatural: Therefore, by applying the convex Glaſs G H, the aforeſaid Pencil of Rays (*a* C *b*) is made to fall leſs diverging upon the Eye, or as if they came from the Object *O B* at a greater Diſtance. By this Means, that Pencil of Rays is duly converg'd to a Focus at the Bottom of the Eye, and thus all other Points in the Object O B will be repreſented in the Image I M on the *Retina*, and thereby produce diſtinct Viſion.

Euphroſ.

Euphrof. All this too I cannot but apprehend, as you have partly explained it to me in a former Conference: ——— And alſo, from the Figure, it is eaſy to infer, that, to a *Preſbyta*, Objects appear through Glaſſes magnified, and at a greater Diſtance, juſt the Reverſe to the Caſe of the *Myops*. ——— You have now led me through the *Rationale* of thoſe we call occular Glaſſes, both Concave and Convex, that are uſed for rectifying Viſion in general. Have you any Thing farther to obſerve, with reſpect to the Manner of applying them to the Eye with the greateſt Advantage?

Cleon. Yes; there are two Things which, by the Laws of Optics, every rational Man muſt think himſelf obliged to obſerve and conform to: The firſt is, that no more Light be admitted upon the Eye than what is neceſſary to illuminate the Object, ſhew it diſtinctly, and to allow of a ſufficient Field of View: But, on this, I have already expatiated to you, which needs no farther Repetition.*

Euphrof. I remember very well what you ſaid to me on that Subject, and am thoroughly convinced of the Reaſon of it: But what is the ſecond Particular to be obſerved in the Uſe of theſe Glaſſes?

Cleon. The ſecond Thing neceſſary in the Application of theſe Glaſſes is, that they are ſo placed before the Eye, that the Axis of each Glaſs may coincide with the Axis of the Eye, and be therefore directed to, and united in the Object that we view: This muſt be obſerved very ſtrictly, with regard to Convex Glaſſes, as by them we view near Objects; but it has little to do with Concaves, as the Objects ſeen by them are generally remote, and therefore the Error, in this Reſpect, almoſt inſenſible: But as this Matter cannot well be explained, without a large Copper-plate, I muſt refer you to a Treatiſe lately publiſhed on this Subject, where you will find ample Information concerning this, and all other uſeful Precautions in the Uſe of VISUAL GLASSES, and their Difference from the abſurd and injurious Structure of common Spectacles.†

* See Dialogue XVII, p. 319, 320.

† See my *Treatiſe on Viſual Glaſſes*; and the *Appendix* to my *Philoſophia Britannica*, 2d Edition.

Euphrof. But after all, you promiſed to illuſtrate this Affair by an *artificial* EYE, which I take to be this round Globe of Braſs on a Pedeſtal, with a Glaſs before and behind. Pray, what is the Structure and Similarity between this and the natural Eye?

Cleon. If great Art and Expence were employed, there might be a very conſiderable likeneſs produced between the Structure of the natural and artificial Eye, ſo far that in every Part they ſhould each of them have nearly the ſame Appearance: ——— But without regard to the Size and Form of the conſtituent Parts, a great Similarity may be produced in the Effects of one and the other; and this is ſufficient for our Purpoſe, as, by Means of this artificial Eye, in a very ſimple Structure, we can eaſily repreſent or illuſtrate the three different Caſes of natural Eyes before-mentioned; and for this Purpoſe only four Glaſſes are neceſſary, three of which are Convex ones, and finely poliſhed, included ſeverally in proper Cells or Rims, and to be ſcrewed into the ſame Hole on the Fore-part of the artificial Eye. The Fourth is a plain Glaſs, ground on one Side with fine Emery to take off the Poliſh, and thereby to render it, as it were, Semi-tranſparent.

Euphrof. By your very Deſcription of this laſt Glaſs, I ſuppoſe it muſt repreſent the *Retina* in the natural Eye, which, I remember, you ſhewed me was neither Opake nor Tranſparent, but between both.

Cleon. I obſerved to you at the ſame Time, that this Quality, or Degree of Tranſparency in the *Retina*, did not appear to be neceſſary to Viſion; but in the artificial Eye it really is ſo, becauſe, were this Glaſs wholly Opake, or Tranſparent, it could not anſwer the Purpoſe; as in one Caſe, no Image of an Object could be ſeen upon it; and in the other, though the Image might perfectly appear, yet its Locality, or particular Place, could not be ſo well determined: But being thus half Tranſparent, will nicely ſhew the *Image*, and the *Place* where it is formed at the ſame Time.

Euphrof. I underſtand you perfectly well; but I obſerve this Glaſs is plain, and has not the true Figure of the hinder Part of the Eye.

Cleon.

Cleon. That Figure would not be eaſily imitated by Art, as it is neither plain nor ſpherical; Nature takes a perfect Method in all her Operations: Art can only imitate by Approximation, but a plain Glaſs will anſwer our preſent and particular Deſign.

Euphroſ. The three Glaſſes which are ſcrewed on in the Fore-part of this Braſs Eye are, I preſume, deſigned to form the Images of Objects on this artificial *Retina*, or Glaſs, behind; and, becauſe you have three in Number, I ſuppoſe one is to repreſent the Caſe of a well-formed Eye, and the other two the deficient Ones of the *Myops* and *Preſbyta?*

Cleon. That is the very Thing, my *Euphroſyne*, as I will now ſhew you by an Experiment. —— The Diameter of the artificial Eye, you obſerve, is two Inches: ——Then I ſcrew on the Glaſs (N°. 1.) whoſe focal Diſtance is juſt 2 Inches: ——— Then I take the artificial Eye, and ſtanding at the Diſtance of about 12 or 15 Feet from the Window, and holding the artificial Eye directly before my own Eye, I ſee the Image of the Window very diſtinctly formed upon the ground Glaſs. —— Now, take the Eye in your own Hand, and ſtanding at the ſame Diſtance, you will obſerve the ſame Thing.

Euphroſ. That I do perfectly; and a very curious Experiment it is: ——— The Window appears in all reſpects like the Picture of Objects in a *Camera Obſcura*, moſt natural, bright, vivid, and every Way the ſame, I preſume, as it would appear on the *Retina* of the Natural Eye, if it was poſſible to be there ſeen.

Cleon. See it you may in the natural Eye, in ſome Meaſure; and, as I know you are very curious in theſe Matters, I have prepared ſuch an Eye on Purpoſe to ſhew you this very Phænomenon therein. ——— You here ſee the large Eye of an Ox diveſted of all its muſcular and membraneous Parts, and then a circular Hole cut in the *Sclerotica*, or external Coat of the Eye, and alſo through the *Choroides* which lies immediately within it, and then a Part of the *Retina* appears entire and in its natural State: —— Then I hold this natural Eye up againſt the Window, and you ſee the Image of the Window perfectly formed on the *Retina*, juſt in the ſame Manner as in the artificial Eye.

Euphrof. This is, indeed, an *experimentum Crucis*, or capital Experiment in Vision, than which nothing can give a more full and exquisite Satisfaction, with regard to the Manner how Vision is performed in the Eye.

Cleon. But now if a Glass, either Convex or Concave, be placed before the *Cornea* of the natural or artificial Eye, the Image no longer appears distinct on the natural or artificial *Retina*, as you may try with each Eye severally, while I apply each Sort of Glass before them.

Euphrof. Then I will take one of the Eyes in one Hand, and the other in the other, and, if you please, first apply the Convex: ——— In each Eye the Image disappears, at least its Appearance is very confused. ——— Now apply the Concave, that I may see the Effect of that: ——— It is very much the same as before, no Beauty or Distinctness of the Image any longer appears, and consequently no Perfection of Vision in the natural Eye. ——— Hence it appears, however useful those Glasses may be on some Occasions, yet, when the Eye has its due Form or Figure, they can never be used without prejudicing the Sight. ——— Please now to shew me the Experiment of the *Myops*.

Cleon. For this Purpose I must screw on the Glass (N°. 2.) whose focal Distance is only one Inch and a Half, arising from its greater Degree of Convexity. In this Respect it will represent the *Cornea* of a short-sighted Eye, as well as in its Effect of forming the Image short of the *Retina*, and, consequently, it must appear very imperfect upon the Glass behind: ——— hold it up against the Window, and see the Consequence of such a convex Glass.

Euphrof. I do: ——— It very plainly appears, that no Image of the Window, or any other Object at a Distance, can have its Image formed in any Degree of Distinctness on the glassy *Retina* of this Eye. ——— Now, please to put before it the concave Glass, for a Remedy.

Cleon. I will: ——— It is now just before the artificial *Cornea*, and, by causing the Rays to go less converging, they proceed to the ground Glass before they unite in a Focus, and there make the Image as perfect as before.

Euphrof. I very plainly perceive it; but I observe at the same Time, that the Image of the Window is not so large as before, which

which gives the Reaſon why ſhort-ſighted People ſee all Objects of leſs apparent Magnitude than other People do, a Thing I remember you formerly obſerved to me. ——— You will next favour me with an Experiment of a long-ſighted Eye, which requires a Convex Glaſs.

Cleon. In order to this, I ſhall put on the Glaſs (N°. 3.) where the focal Diſtance is two Inches and an Half, which, as it exceeds the Diameter of the Eye, the Image will neceſſarily be ſeen very imperfect on the Glaſs behind: ——— But when I apply a Convex Glaſs between the Eye and the Window, you will then ſee, by this additional Convexity, that the Rays will be made to converge to a Focus on the glaſſy *Retina*, and there repreſent the Image of the Window perfect. ——— Take it in your Hand, and try the Experiment.

Euphroſ. I will firſt hold up the Eye without your Viſual-Glaſs: ——— There is not the leaſt Appearance of any diſtinct Image: One may juſt ſee it is a Window, and that is all. ——— Pleaſe to apply the Convex. ——— I now ſee the Image of the Window reſtored to its perfect Form, but much larger than in either of the foregoing Caſes: ——— By this Experiment I am alſo ſatisfied of the Reaſon why thoſe who uſe Viſual-glaſſes muſt neceſſarily ſee all Objects larger than they appear to the naked Eye well formed: And ſince this is the Caſe, how does it come to paſs, *Cleonicus*, that we do not hear ſhort-ſighted People ſpeak of ſeeing Things ſmaller, or old People of ſeeing them larger, than others who uſe no Glaſſes at all?

Cleon. There is no ſuch Thing in Nature as a Standard of real Magnitude, but only of that which is apparent; an Inch, or Foot, or Yard, is as much a Standard-meaſure to a *Myops* or *Preſbyta*, as to a Perſon who views it without a Glaſs: And ſince to each Perſon every Thing appears diminiſhed or magnified in the ſame Proportion, they muſt neceſſarily all of them have the ſame Ideas of apparent Magnitude, as the Scale of Compariſon is ſtill the ſame in all; for Things are only great or ſmall, by Compariſon made in the ſame Scale, or by the ſame Standard. ——— There is only one Thing now which remains to be confirmed by an Experiment, and that is, to ſhew how much more diſtinct the Image of any given Object is formed by a Glaſs

of

of a proper Aperture, than by an another of an exorbitant Size: For Inſtance, that which you have ſeen in the Eye of two Inches Focus is only $\frac{1}{4}$ of an Inch in Diameter: I will now put on another Glaſs which is twice as much, or one Inch and an Half in Diameter; it is of the ſame focal Diſtance, and will form the Image of the Object on the Glaſs as before, but with four Times the Quantity of Light; on which Account, the Diſtinctneſs of the Image will be greatly impaired, and, conſequently, the Perfection of Viſion which depends upon it, as you will obſerve by the Experiment, is deſtroyed.

Euphroſ. This is a very plain Caſe: ——— The Image is now quite ſuffuſed, or overwhelmed, as it were, with Light; and far from being ſo diſtinct and perfect as it was before: By which I am thoroughly convinced what Judgment and Care is neceſſary for giving ſuch Apertures to optical Inſtruments as are neceſſary for their due Perfection, and, particularly, how abſurd it muſt be to covet a large Spectacle-glaſs, when one of a ſmaller Size will ſo much better aſſiſt the Sight. ——— But I ſuppoſe, by this Time, I have ſufficiently tired you with ſuch a tedious Series of Speculations in Optics: —— It will be a Relief and Pleaſure to you, as well as me, to change the Subject, and make a Tranſition to ſome other Object of natural Science, that may afford another kind of Entertainment. What can you think of, *Cleonicus*, that will offer itſelf moſt proper for that Purpoſe?

Cleon. Why truly, my *Euphroſyne*, we have dwelt long on the Science of Optics, and yet have not exhauſted the Subject; but, as my Deſign is to give not a critical, but curſory View of general Topics, I ſhall now direct your Thoughts to another important Branch of Knowledge, which is the *Doctrine of Sounds*, and give you an Idea, ſo far as I am able, of the wonderful Mechaniſm and Structure of the EAR, which is that Organ which renders them perceptible to the Mind, which, I preſume, you will find a Subject not much inferior, in Point of Curioſity and mental Improvement, to that of the Organ of Sight.

DIALOGUE

DIALOGUE XX.

On the general NATURE *and* CAUSE *of* SOUNDS.

Cleonicus.

FROM the Science of OPTICS we now proceed to that which is called ACOUSTICS, which treats of the Philosophy, or Doctrine of SOUNDS, and of the Constitution of the Organ of HEARING, which is placed in the EAR, by which those Sounds are rendered audible, or sensible to us, under all their different Affections and Circumstances.

Euphros. This Subject must necessarily afford me very useful, very instructive and entertaining Lessons; for, as the Subject is that of Sound, I naturally conclude, that the Science of Music will make a considerable Part of our Speculations, as it consists wholly of an artful Modulation and Modification of different Kinds of Notes, or Sounds.

Cleon. MUSIC is undoubtedly the essential and most refined Part of the Philosophy of Sounds; an agreeable Scene in Optics, or Perspective, does not more delight the Eye and regale the Mind, than a Composition of harmonious Sounds delights and pleases the Organ of Hearing, and, perhaps, of all our Sensations: This does more immediately affect both the *pathetic* and *rational Part* of the human System, and hence it is, we see Mankind in general so fond of musical Sounds, as it affects them with the most agreeable and ravishing Sensations: But what inclines me most, at present, to discourse to you on this Subject is, the exquisite Taste and Relish you have for the Pleasure of this Science in every Respect, and consequently a *Rationale* of those Instruments, with which you so frequently delight yourself and Acquaintance, will be very grateful to you.

Euphros. Nothing can prove more so; and I remember you formerly hinted to me, when you treated of Air in general, and shewed the Experiments on the Air-pump, that the Nature of Sounds depended intirely upon a certain Motion of the Particles

of

of Air, and that by one particular Experiment of the Bell it was ſhewn, that when the Air was exhauſted, or taken away, no Sound from the Bell could be heard. It is this Motion of Air therefore, I preſume, and its various Effects, that you now propoſe a farther Explanation of.

Cleon. This is more immediately the Object of our preſent Diſquiſition: But as I have formerly told you there is a two-fold Motion in the Air, which ought to be ſeparately conſidered to have a diſtinct Notion of either, the firſt regards a Motion of the whole Body of the Atmoſphere, or any Part thereof from one Place to another; but the Second reſpects the Motion of the Particles of Air in themſelves ſimply conſidered, and is not ſo much a *local Motion*, from one Place to another, as a pulſive or vibrating Motion, which carries the Particles forward and backward, through the very ſame Space. Do you think you apprehend me in this Diſtinction, my *Euphroſyne?*

Euphroſ. I believe I do, *Cleonicus.* —— By the firſt Motion of the Air, I conceive a great Quantity of it is carried from one Part of the Globe to another, after the Manner we uſually call WIND, as you formerly explained to me, when you treated of the general Nature of the Air and Winds. —— But the ſecond Motion of the Air, or that rather which reſpects the Motion of the Particles of Air in themſelves conſidered, I cannot ſay I have ſo clear an Idea of; but apprehend it muſt reſult from, or depend upon that Power which you convinced me exiſted between the Particles of Air which keeps them all at an equal Diſtance from each other, and is that which you called the *Spring*, or *Elaſticity* of the Air.

Cleon. You recollect very well, my *Euphroſyne*; it is by Means of this Power that, when any one Particle is by any Cauſe urged forward, it muſt neceſſarily propel the Particle next before it; this ſecond Particle, in the ſame Manner, moves the Third; and the Third, the Fourth; and ſo ſucceſſively: By this Means a Motion is produced, and propagated in the ſeveral Particles of Air, thro' a certain Space in a Direction forward; but then, on the other Hand, when the Force which was firſt impreſt upon the elaſtic Particle of Air is remitted, or ceaſes to act, the Particles return again, by the Action of this elaſtic Force, through the

the ſame Space. And, laſtly, if this Force be repeated, at ſtated Intervals, on theſe elaſtic Particles, there muſt neceſſarily be produced in them a mutual vibratory Motion of each Particle, ſo long as the repercuſſive Force continues to act: And it is this Motion of the Particles of Air that is the Cauſe of Sound in general.

Euphroſ. Indeed, *Cleonicus*, this is ſuch a nice Speculation that, without a more circumſtantial and plenary Explanation, I fear I ſhall ſcarcely be able to get ſuch clear and adequate Ideas, as I could wiſh, of the Nature of Sound: But, I ſuppoſe you can render it more facile by Experiments, or ſome Illuſtrations of that Kind?

Cleon. I can aſſure you, my *Euphroſyne*, there is no one Part of natural Philoſophy more intricate and difficult to explain, than the Nature and Action of an elaſtic Fluid. This was experienced and acknowledged by Sir *Iſaac Newton* himſelf; and we find, by his Commentators on his *Principia*, that it was in treating of this Subject only, that they apprehended this great Man capable of a Miſtake: But it will not follow from hence, that, becauſe ſome Parts are exceeding difficult, we ſhould not contemplate and improve our Minds with the Study of thoſe which are more eaſy and uſeful; and therefore, to facilitate your Apprehenſion of what relates to the Doctrine of Sounds, I ſhall conſider, in the firſt Place, the Nature of thoſe Forces, and the Manner in which they act on the elaſtic Medium of Air, by which that peculiar Motion is generated which proves the Cauſe of Sound. —— Secondly, the general Properties of the Pulſes of Air, and the Manner in which they are propagated. —— Thirdly, the artificial Modulation of Sounds, both inſtrumental and vocal, ſo as to render them harmonious and muſical to the Ear. —— Fourthly, the Organs furniſhed by Nature for forming and variouſly modulating animal Notes, or Voice. —— Fifthly, the particular Conſtruction of the Organ of Hearing, placed in the Cavity of the Ear, for raiſing in the Mind the Senſation of Sound.

Euphroſ. Theſe ſeem to be very curious and important Topics, and it will give me great Pleaſure to hear you explain and expatiate upon them: Pleaſe, therefore, to begin with the

firſt of them, in which you ſignify the original Cauſe of Sound conſiſts.

Cleon. The firſt Thing to be conſidered in the general Idea of Sound is, the percuſſive Force, or Stroke, which is made upon the ſonorous Body, whoſe Parts are thereby put into Motion, and this Motion is to be underſtood to be that which is produced by elaſtic Parts, or Particles, of which ſuch Bodies conſiſt; for without ſuch an elaſtic Diſpoſition of Parts they could not by any Means be rendered ſonorous, or capable of emiting Sounds, becauſe the Stroke, being made externally, affects the Particles of ſuch a Body but with one ſingle Act; the Particles of the Body could therefore, in ſuch a Caſe, be moved through a certain ſmall Space, and would there ſtop by the Reſiſtance of the Parts beyond; and without an elaſtic Force the Particles would remain at reſt, after the percutient Body is removed; and therefore, from one ſingle Stroke, the Parts of Bodies unelaſtic could emit but one ſingle Sound, as they can affect the Air but by one ſingle and unrepeated Action: In ſuch Caſes we uſually ſay, *we hear the Stroke*, and that is all, as when we ſtrike with a Hammer on a Piece of Lead, and other ſoft and unſounding Subſtances: ——— But when we conſider the Stroke impreſſed on Bodies whoſe Parts are in any conſiderable Degree elaſtic, they not only yield to the Stroke and go forward through a ſmall Space, but, after the ſtriking Body is removed, thoſe elaſtic Parts, by their renitent Force, return again with a Velocity equal to that by which they were diſplaced: And thus a Motion being produced of a vibratory Nature will continue a ſenſible Time, and produce ſucceſſive Impulſes on the contiguous Air; and the Air being thus agitated by the elaſtic Particles of the Body, tranſmits its Pulſes ſucceſſively to the Ear, and there produce a Senſation of Sound of ſome Duration: And theſe are what we properly call ſonorous, or ſounding Bodies. ——— Thus, a fine wire String being ſtrained with a Weight, or otherwiſe, becomes elaſtic, and if it be properly ſtruck with a Quill, it will emit a Note, or Sound, which will continue audible a conſiderable Time after the Stroke. ——— Alſo, if a Bell, or Glaſs, be ſtruck in a proper Manner, they will emit Sounds of conſiderable Duration; for which Reaſon they become the fitteſt Inſtruments for muſical Modulations.

Euphroſ.

Euphrof. These Things I am well assured of from every Day's Experience; but there is one Thing I observe in the Account you have given, which seems to render the Word *Sound* of a complex Signification, or as if it was one general Idea composed of an infinite Number of simple Sounds, so quick repeated as to be all united in one: For, by what you say, I collect, that at each Return of the vibrating Particles of the Body, a new Motion is impressed upon the elastic Particles of Air, and, consequently, that the Pulses of Air will succeed each other at Intervals of Time equal to those in which the vibrating Motion of the Parts of such Bodies are performed: But as those Intervals, or Moments of Time are so exceeding short, as to be altogether insensible, the distinct Succession of the Pulses of Air must be so too, and consequently they altogether constitute but one general, or compound Sound. Is not this the Case, *Cleonicus?*

Cleon. It is, my *Euphrosyne*, and as accurately as I could have expressed it myself. ——— The Case here is much the same as in Optics: A Beam of Light, consisting of Rays infinitely different in Refrangibility, will cause that each particular Sort of Rays shall make one particular Image of an Object in the Axis of a Glass; and consequently, that though an Infinity of Images are thus formed, yet, being infinitely near each other, they all make but one Compound, yet very distinct, Image to the Eye. ——— Or thus: You have seen an Experiment, no doubt, of a Boy's whirling round a red-hot Coal, which, to Appearance, makes a very compleat fiery Circle; but this is only a general Idea arising from the particular Ideas of the Coal in the several Parts of the Circle, and as the Coal succeeds to those Parts so very quick, that there is no Time for the first Idea to be obliterated before it is excited again; so the Idea of the Coal in every Part of the Circle remaining, they must necessarily exhibit to the Mind the general Idea of a Circle of Fire, as aforesaid. ——— And, indeed, if we rightly consider Things, we shall find that most of our Sensations are performed in the Gross; that our Powers and Faculties are not sufficiently acute and perfect to distinguish or comprehend the most minute and simple Operations of Nature. ——— It is the same in regard to all our other Senses: One *Smell* consists of an infinite Number

of particular Senſations raiſed by the Action of innumerable *Effluvia* on the Organ of that Senſe: And the like may be ſaid of the Senſation of *Taſte*, from *ſaporific* Particles.

Euphroſ. As this is the Caſe, how comes it to paſs that our Ideas of thoſe very complicated Senſations ſhould yet be ſo very diſtinct and perfect as they are?

Cleon. Your Queſtion is very *apropos*, my *Euphroſyne*, and I muſt anſwer you in the Dialect of the Muſicians, that the particular Sounds excited by the elaſtic Particles are all Uniſons, or of the ſame Note, and therefore can make altogether but one Sound to the Ear, or rather a Sound of but one Note. —— An inconceivable Number of ſmall Drops of Water put together form only one larger, or collective Drop, which, in every Reſpect, reſembles each one of the ſmalleſt: ——— So the Action of an infinite Number of Particles, being all of the ſame Tenor, excite only a general, or collective Idea of the ſame Action on the Organ of Smell or Taſte: But this is an Affair which requires not ſo much Prolixity of Explanation to my *Euphroſyne*.

Euphroſ. Indeed, I think you have given me a very clear Account of the firſt Operation of Nature in the Production of Sound. ——— The ſecond Thing you propoſed, I make no doubt, will prove equally ſatisfactory, to the Explication of which I ſhall be equally attentive.

Cleon. The Properties of the Pulſes of Air, in which the immediate Cauſe of Sound conſiſts, I cannot better illuſtrate than by making, in ſome Degree, a Compariſon betwixt them and the Waves of Water, as well in Things wherein they diſagree as thoſe wherein they agree, and they will mutually help to explain each other; the Principal of which are as follow: ——— If a Stone falls on the Surface of Water, by its Weight, or Force, it will ſtrike and deſcend into it: But the Deſcent being ſudden, or momentary, gives no Time for the Particles of Water to move Sideways to make room for the Stone, but are forced to riſe inſtantly, as it were, upwards above the common Level; and being raiſed up, they deſcend again, by Virtue of their Weight, juſt as far below the Surface: In doing which, they muſt drive a Part of the Water beyond them into a higher Situation, and ſo produce a ſecond Wave: This, again, upon its De-

Deſcent, cauſes a third Elevation, or Wave of the Water next beyond it: And this, in deſcending, a Fourth, and ſo on, till at Length they reach the Bank, or Shore upon which they break and vaniſh. ——— And here it is very remarkable, that the Generation of Waves in Water being produced by the Power of Gravity, their Motion will be analagous to that of a Pendulum, which is produced by the ſame Cauſe. ——— The larger the Body is which deſcends in the Water, the larger and more rapid will be the Motion of the Waves; and it is found both from Reaſon and Experience, that if a Pendulum be of a Length juſt equal to the Width of the Wave, their Motions will both Coincide, or be performed in the ſame Time.

Euphroſ. Now let me ſee, *Cleonicus*, before you go farther, if I can illuſtrate to myſelf this Matter by an Example. I have heard you ſay oftentimes, that if the Length of a Pendulum be $39\frac{2}{10}$ Inches, its Vibrations will be performed in a Second of Time; from whence I infer, that if a Stone falls upon the Water that ſhall produce Waves at the Diſtance of $39\frac{2}{10}$ Inches from each other, then they will move through that Space, or ſucceed each other in a Second of Time.

Cleon. You completely underſtand this Affair, I ſee: ——— Therefore, I ſhall next obſerve that the Pulſes of Air and Waves of Water diſagree in their Cauſe, ſince the one is owing to Elaſticity, and the other to Gravity; but this, notwithſtanding, they both agree with the Pendulum in the Nature of their Motion, as they are all of the vibratory Kind. ——— Another Thing in which the aqueous Waves differ from aereal Pulſes is, that the former are of a circular Form, as generated on the plain Surface of the Fluid; but the others are neceſſarily of a ſpherical Form, as they are produced in the Body of an elaſtic Fluid.

Euphroſ. This, on the Surface of the Water, is evident to Senſe; the Waves are there concentric Circles: And in the Body of Air I find no Difficulty in apprehending they muſt be of a ſpherical Form; for as the Motion begins from the ſounding Body, it muſt be communicated to, or equally impreſſed on all Parts, which therefore muſt generate Pulſes of Air, diffuſing themſelves equally every where in a ſpherical Form.

Cleon.

Cleon. You are, indeed, very happy, my *Euphrosyne*, in your Genius for physical Speculations: —— In Consequence of this Property of the Pulses of Water and Air, we may easily observe another, which respects the Degree of Strength in each Pulse, or Wave, as the Force of the first Wave is spent in generating the Second; and that second Wave being a Circle at a greater Distance than the First, will occasion a much greater Quantity of Water to be put into Motion, consequently, the Force in any particular Part of the second Wave will be as much less than it was in a like Part of the first Wave as the Quantity of Matter was greater, *i. e.* the Force in the second Wave is to that of the first Wave, as the Circumference of the First is to that of the Second; or the Forces decrease as the Waves increase in Circumference, or as their Distance from the Center is greater. —— But with Respect to the Waves, or Pulses of Air, the Case is different; for these being of a spherical Form, the Force in each must necessarily decrease in Proportion as the spherical Superficies, or the aereal Pulses increase, which, as the Geometers demonstrate, is in Proportion to the Square of the Distance from the Center.

Euphros. That is, if I understand you right, *Cleonicus*, the Force in the second Wave of Water is but half as great as the First, and the third Wave is 3 Times weaker, and so on; but in regard to the Pulses of Air, the Force of the Second will be 4 Times less than that in the First; and in the Third, it will be 9 Times less; in the Fourth, 16 Times less, and so on. —— But one would think, as the Pulses of Air decrease so fast, they could not have that very great Effect upon the Drum of the Ear, or produce so loud a Sound as they generally do.

Cleon. Our Organs are so constructed as to have the strongest Ideas excited by the smallest Action of natural Bodies upon them. How infinitely small are the Actions of the Particles of Light on the optic Nerve in the Eye, and yet how great and glorious are the Ideas which thence arise! in like Manner, we perceive how very sensible the smallest Motions of the Air will be, by a common Whisper, which is sufficiently audible to a good Ear; or the most feeble Notes produced from a sounding String, as they dye away.

Euphros.

Euphrof. I frequently obſerve the Things you ſpeak of with Wonder and Admiration. —— And another Thing I obſerve will follow from what you have ſaid of the ſpherical Pulſes of Air, and that is, that the Sound of a Body muſt neceſſarily be heard on every Side, and be equally ſtrong at an equal Diſtance.

Cleon. This naturally follows, from the Manner in which they are propagated, as you rightly obſerve; and I ſhall farther add, that if the Waves on the Surface of Water are obſtructed by any Obſtacle, as ſuppoſe a large Plain with a Hole in any Part, the Motion of the Waves, as they apply to the Hole, will be propagated through it, and on the other Side will begin to ſpread themſelves into a circular Form; becauſe the Motion, produced in any Part of a Fluid, is impreſſed every Way equally, and therefore from the Hole, the Agitation of the Water will proceed in a circular Form as well as from the Body itſelf which produced it. —— It is in the ſame Manner that they are continued by the Sides of an Obſtacle, and, after having paſſed beyond it, begin to diffuſe themſelves into circular Forms behind it. This you may eaſily try, by an Experiment even in a Veſſel of Water.

Euphrof. I ſhall amuſe myſelf with Experiments of this Kind at my Leiſure. —— I ſuppoſe you conclude from hence, that the Pulſes of Air too, after they proceed through Holes, and Obſtacles round about their Surfaces, in like Manner diffuſe themſelves, and proceed every Way in a ſpherical Form.

Cleon. They certainly do ſo; and from thence it is that we find, if a Gun be fired on one Side of a Hill, a Perſon placed any where on the other Side will be very ſenſible of it. But as the Waves of Air in this Caſe muſt take a much larger Circuit to reach the Ear, the Sound muſt, of Courſe, be weaker, than where there is no ſuch Obſtacle, and it arrives in its ſhorteſt Courſe and with its full Force.

Euphrof. You have inſtanced ſome Particulars wherein there is a conſiderable Reſemblance between the Effects of Optics and Acouſtics, in the Formation of the Images of Objects, and Sounds in ſtriking Bodies; but pray, *Cleonicus*, is there any Conformity in the Manner in which Light and Sound are propa-

pagated? The Reaſon of my aſking is, that I have read and heard more on that Subject, than I was ever able to comprehend.

Cleon. That you may very eaſily do, my *Euphroſyne:* When People undertake to explain Things by an Hypotheſis not founded on the plaineſt Dictates of Reaſon, and unſupported by the moſt indubitable Experiments, it is no Wonder if we hear them ſay a great deal which muſt be neceſſarily unintelligible to every Body. Such is the Caſe when we are told of a *ſubtle Medium*, by the Undulation of whoſe elaſtic Parts, the Particles of Light are put into a vibrating Motion, (like the Particles of Air we have been ſpeaking of) and therefore the various Senſations of Viſion are occaſioned by theſe *lucific Pulſes* of the ſubtle Medium, in the ſame Manner as Sounds are produced by thoſe of common Air. ——— But if this was the Caſe, you will eaſily apprehend that all the other Properties of Motion, produced in an elaſtic fluid Medium, muſt neceſſarily be allowed: One of which is, that ſuch a pulſive Motion of Light being excited, its Undulations will be continued every Way equally, and, conſequently, in their Paſſage through Holes, and by the Sides of Obſtacles, they will (like thoſe of elaſtic Air) expand themſelves into all the bordering Spaces round about, and even behind thoſe Obſtacles, and, ſo of Courſe, would fill all the Parts behind ſuch Obſtacles with Light: But this we find is contrary to all Experience; the Rays of Light, intercepted by any Sort of Obſtacle, leaving the Spaces wholly dark behind, and thoſe dark Spaces, or Shadows as we uſually call them, are always ſuch as are terminated by Right-lines drawn from the extreme Part of the radiant Object, and that which intercepts its Light. ——— The Motion of Light, therefore, is undoubtedly propagated in Right-line Directions only, from a pulſive Force it originally receives in its proper Fountain the Sun, which renders the Doctrine of a ſubtile Medium unnatural and abſurd, in reſpect to the Propagation of Light.

Euphroſ. I am thoroughly convinced, by what you have ſaid, that Light cannot be propagated in the Manner Sounds are; for, if that were the Caſe, they would bend round the Sides of the Earth, and make us one perpetual Day: ——— An Eclipſe

of

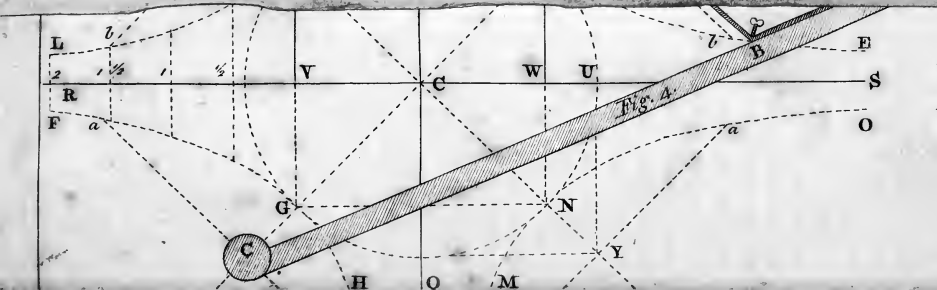

Fig. 4.

Fig. 1.

of the Moon would be a Thing impoſſible in Nature, and we ſhould never have known or have had the leaſt Ideas of a Firmament of uſeful Stars. ——— It appears to me, that the plaineſt Things in Life may be perverted into a Matter of ſurprizing Diſputation, by a Set of People who ſeem to have no intellectual Optics, ſince even the very Doctrine of Shadows itſelf muſt, one would think, have beamed on their Minds the Light of Truth. ——— But to return: Pray, what are the next remarkable Properties of Air in reſpect to Sounds?

Cleon. The next Property of theſe aereal Pulſes is, that they are ſubject to a Reflection from any fixed Plain, or Obſtacle, from the ſame Cauſe with that of the Particles of Light; for the Particles both of Light and Air, being ſolid Bodies, will be equally reflected by the Re-action of the Particles of any fixed Object on which they ſtrike; and this Reflection of the aereal Particles muſt neceſſarily produce Agitations, or Vibration in the Medium, which proceed every Way equally in Form of ſpherical Shells, as before, and this repercuſſive Motion of the ſonorous Air will produce a ſecond Sound, or rather an Image of the Firſt, if one may ſo ſpeak; and this Repetition of the Sound is what you have been ſo often amuſed with under the Name of an ECHO.

Euphroſ. In all this I underſtand you very well, as there is no more Difficulty in conceiving the Relation there is between the Sound and its Echo, than there is between the Object and its Image by reflected Light: —— But a Circumſtance in which they differ is this, that, with regard to Light, the Angle of Reflection, to the Eye, muſt be equal to that of Incidence, that the Image may appear: But, let me ſtand where I will, I hear the Echo, though not equally plain and diſtinct. ——— I have often taken Notice, when I have been walking in the Fields, at a Diſtance from the Town, that this Reflection of Sound has been extremely ſenſible in a Variety of Echos, from every conſiderable Sound which has had Force enough to ſtrike againſt the Side of our Church, for producing ſuch a Repercuſſion, or Reflection: Thus, the Report of a Gun is always heard twice; and it was not long ſince I obſerved a Man cleaving of Wood at about a Quarter of a Mile Diſtance from the

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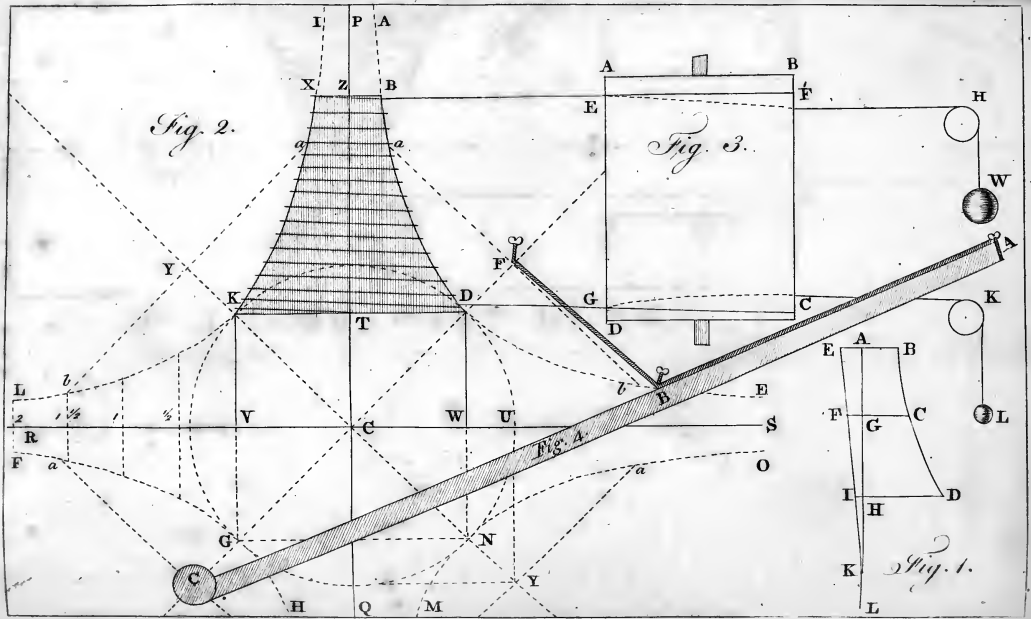

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Euphroſ. In all this I underſtand you very well, as there is no more Difficulty in conceiving the Relation there is between the Sound and its Echo, than there is between the Object and its Image by reflected Light: —— But a Circumſtance in which they differ is this, that, with regard to Light, the Angle of Reflection, to the Eye, muſt be equal to that of Incidence, that the Image may appear: But, let me ſtand where I will, I hear the Echo, though not equally plain and diſtinct. ——— I have often taken Notice, when I have been walking in the Fields, at a Diſtance from the Town, that this Reflection of Sound has been extremely ſenſible in a Variety of Echos, from every conſiderable Sound which has had Force enough to ſtrike againſt the Side of our Church, for producing ſuch a Repercuſſion, or Reflection: Thus, the Report of a Gun is always heard twice; and it was not long ſince I obſerved a Man cleaving of Wood at about a Quarter of a Mile Diſtance from the

Church, and every Stroke upon the Wedge was reſounded, or echoed from the Side of the Church in ſo diſtinct a Manner as afford me no ſmall Amuſement during the Time of Obſervation: But one Thing I took particular Notice of, which was, that the Echo did not ſucceed immediately to the Sound of the Stroke, but after an Interval of Time ſo conſiderable, that I could not help taking particular Notice of, and reflecting ſome Time on the Cauſe, or Reaſon thereof, which, at Length, I concluded muſt be, the temporary and progreſſive Motion of Sound: By which Means, the Time which the Particles of Air employ in this direct progreſſive Motion of their Vibrations from the Man to the Church, and from thence to the Ear, is ſuch as makes the Echo at ſuch a ſenſible Diſtance of Time from the Sound itſelf.

Cleon. Theſe Echos oftentimes afford a pleaſant Amuſement to the Curious, eſpecially where and when you find ſuch Surfaces which are called the *phonocamptic Plane*, that ſhall reflect the Particles of Air with the greateſt Regularity and Perfection: For, in the Writings of Naturaliſts, you will oftentimes find ſuch Hiſtories of Echos as are very ſurprizing, and almoſt incredible; ſuch, for Inſtance, as will repeat not only Syllables, but even Words, diſtinctly, and ſome Times ſo many of them as really to make the Echo ſpeak; from whence theſe Echos are called *polyphonous*, *tautological*, or prattling Echos, which oftentimes afford a pleaſant and ludicrous Theme as well to the Poet as the Philoſopher, as you may ſee in *Biſhe's Art of Poetry*, and other Compoſitions of that Kind, under the Word *Echo*.

Euphroſ. Then, I ſuppoſe, this very Phænomenon of a talkative Echo will have another Inſtance of Reſemblance to that of reflected Light, *viz.* that whereas the Image is ſeen in the Direction of the reflected Ray, and conſequently in or behind the Glaſs, juſt ſo, I imagine, the Voice of the Man who is ſpeaking muſt, in the Echo, be heard as coming from the Plane; and therefore the Man himſelf and his mimic Echo muſt be heard from two diſtant Places; for thus it is, I know, by Experience, in all the ſingle Echos I have heard.

Cleon. In this you are perfectly right: And, to carry the Compariſon ſtill farther in regard to the Reflection of Light and Air, it is to be obſerved, that as the Image by Reflection from a plain Sur-

Surface is nearly as ſtrong, vivid, and perfect as the Object ſeen by direct Rays, ſo, in the Repetition of Sound, the Echo differs but very little from the original Sound, unleſs the Diſtance be great; and ſtill, nearer would it approach thereto if the phonocamptic, or reflecting Plain for Sound, was poliſhed as perfectly as that for the Reflection of Light. And I can aſſure you, my *Euphroſyne*, were I poſſeſſed of that enormous Wealth as many Perſons are, I would make it my Buſineſs to find the beſt Situation of a Plane for reverberating Sounds, and then would directly face the whole with Stone or Marble of a curious poliſhed Surface, on Purpoſe that it might be found, by Experience, what Perfection this Part of *Acouſtics* which relates to Echos is capable of. —— Again as a poliſhed Plain neither magnifies nor diminiſhes an Object, ſo neither can it increaſe or diminiſh the Intenſity of Sound: But as Glaſſes may be fitted ſo as to magnify and diminiſh the Appearance of Objects, ſo likewiſe are Inſtruments to be formed for magnifying or diminiſhing Sounds, when there is Occaſion for it, which not very rarely happens.

Euphroſ. Such Inſtruments, I ſuppoſe you mean, *Cleonicus*, as are called *ſpeaking* and *hearing* TRUMPETS; the former of which magnifies the Sound of the Voice, and thereby occaſions it to be heard at very great Diſtances: For which Purpoſe, I know, they are of very great Uſe at Sea, in tranſmiting the Voice in an audible Manner from one Ship to another, which would otherwiſe be impoſſible to be heard. The latter, I obſerve, are uſed by People who are very deaf, in order to magnify common Sounds upon the Organ of Hearing.

Cleon. It is very true, my *Euphroſyne*; the Speaking-trumpet is analogous to a magnifying Glaſs, or Speculum, in Optics, which makes the Image of an Object bigger than the Object itſelf; ſo the Speaking-trumpets are conſtructed in ſuch a Manner as to magnify the Sound of the Voice; for the Force of the Voice, naturally, is ſpent upon all the circumambient Air; whereas, by Means of the Trumpet, the whole Force of the Voice is made to act upon that Quantity of Air only which is contained in the Tube of the Trumpet, by which Means that ſmall Parcel of Air will be put into a much greater Motion, and have its Vibrations excited and rendered much ſtronger than

they could otherwiſe be at a given Diſtance from the Mouth. Thus, for Inſtance, at the Diſtance of the End of the Trumpet, the whole Force of the Voice agitates the Air only contained in the Area of the ſaid Trumpet's Aperture: Whereas, without the Trumpet, that Force is diffuſed into a whole ſpherical Superficies, whoſe Diameter is twice the Length of the Trumpet, which Superficies may be 400 Times greater than the Aperture of the Trumpet; and therefore the Intenſity, or Strength of the Voice, will be ſo many Times increaſed, or magnified by the Trumpet. Hence, by Means of ſuch a Speaking-trumpet, People at a Diſtance can hear us to the ſame Advantage as they can ſee us by the Uſe of a Teleſcope.

Euphroſ. After the ſame Manner, then, I preſume, a Perſon who is hard of Hearing has this Organ, or Senſe, aſſiſted by a Trumpet of nearly the ſame Form; for as the Vibrations of the Air are too weak to produce an audible Sound on ſuch an Ear diſtinctly, therefore a Trumpet, being applied to the Ear, receives the languid Pulſes of Air, and, by a conſtant Repercuſſion and Agitation of the Air in the Tube, heightens and increaſes its Force in Proportion as the Space becomes leſs, or the Tube is narrower, till it reaches the Drum of the Ear, where it becomes ſo great as to render the original Sound of the Voice diſtinct and audible to that deafened Organ. ——— This Effect, I apprehend, is ſimilar to that of viſual Glaſſes to a deficient, or long ſighted Eye: So that, by the Aſſiſtance of Art, both the Organs of Sight and Hearing may, when deficient by Age, receive conſiderable Improvements, and, as it were, a Renovation to the End of Life.

Cleon. Before we leave this Subject of magnifying Sounds, I muſt put you in mind of the Whiſpering-gallery in St. *Paul*'s, which gave you ſo much Surprize and Entertainment when you was laſt at *London:* You then heard a Voice ſo loud and diſtinct as if the Perſon was within the Diſtance of a few Feet; whereas, he was really at the other Side of the Gallery, and his Voice emitted in Whiſper ſo low as not to have been heard by you near him, had it been expreſſed in a Room of a common Form. But this ſmall Force of the Voice, being impreſſed upon the Air contained in the Room, or Space above that Gallery,

was

was greatly increaſed, by a conſtant Reflection and Reciprocation from the ſpherical Surface of the ſaid Dome, and became as it were at Length converged and condenſed on the Drum of the Ear, which, though at the Diſtance of the whole Diameter of the Dome, are rendered ſufficiently ſtrong to excite the Idea of every Word that is ſpoke. ——— But, after all, it muſt be confeſſed, that few of our accuſtic Writers ſeem to underſtand the Cauſe of this Phænomenon, and, to explain it with that Clearneſs and Satisfaction, as Opticians do with reſpect to the Microſcope, for magnifying the ſmalleſt Objects, or rendering them very diſtinct to the Eye. ——— I ſhall mention only one Inſtance more, in which there is a Similarity between Light and Sound, *viz.* in regard to Velocity; but in this, though the Velocity of Sound be exceeding great, yet it bears ſcarce any Proportion to the Velocity of Light; for the latter cannot be rendered ſenſible, or meaſured by any common Experiment. However, by ſome Obſervations of the new and improved Aſtronomy, the Velocity of Light is found to be about ten Millions of Miles *per* Minute: Whereas, the Velocity of Sound is found, by unexceptionable Experiments, not to exceed 1142 Feet *per* Second: And hence it is, that we find a conſiderable Time intervenes between ſeeing the Action, the Stroke, or Exploſion of a Gun, and hearing the Sound thereof, *viz.* ſo many Seconds as the Number 1142 Feet is contained in the Diſtance between us and the Object that emits the Sound.

Euphroſ. If this be the Caſe, it muſt be eaſy to meaſure the Diſtance of an Object by meaſuring that Interval of Time, which, I ſuppoſe, you can very readily do by Pendulums.

Cleon. Yes, very eaſily, my *Euphroſyne*; and for that Purpoſe I have here provided you a *half-ſecond Pendulum*; for by that alone you may very nearly meaſure the Diſtance of a Cloud, at any Time, when it Thunders and Lightens: For Inſtance, the next Thunder-ſtorm, you hang up the Pendulum on a Pin, and hold the Bob in your Hand ready to let it go upon ſeeing the Flaſh; then, telling the Number of Vibrations which are made between that, and hearing the Clap of Thunder, you have meaſured that Interval of Time in Half-ſeconds; half that Number is the Number of whole Seconds, which the Sound takes up in

in coming from the Cloud to the Ear, to each of which you allow 1142 Feet, and, conſequently, you thereby know the Diſtance of the Cloud in Feet to a great Degree of Exactneſs, and which, indeed, cannot be found ſo truly in any other Way.

Euphroſ. I am obliged to you for this little Inſtrument, and ſhall put it in Uſe, according to your Direction, the firſt Opportunity that offers.

DIALOGUE XXI.

Of the PROPERTIES *of* SOUND, *with reſpect to* MUSIC, *or* HARMONY.

Cleonicus.

WE have hitherto conſidered the Properties of Sound which reſult from the Manner in which they are generated and propagated; and as Sound conſiſts wholly in the vibrating Motion of the Air, it was natural to obſerve, that the different Forces by which thoſe Pulſes ſtrike the Drum of the Ear, will raiſe thoſe Ideas in the Mind which are expreſſed in the various Degrees of *ſtrong* and *weak* Sounds, or otherwiſe diſtinguiſhed by *loud* and *low*; for in Proportion as the Force is greater on the Membrane of the Ear, ſo the Sound will ever be ſtronger or louder, and *vice verſa*.

Euphroſ. This I can very eaſily underſtand: —— But what are thoſe Affections of Sounds which you call their *Notes*, or *Tones*, with their various Diſtinctions, as I find them in my muſical Books? Something of this Kind I ſhould be glad to underſtand, as I ſhould be then ſaid to join a little Theory with my Practice.

Cleon. You muſt not, my *Euphroſyne*, expect much to excel in both: —— It is a Thing hardly ever known, that a Perſon was compleatly ſkilled in the Theory of Muſic, and, at the ſame Time, a great Proficient in Practice. I am very well informed, that HANDEL himſelf knew but very little of the Philoſophy

phy of Muſic, at leaſt the mathematical Part thereof. —— What you enquire after now, are the firſt Principles of natural Muſic, and they are extremely eaſy and ſenſible to what we may properly call an *harmonical Ear*; but to others, they have but very little Diſtinction, or Meaning: Such People hear Talk of the *Seven natural Notes of Muſic*, as a blind Man may of the ſeven different Colours of Light; for in neither Caſe can any diſtinct Ideas be formed of the Objects: But an Ear like yours, naturally formed for hearing Sounds, will readily apprehend what is meant by their Tone, or Tune, with all their Differences and Gradations. You will then, in the firſt Place, conſider, that the human Mind is naturally diſpoſed to be pleaſed and delighted with ſome particular Modification of Sounds above others: Thus, the Sound of a String, properly ſtrained and ſtruck with a Quill, is generally very agreeable to every Ear; but thoſe who have a *muſical Ear* will find the Tone of that String, when put in Motion by the Air, ſtill much finer and more exquiſitely pleaſing, as you yourſelf may be thoroughly convinced by the Experiment of the *Æolus*'s *Harp*. But other Sounds are emitted from Bodies, which are as diſagreeable and uneaſy to the Ear; as in the Caſe of whetting a Saw, *&c.* where we are to obſerve, that all the Degrees from the moſt grating to the moſt pleaſing Sound arrives principally from the Manner, in which the ſame Body is ſtruck, or put into Motion: The finer and more delicate the Touch, the more delightful and exquiſite the Note that enſues, as we, by Experience, find in the *Violin*, the *Spinet*, the *Lyrichord*, the *Dulcimer*, and the *Æolian Harp*: —— Alſo, if a Glaſs be properly ſtruck with a Wire, it will emit a pleaſant Sound; but if it be artfully touched with a Finger a little wet, the Sound will be ſtill much finer and more agreeable: from all which we may collect, that all we mean by the *Notes*, or *Tones* of Sound, is ſuch a Modification thereof as render them more or leſs agreeable to the Ear.

Euphroſ. I believe I underſtand you in all that you have ſaid, and, therefore, ſuppoſe that theſe Sounds, emitted from Bodies, which are moſt agreeable and pleaſing to the Mind, are ſuch as you call *harmonical Sounds*, or muſical *Notes*, and of which the Muſicians ſerve themſelves in their various Compoſi-

poſitions. ——— But what is that you call *Concord*, or *Diſcord*, in Sounds?

Cleon. By *Concord*, is meant the pleaſing Agreement of any two or more Sounds, or Notes; and by *Diſcord*, of Courſe, we mean the diſagreeable Effect of two or more Sounds, upon the Ear, following each other in Succeſſion: For the Mind of Man is alſo naturally formed to receive Pleaſure from a certain ſucceſſion of Sounds, or ſuch as follow each other at proper Intervals; and for this Reaſon they are called, the *muſical Intervals of Sounds*: But when Notes, or Sounds, ſucceed in a different Manner, and at other Intervals, then they become inharmonious and diſagreeable. And it now remains, that I ſhew you what Kind of Intervals of Sound, in Succeſſion, are of a muſical Nature, and on what Principles they depend. ——— The eaſieſt Method for this Purpoſe will be, that of a String properly ſtrained on a Board, on whoſe Vibrations each Tone will be found to depend: Accordingly, I have here provided you with ſeveral of thoſe Strings, of different Sizes, Length, and Degrees of Tenſion; for you muſt obſerve, that according to the Time in which a String vibrates, its Note will vary with reſpect to high or low, or what the Muſicians call *Grave* and *Acute*. For Inſtance; the Wire you ſee here, being ſtrained pretty tight, emits a Sound when I ſtrike it with a Quill, which is conſiderably ſtrong, high, or acute: ——— But now I will relax it a little, and then, ſtriking it, —— you readily obſerve the Difference there is in the Note, *viz.* that it is now much lower, or more grave as they call it; and this Variation, with reſpect to grave and acute, depends, as I ſaid, on the different Time of the Vibrations of the String; for you muſt know, that the Vibrations of a String are analogous to thoſe of a Pendulum, and are all performed in equal Times, while the String continues in the ſame Circumſtances: But the Times of the Vibration of the String will be varied according to its *Size*, Length, or Tenſion. Thus for Illuſtration, ſuppoſe two Strings of equal Lengths, and ſtretched with equal Weights, but the Quantity of Matter in one juſt double that of the other, then the Time of one Vibration of the largeſt will be juſt double to the Time of a Vibration of the Leſſer, and the *Note* or *Tone* will be twice as *low*, or more *grave*, in the firſt than in the laſt. *Euphroſ.*

Euphrof. This I readily apprehend, from the Experiment; for ſtriking the two Strings ſucceſſively, I find that which has the leaſt Diameter has a Note or Tone higher than the other, by what is called an *Octave:* ——— But now I have mentioned that Term, I ſhould be glad if you would give me ſome hint of the Etymology of it.

Cleon. By the Word *Octave*, the Muſicians denote ſuch an Interval in the Tone of muſical Sounds as contain all the ſeven natural Notes of Muſic, as they are called, and which are employed as the Materials of all harmonical Compoſitions: And the ſeveral Intervals of theſe Notes, you know, are included between the two Extremes of the *Firſt* and the *Eighth*, which whole Interval of muſical Notes is therefore called an *Octave*.

Euphrof. The practical Part of your Doctrine I know very well; for on my Harpſichord, when I ſtrike the key C, it is what my Maſter has taught me to call the *Chord*, or *Key Note*, in reference to which others above and below have different Denominations, according as they are higher or lower. Thus the ſix following Notes above D, E, F, G, A, B, and thoſe below the *Chord* are of the ſame Name in a contrary Poſition; ſo that what is called an *Octave*, I find, is the Extent of theſe ſeven Notes, taken either Way, upon the Keys of the Harpſichord; and as the Strings belonging to thoſe different Keys have different Notes or Sounds, I preſume you will next explain to me the Reaſon why theſe are made choice of, in Preference to any other which are contained in the ſame Interval, or *Octave*.

Cleon. I ſhall give you the Reaſon of that by and by; but I muſt now proceed with the *Rationale* of the grand Interval, or *Octave*; for, as I told you, this Interval in the Sound of Bodies is procured in Strings three different Ways; the firſt of which is, the Experiment under Conſideration: You ſee, by this, the Notes are in Proportion to the Quantity of Matter inverſely, ſo that a String twice as big as another will have a Note twice as low, all Things elſe being equal: ——— But the ſame Difference in the Tone or Sound of Strings (that are among themſelves of equal Weight and Length) is procured from a different Degree of TENSION; for if two equal Strings be placed near each other, as you ſee here on this muſical Board, (or *Tonometer*, as it may be called,) and then ſtretched with equal

Weights at the end, there will be no Difference in their Tone. ——— For Inſtance, you ſee, I hang a Pound Weight to each, now ſtrike them with your Quill.

Euphroſ. I do, ——— and find the Tone or Tune of each String exactly the ſame, or *Uniſon.* ——— But now, pray, how much Weight muſt you add to one of them to make the Difference, or *Octave*, as before?

Cleon. Here you muſt know, the Mathematicians have found by the Rules of their analytic Art, that the Tones or Tunes of Strings are higher in Proportion to the Square Roots of the Weights, or Forces by which they are ſtretched; ſo that if I would raiſe the Notes of one of theſe Strings, an *Octave* above the other, or to make it ſound a Note twice as high, or more acute, then it muſt be ſtretched with a four Pound Weight (becauſe twice two is four), and this you ſee will be verified by Experiment; for to the one Pound which now gives it a Tone equal to the other, I will add three Pounds more, ——— which I have done: Now ſtrike them as before.

Euphroſ. Well, this is a very curious Experiment truly: ——— The Difference in their Tone is accurately an *Octave.* ——— From this Experiment I ſee the Reaſon of tuning the Harpſichord, by ſtretching their Strings more, or leſs, to raiſe their Notes higher, or lower, by turning the iron Pegs with my Hammer till I have produced the Note deſired; for as the Tone of a String depends on the Degree of its *Tenſion*, the manner in which we ſtretch the String will make no Alteration: ——— But, according to this Doctrine, by hanging on different Weights to the ſame String, you could produce all the different Notes contained in the *Octave.*

Cleon. Yes, with Eaſe; for Weights adjuſted and determined by the above Rule, being appended at the Ends of ſeven equal Strings, will produce you an *Octave* of the ſeven natural Notes of Muſic. Thus for inſtance: If eight equal Strings are ſtretched by Weights which are in Proportion to the following Numbers, which may be conſidered as Ounces, *viz.* 60, 75, 94, 106, 135, 166, 210, 240, then will their Notes or Tones be thoſe required, for conſtituting a muſical *Octave.* ——— But there is yet another, or third Method, by which the ſame Difference is produced in the Sounds of Strings, and that is, the Difference

of

of their LENGTHS; for two Strings, in all other Reſpects equal, having their Lengths as 2 to 1, will have their Notes inverſly, or as 1 to 2, that is, the Note of the ſhorteſt String will be twice as high at that of the longeſt. ——— This I have likewiſe provided you an Experiment to prove; for of the two Strings which before were ſtretched with equal Weights, *viz.* a Pound each, one of them ſtill continues the ſame; but the other I have made of half the Length, by putting a Bridge under the middle Point of the String, to ſtop the Vibrations, or confine them to half the Length: And now, tho' the Strings are ſtretched with equal Weight, and are of equal Magnitude, yet, upon ſtriking them, you will find they emit very different Sounds. ——— Try the Experiment.

Euphroſ. I will: ——— And as in the two former Caſes, ſo in this, there reſults the Difference of an *Octave* preciſely in their Sounds. ——— Since this is the Caſe, I readily conceive that all the natural Notes of the *Octave* may be produced by proper Lengths of Strings between theſe two, which Lengths, I ſuppoſe, are not difficult to be aſſigned by the mathematical Muſician.

Cleon. Nothing is more eaſy; for which Purpoſe, it is cuſtomary to divide the Length of the longeſt String into 100, or 1000 equal Parts, which, you ſee, is here done upon the Board, or *Tonmeter:* This Line ſo divided is called the MONOCHORD, or *Baſe-Note* to the reſt of the *Octave*, or the Key, with Regard to any particular Air or Species of Muſic. ——— Now, by the Rules of *muſical Arithmetic and Geometry*, the Numbers, or Diviſions of this Line, are eaſily aſſigned for giving the Lengths of the Strings to ſound the ſeven Notes above the Baſs; and by placing the Bridge againſt thoſe Numbers, this other String may receive all thoſe various Lengths, and will accordingly emit the ſeveral muſical Sounds required: thoſe Numbers are as follow, *viz.* 500, 533, 600, 666, 750, 800, 888, 1000; ſo that, for Example, if I ſtop the String with the Bridge placed againſt 500, it gives but half the Length of the Monochord, and ſounds an *Octave* above it, as you have heard. ——— If I place the Bridge againſt 533, it gives the Note which the Muſicians call the *Seventh Greater:* ——— If the Bridge be removed and placed againſt 600, its increaſed Length will give the Note called the *Sixth Greater:* ——— If ſtopped

againſt the Number 666, it gives the *fifth* Note, or *Diapente*, as the Muſicians call it: ——— By placing the Stop againſt 750, you have the *Diateſſaron*, or *fourth* Note above the Key: ——— By ſtopping the String at 800, you have that remarkable Concord called the *Third Note* above the Baſe, — and, laſtly, by placing the Bridge againſt 888, you have the Note called the *Second Greater*; the Key Note being the whole 1000: And thus, you ſee, all the ſeven natural Notes on the ſame String are produced by ſtopping at thoſe muſical Diviſions of the Monochord.

Euphroſ. Indeed, this has given me a more clear and diſtinct Idea of this famous muſical Diviſion, the *Octave*, than ever I had before: But there is one thing I obſerve in your Expreſſion of theſe Notes, which naturally excites the following Query, Whether the Seventh *Greater*, the Sixth *Greater*, Fourth, Third, and Second *Greater*, do not imply that the ſame Notes may be alſo *Leſſer?*

Cleon. Yes; that you will conclude of Courſe; for, in the muſical *Octave*, thoſe Notes mentioned may be made higher or lower, by half a Note; that is, with Regard to the Baſs Note, the third Note above, for Inſtance, may be made a little higher or lower, according as the Air of the Muſic requires: ——— The Higher is called the *Greater*, and the Lower is called the *Leſſer:* But you will better know and diſtinguiſh theſe Differences by other Names that you have been more uſed to, *viz.* FLATS and SHARPS; for a flat Third is a Third Leſſer, and is the very ſame with the Sharp Second, or Second Greater: Thus alſo the Flat Sixth is the Sixth Leſſer, but it is nothing more than the fifth Note made half a Note higher or Sharper: But the ſame fifth Note made half a Note lower, or flatter, becomes the Fourth Greater, and ſo of the reſt. Hence it is that in any muſical Compoſitions thoſe Notes may be adapted to the Nature of the Harmony, or Species of Muſic: Thus, for Example, in all grave and ſolemn Airs, the loweſt and deepeſt Notes of Inſtruments are generally uſed; but in briſk and lively Strains the higher Keys on the Harpſichord are moſtly employed. If the Air be of the mournful, or elegiac Kind, thoſe Notes are lowered, and the Muſic is ſaid to be compoſed in a *Flat Key:* But in Odes and Songs, whoſe Subjects are Love, Mirth, Joy, *&c.* then the *Muſician* in a *Sharp Key* tunes

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all the Strings to their higheſt Notes, and renders, by that Means, the Harmony as chearful as poſſible.

Euphroſ. You are now within the Compaſs of my Comprehenſion, I underſtand all you have ſaid with reſpect to Flats and Sharps: By thoſe half Notes, I obſerve, you mean thoſe five ſecondary Keys that lie between the common Keys of the Spinet, with their black and white Surfaces, by which we render any of the natural Notes, or Keys, between which they are placed, flater or ſharper, at Pleaſure; ſo that theſe five being added to the other eight, make thirteen half Notes in the *Octave* incluſive.

Cleon. This Variety of Notes in the flat and ſharp Keys make the common GAMUT, or *Diatonic Scale of Muſic*; and ſeveral of theſe repeated are contained within the Compaſs of many Inſtruments, *viz.* the Spinet, Harpſichord, Lyrichord, Organ, *&c.*

Euphroſ. Of theſe Notes, the *Octave*, *Fifth*, and *Third* are a Sort of governing ones, or have the principal Regard in every Compoſition: Pray, on what Account are they intitled to this Preemminence?

Cleon. On account of their being the moſt perfect Concords in the Scale, *i. e.* their Sounds, ſucceeding the *Octave*, have a more agreeable Effect upon the Ear than the Sounds of other Strings: The natural Reaſon of which is owing to the frequency of the Coincidencies of their Vibrations; to make which Doctrine as plain as poſſible, I muſt obſerve to you, what I before mentioned, *viz.* That the Tune of a String depends upon the Time of its Vibration; therefore, the ſhorter the Time of the Vibration, the higher the Note will be; and in Vibrations that are performed in different Times, there will, at certain Intervals, be a Coincidence of thoſe Vibrations in all of the muſical Kind: thus, for Inſtance, if two Strings vibrate in equal Times, then the Vibration of one muſt conſtantly coincide with that of the other, and they produce a MONOTONE, or UNISON, in which there is no Variety; and conſequently two ſuch Strings can make no Harmony. But if we conſider that String which is called an *Octave*, as its Tone is twice as high as that of the Key-note, ſo its Vibrations are twice as quick; and

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consequently there will be a Coincidence of Vibrations at every second Vibration of the *Octave*, or every singly Vibration of the Monochord. Now, as this Interval is the shortest that can be between any two Strings in the same *Octave*, therefore, the Effect of such Coincidence will produce the most agreeable Concordance of Sound, (or, in other Words,) will constitute the most perfect Concord in musical Sounds.

——Again, the *Fifth* Note being sounded from the String whose Length is two thirds of that of the Monochord, will vibrate three times while the Monochord vibrates twice; so that there will be a Coincidence of Vibrations at every Second of the latter, which Interval, being twice as great as the former, is not so perfect a Concord as the *Octave*, but is yet next to it in its agreeable Effect and Perfection of Harmony:

——Then if we consider the *Fourth Note*, the String which sounds it is three fourths of the Length of the Monochord, and therefore will vibrate four times to every third Vibration of the Latter; therefore the Interval of Coincidence will be now three times as long as in the *Octave*, and consequently will, in Comparison of that, be a much less perfect Concord:

—— But when we consider the Length of the String that sounds the *Third*, we find it in Proportion to the Monochord, as 8 to 10, or as 4 to 5, and the Interval of Coincidence of Course will be at every fourth Vibration of the Monochord, and therefore, in itself considered, not so perfect a Concord as the fourth; yet its Effect is found, in musical Compositions with other Concords, much more agreeable than that of the *fourth* Note, and therefore is esteemed by Musicians as the third musical Concord. This is the general Principle or Ground of *Concord*; those Notes being reckoned *Discords* whose Pulses, or Vibrations rarely coincide with those of the Monochord, as thereby they produce a more dissonant and less agreeable Sound.

Euphros. As the Tones of Sounds depends on the times of the Vibrations, I should be glad if my Curiosity could be satisfied with regard to the greatest extent of Note, or Sound, which Bodies are capable of emitting, or which the Ear can well bear.

Cleon.

Cleon. An Anſwer to this Queſtion requires more Experience in muſical Sounds than I can pretend to: But a certain Gentleman abroad, Mr. SAUVEUR, has made great Numbers of Experiments on the Vibration of muſical Strings, and conſequently of muſical Sounds; has found that ſuch Sounds as can be heard diſtinctly and with Pleaſure, and in whoſe Tone a difference can be clearly perceived by the Ear, lie within the Compaſs of ten *Octaves*; and if we include the loweſt harmonic Sounds, on the one Hand, that can be heard, and the higheſt that the human Ear can bear, on the other, they will all be contained within the Limits of twelve *Octaves*: and if this be the Caſe, it follows, that the Body which gives the ſhrilleſt Sound that the Ear can bear, makes 4096 Vibrations in the time that one Vibration is performed by that Body that gives the graveſt harmonic Sound, and that 12 $\frac{1}{2}$ of theſe Vibrations are performed in one Second; therefore the Vibrations of the ſhrilleſt ſounding Body will be 51100 in the ſame time, ſo great are the Motions of the Parts of Bodies produced in exciting ſuch very quick Vibrations.

Euphroſ. As this is the Caſe, I do not wonder at an Effect which I have often heard of, that is, the breaking of a Drinking-glaſs by ringing of it, or raiſing its Tone higher and higher; for, by this Means, having its Parts put into ſuch a violent vibrating Motion, it is no Wonder if they are ſhaken in ſunder, and fly into Pieces.

Cleon. I could very eaſily ſhow you this Experiment, but do not think it ſafe, the Note being at laſt ſo exceeding ſhrill and acute, that I fear it might have a bad Effect on the Drum of your Ear, as it is but too well known that many People have been hurt by ſuch Kind of Sounds.——— However, I ſhall ſubſtitute a very innocent one in its ſtead, which will ſufficiently ſhow the prodigious Degree of Vibrations, and the vaſt Extent of Tone the Subſtance of Glaſs is capable of.——— You ſee here a very large Glaſs, of a Bell form, provided for the Purpoſe, into which I pour Water to fill $\frac{1}{4}$ Part:——— Then, dipping my Finger in the Water, I gently paſs it round the Rim of the Glaſs, and thereby, excite, firſt, a very pleaſant grave and muſical Sound; but, as the circular Motion of my Finger continues, the Vibrations of the Glaſs are in-

increaſed, which becomes extremely ſenſible both to the Ear and to the Eye; for you hear the Tone ſtill more and more intenſe and acute, and you ſee its prodigious Effect on the contained Water, in which it firſt produces Undulations, then very quick Gyrations; at Length, there appears ſuch an Agitation as may be compared to a kind of Hurricane, throwing with the utmoſt Violence, the Particles of Water into the Atmoſphere all *around*, and to a great Height above the Glaſs: ——and ſtill might we raiſe this artificial *Tempeſt* to a greater Height, but that I ſee the Tone of the Glaſs has a greater Effect upon you already than you can well bear.

Euphroſ. Indeed, I cannot help ſhrinking, as it were, from it; but am pleaſed to ſee the wonderful Effect it has in the Body of Water, in theſe turbulent Emotions which it occaſions, ſuch as we could ſcarce have ſuppoſed, or believed, if they had not been evinced by Experiment:——But I ſhall trouble you no longer, at preſent, as you propoſe, at our next Meeting, to explain the *Rationale* of the general Part of muſical Inſtruments.

DIALOGUE XXI.

The Rationale *of different Kinds of* MUSICAL INSTRUMENTS, *conſidered.*

Euphroſyne.

I Have pleaſed myſelf with the Proſpect of the preſent Opportunity of being inſtructed in the Nature, Conſtruction, and *Rationale* of muſical Inſtruments; which you informed me was to be the Subject of our Converſation at this Time. You have always known my Diſpoſition is ſuch, as to be equally inquiſive after the *Reaſon*, as well as the *Practice* of every Art I delight in; as I have always looked on it as an Argument of Indelicacy, and want of Taſte in thoſe who are wholly occupied in Learning the mechanical or practical Part of an Art, with a View to ſenſual Entertainment only, without regard-

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ing the ſublimer Pleaſures that ariſe to the Mind from a Contemplation of the Principles which conſtitues the Theory, or Reaſon of the ſame.

Cleon. I was ever glad to ſee ſuch a Turn of Genius in you, and every one elſe: Though, as I have hinted to you before, the Principles, or Theory of Muſic are not quite ſo obvious as thoſe of any other Siences; yet, as they principally conſiſt in the Doctrine of Vibrations of the conſtituent Parts of Bodies, if this were well attended to, and properly explained and illuſtrated by Experiment, you yourſelf are a Proof, my *Euphroſyne*, that they fall within the Comprehenſion and Capacity of the Fair-ſex; and how delightful, as well as graceful, is it both in common and ſacred Muſic, to ſee and hear a Gentleman or Lady not only play with their Hands, and ſing with their Voice, but with their Underſtanding and Judgment alſo?

Euphroſ. I have great Ambition to excel in both, as far as I am able: —— I pretty clearly underſtand what you have hitherto ſaid in regard to the vibrating Parts of Bodies ——— That Sounds in general are occaſioned by the Pulſes of Air produced by thoſe Vibrations: ——— That muſical Sounds in particular are ſuch as have a delightful and melodious Effect upon the Ear: ——— That Concords and Diſcords proceed from a greater or leſs Frequency of the Coincidence of thoſe Vibrations in ſounding Bodies: ——— From theſe Principles I can eaſily infer, that all Kind of ſtringed Inſtruments, as alſo Glaſſes, Bells, and other ſonorous Bodies, are capable of emitting harmonious Sounds; and of Courſe, by the Rules of Art, may be formed into muſical Inſtruments: But how, and in what Manner this is done, I cannot pretend as yet to have ſo clear an Idea of, and therefore ſhall beg your Aſſiſtance in theſe Points of Information.

Cleon. With reſpect to ſtringed Inſtruments in general, the Principle of their Conſtruction is this, that as they conſiſt of ſeveral DIAPASONS, or OCTAVES, ſo they afford three different Degrees of muſical Notes, the *Treble*, *Tenor*, and *Baſe*; the firſt of which contains the Notes of the higheſt and moſt acute Sounds; the Second, or Tenor, thoſe of a mean Degree of Sound; and the laſt, or Baſe, thoſe of the loweſt or graveſt Or-

der. And, according to the Form and Extent of the Instrument, the Strings which compose the several *Octaves* are modulated and fitted to emit their proper Notes, or Sounds, by one or other of the three Ways that I mentioned to you in the last Conference; for, as I then shewed you by Experiment, the Instrument-maker has it in his Power to produce any given Note in a String in any of those Ways, as Occasion or Necessity requires; or he can raise or lower the Note by a smaller or a larger String of the same Length: —— By a shorter or longer String of equal Size: —— And, lastly, by giving a different Degree of Tension to one and the same String: And thus in all the Instruments where the Strings are to be of a fixed and determinate Length, as in the *Dulcimer*, *Spinet*, *Harpsichord*, *the Lyre*, *the Lyrichord*, *&c.* the Strings of the various *Octaves* are always adjusted and tuned in this Manner.

Euphros. This I apprehend pretty easily, with regard to the Instruments that I have every Day before my Eyes; in these, as the *Octaves* and Strings in each are of a given Length, or invariable, if they are once put in Tune, a Person has nothing to do but to get the fingering Part, and he must necessarily play the Tune by striking the Keys proper to the Notes of the Music: But this seems to me, though a very fine Species of practical Music, the most mechanical of any.

Cleon. It is so, to be sure; since it is possible for a Person, without any Ear or Genius for Music at all, to learn to play on those Sort of Instruments, after a Manner: But mechanical as they are, no fine Music can be produced from them but by a curious Hand and judicious Ear. However, it must be confessed, that other Sorts of stringed Instruments are, in their own Nature, of a more curious and artful Construction, and of a more universal Nature.

Euphros. I suppose you mean, by these, all that Class of Instruments comprehended under the general Names of Violins, Harps, *&c.* I cannot say there is much of a Wonder in producing such a Variety of Notes from a Harpsichord, where there are such a Number of Strings; but I have oftentimes very much wondered how they produce such a Variety of Notes, and play

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an Infinity of Tunes, on an Inſtrument of ſo few Strings as that of a Violin, for Inſtance.

Cleon. The Wonder here will ſoon ceaſe if you conſider, that an infinite Variety of Notes may be produced from a ſingle String; for it affords as many different Notes as Points in which you can ſtop it: Thus, for Inſtance, if you ſtop it in the middle Point, you have a Note which is an Octave above that which is produced by the String at its whole Length: If you divide the remaining Part into two equal Parts, or ſtop that in the middle Point, then, ſtriking that 4th Part with the Bow, it will emit a Sound which is a double Octave, or ſixteen Notes above the Baſe Note, or that of the whole String: This 4th Part being again divided, or ſtopped in the Middle, produces a 3d Octave of Notes; and ſuppoſing another String of a different Size added to this, you have, by ſtoping that in the like Manner, other Octaves produced, all differing from the former; and ſo of a third and fourth String: And therefore, in the Violin of four Strings, a ſkillful Muſician may extend his Scale of Muſic to 8 or 12 Octaves, or even farther if there was Occaſion, by properly ſtoping the Strings: But in this Caſe, there muſt be Velocity and Judgment at the Finger's End, ſuch as is required for performing all the different Kinds of Muſic. The former of which is attainable only by Practice, and the latter by the Aſſiſtance of a good Ear, naturally conſtructed for a nice Diſcernment of muſical Sounds. On theſe Inſtruments, Nature is the ſole Miſtreſs in the School of Muſic; and it is ſurprizing, to find what Proficiency ſome Pupils have been ſeen to make in this ſeemingly difficult Part of the Art: But it is in Muſic as in Poetry; if Nature dictates, her Leſſons are very plain and eaſy, and give us no trouble either in learning or practiſing. The Poet writes Verſes, perhaps, more naturally and elegantly than he can talk in Proſe; and the Muſician plays the moſt difficult Pieces with ſo much Eaſe, as if they had acquired this Knowledge before they came into the World, according to the ancient Doctrine of Tranſmigration of Souls.

Euphroſ. All you obſerve, I think is very juſt, and it gives me a clear Idea how an Inſtrument of a ſmall Number of Strings might be of an unlimitted Extent in Muſic, while one of a much

greater Number is perfectly confined: But, pray, *Cleonicus*, can you solve me one Query on this Head, *viz.* how it is possible to produce all the natural Notes in a musical Octave by one Stroke of the Bow, and the same Length of the String; for this I actually saw, and heard from a very skillful Musician the other Day?

Cleon. I have likewise seen and heard the same Thing; it is a Paradox in Music, I allow, and has been strongly denied by many who have not been convinced by the Fact: It is true, the three Principles, *viz.* the Length, Tension, and Diameter of the Strings, are those which in general cause any Variation in the Notes of sounding Bodies; but, from this and many other Experiments, it is very certain there are other less evident Causes which concur in producing that Effect, such as the greater or lesser Degree of Pressure on the String, in the Motion of the Bow over it; also, the Distance from the End of the String, at which it is touched; as likewise, the greater or less Pressure of the String by the Finger; and some other Circumstances may enable a Person, with a good musical Ear, to vary the Sound of the String in the Manner before-mentioned.

Euphros. You observed to me, in speaking of the Harpsichord, that the Octave there was limited to thirteen musical Notes, inclusive; but in this free and unconfined Instrument, the Violin, I presume, the Musician has a larger Scope, and may be more critically Nice in the Division, or Choice of his Notes, and thereby render his Music more refined and harmonious.

Cleon. What you observe is very just; but for this Purpose, a Man must have a very nice and critical Ear: For, when you go beyond the common Flats and Sharps, it will not be easy for an ordinary Practitioner to know where, or how to stop in Tune, or to make them more or less flat, or sharp than he has been taught by the common Gamut, or Scale of Music. Your great Performers, and Masters in this Science, extend their Scale to thirty-two Notes, inclusive, by raising, or depressing each of the natural Notes to such a Degree as only their Judgment and natural Skill can direct; and, in this Respect, can even transcend the musical Proportions of Geometry itself. These stringed

ed Inſtruments, therefore, properly fretted or ſtopped, are capable of all the Variety that can be produced in the Science of Muſic and Harmony.

Euphroſ. You ſeem to be more than commonly pleaſed with the Structure of the LYRICHORD, as I have often obſerved from the Manner in which you make mention of that Inſtrument; and, by what I have ſeen of it, it ſeems more perfect in its Nature than any common Harpſichord: Pray, what are the Peculiarities of this muſical Conſtruction?

Cleon. It partakes of the Nature of the Harp and the Violin, and is poſſeſſed of the principal Properties of both, and, at the ſame Time, exempt in a great Meaſure from the Imperfections of either: It has, indeed, a certain or determinate Number of Strings, with Keys proper to each, like the Harpſichord; but, as you obſerve, thoſe Strings are not ſtruck by Quills in the Jacks, but are brought down to the Surfaces of ſmall Wheels, which move with great Velocity under them, and by this Means they are ſuſceptible of a Stroke from the Wheels, in the ſame Manner as the Strings of a Violin are from a Bow, and therefore may, in a like Manner, have the Note produced, or contracted, as the Nature of Muſic requires: Whereas, in the Spinet, or Harpſichord, the Notes are but of a Momentary Duration, being ſtoped by the Cloth on the Jacks on ſoon as they are excited. ——— By this Opportunity of extending, or ſwelling out the Note, they make the Harmony more full or ſonorous, not altogether unlike thoſe noble and high ſounding Notes of the Organ itſelf. ——— But even in this Inſtrument, unleſs it be furniſhed with ſplit Keys, as they are called, you are ſtill confined to the imperfect and ſcanty Diviſions of the common Gamut.

Euphroſ. But there ſeems to me an Apparatus in this Inſtrument which I have never obſerved in any other, and that is of a great Number of Leaden-weights, very curiouſly and artificially diſpoſed in the Fore-part of the Inſtrument, which, I am informed, is for keeping the Strings conſtantly in Tune: ——— What have you to ſay in regard to this Contrivance, *Cleonicus?*

Cleon.

Cleon. I think it a very curious and philoſophical one; for, by Means of the large Weights, the Strings of each, reſpectively, have their due Degree of Tenſion, proper to the Places they hold in each Octave: And by the Screws in the Mechaniſm for moving the leſſer Weights, the Tone of each String is adjuſted to the niceſt Ear; and when the Strings of the Lyrichord are once put in Tune, they muſt neceſſarily continue ſo, as the ſame Weight, always acting uniformly, muſt produce the ſame Degree of Tenſion: This in a given String muſt always produce the ſame Note, and is the moſt excellent Property of this new conſtructed Inſtrument, and quite peculiar to its ſelf. ——— Though this Invention might, without much Trouble or Expence, with a little Alteration, be applied to the Harpſichord and Spinet, and thereby prevent the very frequent Trouble and Expence of tuning thoſe Inſtruments.

Euphroſ. I could wiſh, with all my Heart, this was once done; for as I am not likely to be Miſtreſs of a Lyrichord very ſoon, I ſhould be glad if that Inſtrument which I have could be contrived to be kept in Time, without ſuch a frequent and neceſſary Rectification: But pray, *Cleonicus*, in what Method would you propoſe this to be done?

Cleon. Were I a muſical Inſtrument-maker, my *Euphroſyne*, I ſhould attempt it in the Harpſichord in the following Manner: ——— You know that the Tone of a String varies with the Quantity of the Weight by which it is ſtretched; therefore any Contrivance that would increaſe, or diminiſh the Weight hanging to the End of the String, in any ſmall Degree, would be ſufficient for keeping that String to its requiſite Tone. Now it is well known that a Weight lying upon an inclined Plane will have its Force increaſed, or remitted, in Proportion as the Plane is leſs or more inclined; and therefore, if on the back Part of the Spinet, or Harpſichord, proper Weights were appended to the Strings, and theſe Weights ſupported on inclined Planes, on which they might freely move, thoſe Planes by a ſingle Screw in each might be elevated, or depreſſed to ſuch a Degree, as that the Strings ſhould be all of them exactly tuned, and of Courſe they muſt ſo remain. ——— Thus, one Set of Weights would be ſufficient to anſwer this Purpoſe; and the Appli-

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cation leſs cumberſome and expenſive than in the Lyrichord.*

Euphroſ. Well, I find I muſt be content with my Harpſichord as it is, ſince it is likely that this Alteration will not very ſoon take Place: —— But, pray, what new Species of Glaſs-muſic is that which of late has been the Subject of ſo much Diſcourſe and Enquiry amongſt the muſical Virtuoſi?

Cleon. Why, truly, my *Euphroſyne*, it is in this as in moſt other Caſes, that new Things make a very great Noiſe, and are generally conceived in a magnificent Idea at a diſtant view; but, upon a nearer Approach, and nicer Inſpection, they are ſeldom found to anſwer our preconceived Notions of them: I believe, many People think this to be the Caſe of our new vitreous Muſic. —— But why do you aſk my Opinion of it, when it cannot be ſuppoſed but you yourſelf are a proper Judge, as you have both heard and ſeen it?

Euphroſ. I was willing to know your Sentiments before I diſcovered my own: I confeſs, with reſpect to myſelf, it is as you ſay, the Fame of it ſeems to exceed its Merit; for the Performance, at which I was preſent, the firſt Time, fell greatly ſhort of my Expectation; a Second, anſwered better: But, pray, *Cleonicus*, why was Water uſed in ſome of thoſe Glaſſes, and others were played on without any?

Cleon. The Glaſſes will have their Tones altered, or varied, different Ways, ſuch as make the Vibrations of a different Duration; for, as I obſerved to you before, the larger Glaſs has the ſloweſt Vibration, and conſequently the graveſt Note; and therefore, in any Glaſs, if you can leſſen the Bulk of its Sounding, or vibrating Part, you will thereby raiſe its Note to the required Pitch: And this may be done two different Ways, the firſt is by putting Water into the Glaſs, which will leſſen the Dimenſions of the ſonorous Part; for the Vibrations will extend

* In order to accommodate our muſical Readers with a Print of this moſt curious Inſtrument, we ſhall here inſert that which we formerly gave in the miſcellaneous Part of the Magazine; as few of our Readers will have an Opportunity of ſeeing the Inſtrument itſelf, they may derive, from a bare Inſpection of this, a ſufficient Idea of its Nature and Conſtruction, which we hope will prove no ſmall Gratification.

tend no farther than to the Water, where they will entirely ceaſe, and therefore, by putting more or leſs Water into any Glaſs, the Vibrations will be rendered of a longer or ſhorter Duration, and thereby the Glaſs may be tuned to any Note required. ——— The ſecond Way is, by grinding the Glaſs on the Edge till you have ſufficiently leſſened its Quantity, to produce the Note deſigned; and this is the ſame Method, in Effect, they take for tuning Bells, by turning off ſo much from the Rim, or Surface, as is neceſſary for that Purpoſe. ——— And in each of theſe Ways the Glaſſes are rendered truly muſical, or harmonious.

Euphroſ. One of thoſe Performers, I obſerved, had all his Glaſſes ſtanding ſingly before him, fixed down to a Board: ——— Another had them placed round a common Axis, one within another, in the Manner as Bells are placed about a common Axis for the Chimes of a Clock: ——— The laſt of theſe Methods is, in my Opinion, much preferable to the former: But though I think the Notes from Glaſs much ſweeter and finer than thoſe from a String, yet is the Muſic itſelf of a much inferior Nature, as conſiſting only of plain Notes, without admitting of any Shakes, or other Graces, which all common Inſtruments is capable of: Beſides, this Sort of Muſic ſeems confined to very ſlow Time, as a temporary Stroking, rather than a mometary touching the Glaſs, is here neceſſary, and therefore nothing of that Agility in fingering can here be expected, which ſo greatly diſtinguiſhes the Performers on other Inſtruments.

Cleon. All that you have now obſerved are certainly Facts, that will render this Muſic of no great Conſequence among the greateſt Genius's of this Sort: It is more accommodated to Melody, or vocal Muſic, than to that of common Concerts; for as the Notes of Glaſs are ſoft and flowing, they are over-powered and abſorbed by the ſtronger and higher Notes of other Inſtruments. It is, however, a diſtinct Sort of real Muſic, which is more than can be ſaid of the ÆOLIAN HARP, whoſe Notes obſerve no muſical Proportion of Sound, though they are all of them, from the higheſt to the loweſt, moſt exquiſitely pleaſing, or rather raviſhing to the Ear.

Euphroſ.

Euphros. I know this by frequent Experience; for the Harp which I have, and often apply under the Sash of my Window, fills me, as it were, with the Sensation of celestial Sounds and Harmony: ——— And it is amazing to find how the Notes will successively arise from nothing, swell to the most exalted Tones, and then gradually die away: ——— They seem sometimes very near at Hand; at others, you hear them, as it were, from the remotest Distance. ——— And I have oftentimes observed that, from a different Number of Strings in the Harp, the same wonderful Variety of Sounds will arise. ——— And, furthermore, whether all those Strings are in Unison, or tuned to the various Notes of an Octave, no sensible Difference will arise in the Sounds which are produced from the Strokes which are made by the invisible Hand of Nature.

Cleon. What you say, my *Euphrosyne*, I have often experienced the Truth of myself. ——— And from these and such like Phænomena it evidently appears to me, that we are not yet fully acquainted with the PHILOSOPHY OF SOUNDS, especially those of a musical Sort; and that they have many other Causes concurring to produce and vary them, besides the three mathematical Quantities, *viz. Diameter*, *Length*, and *Tension* of *Strings*. ——— As a farther Proof of this, I shall entertain you with one Experiment more to shew how, and in what a surprizing Manner, musical Strings are affected by each other's Vibrations: To which End, I have here provided you with a sounding Box, and two Strings of equal Size and Length on the Top of it: If one of these, which I shall call A, be strained to any particular Degree, and then we begin to stretch the other, which I call B, (and is placed very near to A) then will the String A be quiescent, or at rest, under all Degrees of Tension in the String B when it is struck with a Quill, excepting that only which is the same with its own, and in that Case the String A will begin and continue to vibrate equally with the String B. The two Strings therefore, as they have equal Degrees of Motion, will produce an Equality of Sound when equally struck with a Quill: And hence we see the natural Cause of that Concordance of Sound which is called *Unison*. But the Motion which is given to the String A by the Vibrations of B only, will be very small,

and therefore produce but a very faint and almoſt imperceptible Sound: Yet ſtill the Sound is *audible* to a good Ear, and the Vibration is viſible to a common Eye. —— However, that theſe Things may be extremely ſenſible to you, I have placed a Microſcope over the Middle of the String, wherein you will obſerve the Phænomenon to the greateſt Advantage.

Euphroſ. I am greatly obliged to you, *Cleonicus*, for taking ſo much Care to inſtruct and improve me in the Knowledge of natural Things. —— I'll try the Experiments ſucceſſively; and, firſt, while the Strings have two different Degrees of Tenſion, I ſtrike one of them, and obſerve the other has no Motion even to the Eye aſſiſted by the Microſcope: —— But now, as I turn the Nutt and gradually ſtretch the String B, I obſerve, as it comes nearly to the Tenſion of the String A, that the latter begins to move, till at Length the Tremor increaſes and ſhews the Vibration of the String not leſs in Appearance in the Microſcope than $\frac{1}{4}$ of an Inch: —— And it is very curious to obſerve how this Space gradually leſſens, as I increaſe or remit the Tenſion of the String B, above or below that of A, till on either Side it vaniſhes: —— Indeed, I can plainly ſee the Motion in the String A with my naked Eye, and can even hear the Sound when that of B is ſtopped. —— By this Method, I apprehend, a Perſon that has no muſical Ear at all, may, with his Eye, aſſiſted by a Microſcope, put two Strings in Uniſon to the utmoſt Perfection.

Cleon. You obſerve very rightly, my *Euphroſyne*, and not only in Uniſon, but likewiſe in any other comparative Degree of Sound: Thus, if I take the String B away, and ſubſtitute in its Room another which I call C, of juſt half the Length of B, then you know, when they are under the ſame Degree of Tenſion, there will be an Octave Difference in their Tone; or the Sound of C will be an Octave above that of A: —— But now what is very myſterious is, the Effect which the String C has upon the String A; for, when it is ſtruck, it will cauſe the String A to vibrate in two equal Parts: That is, with reſpect to its Motion, the String A is divided in the middle Point, and each Half vibrates equally with the String C, and that middle Point is entirely at reſt: A Thing, which the moſt acute Philoſopher

ſopher would never have ſurmiſed had it not been demonſtrated by Experiment, which it is two ſeveral Ways.

Euphroſ. This will afford me very great Pleaſure indeed: ——— Could any one have thought that a String could poſſibly be put into Motion by two Parts, and yet at Reſt in a Point between them, at the ſame Time!

Cleon. So it is, my *Euphroſyne*, and the following Experiment will evince the Truth of it. ——— I cut 3 ſmall angular Pieces of Paper in this Form and Size, (∧) ſo that they may conveniently hang upon the String; then I place one of them preciſely on the Middle of the String A, and the other two juſt over the Middle of each Half of the ſaid String: ——— Now, my *Euphroſyne*, I ſtrike the String C in a gentle Manner, and you obſerve the two laſt mentioned Papers are inſtantly thrown off, while that in the Middle of the String A remains entirely at reſt.

Euphroſ. I view the Fact with Aſtoniſhment; nor can it need any thing more than this ſimple Experiment to ſupport it. But could it not be otherwiſe ſhewn by the Microſcope as in the former Caſe?

Cleon. Very eaſily, my *Euphroſyne*; ——— for now I place the Microſcope over the middle Point of the String A, and when you have placed your Eye over it, for the View, I will ſtrike the String C when you give the Word.

Euphroſ. I have a perfect View of the String A, and without any Motion at all: ——— Therefore, now ſtrike the String C: ——— Well, tho' I hear you ſtrike it, I proteſt I ſee no Motion in the Part of the String I look at, any more than before; but it ſtill continues at Reſt. ——— Now let me view the Middle of each Half.

Cleon. I'll firſt place it over that Half which is by the String C: ——— Obſerve the String, and give me the Word.

Euphroſ. I ſee the String at preſent perfectly quieſcent; ——— you may now ſtrike it: ——— A Tremor ſeizes the String at once, and it is dilated into a very conſiderable Breadth, at leaſt 4 or 5 Times as wide as its natural Size: ——— And will the other Half produce the ſame Appearance, *Cleonicus?*

Cleon. The very same. ——— I will place the Microscope over the middle Point of the other Half, and then you will be satisfied.

Euphros. At present the String appears at Rest, as before: ——— Now give the Stroke to the String C. ——— Immediately the String is all in Motion, with all the same Appearance as before. ——— I am doubly convinced of this wonderful Event, and should be glad if you will give me to understand how, and in what Manner such wonderful Motion is communicated from C to A.

Cleon. It is said, by Philosophers, that as the String A can be affected only by the Pulses of Air excited by the Motion of the String C, and those Pulses being of the same Length with the String C, therefore they can strike it only in half its Length at the same Time; and therefore, by this Means, can put it in Motion only in those two Halves; and so the middle Point of the String, having nothing to strike it, remains at Rest. ——— This is accounting for it in a Manner somewhat similar to the Thing, I allow; but I will not answer for its being satisfactory to every scrupulous Mind: ——— But that this is a Fact in every different Length of Strings, where the shorter is an aliquot Part of the larger, is certainly true, and it will be worth while to give one Experiment more to confirm it: ——— Therefore, I have here provided two other Strings, A and D; the Length of A is 4 Feet, and that of D but one Foot, they are placed at the Distance of $\frac{1}{10}$ of an Inch distant from each other, and both begin at the same Line: When they are properly tuned, or the String D a double Octave, or 16 Notes above A, then, when it is struck, the Pulses of Air which it produces can be only one Foot in Length; these Pulses therefore will affect the String A in 4 equal Parts at once, and consequently divide the String in three equal Points between the two Extremes, which Points, together with the two extreme Points, or Ends, are all to be considered at Rest, while the 4 intermediate Parts, or Quarters of the String, do severally vibrate at the same Time. ——— And in order to prove that this is really the Case, nine of those small Pieces of Paper will be necessary, to be placed at every 6 Inches along the String A; for then, when the String D

is

is ſtruck with a Quill, every other Paper ought to be thrown off, and the reſt remain on the String: ——— And this, you ſee, will be done by fixing your Eye attentively on the String A, while I ſtrike the String D.

Euphroſ. How wonderful is the Sight! ——— The Papers alternately fly off and remain at Reſt: ——— Thoſe which go off, do it with ſuch Violence and Suddenneſs, that it can ſcarcely be perceived by the Eye; ——— while thoſe at Reſt appear not in the leaſt to have been ſhocked. ——— I do not know that I ever ſaw an Effect in Nature ſo very ſtupendious, and, at the ſame Time, capable of being demonſtrated in ſo ſimple a Manner.

Cleon. I ſhall entertain you with more of the Wonders of Nature in this Way at another Time: At preſent, I think I have kept your Mind ſufficiently upon the Stretch, and therefore ſhall poſtpone the Conſideration of thoſe called Wind-inſtruments to the next Opportunity.

DIALOGUE XXII.

The Rationale *of different Kinds of* MUSICAL INSTRUMENTS, *continued.*

Euphroſyne.

YOU have given me a large and particular Account of many Sorts of muſical Inſtruments, particularly thoſe whoſe delightful Effects are produced by the Vibrations of Strings; and you promiſed me, at the Concluſion of our laſt Conference, that the Subject of our next muſical Speculation was to be the PHILOSOPHY of *Wind-inſtruments:* Of this Sort, I muſt confeſs, I have but a very ſlender Notion, and here, if you do not take Care, you will ſoon get out of my Latitude.

Cleon. I ſhall trouble you with nothing very myſterious on this Head; for all Kind of Wind-inſtruments, from the *Jews Harp* to the ORGAN, depend upon one ſimple Principle, *viz.* the

the vibrating Motion of condenſed Air; for as all ſtringed Inſtruments produce their Effects by exciting Vibrations in the Air by the Vibrations of their Strings, ſo all Kind of hollow Pipes may have their contained Air impreſſed, and condenſed by the different Force of the Breath, or Blaſt from the Mouth, or by other Means, and thereby the Action of that condenſed Air variouſly modified, and which, communicated to the external Air, will be the Cauſe of as great a Diverſity of Vibrations therein, and conſequently of muſical Sounds or Notes, which, as I have ſhewn you, conſiſt in nothing more than the Pulſes of Air properly modified and modulated for that Purpoſe.

Euphroſ. Then I ſuppoſe, by what you ſay, *Cleonicus*, if a Perſon applies a common Trumpet to his Mouth, and puts the Air in Motion by the Force of his Breath, the Vibrations of that condenſed Air will make a loud Sound: ——— Then another Perſon blowing through a Trumpet of the ſame Dimenſions with ſuch a Force of Breadth as will condenſe the Air to twice the Degree, will cauſe the Vibrations to be twice as quick, and, conſequently, to produce in the external Air a Sound, whoſe Note, or Tone ſhall be twice as high, or more acute than the other: And therefore the Tones, or Notes of thoſe two Trumpets will be an *Octave* diſtant from each other: Am I not right ſo far, *Cleonicus?*

Cleon. You certainly are, my *Euphroſyne:* And if the ſecond Perſon was to agitate the Air with a leſs Force of Breath, ſo that its Vibrations ſhould be in Proportion to thoſe of the other Trumpet, as 3 to 2, then would the Notes of the two Trumpets be that Concord called the *Fifth.* If the Breath be farther weakened, ſo as to cauſe but 4 Vibrations in this Trumpet to 3 of the Firſt, the latter will be a *Fourth* above the former, and ſo on for a *Third*, *Second*, &c. whence it appears, that two Trumpets being ſounded together, are capable of producing all the Variety of muſical Sounds in Common with ſtringed Inſtruments.

Euphroſ. So far I underſtand you pretty clearly, and, at the ſame Time, I ſee in general the Reaſon why a TRUMPET, *French* HORN, &c. is of itſelf a muſical Inſtrument; becauſe, by variouſly agitating the Air with different Forces of the Breath,

any

any Variety of musical Notes may be produced by Succession, and, consequently, any Piece of Music may be performed in a single Part by those Instruments, and two of them together in Concert; and because of the Greatness of their Sound, or Loftiness of their Notes, this Sort of Wind-music is generally appropriated to all joyful and triumphal Occasions, and are particularly pleasing in the Gloom of a serene Night, and have their Effects greatly heightened by their Reverberation from an extended Surface of Water. In this Trumpet-music, the Air seems not to be confined or agitated in the same Manner as in those Pipes or Tubes we call FLUTES: Pray, how am I to understand the Effect of this Sort of Wind-instruments?

Cleon. The Air in the Body of any Pipe or Flute, will, by other Air forced in upon it, be put into Motion, and, being thereby more or less condensed, will have such Vibrations exited as are proportionably quicker or slower; and these, by Means of the Holes producing similar Vibrations in the external Air, will cause all that Variety of musical Sounds, as before: But the Notes of those Sounds will be variable, according to the Bulk and Length of the included Column, or Cylinder of Air; for the larger the Tube or Pipe, the greater will the Quantity of Air to be put in Motion by the same Force of the Breath, and, consequently, the less will be its Condensation, therefore the slower its Vibrations, the lower will be the Note or Tone of Sound which it emits. ——— But as one Length of String will produce only one Sort of Note, (with the same Degree of Tension) so one Body or Quantity of Air will be capable only of one Degree of Vibration, and therefore of producing only one Note, which, indeed, may be higher or lower, as the Force of the Breath may be stronger or weaker impressed. But what I now say must be understood to relate to the common Method of sounding those Instruments; for, if you please, you may blow with Force enough to cause Vibrations twice as quick in the same Body of Air, and consequently to make the Sounds emitted an Octave one above another: But you cannot, in this Case, produce any Note between the Octaves, which is something of a very odd and extraordinary Nature.

Euphros.

Euphrof. Pray, *Cleonicus*, what is it makes that which is called the *Pitch-pipe* of ſuch general Uſe in tuning muſical Inſtruments?

Cleon. As we are now diſcourſing of Wind-muſic of the tubular Kind, your Queſtion is very *apropos*, and the *Rationale* of the Pitch-pipe will be very eaſy to conceive from what hath been ſaid: For as the Vibrations of the Air will be proportioned to its Quantity in a uniform Tube, whether ſquare or round, it matters not; therefore as you increaſe or diminiſh the Length of the Bore, or Capacity of the Pipe, by the ſolid Part that is moveable in it, ſo you may give ſuch Lengths to the included Body of Air as ſhall render it productive of Vibrations of any given Degree of Velocity, and thereby produce any given Note of an Octave.

Euphrof. If I underſtand you right, when the Air of the Pipe has its full Length, it will produce the loweſt or *Baſe Note*; but when the ſolid Part is placed ſo far in the Pipe as to diminiſh the Length of the Body of included Air, by one Half, and the Note be ſounded, it will be now an *Octave* above the former, or twice as high: Is it not ſo, *Cleonicus?*

Cleon. It is, my *Euphroſyne*, juſt as you have expreſſed it: ——— And farthermore, if the Stopple be moved ſtill farther up the Pipe, ſo as to leave the Column of Air but $\frac{1}{4}$ of its firſt Length, its Vibrations will be then twice as quick as in the laſt Caſe, and therefore will produce a Note twice as high, and conſequently will be a double Octave above the Baſe Note: ——— Therefore it is, that this ſolid Part or Stopple may be conſidered as a *Monochord* in its whole Length, and may be ſo divided into a Hundred equal Parts, in the ſame Manner as I obſerved to you of the Baſe or Key-note when it was a String: ——— But here the Beginning of the Diviſion is from the End that enters the Pipe; therefore, if you place it in the Tube to the Diviſion 50, it will ſound an Octave; but if you draw it back to 53, the Note will be a *7th* greater; ——— if you ſtop at 60, it will be a *6th* greater; ——— and after that at 40 $\frac{6}{10}$, the *Fifth* Note will be produced; again, by placing it to 75, you have the *Fourth* Note; ——— then again at 80, and you have the *Third* Note; ——— and, laſtly, againſt 80 $\frac{8}{10}$, you have the *Second* Note, or that

next

next to the Key or Base Note. ——— Thus, any Note of the Octave may be produced by the Pitch-pipe: And if the Notes in this first Octave be not high enough, you may go an Octave higher on the same Monochord, and so have a very great Extent of Notes in this Pipe.

Euphros. Then, I presume, the Reason why it is called a Pitch-pipe is because, by this Means, he that tunes the Harpsichord, or other Instrument, may be thereby able to pitch the Note, or Tune, to the proper Height above, or Distance from the Base Note; so that any of the seven Notes in the Octave may be ascertained by this Pipe: And thus all the Octaves, and consequently the whole Instrument, may be put into Tune, at any Time, by this mechanical Method. ——— I suppose, the *Rationale* of all Wind-instruments is nearly the same; as you have given me to understand, that Notes or Sounds of this Kind depend upon, and result from the different Agitations and Vibrations of the included Air in the Pipes.

Cleon. What you observe is in general very just: But there is, at the same Time, great Art and Contrivance required in the Instrument-maker, with respect to the internal Structure and Bore of the Tube, or Pipe; and also the Form and Size of the Holes, or Ventages, by which those Sounds are modulated by the Fingers in Flutes, Hautboys, *&c.* ——— But the Capital, or most noble and magnificent of all the Instruments for Wind-music is, the ORGAN, so called by Way of Pre-eminence; because the Word *Organ* signifies, in the original *Greek*, nothing more than an *Instrument*. ——— The Principle of Organ-music is in itself very simple and easy, as I have already shewn; nor is its Structure so very difficult, or complicated, as might be imagined from its pompous Appearance.

Euphros. The Aspect and Effect of the Organ are both in a superlative Degree: I am always ravished with its majestic Form, as well as with its divine and celestial Sounds. I think it is with the greatest Propriety consecrated to the Worship of the Deity; as it must be allowed greatly to assist all that Part of our Devotion which relate to the sacred Music and Harmony, such as singing Anthems, Psalms of Praise, *&c.* and something of this Kind we find has always been in Use in Royal Chapels,

and other chief Places of Worſhip. ——— But, methinks, I ſhould be glad to know ſomething of the internal Structure of this Inſtrument, as I have never yet had an Opportunity of gratifying my Curioſity by an Inſpection thereof.

Cleon. It will not be a great while before I ſhall take you with me to the Organ-builder's Room, where you will ſee and examine every Part which enters into its Structure; and, indeed, there is no Way for a Perſon to have a juſt Idea of the Structure of this Inſtrument, or any other Piece of Machinery, than by a real View of the ſeveral Parts that compoſe it, and the Manner in which they are put together by the Artificer: But, for the preſent, I ſhall give you a general Account of the ſeveral Parts of which it conſiſts: ——— Under the Range of Pipes is a long Trunk, or hollow Box of Wood, made perfectly *Air-tight*, with which the Pipes communicate, and which, at the Time the Organ is playing, is conſtantly filled with condenſed Air by Means of Bellows appropriated to that Uſe. ——— Externally, you obſerve a Set of Keys like thoſe of a Harpſichord, each of which is adapted to its peculiar Pipe in the Organ: ——— Theſe Keys, when put in Motion by the Organiſt, lift up little Springs, by which the condenſed Air ruſhes out of the Magazine into the Pipes of the Organ. ——— The nether End of the Pipe is formed ſomething like the Mouthpiece of a Flute, by which ſuch a particular Portion of Air is admitted as is ſufficient to put the internal Air into thoſe Tremours, and Vibrations, as are neceſſary to ſound the intended Note, the other Part of the Air running Waſte on the Outſide of the Tube: ——— And thus the ſeveral Pipes of the Organ, like the Strings of a Harpſichord, have their muſical Effects produced, by one and the ſame Contrivance of a Set of Keys, which is a very lucky Circumſtance, becauſe the ſame Perſon can, by this Means, play either Inſtrument.

Euphroſ. From what you have ſaid, I am able to form a tolerable Idea of the Nature of this Inſtrument, and the Manner in which this ſuperior Kind of Muſic is effected: ——— But let me ask you one Queſtion more, does not the Matter and Form of the Tubes contribute to meliorate the Notes, or Sounds, as well

well as the Sound-boards with which ſtringed Inſtruments are conſtructed?

Cleon. There is doubt of it, my *Euphroſyne*; the more elaſtic the Tube is, the ſtronger and finer, and more ſonorous and vivid will be the Sound, if I may ſo expreſs myſelf: Of this you would ſoon be ſenſible, were the Air agitated in the ſame Manner of equal Pipes of Copper or Lead. The Strings of a Harpſichord would make but indifferent Muſic without the Sound-board, and elaſtic Air below, contributing, by their Elaſticity, to heighten and perfect its various Notes. ——— In the Structure, therefore, of all Kinds of muſical Inſtruments, we are not only to conſider the eſſential Principle of each peculiar Specie of Muſic, but, alſo, we muſt have a great regard to all concomitant Circumſtances and Incidents which contribute to improve the ſame; for it is in MUSIC as in PAINTING, unleſs the Expreſſions of Nature are enlivened and embelliſhed by the Graces borrowed from Art, the Performance will ever prove flat, cold, and unaffecting. ——— Thus I have, in a general Way, ſketched out to you a comprehenſive Plan of the Philoſophy of muſical Sounds, by which you will be enabled to read, with Improvement, the Works of thoſe who have wrote largely on this Subject, and therefore ſhall conclude with a few Reflections not improper on this Occaſion: ——— The firſt is, a Curioſity relative to muſical Proportion, worth your Notice; by which there ſeems to be ſome Connection between the *Sciences* of MUSIC and OPTICS. ——— You remember all that I have ſaid to you concerning the Reflection of Light from Speculums, and the Formation of Images thereby, from a given Diſtance and Situation of the reſpective Objects.

Euphroſ. What I can recollect of that Kind is principally this, that the ſolar Focus of a Speculum is at the Diſtance of $\frac{1}{4}$ Part of the Diameter of the Sphere, of which it is a Segment; and, farther, that when an Object is at any near, or definite Diſtance, the focal Diſtance, or Place of the Image, will exceed the Diſtance of the ſolar Focus, and ſo much the more as the Object is nearer to the Mirrour.

Cleon. Very well, my *Euphroſyne:* Then what I have now to advance, is this, that if a Right-line be conceived to be drawn,

and a Mirrour be placed on any one Part of that Line, and an Object at a Diſtance in another Part of that Line, *then the Place of the Mirrour, and of its Center, and the Place of the Object and its Image, are four Points, which will ever divide that Line into* MUSICAL PROPORTION: From whence we have this harmonical Analogy, *as the Diſtance of the Object from the Center of the Mirrour is to its Diſtance from the Vertex thereof, ſo is the Diſtance of the Image from the ſaid Center to its Diſtance from the Vertex:* Or, in other Words, the *Ratio* of the Diſtances of the Object and its Image, from the Center and Vertex of the Speculum, will ever be the ſame.

Euphroſ. This, no doubt, is a very curious Propoſition, both in Muſic and Optics; but I ſhould have a much clearer Idea of it, if you could contrive to illuſtrate it by Example, or Experiment.

Cleon. That nothing may be wanting to your eaſy Conception of the Nature of ſo ſingular a Phænomenon, I ſhall illuſtrate it both by an Example and Experiment. For this Purpoſe I have provided a Speculum, which is the Segment of a Sphere juſt 10 Inches in Diameter, whoſe Center is therefore at the Diſtance of 5 Inches from the Vertex. Now, if I draw a Line juſt 10 Inches long, and place the Mirrour at one End of that Line, and any Object at the other End, then will the Center of the Mirrour fall on the middle Point of the ſaid Line: there-there, if this Line be conſidered as a *Monochord*, it is evident, the Center of the Speculum falls upon that Point which is called the *Octave*, and the ſolar Focus is upon the Point at 2 $\frac{1}{2}$ Inches diſtant from the Vertex, which is that Note called the *Fourth*. Then the Object being placed at the End of the Monochord, its Diſtance from the Center to its Diſtance from the Vertex of the Mirrour will be in Proportion, as 1 to 2: Conſequently, the Octave, or Diſtance from 5 to 10, muſt be divided by the Image in the ſame *Ratio*, and therefore it will fall on the Point which is 6 $\frac{6}{10}$ Inches from the Beginning of the Monochord, and therefore will be formed on that diſtinguiſhed Concord called the *Fifth:* So that, in this Example, the Place of the Object and its Image, the Place of the Speculum, its Center and ſolar

Focus

Focus divide the Monochord in all the capital Points of harmonical Proportion.

Euphrof. But ſtill, *Cleonicus*, though I do not diſpute the Truth of all you ſay, it will be neceſſary to evince the ſame to me by an Experiment.

Cleon. That is the next Thing I propoſe, and which will not prove tedious or difficult in the leaſt Degree; for having placed the Mirrour in its Frame, with the Center of the Pediſtal at the End of the Diviſions of the Line, or Monochord, I place a ſmall lighted Wax-candle exactly on the Beginning of the ſaid Line: ——— Then you ſee, by ſtanding on this Spot, the Image of the Candle inverted, and the Point of its Flame exactly directed to the *fifth* Note, or Diviſion of the Monochord.

Euphrof. This, I obſerve, is really Fact, and fully ſatisfies me of the Truth of this moſt extraordinary Inſtance of Harmony in Optics. ——— Pray, is there any Caſe of a like Nature in any other Sciences?

Cleon. None, that I know of. You may have heard talk of the Muſic and Harmony of the Spheres, or Orbits and Motions of the heavenly Bodies; but there is no real muſical Proportion in the Diſtances of their Orbits from the Sun, or their periodical Revolutions about it. ——— I have likewiſe, heretofore obſerved to you, that in the Refraction of Light by a Priſm, the Spaces occupied by the different Colours in the variegated ſolar Image were nearly the ſame as the Parts, or Intervals between the muſical Notes of an Octave: But this is a Matter, for ought we know, merely caſual, as there is no geometrical or phyſical Demonſtration of a muſical *Ratio* in refracted Light in any Reſpect. ——— In ſhort, there is no other Inſtance in Nature where it can be found, but in the Law of reflected Light, which therefore may be juſtly eſteemed the moſt amazing Singularity of Nature.

Euphrof. For my Part, I ſhall always eſteem it as ſuch: ——— But what have you farther to obſerve, with regard to the Nature and Effects of Muſic?

Cleon. It may be very proper here to animadvert upon one Thing, *viz.* that when we know of any extraordinary Power, or Agent

Agent in Nature, we are generally apt to over-rate it, or to aſcribe more to its Virtue and Efficacy than was ever naturally due to it. To this injudicious Diſpoſition in Mankind, we owe moſt of thoſe ridiculous and extravagant Notions of Aſtrologers, or Auruſpices, Soothſayers, and Conjurers of every Kind, which have formerly ſo much infatuated the Minds of weak and wicked People, to the great Diſhonour of an allwiſe Governor of the World, and the Shame and Diſgrace of human Nature. ——— This ſeems to have been the Fate even of Muſic itſelf: Its Powers are well known to affect the human Fabric, which is chiefly a Compages, or Syſtem of nervous Fibres and muſcular Filaments, and thereby ſubject to all the Motions and Vibrations of Air; and, conſequently, by thoſe occaſioned by muſical Sounds in a very high Degree: and as the Paſſions of the Mind are affected, and variouſly excited by the Impulſes of the nervous Syſtem, it is no Wonder that we oftentimes ſee the Power of Muſic affecting the Paſſions of Men, in reſpect to Joy, Mirth, Devotion, *&c.* in a very extraordinary Manner: Nor are we to wonder, if we find a Set of People ready to extend the Power of Muſic beyond the Force of Nature, and aſcribing to it many Effects which it was never capable of producing.

Euphroſ. I ſuppoſe, by this Parody on the Weakneſs and Superſtition of Mankind in regard to the Power of Muſic, you have ſome Object in View, like the famous Story of the BITE of the *Tarantula*, which is ſaid to be *curable by Muſic alone.*

Cleon. That is the very Thing I hinted at: ——— It is amazing, to conſider how ſuch a Story gained ſo long and conſtant Credit with the moſt ſenſible Part of Mankind. ——— Dr. MEAD, very probably, might write from hear-ſay; but BAGLIVI, the famous Philoſopher in *Italy*, who could not but have good Opportunities of informing himſelf with reſpect to this Inſect, (which is a Native of *Apulia*) has written a Treatiſe expreſsly on the Subject. ——— But notwithſtanding theſe, and many other great Authorities, in favour of this Story, it is now deſervedly looked upon as a mere Fiction, founded in Tradition and vulgar Error only: ——— As ſuch, it has been treated by an *Italian* Phyſician of Eminence, in the *Philoſophical Tranſactions,*

tions, and a great many Gentlemen of unqueſtionable Veracity, who reſided at *Taranto* in *Naples* many Months, and during the Time in which the Bite of the *Tarantula* is ſaid to be moſt pernicious, affirm, that there was not a Phyſician in the Country who believed there was ever ſuch a Diſtemper, from ſuch a Cauſe, and that Nobody ever remembers a ſingle Inſtance of ſuch a Thing; and, laſtly, that there is no Spider to be found in that Country different from thoſe which are common in moſt warm Climates.

Euphroſ. If this be the Caſe, how ſtrongly have your great Philoſophers, Phyſicians, and Divines been impoſed upon, by ſo trifling a Thing as the fabulous Story of the *Tarantula*. —— Does it not argue them to have been equally indolent and credulous? —— Was it not in their Power, 100 Years ago, to have detected this Impoſture? —— Should not this prove a Leſſon of Inſtruction to the *Virtuoſi* of the next Generation, to be more circumſpect in their Enquiries into the Powers of Nature, and not to be credulouſly aſſenting to every vulgar Report, to the no ſmall Diſgrace of their high Reputation? —— Laſtly, I think you have ſaid enough for a *Memento* to the great Gentlemen of your own Sex, who are apt to value themſelves ſo much on their ſuperior Wiſdom and Abilities, to be very moderate, for the Future, in their Reflections on the Weakneſs and Credulity of ours, ſince learned Men, as well as ſilly Women, it ſeems, can, for Centuries together, believe and acquieſe in ſuch an old Woman's Story. —— You forgive me, *Cleonicus*, theſe general Reflections, as you cannot but know they are highly due from our Sex, for the many genteel Strictures we daily receive from the *Literati* of yours.

Cleon. I think, my *Euphroſyne*, all that you have ſaid is but too juſt a Retaliation, and you are certainly very right in ſo equitable a Vindication of the Honour and Character of the Ladies in general: —— But, at preſent, we ſhall put an End to this Converſation, and, in our next, proceed to conſider of thoſe Organs with which Nature has furniſhed all Animals, and, in Particular, the human Species, both for forming and uttering of Sounds, as well as for perceiving and hearing the ſame.

DIALOGUE XXIII.

On the ORGANS *furnished by* NATURE, *for forming and variously modifying* Animal NOTES, *and* Voice, *or* SPEECH *in the* human Species.

Euphrosyne.

I Am not very clear in the Subject of our present Conversation, *Cleonicus*; I remember you told me, when we last parted, that you should next discourse with me upon the natural Organs of Voice, or Speech, and, in general, how all animal Notes, or Sounds, are thereby formed and modulated. How am I to have a clear and distinct Idea of this natural Organization for forming and emitting animal Sounds?

Cleon. In this Affair, my *Euphrosyne*, I apprehend you will meet with very little Difficulty, since all the Parts of the general Organ for forming animal Sounds are such as you are well acquainted with, by daily Observation and Inspection. —— Indeed, the Parts of this Organ are not solely appropriated to this Use; but, like many other Parts of the animal System, they are wisely designed, by the Author of Nature, to answer many Purposes, and to perform different Functions in the animal Oeconomy. —— The Parts of the vocal Organ are as follow, (1.) The *Lungs*. (2.) The *Trachea*, or Wind-pipe. (3.) The *Larynx*, which is the Upper-part of the Wind-pipe. (4.) The *Epiglottis*, which lies over the Aperture, or Mouth of the *Larynx*. (5.) The *Uvula*, which hangs from the Palate at the End of the Passage of the Nose. (6.) The *Tongue*. (7.) The *Teeth*. (8.) The *Lips*. These are are all the principal Parts concerned in the Formation of animal Sounds.

Euphros. These seem to me to be hard anatomical Names, many of them; but, I suppose, the Things themselves will be easier to be understood: And, farther, as we observe in every different Species of Animals a peculiar Note, or Tone of Voice, or Sounds, which they naturally emit, therefore, in each of them,

them, we are to ſuppoſe there is a peculiar Diſpoſition and Conſiguration of thoſe Parts, to anſwer thoſe different Modulations of Sounds.

Cleon. No doubt is to be made of this; for though the Parts may be eſſentially the ſame in all, yet their Shape, their Size, and their different Apparatus of Muſcles, and many other Circumſtances, may be infinitely varied in the numberleſs Species of Animals, and thereby an endleſs Variety of animal Sounds, Notes, or Voice is producible. ——— It is by this Means, that each Species has its peculiar Note. ——— Thus, the Dog *Barks*, ——— the Cat *Mews*, ——— the Cock *Crows*, ——— the Doves *Coo*, ——— the Sheep *Bleats*, ——— the Cow *Lowes*, ——— the Lion *Roars*; ——— but MAN alone SPEAKS. ——— It is obſervable, that the Fiſh alone, though they have many Parts of the aforeſaid Organ, are yet entirely mute, or incapable of emitting any Note.

Euphroſ. You will next, *Cleonicus*, pleaſe to let me know the particular Office which each of theſe Parts perform in the Formation of animal Voice, or Sound.

Cleon. The LUNGS, which I have mentioned as the firſt and principal Part, are, in this Reſpect to the Animal, as the Bellows and Air-box is to an Organ; that is to ſay, by them the Air is inſpired, or drawn into the Lungs in a ſufficient Quantity by their Dilatation, as may ſuffice not only for Reſpiration, or Breathing; (which is their general Function) but alſo, by their Compreſſion, to give a proper Impulſe to the Air requiſite for the intended Intenſity of the Sound, or, in other Words, by a greater or leſs Compreſſion of the Lungs we can expreſs the Air through the Wind-pipe with different Degrees of Force, and thereby raiſe, or lower the Voice, as Occaſion requires: In ſhort, the Lungs are the general Magazine of Air for all the numerous Purpoſes in the animal Oeconomy, of which, this of the Voice may be juſtly reckoned in the ſecond Degree.

Euphroſ. Is this important Organ formed alike in all Animals, *Cleonicus?*

Cleon. I have obſerved ſome very conſiderable Difference in the Formation of this Part, in the Accounts which Naturaliſts give us of it; but I ſhall refer you, for further Satisfaction in

this Point, to a moſt noble and valuable Work, *viz.* the anatomical Part of the *Memoirs of the Royal Academy of Sciences at Paris*, from the Year 1666 to 1699, where you will find not only the beſt Iconiſms of all the capital Beaſts, Birds, Reptiles, Serpents, *&c.* that has been ever publiſhed, but a particular Account of all their Parts by a Diſſection of each: And if you read it in *French*, it will at the ſame Time be an Improvement of your Knowledge in that Language.

Euphroſ. I thank you for your kind Direction and Advice: I ſhall take the firſt Opportunity for procuring ſo uſeful a Treatiſe. ——— Pray, what is the next Part conducive to the Formation of Sounds?

Cleon. The ſecond great Part in the Organ for animal Notes, or Sounds, is the *Trachea* or WIND-PIPE. ——— I have obſerved to you that, in all Wind-inſtruments, Pipes of one Form or other are neceſſary; but the Wind-pipe is moſt fitly compared to the Pipe of an Organ; and as it ſerves only for the Conveyance of the Air to the Upper-part, or *Larynx*, it is of different Sizes, peculiarly adapted for expreſſing the different Sounds in various Species of Animals. A larger Account of this Part you will find in Dr. *Grew*'s *Coſmologia Sacra*, or Mr. *Derham*'s *Phyſico Theology*, both which Books are highly worthy of Peruſal: But one Thing I cannot omit mentioning to you, as it is an Argument of the moſt obvious Deſign and wiſe Contrivance, *viz.* that as this Part lies immediately in the Fore-part of the Throat, and bares on its Hind-part upon the *Oeſophagus*, or *Gullet*, by which our Food deſcends into the Stomach; and as it conſiſts of Cartilaginous *Annuli*, or Rings, theſe, leſt they ſhould bare hard on the Gullet, are diſcontinued or broke off on the hinder Part, where it is altogether ſoft and membranous, as you may remember oftentimes to have ſeen, in this Part, in a Diſh that frequently comes to your Table.

Euphroſ. I ſhall take more particular Notice of this Part the next Time I ſee it, as it is ſo highly deſerving thereof. ——— Pray, what is the next Part concerned?

Cleon. The LARYNX, I mentioned to you as the third Part of the complex Mechaniſm for animal Voice: This Part is

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no leſs uſeful, than wonderful in its particular Structure; it is placed on the upper Part of the Wind-pipe in the Throat, it may juſtly be conſidered as the moſt muſical Part of the whole Organ, as it is particularly adapted to modulate or vary the Sound, or Voice, in every reſpect, that any particular Animal is capable of: For this Purpoſe, it conſiſts of no leſs than five very curious cartilaginous Parts, all moved and actuated by particular Muſcles appropriated to each. In the human Species, this Part has a peculiar Configuration, and is one of that infinite Number, in the human Fabric, that might juſtly excite the devout Exclamation of the Pſalmiſt.* —— In the before-mentioned Authors you will find a great Variety in the Conſtruction of this Part in different Species of Animals: In ſhort, the *Larynx* anſwers to the Mechaniſm in the lower Part of an Organ-pipe, or Mouth-piece in Flutes, for modulating the Ingreſs and Regreſs of the Air in Speaking, Singing, *&c.*

Euphroſ. So far I have at leaſt a general Idea of the organical Parts of Speech. Pray, what is the next which follows, contributing to this End?

Cleon. The next, or fourth Part, is the EPIGLOTTIS, ſo called, as being ſomething in the Form of a little Tongue lying over the *Rimula*, or Mouth of the *Larynx*, always raiſed a little above it by an elaſtic Muſcle, ſo that when the Aliments glide over it into the *Oeſophagus*, it cloſes the Mouth of the *Larynx* ſo that nothing may get down the Wind-pipe; but when they are paſt it, it riſes again by its natural Reſort. This anſwers to that particular moveable Piece in the *German* Flute, Organ-pipes, *&c.* by which the *Rimula*, or Paſſage for the Air, is made greater or leſs for the proper Modulation of the intended Note, or Tone of the Sound: But this Part in the animal Structure as much exceeds the other, as the Voice, or Notes of Animals is an Effect ſuperior to the Notes of a common Pipe: The manifeſt Deſign and Contrivance of this Part being beyond Admiration itſelf.

Euphroſ. The Part which you have now deſcribed, I apprehend, is concerned in the original Production and Modification

* *Pſalm* cxix. ver. 14.

of the Voice; but the other Parts which follow, I presume, are to render the Voice or Speech more articulate and distinct?

Cleon. That is their particular Office; for without them the Wind-pipe would be no more than a common Flute, for barely modulating Notes of Sound: But, by the Assistance of the other Parts of this Organ, those Notes or Sounds may be said to be properly configurated, or formed into all that infinite Variety of Sounds which are necessary to constitute Voice, or Speech: Amongst these, the first is the *Uvula*, which I mentioned to you as the fifth Part concerned; this hangs from the Palate, in the upper and hinder Part of the Mouth, before the Passage into the Nose: It has two Uses, one is to prevent any Thing regurgitating into the Nose in Deglutition, and the other is, by its various Muscles and Motion, to contribute to the particular or special Modulation and Articulation of Sounds, at its first Entrance into the Mouth: Since we find this is very often experienced when, by a Disorder in this Part, it is necessary to extract it; that the Voice without it is very obtuse and indistinct, and the Person speaks, as we say, *through the Nose.* ——— By looking into any Person's Mouth, you will readily discern this Part pendant from the Palate over the Throat.

Euphros. Well; but notwithstanding this, I presume the *Tongue* is the principal Instrument for rendering the Voice articulate?

Cleon. Undoubtedly it is; the TONGUE is the sixth Part which I mentioned in the Structure of this general Organ, and is not only the Principal but the most absolutely necessary Part, for the general Articulation of Sounds, especially for verbal Notes or Speech, which are wholly indistinct and unintelligible where this Part is unhappily wanting, as you too often find by Experience; there is so much natural Art in the Use of the Tongue in this Respect, that the Tongue itself is not capable of expressing; it is an Instance of that divine Energy which we can only admire, but never fully understand: It is the grand Instrument of Speech to the human Species, and serves to modulate the Expressions of the Passions, by proper Notes of Sound in all others.

Euphros.

Euphrof. As you are upon the Subject of the Tongue, *Cleonicus*, you will give me Leave to ask, what further Purposes it serves besides that of Speech? It seems to me to be the *Seat*, or the Organ of *Taste*. I should be glad to have your Sentiments on this Subject.

Cleon. You may command me in any such Respects as freely as you please: —— And, to tell you the plain Truth, it is so eminently distinguished as the Organ of TASTE, that it is, for ought I know, its primary Function or Faculty; for it is well known to Anatomists, that there is a Pair of Nerves which proceed from the Brain to the Root of the Tongue, and there disperse in a wonderful Manner through all its Parts; and terminating in little capillary Eminences on the upper Side of the Tongue, occasions that small Degree of Asperity, or Roughness, which we there perceive: These are called the *Gustatory* NERVES, because being affected by the *saporific* Particles of the Aliment, or any other Body to which the Tongue is applied, they render us immediately sensible of that Quality which is called, their *Sapor*, *Gust* or TASTE; and this is the Substance of the general Doctrine of this SENSATION.

Euphrof. It is sufficient to give me a general Idea of Taste, and that is all I can expect at this Time. You will now proceed to the other Parts of this general Organ of Speech.

Cleon. The TEETH and PALATE are the next Instruments of Speech; you will easily find how considerable their Office is in this Respect, if you only attend to the different Notes or Tones of the Sound expressed with the Teeth, shut and open; or by pronouncing the different Letters of the Alphabet without applying the Tongue to the Teeth and Palate; also, it is a very common Observation, that the Voice of Persons who have lost any of their Fore-teeth is very different from what is was before, and considerably less articulate. It would be endless to be particular in shewing how far the Teeth are concerned in rendering the human Voice perfect, though, in regard to other Animals, they are of little Importance in this respect.

Euphrof. I can easily experiment the Truth of what you have now said, and am fully satisfied of it from common Observation.

——— I think you mentioned the *Mouth* as the laſt Part of this Organ of animal Voice?

Cleon. The MOUTH and Lips are the moſt eſſential of all the Parts to modulate and articulate the Sounds, eſpecially in our own Species; all the Variations of Sound, from the loweſt Wiſper to the loudeſt Vociferation, depends on the different Aperture and Configuration of the Lips. This likewiſe is evident in the Whiſtling and Singing of moſt Kind of Birds, their warbling and tuneful Notes being in a great Meaſure formed and modulated thereby. ——— And thus, I think, I have enumerated to you all the different and eſſential Parts concerned in compoſing this grand Contrivance, or Organization for animal Sounds; though there is one more moſt eminent Part, in the animal Fabric, that cannot be excluded from having ſome Share in the Production, or, at leaſt, in the Perfection of this great Faculty.

Euphroſ. By your Manner of Expreſſion, *Cleonicus*, I gueſs you mean the NOSE; this, we know, is the Seat of the Senſation of SMELLING, and I am fully ſatisfied, at the ſame Time, that a free Paſſage through the Noſtrils does greatly contribute to a diſtinct Expreſſion of the Voice, as we eaſily find by holding the Noſe when we ſpeak.

Cleon. Your Obſervation is very juſt; the Noſtrils undoubtedly contribute to a free and clear Expreſſion and Formation of animal Sounds, or Voice; but I did not chuſe to mention this before as one of the Parts of the Organ of Speech, as it is in itſelf a capital Organ of Senſation: I mean, that of SMELLING, as you juſt now obſerved; for the Anatomiſts ſhew us a Pair of Nerves which, in a moſt obvious and curious Manner, are detached from the Brain to the Origin of the Noſe, and there, in a wonderful Divarication, are ſpread over all the Surface of the Noſtrils, whoſe fine capillary Extremities, being affected by thoſe particular Particles in Bodies in which their ODOURS conſiſt, prove the Means of exciting in our Minds the Notions, or Ideas of that odorific SENSATION, or Faculty, we call the SMELL. I ſhall, one Day or other, take an Opportunity of diſſecting the Bill of a *Mallard*, or *Drake*, where you will be apprized of the moſt exquiſite Scene of Wiſdom and Deſign in the

the Structure of this Organ in that and other such Species of Animals, who are obliged to smell out their Food, or proper Aliment, when it lies concealed from the Sight. I think, for my own Part, the curious Disposition of the *olfactory Nerves*, and their amazing Ramification through all the broad Part of the Beak of this Bird, is one of the most delightful and astonishing Sights I ever beheld. ——— I make no Doubt but the Case would appear the same, or, perhaps, much more exquisite in the nervous Structure of this Organ in the Nose of Dogs, whose Powers of Sensation in this Kind are well known by Instances which exceed all human Conception and Description, and, I take it, that excepting the *Sight* alone, the *Organ of Smelling* is the most exquisite in the animal Oeconomy.

DIALOGUE XXIV.

Of the FACULTY, *or* SENSATION *of* HEARING; *with a* DESCRIPTION *of the particular Parts concerned in the* Organization *of the* EAR.

Euphrosyne.

AS you have obliged me with a general Account of the philosophical Principles of Sounds, both animate and inanimate, which has not a little contributed to the Expansion of my Mind and Improvement of my Understanding; yet I remember you told me, I should never be perfect in this Part of the Science, till the very Organ itself, by which those Sounds are rendered perceptible to us, be fully considered and understood; which, I apprehend, will be very difficult for any one to comprehend without having the several Parts of this Organ exposed to View, by an actual Dissection of the EAR: This, when we parted last, you was so kind as to tell me you would provide for the Subject of my next Entertainment.

Cleon.

Cleon. This I have accordingly done, having obtained the Favour of a Preparation of all the Parts of the *human* EAR, curiously preserved, from an ingenious Acquaintance, whose Character, as a Surgeon and Anatomist, is not the least eminent in his Profession. ——— You see them here nicely disposed, upon Cotton, in the little Compartments in this Box.

Euphros. It is, no doubt, a fine Curiosity of this Kind; but, by a general View of the several Parts thus dislocated and detached from each other, I cannot form any consistent Idea of the Form and Structure of this Organ, as it naturally exists in the Head.

Cleon. But that you will more readily do by another anatomical Preparation of the Ear, in which all the Parts have their natural Position, and, by a particular Contrivance, are easily exhibited to the View: ——— See, in this other Box, the ORGAN of the EAR entire.

Euphros. This is, indeed, a most extraordinary and noble Sight; but even in this Case I see a miscellaneous System of I know not what, till you shall please to describe the several Parts of this complex Organ, and give me a particular Account of the Uses of each, in producing this wonderful Sensation.

Cleon. That is more immediately the Business and Purpose of our Meeting at this Time. I well know how difficult it is for any Person to have an Idea of the Nature and Manner of this perceptive Faculty, without an actual View of the Organ itself, and its several Parts distinctly. The other Organs of Sensation, as you have seen, are not so difficult of Access or Comprehension, and therefore I have been the more solicitous to make this of HEARING in particular, equally understood by you.

Euphros. I am vastly obliged to you, for your Care and Solicitude to inform and enrich my Mind with every valuable Acquisition of Knowledge: ——— You will please then to begin, and proceed in your Description of the several Parts of this curious Organ.

Cleon. I will: ——— But I must first of all observe to you, that the Parts which you here see in Boxes are the *internal Parts* of

of the Ear only; but we must begin our Description with the external, and intermediate Parts, to render the whole Compleat. Therefore,

First, the external Part, which we vulgarly call the Ear, is of a curious Form for the better Collection of Sounds, and is placed on each Side of the Head of Animals, (like two natural Hearing-trumpets,) to collect the Sound which comes from every Part, and the Duplicature of this Organ is a benign Provision for any Accident by which we may be deprived of one, as we have remarked before in the Case of Vision.

Secondly, the *Meatus Auditorius*, or Passage to the internal Ear, receives the Sound from the external Part, where it is augmented as in the Tube of a Trumpet, and, as it were, condensed upon,

Thirdly, the *Membrana Tympani*; or Drum of the Ear, which is this curious membraneous Part which you see here extended quite across the Ear, and being almost of a circular Form, represents the Parchment Membrane, or Head of a Drum: In the *Sinus*, where this Membrane is placed, there are some Parts in the Nature of little Springs, (as you may observe in this Preparation,) by which this Membrane is extended, or relaxed, in order that the Vibrations of the internal Air may be thereby rendered more or less intense, as the Occasions of this Sensation may require; for, if the external Sound be too great, this Membrane may be relaxed to moderate it; or, if too low, it may be strained higher to augment or heighten it; all which is analogous to the Mechanism I have formerly observed to you in the Pupil of the Eye, with regard to too intense or too weak a Light.

Euphros. A most wise and very wonderful Contrivance, indeed! ——— Those little Parts which appear like Bones on the Inside of that Membrane, I presume are the little Springs that you speak of.

Cleon. They are: The first of these consists of two little Bones, called the *Malleus* and *Incus*, or the Hammer and Anvil: These contribute to extend and relax the Membrane principally. ——— The second Spring consists of the same *Incus*, and another little Bone called the *Stapes* or Stirup, joined together by a

third little Bone called the *Os Orbiculare*, and the Basis or Foot of the Stirup is the Passage, or makes the Entry into the second *Sinus* or Cavity of the Ear.

Euphros. Pray, is this Membrane so perfectly extended over the Passage of the Ear as entirely to cut off all Communication between the internal and external Air?

Cleon. It is but very lately that it has been discovered to have a small Perforation on one Side, which opens into a Canal called *Eustachius*'s Tube, from the Author's Name who first observed it: This Tube opens itself towards that Part of the Mouth which communicates with the Nose; and hence it is that some People, by shutting their Mouth and holding their Nose, can force the Smoke of Tobacco in a visible Manner through their Ears, through this small Chink first detected by *Rivinus*.

Euphros. By such an odd Kind of Experiment a Communication between the internal and external Ear is put beyond all Dispute: ——— But, pray, *Cleonicus*, is not such a Hole necessary in the Nature of an Organ of Sound? Because I have always observed it in all Instruments, as the *Æolian* Harp, Violin, *&c.* where a Body of Air is contained under a Sound-board beneath the Strings.

Cleon. There is no Doubt but that every Part in the Ear is perfectly adapted to a just Modulation of harmonious Sounds, and to meliorate their Tones; and that this Perforation in particular may not a little contribute thereto, as you well observed, we find it does in most Wind-instruments.

Euphros. Pray, what are those Parts which I observe within the Ear, in the curious Form of a Snail-shell?

Cleon. The Passage or Part just behind the Drum of the Ear is called the *Vestibulum*, being, as it were, the Anti-chamber or Entrance to two other Cavities or Apartments in the Ear: The first of these Cavities is called the *Labyrinth*, consisting of these Semi-circular Canals; and the Second is called *Cochlea*, or *Snail*, from its Resemblance of a Snail-shell, as you may see by their Appearance in these Preparations.

Euphros. They seem to be very curious Parts, indeed; and what you call the Labyrinth appears to me to have something of the Mechanism of a Winding-horn, or Hearing-trumpet.

Cleon.

Cleon. Not only the Form, but its Use is undoubtedly of the same Kind, *viz.* to increase the Agitations of the internal Air, or to make them more sensibly affect the Fibres of the auditory Nerve, to which a *Vestibulum*, or Passage with which they all communicate, may not a little contribute; as also, those little Membranes which you here see extended in the Entrance into each of them. This *Labyrinth* of Winding-tubes is supposed to be the general Organ of Hearing: ——— But that which is destined for the more delicate and refined Uses of Hearing, such as the forming and modulating musical or harmonical Sounds, seems to be this other second Cavity of the *Cochlea*, in whose curious and most perfect Mechanism you observe two spiral Windings, or Canals, separated from one another by a thin and nervous Membrane, supported through its Length by the Projection of bony *Laminæ*, as you may see in this *Cochlea* by a proper Section through it.

Euphros. I observe it with a great deal of Pleasure; and, as this Winding-passage grows narrower towards the Summit, I apprehend the Fibres of the auditory Nerve, displayed through the same, may be supposed to have some Resemblance to the System of Strings in a Harpsichord, and that in this Part we may expect to find the true Seat or Cause of Concords and Discords, or of the Harmony and Dissonance of Sounds?

Cleon. Your Conjectures perfectly coincide with those of the best and most experienced Naturalist, who have always conceived this to be the Case, but in an infinitely superior Degree to any Thing that we can find in the human Construction of a musical Instrument; for in such an infinite Variety, in the Lengths of nervous Chords, it will always happen that some or other of them will be in Unison, or some other Concord with the Vibrations of the Air impressed; and other Nerves in Discord with other Vibrations of the said Air. — This, at least, is some Way of accounting for the mechanical Production of Sounds, and musical Notes in this Organ: But you are not to expect that we can, at all Times, declare the full Intent and Purpose of every Part which we observe in the Contrivance of this, or any other Organ of Sensation.

Euphros. It is to be esteemed a great Condescention, that we are admitted to so near and affecting a View of Nature and

her great Operations, as to give us thoſe extended and exalted Notions and Ideas which we thereby acquire of the divine Author himſelf. How little can they be properly ſaid to know of the Deity, who are ignorant of the Works of his Hands? For my Part, I ſhall ever think it my greateſt Felicity to have been thus conducted, by you, through a Series of theſe moſt uſeful Speculations, on the moſt intereſting Subjects of this Kind, and which will ever endear you to me under all the Relations of a *Friend*, a *Brother*, and a *Tutor*; and which is all the Acknowledgment I can, at preſent, make for your aſſiduous and indefatigable Care to enrich my Mind, and to improve it with the moſt invaluable Principles and Parts of human Knowledge.

A Deſcription of the ſeveral Parts of the EAR.

Fig. I. A B, the external Ear. C D, the internal Part, or Organ of the Ear, conſiſting of the *Drum*, the *Labyrinth* and *Cochlea*. E, *Euſtachius*'s Tube.

Fig. II. Shews the *Tympanum*, or Drum of the Ear, with its proper Apparatus of Bones in their natural Situation, *viz.* A, the *Tympanum*; B, the *Malleus*; C, the *Incus*, or Anvil; D, the *Stapes*, or Stirup.

Fig. III. Shews thoſe Bones ſeparately, *viz.* B, the *Malleus*; C, the *Incus*; D, the Forepart; and E, the hind Part of the *Stapes*.

Fig. IV. Is a View of the *Labyrinth* and *Cochlea* connected: A, the Superior; B, the Middlemoſt; and, C, the inferior *Semicircular Canals* of the *Labyrinth*.

D E, the *Veſtibulum* of the *Labyrinth*; F G, the *Cochlea* with one of its Spirals opening into the *Veſtibulum* D E, and the other into the Drum at H.

Fig. V. Another View of the *Labyrinth* and *Cochlea*, ſhewing thoſe Bones in the *Tympanum* which open into them, *viz.* the Holes called

1. The *Feneſtra Rotunda*, which opens into the *Cochlea*.
2. The *Feneſtra Ovalis*, which opens into the *Veſtibulum*.
3. The *Exit*, or opening of another Canal.
4. The *Spiral* of the *Cochlea*, opening into the *Veſtibulum*.
5. The other *Spiral* opening into the *Tympanum*.

Fig. 6. A Section of the *Cochlea*, with the membraneous Partition taken away, ſhewing the Blood-veſſels ramified through its two ſpiral Cavities, A and B.

Fig. VII. Another Section of the *Cochlea*, ſhewing the Holes for the Paſſage of the auditory Nerve to the *Cochlea*.

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A DISSECTION of the EAR.

Plate LII.

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