

Micrographia:

OR SOME Physiological Descriptions OF MINUTE BODIES MADE BY
MAGNIFYING GLASSES WITH OBSERVATIONS and INQUIRIES
thereupon.

Robert Hooke

1 Preface

It is the great prerogative of Mankind above other Creatures, that we are not only able to behold the works of Nature, or barely to sustain our lives by them, but we have also the power of considering, comparing, altering, assisting, and improving them to various uses. And as this is the peculiar privilege of humane Nature in general, so is it capable of being so far advanced by the helps of Art, and Experience, as to make some Men excel others in their Observations, and Deductions, almost as much as they do Beasts. By the addition of such artificial Instruments and methods, there may be, in some manner, a reparation made for the mischiefs, and imperfection, mankind has drawn upon it self, by negligence, and intemperance, and a wilful and superstitious deserting the Prescripts and Rules of Nature, whereby every man, both from a deriv'd corruption, innate and born with him, and from his breeding and converse with men, is very subject to slip into all sorts of errors.

The only way which now remains for us to recover some degree of those former perfections, seems to be, by rectifying the operations of the Sense, the Memory, and Reason, since upon the evidence, the strength, the integrity, and the right correspondence of all these, all the light, by which our actions are to be guided is to be renewed, and all our command over things it to be establisht.

It is therefore most worthy of our consideration, to recollect their several defects, that so we may the better understand how to supply them, and by what assistances we may enlarge their power, and secure them in performing their particular duties.

As for the actions of our Senses, we cannot but observe them to be in many particulars much outdone by those of other Creatures, and when at best, to be far short of the perfection they seem capable of: And these infirmities of the Senses arise from a double cause, either from the disproportion of the Object to the Organ, whereby an infinite number of things can never enter into them, or else from error in the Perception, that many things, which come within their reach, are not received in a right manner.

The like frailties are to be found in the Memory; we often let many things slip away from us, which deserve to be retain'd, and of those which we treasure up, a great part is either frivolous or false; and if good, and substantial, either in tract of time obliterated, or at best so overwhelmed and buried under more frothy notions, that when there is need of them, they are in vain sought for.

The two main foundations being so deceivable, it is no wonder, that all the succeeding works which we build upon them, of arguing, concluding, defining, judging, and all the other degrees of Reason, are lyable to the same imperfection, being, at best, either vain, or uncertain: So that the errors of the understanding are answerable to the two other, being defective both in the quantity and goodness of its knowledge; for the limits, to which our thoughts are confin'd, are small in respect of the vast extent of Nature it self; some parts of it are too large to be comprehended, and some too little to be perceived. And from thence it must follow, that not having a full sensation of the Object, we must be very lame and imperfect in our conceptions about it, and in all the proportions which we build upon it; hence, we often take the shadow of things for the substance, small appearances for good similitudes, similitudes for definitions; and even many of those, which we think, to be the most solid definitions, are rather expressions of our own misguided apprehensions than of the true nature of the things themselves.

The effects of these imperfections are manifested in different ways, according to the temper and disposition of the several minds of men, some they incline to gross ignorance and stupidity, and others to a presumptuous imposing on other mens Opinions, and a confident dogmatizing on matters, whereof there is no assurance to be given.

Thus all the uncertainty, and mistakes of humane actions, proceed either from the narrowness and wandring of our Senses, from the slipperiness or delusion of our Memory, from the confinement or rashness of our Understanding, so that 'tis no wonder, that our power over natural causes and effects is so slowly improv'd, seeing we are not only to contend with the obscurity and difficulty of the things whereon we work and think, but even the forces of our own minds conspire to betray us.

These being the dangers in the process of humane Reason, the remedies of them all can only proceed from the real, the mechanical, the experimental Philosophy, which has this advantage over the Philosophy of discourse and disputation, that whereas that chiefly aims at the subtilty of its Deductions and Conclusions, without much regard to the first ground-work, which ought to be well laid on the Sense and Memory; so this intends the right ordering of them all, and the making them serviceable to each other.

The first thing to be undertaken in this weighty work, is a watchfulness over the failings and an enlargement of the dominion, of the Senses.

To which end it is requisite, first, That there should be a scrupulous choice, and a strict examination, of the reality, constancy, and certainty of the Particulars that we admit: This is the first rise whereon truth is to begin, and here the most severe, and most impartial diligence, must be employed; the storing up of all, without any regard to evidence or use, will only tend to darkness and confusion. We must not therefore esteem the riches of our Philosophical treasure by the number only, but chiefly by the weight; the most vulgar Instances are not to be neglected, but above all, the most instructive are to be entertain'd; the footsteps of Nature are to be trac'd, not only in her ordinary course, but when she seems to be put to her shifts, to make many doublings and turnings, and to use some kind of art in endeavouring to avoid our discovery.

The next care to be taken, in respect of the Senses, is a supplying of their infirmities with Instruments, and, as it were, the adding of artificial Organs to the natural; this in one of them has been of late years accomplit with prodigious benefit to all sorts of useful knowledge, by the invention of Optical Glasses. By the means of Telescopes, there is nothing so far distant but may be represented to our view; and by the help of Microscopes, there is nothing so small, as to escape our inquiry; hence there is a new visible World discovered to the understanding. By this means the Heavens are open'd, and a vast number of new Stars, and new Motions, and new Productions appear in them, to which all the ancient Astronomers were utterly Strangers. By this the Earth it self, which lyes so neer us, under our feet, shews quite a new thing to us, and in every little particle of its matter; we now behold almost as great a variety of Creatures, as we were able before to reckon up in the whole Universe it self.

It seems not improbable, but that by these helps the subtilty of the composition of Bodies, the structure of their parts, the various texture of their matter, the instruments and manner of their inward motions, and all the other possible appearances of things, may come to be more fully discovered; all which the ancient Peripateticks were content to comprehend

in two general and (unless further explain'd) useless words of Matter and Form. From whence there may arise many admirable advantages, towards the increase of the Operative, and the Mechanick Knowledge, to which this Age seems so much inclined, because we may perhaps be inabled to discern all the secret workings of Nature, almost in the same manner as we do those that are the productions of Art, and are manag'd by Wheels, and Engines, and Springs, that were devised by humane Wit.

In this kind I here present to the World my imperfect Indeavours; which though they shall prove no other way considerable, yet, I hope, they may be in some measure useful to the main Design of a reformation in Philosophy, if it be only by shewing, that there it not so much requir'd towards it, any strength of Imagination, or exactness of Method, or depth of Contemplation (though the addition of these, where they can be had, must needs produce a much more perfect composure) as a sincere Hand, and a faithful Eye, to examine, and to record, the things themselves as they appear.

...
...

The truth is, the Science of Nature has been already too long made only a work of the Brain and the Fancy: It is now high time that it should return to the plainness and soundness of Observations on material and obvious things. It is said of great Empires, That the best way to preserve them from decay, is to bring them back to the first Principles, and Arts, on which they did begin. The same is undoubtedly true in Philosophy, that by wandring far away into invisible Notions, has almost quite destroy'd it self, and it can never be recovered, or continued, but by returning into the same sensible paths, in which it did at first proceed.

If therefore the Reader expects from me any infallible Deductions, or certainty of Axioms, I am to say for my self, that those stronger Works of Wit and Imagination are above my weak Abilities; or if they had not been so, I would not have made use of them in this present Subject before me: Whenever he finds that I have ventur'd at any small Conjectures, at the causes of the things that I have observed, I beseech him to look, upon them only as doubtful Problems, and uncertain ghesses, and not as unquestionable Conclusions, or matters of unconfutable Science; I have produced nothing here, with intent to bind his understanding to an implicit consent; I am so far from that, that I desire him, not absolutely to rely upon these Observations of my eyes, if he finds them contradicted by the future Ocular Experiments of other and impartial Discoverers.

As for my part, I have obtained my end, if these my small Labours shall

be thought fit to take up some place in the large stock, of natural Observations, which so many hands are busie in providing. If I have contributed the meanest foundations whereon others may raise nobler Superstructures, I am abundantly satisfied; and all my ambition is, that I may serve to the great Philosophers of this Age, as the makers and the grinders of my Glasses did to me; that I may prepare and furnish them with some Materials, which they may afterwards order and manage with better skill, and to far greater advantage.

The next remedies in this universal cure of the Mind are to be applied to the Memory, and they are to consist of such Directions as may inform us, what things are best to be stor'd up for our purpose, and which is the best way of so disposing them, that they may not only be kept in safety, but ready and convenient, to be at any time produc'd for use, as occasion shall require. But I will not here prevent my self in what I may say in another Discourse, wherein I shall make an attempt to propose some Considerations of the manner of compiling a Natural and Artificial History, and of so ranging and registering its Particulars into Philosophical Tables, as may make them most useful for the raising of Axioms and Theories.

The last indeed is the most hazardous Enterprize, and yet the most necessary; and that is, to take such care that the Judgment and the Reason of Man (which is the third Faculty to be repair'd and improv'd) should receive such assistance, as to avoid the dangers to which it is by nature most subject. The Imperfections, which I have already mention'd, to which it is lyable, do either belong to the extent, or the goodness of its knowledge; and here the difficulty is the greater, least that which may be thought a remedy for the one should prove destructive to the other, least by seeking to enlarge our Knowledge, we should render it weak, and uncertain; and least by being too scrupulous and exact about every Circumstance of it, we should confine and streighten it too much.

In both these the middle wayes are to be taken, nothing is to be omitted, and yet every thing to pass a mature deliberation: No Intelligence from Men of all Professions, and quarters of the World, to be slighted, and yet all to be so severely examin'd, that there remain no room for doubt or instability; much rigour in admitting, much strictness in comparing, and above all, much slowness in debating, and shyness in determining, is to be practised. The Understanding is to order all the inferiour services of the lower Faculties; but yet it is to do this only as a lawful Master, and not at a Tyrant. It must not inroach upon their Offices, nor take upon it self the employments which belong to either of them. It must watch the irregularities of the Senses, but it must not go before them, or prevent their information. It must examine,

range, and dispose of the bank which it laid up in the Memory: but it must be sure to make distinction between the sober and well collected heap, and the extravagant Ideas, and mistaken Images, which there it may sometimes light upon. So many are the links, upon which the true Philosophy depends, of which, if any one be loose, or weak, the whole chain is in danger of being dissolv'd; it is to begin with the Hands and Eyes, and to proceed on through the Memory, to be continued by the Reason; nor is it to stop there, but to come about to the Hands and Eyes again, and so, by a continual passage round from one Faculty to another, it is to be maintained in life and strength, as much as the body of man it by the circulation of the blood through the several parts of the body, the Arms, the Feet, the Lungs, the Heart, and the Head.

If once this method were followed with diligence and attention, there is nothing that lyes within the power of human Wit (or which is far more effectual) of human Industry, which we might not compass; we might not only hope for Inventions to equalize those of Copernicus, Galileo, Gilbert, Harvy, and of others, whose Names are almost lost, that were the Inventors of Gun-powder, the Seamans Compass, Printing, Etching, Graving, Microscopes, &c. but multitudes that may far exceed them: for even those discoveries seem to have been the products of some such method, though but imperfect; What may not be therefore expected from it if thoroughly prosecuted? Talking and contention of Arguments would soon be turn'd into labours; all the fine dreams of Opinions, and universal metaphysical natures, which the luxury of subtil Brains has devis'd, would quickly vanish, and give place to solid Histories, Experiments and Works. And as at first, mankind fell by tasting of the forbidden Tree of Knowledge, so we, their Posterity, may be in part restor'd by the same way, not only by beholding and contemplating, but by tasting too those fruits of Natural knowledge, that were never yet forbidden.

From hence the World may be assisted with variety of Inventions, new matter for Sciences may be collected, the old improv'd, and their rust rubb'd away; and as it is by the benefit of Senses that we receive all our Skill in the works of Nature, so they also may be wonderfully benefited by it, and may be guided to an easier and more exact performance of their Offices; 'tis not unlikely, but that we may find out wherein our Senses are deficient, and as easily find wayes of repairing them.

...
...

'Tis not unlikely, but that there may be yet invented several other helps

for the eye, at much exceeding those already found, as those do the bare eye, such as by which we may perhaps be able to discover living Creatures in the Moon, or other Planets, the figures of the compounding Particles of matter, and the particular Schematisms and Textures of Bodies.

And as Glasses have highly promoted our seeing, so 'tis not improbable, but that there may be found many Mechanical Inventions to improve our other Senses, of hearing, smelling, tasting, touching. 'Tis not impossible to hear a whisper a furlongs distance, it having been already done

...
...

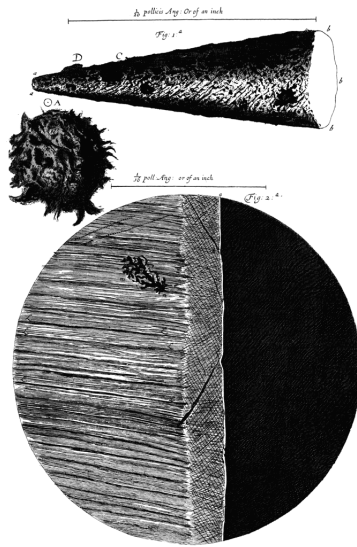
And this was undertaken in prosecution of the Design which the ROYAL SOCIETY has propos'd to it self. For the Members of the Assembly having before their eyes so many fatal Instances of the errors and falshoods, in which the greatest part of mankind has so long wandred, because they rely'd upon the strength of humane Reason alone, have begun anew to correct all Hypotheses by sense, as Seamen do their dead Reckonings by Clestial Observations; and to this purpose it has been their principal indeavour to enlarge & strengthen the Senses by Medicine, and by such outward Instruments as are proper for their particular works. By this means they find some reason to suspect, that those effects of Bodies, which have been commonly attributed to Qualities, and those confess'd to be occult, are perform'd by the small Machines of Nature, which are not to be discern'd without these helps, seeming the meer products of Motion, Figure, and Magnitude; and that the Natural Textures, which some call the Plastick faculty, may be made in Looms, which a greater perfection of Opticks may make discernable by these Glasses; so as now they are no more puzzled about them, then the vulgar are to conceive, how Tapestry or flowred Stuffs are woven. And the ends of all these Inquiries they intend to be the Pleasure of Contemplative minds, but above all, the ease and dispatch of the labours of mens hands. They do indeed neglect no opportunity to bring all the rare things of Remote Countries within the compass of their knowledge and practice. But they still acknowledg their most useful Informations to arise from common things, and from diversifying their most ordinary operations upon them. They do not wholly reject Experiments of meer light and theory; but they principally aim at such, whose Applications will improve and facilitate the present way of Manual Arts.

...
...

Observ. I. Of the Point of a sharp small Needle.

Illuminated A in Ass in Geometry, the most natural way of beginning is from a Mathematical point; so is the same method in Observations and Natural history the most genuine, simple, and instructive. We must first endeavour to make letters, and draw single strokes true, before we venture to write whole Sentences, or to draw large Pictures. And in Physical Enquiries, we must endeavour to follow Nature in the more plain and easie ways she treads in the most simple and uncompounded bodies, to trace her steps, and be acquainted with her manner of walking there, before we venture our selves into the multitude of meanders she has in bodies of a more complicated nature; lest, being unable to distinguish and judge of our way, we quickly lose both Nature our Guide, and our selves too, and are left to wander in the labyrinth of groundless opinions; wanting both judgment, that light, and experience, that clew, which should direct our proceedings.

We will begin these our Inquiries therefore with the Observations of Bodies of the most simple nature first, and so gradually proceed to those of a more compounded one. In prosecution of which method, we shall begin with a Physical point; of which kind the Point of a Needle is commonly reckon'd for one; and is indeed, for the most part, made so sharp, that the naked eye cannot distinguish any parts of it: It very easily pierces, and makes its way through all kind of bodies softer then it self: But if view'd with a very good Microscope, we may find that the top of a Needle (though as to the sense very sharp) appears a broad, blunt, and very irregular end; not resembling a Cone, as is imagin'd, but onely a piece of a tapering body, with a great part of the top remov'd, or deficient. The Points of Pins are yet more blunt, and the Points of the most curious Mathematical Instruments do very seldome arrive at so great a sharpness; how much therefore can be built upon demonstrations made onely by the productions of the Ruler and Compasses, he will be better able to consider that shall but view those points and lines with a Microscope.



A needle point and razor's edge

...
...

Observ. II. Of the Edge of a Razor

The sharpest Edge hath the same kind of affinity to the sharpest Point in Physicks, as a line hath to a point in Mathematicks; and therefore the Treaty concerning this, may very properly be annexed to the former. A Razor doth appear to be a Body of a very neat and curious aspect, till more closely viewed by the Microscope, and there we may observe its very Edge to be of all kind of shapes, except what it should be. For examining that of a very sharp one, I could not find that any part of it had any thing of sharpness in it; but it appeared a rough surface of a very considerable bredth from side to side, the narrowest part not seeming thinner then the back of a pretty thick Knife. Nor is't likely that it should appear any otherwise, since as we just now shew'd that a point appear'd a circle, 'tis rational a line should be a parallelogram.

...
...

Observ. V. Of watered Silks, or Stuffs.

There are but few Artificial things that are worth observing with a Microscope, and therefore I shall speak but briefly concerning them. For the Productions of art are such rude mis-shapen things, that when view'd with a Microscope, is little else observable, but their deformity. The most curious Carvings appearing no better then those rude Russian Images we find mention'd in Purchas, where three notches at the end of a Stick, stood for a face. And the most smooth and burnish'd surfaces appear most rough and unpolisht: So that my first Reason why I shall add but a few observations of them, is, their mis-shapen form; and the next, is their uselessness. For why should we trouble our selves in the examination of that form or shape (which is all we are able to reach with a Microscope) which we know was design'd for no higher a use, then what we were able to view with our naked eye? Why should we endeavour to discover mysteries in that which has no such thing in it? And like Rabbins find out Caballisms, and nigms in the Figure, and placing of Letters, where no such thing lies hid: whereas in natural forms there are some so small, and so curious, and their design'd business so far remov'd beyond the reach of our sight, that the more we magnify the object, the more excellencies and mysteries do appear; And the more we discover the imperfections of our senses; and the Omnipotency and Infinite perfections of the great Creatour. I shall therefore onely add one or two Observations more artificial things, and then come to the Treaty concerning such matters as are the Productions of a more curious Workman.

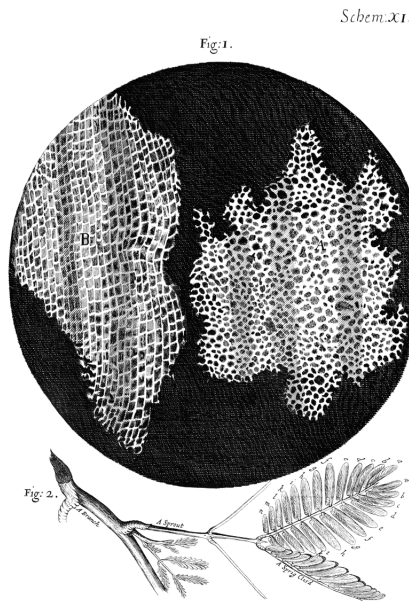
...
...

Observ. XVIII. Of the Schematisme or Texture of Cork, and of the Cells and Pores of some other such frothy Bodies.

I took a good clear piece of Cork, and with a Pen-knife sharpen'd as keen as a Razor, I cut a piece of it off, and thereby left the surface of it exceeding smooth, then examining it very diligently with a Microscope, me thought I could perceive it to appear a little porous; but I could not so plainly distinguish them, as to be sure that they were pores, much less what Figure they were of: But judging from the lightness and yielding quality of the Cork, that certainly the texture could not be so curious, but that possibly,

if I could use some further diligence, I might find it to be discernable with a Microscope, I with the same sharp Penknife, cut off from the former smooth surface an exceeding thin piece of it, and placing it on a black object Plate, because it was it self a white body, and casting the light on it with a deep plano-convex Glass, I could exceeding plainly perceive it to be all perforated and porous, much like a Honey-comb, but that the pores of it were not regular; yet it was not unlike a Honey-comb in these particulars.

First, in that it had a very little solid substance, in comparison of the empty cavity that was contain'd between, as does more manifestly Schem. 11. Fig. 1. appear by the Figure A and B of the XI. Scheme, for the Interstitia, or walls (as I may so call them) or partitions of those pores were neer as thin in proportion to their pores, as those thin films of Wax in a Honey-comb (which enclose and constitute the sexangular celts) are to theirs.



Schem 11, Fig 1.: A piece of cork

Next, in that these pores, or cells, were not very deep, but consisted of a great many little Boxes, separated out of one continued long pore, by certain Diaphragms, as is visible by the Figure B, which represents a sight of those pores split the long-ways.

I no sooner discern'd these (which were indeed the first microscopical pores I ever saw, and perhaps, that were ever seen, for I had not met with

any Writer or Person, that had made any mention of them before this) but me thought I had with the discovery of them, presently hinted to me the true and intelligible reason of all the Phaenomena of Cork; As,

First, if I enquir'd why it was so exceeding light a body? my Microscope could presently inform me that here was the same reason evident that there is found for the lightness of froth, an empty Honey-comb, Wool, a Spunge, a Pumice-stone, or the like; namely, a very small quantity of a solid body, extended into exceeding large dimensions.

Next, it seem'd nothing more difficult to give an intelligible reason, why Cork is a body so very unapt to suck and drink in Water, and consequently preserves it self, floating on the top of Water, though left on it never so long: and why it is able to stop and hold air in a Bottle, though it be there very much condens'd and consequently presses very strongly to get a passage out, without suffering the least bubble to pass through its substance. For, as to the first, since our Microscope informs us that the substance of Cork is altogether fill'd with Air, and that that Air is perfectly enclosed in little Boxes or Cells distinct from one another. It seems very plain, why neither the Water, nor any other Air can easily insinuate it self into them, since there is already within them an intus existens, and consequently, why the pieces of Cork become so good floats for Nets, and stopples for Viols, or other close Vessels.

And thirdly, if we enquire why Cork has such a springiness and swelling nature when compress'd? and how it comes to suffer so great a compression, or seeming penetration of dimensions, so as to be made a substance as heavie again and more, bulk for bulk, as it was before compression, and yet suffer'd to return, is found to extend it self again into the same space? Our Microscope will easily inform us, that the whole mass consists of an infinite company of small Boxes or Bladders of Air, which is a substance of a springy nature, and that will suffer a considerable condensation (as I have several times found by divers trials, by which I have most evidently condens'd it into less then a twentieth part of its usual dimensions neer the Earth, and that with no other strength then that of my hands without any kind of forcing Engine, such as Racks, Leavers, Wheels, Pullies, or the like, but this onely by and by) and besides, it seems very probable that those very films or sides of the pores, have in them a springing quality, as almost all other kind of Vegetable substances have, so as to help to restore themselves to their former position.

And could we so easily and certainly discover the Schematisme and Texture even of these films, and of several other bodies, as we can these of Cork; there seems no probable reason to the contrary, but that we might as read-

ily render the true reason of all their Phnomena; as namely, what were the cause of the springingess, and toughness of some, both as to their flexibility and restitution. What, of the friability or brittleness of some others, and the like; but till such time as our Microscope, or some other means, enable us to discover the true Schematism and Texture of all kinds of bodies, we must grope, as it were, in the dark, and onely gness at the true reasons of things by similitudes and comparisons.

But, to return to our Observation. I told several lines of these pores, and found that there were usually about threescore of these small Cells placed end-ways in the eighteenth part of an Inch in length, whence I concluded there must be neer eleven hundred of them, or somewhat more then a thousand in the length of an Inch, and therefore in a square Inch above a Million, or 1166400. and in a Cubick Inch, above twelve hundred Millions, or 1259712000. a thing almost incredible

...
...

Nor is this kind of Texture peculiar to Cork onely; for upon examination with my Microscope, I have found that the pith of an Elder, or almost any other Tree, the inner pulp or pith of the Cany hollow stalks of several other Vegetables: as of Fennel, Carrets, Daucus, Bur-docks, Teasels, Fearn, some kinds of Reeds, &c. have much such a kind of Schematisme, as I have lately shewn that of Cork, save onely that here the pores are rang'd the long-ways, or the same ways with the length of the Cane, whereas in Cork they are transverse.

...
...

Now, though I have with great diligence endeavoured to find whether there be any such thing in those Microscopical pores of Wood or Piths, as the Valves in the heart, veins, and other passages of Animals, that open and give passage to the contain'd fluid juices one way, and shut themselves, and impede the passage of such liquors back again, yet have I not hitherto been able to say any thing positive in it; though, me thinks, it seems very probable, that Nature has in these passages, as well as in those of Animal bodies, very many appropriated Instruments and contrivances, whereby to bring her designs and end to pass, which 'tis not improbable, but that some diligent Observer, if help'd with better Microscopes, may in time detect.

...
...

