

Chapter Four Crisis in Italy

4.1 (a) Galileo, *Letter to Grand Duchess Christina* [1615], 1636, and
(b) Cardinal Bellarmine, letter to Paolo Foscarini, 12 April 1615,
both trans. Stillman Drake in *Discoveries and Opinions of Galileo*
(New York: Doubleday, 1957), pp. 181–200, 162–4

(a) Galileo, *Letter to Grand Duchess Christina*

The reason produced for condemning the opinion that the earth moves and the sun stands still is that in many places in the Bible one may read that the sun moves and the earth stands still. Since the Bible cannot err, it follows as a necessary consequence that anyone takes an erroneous and heretical position who maintains that the sun is inherently motionless and the earth movable.

With regard to this argument, I think in the first place that it is very pious to say and prudent to affirm that the holy Bible can never speak untruth – whenever its true meaning is understood. But I believe nobody will deny that it is often very abstruse, and may say things which are quite different from what its bare words signify. Hence in expounding the Bible if one were always to confine oneself to the unadorned grammatical meaning, one might fall into error. Not only contradictions and propositions far from true might thus be made to appear in the Bible, but even grave heresies and follies. Thus it would be necessary to assign to God feet, hands, and eyes, as well as corporeal and human affections, such as anger, repentance, hatred, and sometimes even the forgetting of things past and ignorance of those to come. These propositions uttered by the Holy Ghost were set down in that manner by the sacred scribes in order to accommodate them to the capacities of the common people, who are rude and unlearned. For the sake of those who deserve to be separated from the herd, it is necessary that wise expositors should produce the true senses of such passages, together with the special reasons for which they were set down in these words. This doctrine is so

THE
Ancient and Modern
DOCTRINE
OF
Holy Fathers,
AND
Iudicious Divines,

CONCERNING

The rash citation of the Testimony of SACRED
SCRIPTURE, in Conclusions meerly Natural, and
that may be proved by Sensible Experiments, and
Necessary Demonstrations.

Written, some years since, to Gratifie The most SERENE
CHRISTINA LOTHARINGA, Arch-
Duchess of TUSCANY;

By GALILÆO GALILÆI, A Gentleman of
Florence, and Chief Philosopher and Mathematician to
His most Serene Highness the Grand DUKE.

And now rendered into English from the Italian,
BY

THOMAS SALUSBURY.

*Naturam Rerum invenire, difficile; & ubi inveneris, indicare
in vulgus, nefas. Plato.*

LONDON;

Printed by WILLIAM LEYBOURN, 1661.
Hhh

The title-page of Galileo's Letter to the Grand Duchess in Thomas Salusbury's translation, Mathematical Collections (London, 1661).

widespread and so definite with all theologians that it would be superfluous to adduce evidence for it.

Hence I think that I may reasonably conclude that whenever the Bible has occasion to speak of any physical conclusion (especially those which are very abstruse and hard to understand), the rule has been observed of avoiding

confusion in the minds of the common people which would render them contumacious toward the higher mysteries. Now the Bible, merely to condescend to popular capacity, has not hesitated to obscure some very important pronouncements, attributing to God himself some qualities extremely remote from (and even contrary to) His essence. Who, then, would positively declare that this principle has been set aside, and the Bible has confined itself rigorously to the bare and restricted sense of its words, when speaking but casually of the earth, of water, of the sun, or of any other created thing? Especially in view of the fact that these things in no way concern the primary purpose of the sacred writings, which is the service of God and the salvation of souls – matters infinitely beyond the comprehension of the common people.

This being granted, I think that in discussions of physical problems we ought to begin not from the authority of scriptural passages, but from sense-experiences and necessary demonstrations; for the holy Bible and the phenomena of nature proceed alike from the divine Word, the former as the dictate of the Holy Ghost and the latter as the observant executrix of God's commands. It is necessary for the Bible, in order to be accommodated to the understanding of every man, to speak many things which appear to differ from the absolute truth so far as the bare meaning of the words is concerned. But Nature, on the other hand, is inexorable and immutable; she never transgresses the laws imposed upon her, or cares a whit whether her abstruse reasons and methods of operation are understandable to men. For that reason it appears that nothing physical which sense-experience sets before our eyes, or which necessary demonstrations prove to us, ought to be called in question (much less condemned) upon the testimony of biblical passages which may have some different meaning beneath their words. For the Bible is not chained in every expression to conditions as strict as those which govern all physical effects; nor is God any less excellently revealed in Nature's actions than in the sacred statements of the Bible. [...]

But I do not feel obliged to believe that that same God who has endowed us with senses, reason, and intellect has intended to forgo their use and by some other means to give us knowledge which we can attain by them. He would not require us to deny sense and reason in physical matters which are set before our eyes and minds by direct experience or necessary demonstrations. This must be especially true in those sciences of which but the faintest trace (and that consisting of conclusions) is to be found in the Bible. Of astronomy, for instance, so little is found that none of the planets except Venus are so much as mentioned, and this only once or twice under the name of 'Lucifer'. If the sacred scribes had had any intention of teaching people certain arrangements and motions of the heavenly bodies, or had they wished us to derive such knowledge from the Bible, then in my opinion they would not have spoken of these matters so sparingly in comparison with the infinite number of admirable conclusions which are demonstrated

in that science. Far from pretending to teach us the constitution and motions of the heavens and the stars, with their shapes, magnitudes, and distances, the authors of the Bible intentionally forbore to speak of these things, though all were quite well known to them. [...]

Let us grant then that theology is conversant with the loftiest divine contemplation, and occupies the regal throne among sciences by dignity. But acquiring the highest authority in this way, if she does not descend to the lower and humbler speculations of the subordinate sciences and has no regard for them because they are not concerned with blessedness, then her professors should not arrogate to themselves the authority to decide on controversies in professions which they have neither studied nor practiced. Why, this would be as if an absolute despot, being neither a physician nor an architect but knowing himself free to command, should undertake to administer medicines and erect buildings according to his whim – at grave peril of his poor patients' lives, and the speedy collapse of his edifices.

Again, to command that the very professors of astronomy themselves see to the refutation of their own observations and proofs as mere fallacies and sophisms is to enjoin something that lies beyond any possibility of accomplishment. For this would amount to commanding that they must not see what they see and must not understand what they know, and that in searching they must find the opposite of what they actually encounter. Before this could be done they would have to be taught how to make one mental faculty command another, and the inferior powers the superior, so that the imagination and the will might be forced to believe the opposite of what the intellect understands. I am referring at all times to merely physical propositions, and not to supernatural things which are matters of faith.

I entreat those wise and prudent Fathers to consider with great care the difference that exists between doctrines subject to proof and those subject to opinion. Considering the force exerted by logical deductions, they may ascertain that it is not in the power of the professors of demonstrative sciences to change their opinions at will and apply themselves first to one side and then to the other. There is a great difference between commanding a mathematician or a philosopher and influencing a lawyer or a merchant, for demonstrated conclusions about things in nature or in the heavens cannot be changed with the same facility as opinions about what is or is not lawful in a contract, bargain, or bill of exchange. [...]

Now if truly demonstrated physical conclusions need not be subordinated to biblical passages, but the latter must rather be shown not to interfere with the former, then before a physical proposition is condemned it must be shown to be not rigorously demonstrated – and this is to be done not by those who hold the proposition to be true, but by those who judge it to be false. This seems very reasonable and natural, for those who believe an argument to be false may much more easily find the fallacies in it than men who consider it to be true and conclusive. Indeed, in the latter case it will happen that the more the adherents of an opinion turn over their pages,

examine the arguments, repeat the observations, and compare the experiences, the more they will be confirmed in that belief. And Your Highness knows what happened to the late mathematician of the University of Pisa who undertook in his old age to look into the Copernican doctrine in the hope of shaking its foundations and refuting it, since he considered it false only because he had never studied it. As it fell out, no sooner had he understood its grounds, procedures, and demonstrations than he found himself persuaded, and from an opponent he became a very staunch defender of it. I might also name other mathematicians who, moved by my latest discoveries, have confessed it necessary to alter the previously accepted system of the world, as this is simply unable to subsist any longer.

If in order to banish the opinion in question from the world it were sufficient to stop the mouth of a single man – as perhaps those men persuade themselves who, measuring the minds of others by their own, think it impossible that this doctrine should be able to continue to find adherents – then that would be very easily done. But things stand otherwise. To carry out such a decision it would be necessary not only to prohibit the book of Copernicus and the writings of other authors who follow the same opinion, but to ban the whole science of astronomy. Furthermore, it would be necessary to forbid men to look at the heavens, in order that they might not see Mars and Venus sometimes quite near the earth and sometimes very distant, the variation being so great that Venus is forty times and Mars sixty times as large at one time as another. And it would be necessary to prevent Venus being seen round at one time and forked at another, with very thin horns; as well as many other sensory observations which can never be reconciled with the Ptolemaic system in any way, but are very strong arguments for the Copernican. And to ban Copernicus now that his doctrine is daily reinforced by many new observations and by the learned applying themselves to the reading of his book, after this opinion has been allowed and tolerated for those many years during which it was less followed and less confirmed, would seem in my judgment to be a contravention of truth, and an attempt to hide and suppress her the more as she revealed herself the more clearly and plainly. Not to abolish and censure his whole book, but only to condemn as erroneous this particular proposition, would (if I am not mistaken) be a still greater detriment to the minds of men, since it would afford them occasion to see a proposition proved that it was heresy to believe. [...]

Regarding the state of rest or motion of the sun and earth, experience plainly proves that in order to accommodate the common people it was necessary to assert of these things precisely what the words of the Bible convey. Even in our own age, people far less primitive continue to maintain the same opinion for reasons which will be found extremely trivial if well weighed and examined, and upon the basis of experiences that are wholly false or altogether beside the point. Nor is it worth while to try to change their opinion, they being unable to understand the arguments on the opposite

side, for these depend upon observations too precise and demonstrations too subtle, grounded on abstractions which require too strong an imagination to be comprehended by them. Hence even if the stability of heaven and the motion of the earth should be more than certain in the minds of the wise, it would still be necessary to assert the contrary for the preservation of belief among the all-too-numerous vulgar. Among a thousand ordinary men who might be questioned concerning these things, probably not a single one will be found to answer anything except that it looks to him as if the sun moves and the earth stands still, and therefore he believes this to be certain. But one need not on that account take the common popular assent as an argument for the truth of what is stated; for if we should examine these very men concerning their reasons for what they believe, and on the other hand listen to the experiences and proofs which induce a few others to believe the contrary, we should find the latter to be persuaded by very sound arguments, and the former by simple appearances and vain or ridiculous impressions.

It is sufficiently obvious that to attribute motion to the sun and rest to the earth was therefore necessary lest the shallow minds of the common people should become confused, obstinate, and contumacious in yielding assent to the principal articles that are absolutely matters of faith. And if this was necessary, there is no wonder at all that it was carried out with great prudence in the holy Bible. I shall say further that not only respect for the incapacity of the vulgar, but also current opinion in those times, made the sacred authors accommodate themselves (in matters unnecessary to salvation) more to accepted usage than to the true essence of things. [...]

(b) Cardinal Bellarmine, letter to Paolo Foscarini, 12 April 1615

I have gladly read the letter in Italian and the essay in Latin that Your Reverence has sent me, and I thank you for both, confessing that they are filled with ingenuity and learning. But since you ask for my opinion, I shall give it to you briefly, as you have little time for reading and I for writing.

First. I say that it appears to me that Your Reverence and Sig. Galileo did prudently to content yourselves with speaking hypothetically and not positively, as I have always believed Copernicus did. For to say that assuming the earth moves and the sun stands still saves all the appearances better than eccentrics and epicycles is to speak well. This has no danger in it, and it suffices for mathematicians. But to wish to affirm that the sun is really fixed in the centre of the heavens and merely turns upon itself without travelling from east to west, and that the earth is situated in the third sphere and revolves very swiftly around the sun, is a very dangerous thing, not only by irritating all the theologians and scholastic philosophers, but also by injuring our holy faith and making the sacred Scripture false. For

your Reverence has indeed demonstrated many ways of expounding the Bible, but you have not applied them specifically, and doubtless you would have had a great deal of difficulty if you had tried to explain all the passages that you yourself had cited.

Second. I say that, as you know, the Council of Trent would prohibit expounding the Bible contrary to the common agreement of the holy Fathers. And if Your Reverence would read not only all their works but the commentaries of modern writers on Genesis, Psalms, Ecclesiastes, and Joshua, you would find that all agree in expounding literally that the sun is in the heavens and travels swiftly around the earth, while the earth is far from the heavens and remains motionless in the centre of the world. Now consider whether, in all prudence, the Church could support the giving to Scripture of a sense contrary to the holy Fathers and all the Greek and Latin expositors. Nor may it be replied that this is not a matter of faith, since if it is not so with regard to the subject matter, it is with regard to those who have spoken. Thus that man would be just as much a heretic who denied that Abraham had two sons and Jacob twelve, as one who denied the virgin birth of Christ, for both are declared by the Holy Ghost through the mouths of the prophets and apostles.

Third. I say that if there were a true demonstration that the sun was in the centre of the universe and the earth in the third sphere, and that the sun did not go around the earth but the earth went around the sun, then it would be necessary to use careful consideration in explaining the Scriptures that seemed contrary, and we should rather have to say that we do not understand them than to say that something is false which had been proven. But I do not think there is any such demonstration, since none has been shown to me. To demonstrate that the appearances are saved by assuming the sun at the centre and the earth in the heavens is not the same thing as to demonstrate that in fact the sun is in the centre and the earth in the heavens. I believe that the first demonstration may exist, but I have very grave doubts about the second; and in case of doubt one may not abandon the Holy Scriptures as expounded by the holy Fathers. I add that the words 'The sun also riseth and the sun goeth down, and hasteth to the place where he ariseth' (Ecclesiastes 1:5) were written by Solomon, who not only spoke by divine inspiration, but was a man wise above all others of all created things, which wisdom he had from God; so it is not very likely that he would affirm something that was contrary to demonstrated truth, or truth that might be demonstrated. And if you tell me that Solomon spoke according to the appearances, and that it seems to us that the sun goes round when the earth turns, as it seems to one aboard ship that the beach moves away, I shall answer thus. Anyone who departs from the beach, though to him it appears that the beach moves away, yet knows that this is an error and corrects it, seeing clearly that the ship moves and not the beach; but as to the sun and earth, no sage has needed to correct the error, since he clearly experiences that the earth stands still and that his eye is not deceived when

it judges the sun to move, just as he is likewise not deceived when it judges that the moon and the stars move. And that is enough for the present.

4.2 Galileo, *The Assayer*, 1623, in *Discoveries and Opinions of Galileo*, trans. Stillman Drake (New York: Doubleday, 1957), pp. 274–7

[...] But first I must consider what it is that we call heat, as I suspect that people in general have a concept of this which is very remote from the truth. For they believe that heat is a real phenomenon, or property, or quality, which actually resides in the material by which we feel ourselves warmed. Now I say that whenever I conceive any material or corporeal substance, I immediately feel the need to think of it as bounded, and as having this or that shape; as being large or small in relation to other things, and in some specific place at any given time; as being in motion or at rest; as touching or not touching some other body; and as being one in number, or few, or many. From these conditions I cannot separate such a substance by any stretch of my imagination. But that it must be white or red, bitter or sweet, noisy or silent, and of sweet or foul odor, my mind does not feel compelled to bring in as necessary accompaniments. Without the senses as our guides, reason or imagination unaided would probably never arrive at qualities like these. Hence I think that tastes, odors, colors, and so on are no more than mere names so far as the object in which we place them is concerned, and that they reside only in the consciousness. Hence if the living creature were removed, all these qualities would be wiped away and annihilated. But since we have imposed upon them special names, distinct from those of the other and real qualities mentioned previously, we wish to believe that they really exist as actually different from those.

I may be able to make my notion clearer by means of some examples. I move my hand first over a marble statue and then over a living man. As to the effect flowing from my hand, this is the same with regard to both objects and my hand; it consists of the primary phenomena of motion and touch, for which we have no further names. But the live body which receives these operations feels different sensations according to the various places touched. When touched upon the soles of the feet, for example, or under the knee or armpit, it feels in addition to the common sensation of touch a sensation on which we have imposed a special name, 'tickling'. This sensation belongs to us and not to the hand. Anyone would make a serious error if he said that the hand, in addition to the properties of moving and touching, possessed another faculty of 'tickling', as if tickling were a phenomenon that resided in the hand that tickled. A piece of paper or a feather drawn lightly over any part of our bodies performs intrinsically the same operations of moving and touching, but by touching the eye, the nose, or the upper lip it excites in us an almost intolerable titillation, even though elsewhere it is scarcely felt. This titillation belongs entirely to us and not to the feather; if the live and sensitive body were removed it would remain no more than a mere

word. I believe that no more solid an existence belongs to many qualities which we have come to attribute to physical bodies – tastes, odors, colors, and many more.

A body which is solid and, so to speak, quite material, when moved in contact with any part of my person produces in me the sensation we call touch. This, though it exists over my entire body, seems to reside principally in the palms of the hands and in the finger tips, by whose means we sense the most minute differences in texture that are not easily distinguished by other parts of our bodies. Some of these sensations are more pleasant to us than others. . . . The sense of touch is more material than the other sense; and, as it arises from the solidity of matter, it seems to be related to the earthly element.

Perhaps the origin of two other senses lies in the fact that there are bodies which constantly dissolve into minute particles, some of which are heavier than air and descend, while others are lighter and rise up. The former may strike upon a certain part of our bodies that is much more sensitive than the skin, which does not feel the invasion of such subtle matter. This is the upper surface of the tongue; here the tiny particles are received, and mixing with and penetrating its moisture, they give rise to tastes, which are sweet or unsavory according to the various shapes, numbers, and speeds of the particles. And those minute particles which rise up may enter by our nostrils and strike upon some small protuberances which are the instrument of smelling; here likewise their touch and passage is received to our like or dislike according as they have this or that shape, are fast or slow, and are numerous or few. The tongue and nasal passages are providently arranged for these things, as the one extends from below to receive descending particles, and the other is adapted to those which ascend. Perhaps the excitation of tastes may be given a certain analogy to fluids, which descend through air, and odors to fires, which ascend.

Then there remains the air itself, an element available for sounds, which come to us indifferently from below, above, and all sides – for we reside in the air and its movements displace it equally in all directions. The location of the ear is most fittingly accommodated to all positions in space. Sounds are made and heard by us when the air – without any special property of ‘sonority’ or ‘transonority’ – is ruffled by a rapid tremor into very minute waves and moves certain cartilages of a tympanum in our ear. External means capable of thus ruffling the air are very numerous, but for the most part they may be reduced to the trembling of some body which pushes the air and disturbs it. Waves are propagated very rapidly in this way, and high tones are produced by frequent waves and low tones by sparse ones.

To excite in us tastes, odors, and sounds I believe that nothing is required in external bodies except shapes, numbers, and slow or rapid movements. I think that if ears, tongues, and noses were removed, shapes and numbers

and motions would remain, but not odors or tastes or sounds. The latter, I believe, are nothing more than names when separated from living beings, just as tickling and titillation are nothing but names in the absence of such things as noses and armpits. . . .

Having shown that many sensations which are supposed to be qualities residing in external objects have no real existence save in us, and outside ourselves are mere names, I now say that I am inclined to believe heat to be of this character. Those materials which produce heat in us and make us feel warmth, which are known by the general name of ‘fire’, would then be a multitude of minute particles having certain shapes and moving with certain velocities. Meeting with our bodies, they penetrate by means of their extreme subtlety, and their touch as felt by us when they pass through our substance is the sensation we call ‘heat’. This is pleasant or unpleasant according to the greater or smaller speed of these particles as they go pricking and penetrating; pleasant when this assists our necessary transpiration, and obnoxious when it causes too great a separation and dissolution of our substance. The operation of fire by means of its particles is merely that in moving it penetrates all bodies, causing their speedy or slow dissolution in proportion to the number and velocity of the fire-corpuscles and the density or tenuity of the bodies. . . .

4.3 MS G3 in the Archive of the Sacred Congregation for the Doctrine of the Faith, ser. AD EE [1624?], trans. P. Rosenthal in P. Redondi, *Galileo Heretic* (London: Allen Lane, 1988), pp. 333–5

Having in past days perused Signor Galileo Galilei’s book entitled *The Assayer*, I have come to consider a doctrine already taught by certain ancient philosophers and effectively rejected by Aristotle, but renewed by the same Signor Galilei. And having decided to compare it with the true and undoubted Rule of revealed doctrines, I have found that in the Light of that Lantern which by the exercise and merit of our faith shines out indeed in murky places, and which more securely and more certainly than any natural evidence illuminates us, this doctrine appears false, or even (which I do not judge) very difficult and dangerous. So that he who receives the Rule as true must not falter in speech and in the judgment of more serious matters, I have therefore thought to propose it to you, Very Reverend Father, and beg you, as I am doing, to tell me its meaning, which will serve as my warning.

Therefore, the aforesaid Author, in the book cited (on page 196, line 29), wishing to explain that proposition proffered by Aristotle in so many places – that motion is the cause of heat – and to adjust it to his intention, sets out to prove that these accidents which are commonly called colors, odors, tastes, etc., on the part of the subject, in which it is commonly believed that they are found, are nothing but pure words and are only in the sensitive body of the animal that feels them. He explains this with the example of the

Tickle, or let us say Titillation, caused by touching a body in certain parts, concluding that like the tickle, as far as the action goes, once having removed the animal's sensitivity, it is no different from the touch and movement that one makes on a marble statue, for everything is our subjective experience; thus, these accidents which are apprehended by our senses and are called tastes, smells, colors, etc., are not, he says, subjects as one holds them generally to be, but only our senses, since the titillation is not in the hand or in the feather, which touches, for example, the sole of the foot, but solely in the animal's sensitive organ.

But this discourse seems to me to be at fault in taking as proved that which it must prove, i.e. that in all cases the object which we feel is in us, because the act that is involved is in us. It is the same as saying: the sight with which I see the light of the sun is in me; therefore, the light of the sun is in me. What might be the meaning of such reasoning, however, I shall not pause to examine.

The author then goes on to explain his Doctrine, and does his best to demonstrate what these accidents are in relation to the object and the end of our actions; and as one can see on page 198, line 12, he begins to explain them with the atoms of Anaxagoras or of Democritus, which he calls minims or minimal particles; and in these, he says continually, are resolved the bodies, which, however, applied to our senses penetrate our substance, and according to the diversity of the touches, and the diverse shapes of those minims, smooth or rough, hard or yielding, and according to whether they are few or many, prick us differently, and piercing with greater or lesser division, or by making it easier for us to breathe, and hence our irritation or pleasure. To the more material or corporeal sense of touch, he says, the minims of earth are most appropriate. To the taste, those of water and he calls them fluids; to the smell, those of fire and he calls them fiery particles; to the hearing, those of the air; and to the sight he then attributes the light, about which he says he has little to say. And on page 199, line 25, he concludes that in order to arouse in us tastes, smells, etc., all that is needed in bodies which commonly are tasteful, odorous, etc. are sizes, many varied shapes; and that the smells, tastes, colors, etc. are nowhere but in the eyes, tongues, noses, etc., so that once having taken away those organs, the aforesaid accidents are not distinguished from atoms except in name.

Now if one admits this philosophy of accidents as true, it seems to me, that makes greatly difficult the existence of the accidents of the bread and wine which in the Most Holy Sacrament are separated from their substance; since finding again therein the terms, and the objects of touch, sight, taste, etc., one will also have to say according to this doctrine that there are the very tiny particles with which the substance of the bread first moved our senses, which if they were substantial (as Anaxagoras said, and this author seems to allow on page 200, line 28), it follows that in the Sacrament there are substantial parts of bread or wine, which is

the error condemned by the Sacred Tridentine Council, Session 13, Canon 2.

Or actually, if they were only sizes, shapes, numbers, etc., as he also seems clearly to admit, agreeing with Democritus, it follows that all these are accidental modes, or, as others say, shapes of quantity. While the Sacred Councils, and especially the Trident Council in the passage cited, determine that after the Consecration there remain in the Sacrament only the Accidents of the bread and wine, he instead says that there only remains the quantity with triangular shapes, acute or obtuse, etc., and that with these accidents alone is saved the existence of accidents or sensible species – which consequence seems to me not only in conflict with the entire communion of Theologians who teach us that in the Sacrament remain all the sensible accidents of bread, wine, color, smell, and taste, and not mere words, but also, as is known, with the good *judgment* that the quantity of the substance does not remain. Again, this is inevitably repugnant to the truth of the Sacred Councils; for, whether these minims are explained with Anaxagoras or Democritus, if they remain after the Consecration there will not be less substance of the bread in a consecrated host than in an unconsecrated host, since to be corporeal substance, in their opinion, consists, in an aggregation of atoms in this or that fashion, with this or that shape, etc. But if these particles do not remain, it follows that no accident of bread remains in the consecrated Host; since other accidents do not emerge, this Author says on page 197, line 1, that shapes, sizes, movements, etc. do so, and (these being the effects of a quantity or quantum substance) it is not possible, as all philosophers and Theologians teach, to separate them in such a way that they would exist without the substance or quantity of which they are accidents.

And this is what seems to me difficult in this Doctrine; and I propose and submit it, as regards my already expressed judgment, to what you, Most Reverend Father, will be pleased to tell and to which I make obeisance.

4.4 Galileo, *Dialogue Concerning the Two Chief World Systems, Ptolemaic and Copernican*, 1632, trans. Stillman Drake (Berkeley, CA: University of California Press, 1962), pp. 139, 141–2, 144–9

SALV. . . . Aristotle says, then, that a most certain proof of the earth's being motionless is that things projected perpendicularly upward are seen to return by the same line to the same place from which they were thrown, even though the movement is extremely high. This, he argues, could not happen if the earth moved, since in the time during which the projectile is moving upward and then downward it is separated from the earth, and the place from which the projectile began its motion would go a long way toward the east, thanks to the revolving of the earth, and the falling

projectile would strike the earth that distance away from the place in question. [...]

SIMP.... Besides which, there is the very appropriate experiment of the stone dropped from the top of the mast of a ship, which falls to the foot of the mast when the ship is standing still, but falls as far from that same point when the ship is sailing as the ship is perceived to have advanced during the time of the fall, this being several yards when the ship's course is rapid.

SALV. There is a considerable difference between the matter of the ship and that of the earth under the assumption that the diurnal motion belongs to the terrestrial globe. For it is quite obvious that just as the motion of the ship is not its natural one, so the motion of all the things in it is accidental; hence it is no wonder that this stone which was held at the top of the mast falls down when it is set free, without any compulsion to follow the motion of the ship. But the diurnal rotation is being taken as the terrestrial globe's own and natural motion, and hence that of all its parts, as a thing indelibly impressed upon them by nature. Therefore the rock at the top of the tower has as its primary tendency a revolution about the center of the whole in twenty-four hours, and it eternally exercises this natural propensity no matter where it is placed. [...]

Now tell me: If the stone dropped from the top of the mast when the ship was sailing rapidly fell in exactly the same place on the ship to which it fell when the ship was standing still, what use could you make of this falling with regard to determining whether the vessel stood still or moved?

SIMP. Absolutely none....

SALV. Very good. Now, have you ever made this experiment of the ship?

SIMP. I have never made it, but I certainly believe that the authorities who adduced it had carefully observed it. Besides, the cause of the difference is so exactly known that there is no room for doubt.

SALV. You yourself are sufficient evidence that those authorities may have offered it without having performed it, for you take it as certain without having done it, and commit yourself to the good faith of their dictum. Similarly it not only may be, but must be that they did the same thing too – I mean, put faith in their predecessors, right on back without ever arriving at anyone who had performed it. For anyone who does will find that the experiment shows exactly the opposite of what is written; that is, it will show that the stone always falls in the same place on the ship, whether the ship is standing still or moving with any speed you please. Therefore, the same cause holding good on the earth as on the ship, nothing can be inferred about the earth's motion or rest from the stone falling always perpendicularly to the foot of the tower.

SALV. If you had referred me to any other agency than experiment, I think that our dispute would not soon come to an end; for this appears to me to be a thing so remote from human reason that there is no place in it for credulity or probability.

SALV. For me there is, just the same.

SIMP. So you have not made a hundred tests, or even one? And yet you so freely declare it to be certain? I shall retain my incredulity, and my own confidence that the experiment has been made by the most important authors who make use of it, and that it shows what they say it does.

SALV. Without experiment, I am sure that the effect will happen as I tell you, because it must happen that way; and I might add that you yourself also know that it cannot happen otherwise, no matter how you may pretend not to know it – or give that impression. But I am so handy at picking people's brains that I shall make you confess this in spite of yourself.

Sagredo is very quiet; it seemed to me that I saw him move as though he were about to say something.

SAGR. I was about to say something or other, but the interest aroused in me by hearing you threaten Simplicio with this sort of violence in order to reveal the knowledge he is trying to hide has deprived me of any other desire; I beg you to make good your boast. [...]

SALV. I do not want you to declare or reply anything that you do not know for certain. Now tell me: Suppose you have a plane surface as smooth as a mirror and made of some hard material like steel. This is not parallel to the horizon, but somewhat inclined, and upon it you have placed a ball which is perfectly spherical and of some hard and heavy material like bronze. What do you believe this will do when released? Do you not think, as I do, that it will remain still?

SIMP. If that surface is tilted?

SALV. Yes, that is what was assumed.

SIMP. I do not believe that it would stay still at all; rather, I am sure that it would spontaneously roll down.

SALV. Pay careful attention to what you are saying, Simplicio, for I am certain that it would stay wherever you placed it.

SIMP. Well, Salviati, so long as you make use of assumptions of this sort I shall cease to be surprised that you deduce such false conclusions.

SALV. Then you are quite sure that it would spontaneously move downward?

SIMP. What doubt is there about this? [...]

SALV.... Now how long would the ball continue to roll, and how fast? Remember that I said a perfectly round ball and a highly polished surface, in order to remove all external and accidental impediments. Similarly I want you to take away any impediment of the air caused by its resistance to separation, and all other accidental obstacles, if there are any.

SIMP. I completely understood you, and to your question I reply that the ball would continue to move indefinitely, as far as the slope of the surface extended, and with a continually accelerated motion....

SALV. But if one wanted the ball to move upward on this same surface, do you think it would go?

SIMP. Not spontaneously, no; but drawn or thrown forcibly, it would.

SALV. And if it were thrust along with some impetus impressed forcibly upon it, what would its motion be, and how great?

SIMP. The motion would constantly slow down and be retarded, being contrary to nature, and would be of longer or shorter duration according to the greater or lesser impulse and the lesser or greater slope upward.

SALV. Very well . . .

Now tell me what would happen to the same movable body placed upon a surface with no slope upward or downward.

SIMP. Here I must think a moment about my reply. There being no downward slope, there can be no natural tendency toward motion; and there being no upward slope, there can be no resistance to being moved, so there would be an indifference between the propensity and the resistance to motion. Therefore it seems to me that it ought naturally to remain stable. . . .

SALV. I believe it would do so if one set the ball down firmly. But what would happen if it were given an impetus in any direction?

SIMP. It must follow that it would move in that direction.

SALV. But with what sort of movement? One continually accelerated, as on the downward plane, or increasingly retarded as on the upward one?

SIMP. I cannot see any cause for acceleration or deceleration, there being no slope upward or downward.

SALV. Exactly so. But if there is no cause for the ball's retardation, there ought to be still less for its coming to rest; so how far would you have the ball continue to move?

SIMP. As far as the extension of the surface continued without rising or falling.

SALV. Then if such a space were unbounded, the motion on it would likewise be boundless? That is, perpetual?

SIMP. It seems so to me, if the movable body were of durable material.

SALV. That is of course assumed, since we said that all external and accidental impediments were to be removed, and any fragility on the part of the moving body would in this case be one of the accidental impediments.

Now tell me, what do you consider to be the cause of the ball moving spontaneously on the downward inclined plane, but only by force on the one tilted upward?

SIMP. That the tendency of heavy bodies is to move toward the center of the earth, and to move upward from its circumference only with force; now the downward surface is that which gets closer to the center, while the upward one gets farther away.

SALV. Then in order for a surface to be neither downward nor upward, all its parts must be equally distant from the center. Are there any such surfaces in the world?

SIMP. Plenty of them; such would be the surface of our terrestrial globe if it were smooth, and not rough and mountainous as it is. But there is that of the water, when it is placid and tranquil.

SALV. Then a ship, when it moves over a calm sea, is one of these movables which courses over a surface that is tilted neither up nor down, and if all external and accidental obstacles were removed, it would thus be disposed to move incessantly and uniformly from an impulse once received?

SIMP. It seems that it ought to be.

SALV. Now as to that stone which is on top of the mast; does it not move, carried by the ship, both of them going along the circumference of a circle about its center? And consequently is there not in it an ineradicable motion, all external impediments being removed? And is not this motion as fast as that of the ship?

SIMP. All this is true, but what next?

SALV. Go on and draw the final consequence by yourself, if by yourself you have known all the premises.

SIMP. By the final conclusion you mean that the stone, moving with an indelibly impressed motion, is not going to leave the ship, but will follow it, and finally will fall at the same place where it fell when the ship remained motionless. And I, too, say that this would follow if there were no external impediments to disturb the motion of the stone after it was set free. But there are two such impediments; one is the inability of the movable body to split the air with its own impetus alone, once it has lost the force from the oars which it shared as part of the ship while it was on the mast; the other is the new motion of falling downward, which must impede its other, forward, motion.

SALV. As for the impediment of the air, I do not deny that to you, and if the falling body were of very light material, like a feather or a tuft of wool, the retardation would be quite considerable. But in a heavy stone it is insignificant, and if, as you yourself just said a little while ago, the force of the wildest wind is not enough to move a large stone from its place, just imagine how much the quiet air could accomplish upon meeting a rock which moved no faster than the ship! All the same, as I said, I concede to you the small effect which may depend upon such an impediment, just as I know you will concede to me that if the air were moving at the same speed as the ship and the rock, this impediment would be absolutely nil.

As for the other, the supervening motion downward, in the first place it is obvious that these two motions (I mean the circular around the center and the straight motion toward the center) are not contraries, nor are they destructive of one another, nor incompatible. As to the moving body, it has no resistance whatever to such a motion, for you yourself have already granted the resistance to be against motion which increases the distance from the center, and the tendency to be toward motion which approaches the center. From this it follows necessarily that the moving body has neither a resistance nor a propensity to motion which does not approach toward or depart from the center, and in consequence no cause for diminution in the property impressed upon it. Hence the

cause of motion is not a single one which must be weakened by the new action, but there exist two distinct causes. Of these, heaviness attends only to the drawing of the movable body toward the center, and impressed force only to its being led around the center, so no occasion remains for any impediment. [...]

4.5 Tommaso Campanella, *Civitas Solis (City of the Sun)*, 1623, trans. and intro. Daniel Donno (Berkeley, CA: University of California Press, 1981), pp. 27–37, 43–5

THE CITY OF THE SUN

A POETICAL DIALOGUE

INTERLOCUTORS

A Knight Hospitaller and a Genoese, one of Columbus' sailors

HOSPITALER. Tell me, please, all that happened to you on this voyage.

GENOESE. I have already told you how I sailed around the world and came to Taprobana, where I was forced to put ashore, how I hid in a forest to escape the fury of the natives, and how I came out onto a great plain just below the equator.

HOSPITALER. What happened to you there?

GENOESE. I soon came upon a large company of armed men and women, and many of them understood my language. They led me to the City of the Sun.

HOSPITALER. Tell me, what is that city like, and how is it ruled?

GENOESE. Rising from a broad plain, there is a hill upon which the greater part of the city is situated, but its circling walls extend far beyond its base, so that the entire city is two miles and more in diameter and has a circumference of seven miles; but because it is on a rise, it contains more habitations than it would if it were on a plain.

The city is divided into seven large circuits, named after the seven planets. Passage from one to the other is provided by four avenues and four gates facing the four points of the compass. [...]

At the summit of the hill there is a spacious plain in the center of which rises an enormous temple of astonishing design.

HOSPITALER. Tell me more, I beg you, tell me more.

GENOESE. The temple is perfectly circular and has no enclosing walls. It rests on large, well-proportioned columns. The large dome has a cupola at its center with an aperture directly above the single altar in the middle of the temple. The columns are arranged in a circle having a

circumference of three hundred paces or more. Eight paces beyond them are cloisters with walls scarcely rising above the benches which are arranged along the concave exterior wall. Among the interior columns, which support the temple with no interposing walls, there are a large number of portable chairs.

Nothing rests on the altar but a huge celestial globe, upon which all the heavens are described, with a terrestrial globe beside it. On the vault of the dome overhead appear all the larger stars with their names and the influences they each have upon earthly things set down in three verses. The poles and circles are indicated, but not entirely since there is no wall below. Instead they are completed on the globes resting on the altar below. Seven lamps, each named for one of the seven planets, are always kept burning. ...

HOSPITALER. In good faith, tell me the manner of government you found among these people.

GENOESE. They have a Prince Prelate among them whom they call Sun, but in our language he would be called Metaphysician. He is both their spiritual and their temporal chief, and all decisions terminate with him.

There are also three collateral princes: Pon, Sin, and Mor, that is to say Power, Wisdom, and Love.

Power has charge of war and peace and of military affairs. He is supreme in war, but not above Sun. He has charge over officers, warriors, soldiers, munitions, fortifications, and sieges.

Wisdom has charge of all the sciences and of all the doctors and masters of the liberal and mechanical arts. Below him there are as many officers as there are sciences. There is an Astrologer, a Cosmographer, a Geometer, a Logician, a Rhetorician, a Grammarian, a Physician, a Physical Scientist, a Politician, and a Moralist. Wisdom has but one book in which all the sciences are treated and which is taught to all the people after the manner of the Pythagoreans. He has had all of the sciences pictured on all of the walls and on the ravelins, both inside and out.

On the exterior walls of the temple, on the curtains which are let down when there is preaching so that it may be heard, all the stars are drawn in order, with three descriptive verses assigned to each one.

On the inner wall of the first circuit, all the mathematical figures – more than Euclid or Archimedes speaks of – are shown in their significant propositions. On the outer wall there is a map of the entire world with charts for each country setting forth their rites, customs, and laws; and the alphabet of each is inscribed above the native one.

On the inner wall of the second circuit there are both samples and pictures of all minerals, metals, and stones, both precious and nonprecious, with two descriptive verses for each one. On the outer wall all kinds of lakes, seas, rivers, wines, oils, and other liquids are shown with their sources of origin, their powers, and their qualities indicated. There are also carafes full of diverse liquids, a hundred and even three hundred years old, with which nearly all infirmities are cured.

205. *That it is morally certain that all the things of this world are such as it has been demonstrated here that they can be.*

[...] Suppose for example that someone wants to read a letter written in Latin but encoded so that the letters of the alphabet do not have their proper value, and he guesses that the letter B should be read whenever A appears, and C when B appears, i.e. that each letter should be replaced by the one immediately following it. If, by using this key, he can make up Latin words from the letters, he will be in no doubt that the true meaning of the letter is contained in these words. It is true that his knowledge is based merely on a conjecture, and it is conceivable that the writer did not replace the original letters with their immediate successors in the alphabet, but with others, thus encoding quite a different message; but this possibility is so unlikely (especially if the message contains many words) that it does not seem credible. Now if people look at all the many properties relating to magnetism, fire and the fabric of the entire world, which I have deduced in this book from just a few principles, then, even if they think that my assumption of these principles was arbitrary and groundless, they will still perhaps acknowledge that it would hardly have been possible for so many items to fit into a coherent pattern if the original principles had been false.

206. *Indeed, my explanations possess more than moral certainty.*

Besides, there are some matters, even in relation to the things in nature, which we regard as absolutely... certain. Absolute certainty arises when we believe that it is wholly impossible that something should be otherwise

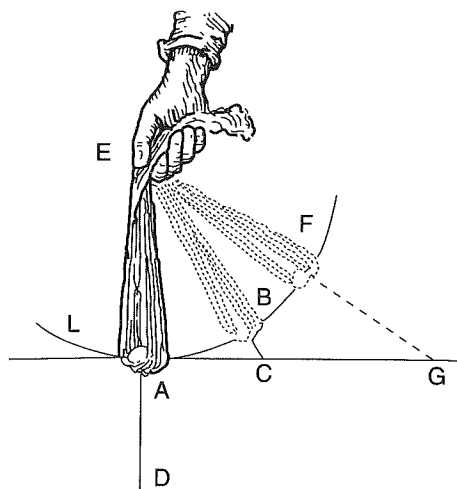


Fig. 5

than we judge it to be. This certainty is based on a metaphysical foundation, namely that God is supremely good and in no way a deceiver, and hence that the faculty which he gave us for distinguishing truth from falsehood cannot lead us into error, so long as we are using it properly and are thereby perceiving something distinctly. Mathematical demonstrations have this kind of certainty, as does the knowledge that material things exist; and the same goes for all evident reasoning about material things. And perhaps even these results of mine will be allowed into the class of absolute certainties, if people consider how they have been deduced in an unbroken chain from the first and simplest principles of human knowledge. Their certainty will be especially appreciated if it is properly understood that we can have no sensory awareness of external objects unless these objects produce some local motion in our nerves; and that the fixed stars, owing to their enormous distance from us, cannot produce such motion unless there is also some motion occurring both in them and also throughout the entire intervening part of the heavens. Once this is accepted, then it seems that all the other phenomena, or at least the general features of the universe and the earth which I have described, can hardly be intelligibly explained except in the way I have suggested.

207. *I submit all my views to the authority of the Church.*

Nevertheless, mindful of my own weakness, I make no firm pronouncements, but submit all these opinions to the authority of the Catholic Church and the judgement of those wiser than myself. And I would not wish anyone to believe anything except what he is convinced of by evident and irrefutable reasoning.

7.2 Blaise Pascal, *Story of the Great Experiment on the Equilibrium of Fluids*, 1648, trans. I. Spiers and A. Spiers from *The Physical Treatises of Pascal* (New York: Octagon Books, 1973), pp. 97–112

The weather on Saturday last, the nineteenth of this month, was very unsettled. At about five o'clock in the morning, however, it seemed sufficiently clear; and since the summit of the Puy de Dôme was then visible, I decided to go there to make the attempt. To that end I notified several people of standing in this town of Clermont, who had asked me to let them know when I would make the ascent. Of this company some were clerics, others laymen. Among the clerics was the Very Revd. Father Bannier, one of the Minim Fathers of this city, who has on several occasions been 'Corrector' (that is, Father Superior), and the Monsieur Mosnier, Canon of the Cathedral Church of this city; among the laymen were Messieurs La Ville and Begon, councillors to the Court of Aids, and Monsieur La Porte, a doctor of medicine, practising here. All these men are very able, not only in the practice of their professions, but also in every field of intellectual interest. It was a delight to have them with me in this fine work.

On that day, therefore, at eight o'clock in the morning, we started off all together for the garden of the Minim Fathers, which is almost the lowest spot in the town, and there began the experiment in this manner.

First, I poured into a vessel six pounds of quicksilver which I had rectified during the three days preceding; and having taken glass tubes of the same size, each four feet long and hermetically sealed at one end but open at the other, I placed them in the same vessel and carried out with each of them the usual vacuum experiment. Then, having set them up side by side without lifting them out of the vessel, I found that the quicksilver left in each of them stood at the same level, which was twenty-six inches and three and a half lines above the surface of the quicksilver in the vessel. I repeated this experiment twice at this same spot, in the same tubes, with the same quicksilver, and in the same vessel; and found in each case that the quicksilver in the two tubes stood at the same horizontal level, and at the same height as in the first trial.

That done, I fixed one of the tubes permanently in its vessel for continuous experiment. I marked on the glass the height of the quicksilver, and leaving that tube where it stood, I requested Revd. Father Chastin, one of the brothers of the house, a man as pious as he is capable, and one who reasons very well upon these matters, to be so good as to observe from time to time all day any changes that might occur. With the other tube and a portion of the same quicksilver, I then proceeded with all these gentlemen to the top of the Puy de Dôme, some 500 fathoms above the Convent. There, after I had made the same experiments in the same way that I had made them at the Minims, we found that there remained in the tube, a height of only twenty-three inches and two lines of quicksilver; whereas in the same tube, at the Minims we had found a height of twenty-six inches and three and a half lines. Thus between the heights of the quicksilver in the two experiments there proved to be a difference of three inches one line and a half. We were so carried away with wonder and delight, and our surprise was so great that we wished, for our own satisfaction, to repeat the experiment. So I carried it out with the greatest care five times more at different points on the summit of the mountain, once in the shelter of the little chapel that stands there, once in the open, once shielded from the wind, once in the wind, once in fine weather, once in the rain and fog which visited us occasionally. Each time I most carefully rid the tube of air; and in all these experiments we invariably found the same height of quicksilver. This was twenty-three inches and two lines, which yields the same discrepancy of three inches, one line and a half in comparison with the twenty-six inches, three lines and a half which had been found at the Minims. This satisfied us fully.

Later, on the way down at a spot called Lafon de l'Arbre, far above the Minims but much farther below the top of the mountain, I repeated the same experiment, still with the same tube, the same quicksilver, and the same vessel, and there found that the height of the quicksilver left in

the tube was twenty-five inches. I repeated it a second time at the same spot; and Monsieur Mosnier, one of those previously mentioned, having the curiosity to perform it himself, then did so again, at the same spot. All these experiments yielded the same height of twenty-five inches, which is one inch, three lines and a half less than that which we had found at the Minims, and one inch and ten lines more than we had just found at the top of the Puy de Dôme. It increased our satisfaction not a little to observe in this way that the height of the quicksilver diminished with the altitude of the site.

On my return to the Minims I found that the [quicksilver in the] vessel I had left there in continuous operation was at the same height at which I had left it, that is, at twenty-six inches, three lines and a half; and the Revd. Father Chastin, who had remained there as observer, reported to us that no change had occurred during the whole day, although the weather had been very unsettled, now clear and still, now rainy, now very foggy, and now windy.

Here I repeated the experiment with the tube I had carried to the Puy de Dôme, but in the vessel in which the tube used for the continuous experiment was standing. I found that the quicksilver was at the same level in both tubes and exactly at the height of twenty-six inches, three lines and a half, at which it had stood that morning in this same tube, and as it had stood all day in the tube used for the continuous experiment.

I repeated it again a last time, not only in the same tube I had used on the Puy de Dôme, but also with the same quicksilver and in the same vessel that I had carried up the mountain; and again I found the quicksilver at the same height of twenty-six inches, three lines and a half which I had observed in the morning, and thus finally verified the certainty of our results.

the Interpretation of Nature what the doctrine of the refutation of Sophisms is to common Logic.

XLI.

The Idols of the Tribe have their foundation in human nature itself, and in the tribe or race of men. For it is a false assertion that the sense of man is the measure of things. On the contrary, all perceptions as well of the sense as of the mind are according to the measure of the individual and not according to the measure of the universe. And the human understanding is like a false mirror, which, receiving rays irregularly, distorts and discolours the nature of things by mingling its own nature with it.

XLII.

The Idols of the Cave are the Idols of the individual man. For every one (besides the errors common to human nature in general) has a cave or den of his own, which refracts and discolours the light of nature; owing either to his own proper and peculiar nature; or to his education and conversation with others; or to the reading of books, and the authority of those whom he esteems and admires; or to the differences of impressions, accordingly as they take place in a mind preoccupied and predisposed or in a mind indifferent and settled; or the like. So that the spirit of man (according as it is meted out to different individuals) is in fact a thing variable and full of perturbation, and governed as it were by chance. Whence it was well observed by Heraclitus that men look for sciences in their own lesser worlds, and not in the greater or common world.

XLIII.

There are also Idols formed by the intercourse and association of men with each other, which I call Idols of the Market-place, on account of the commerce and consort of men there. For it is by discourse that men associate; and words are imposed according to the apprehension of the vulgar. And therefore the ill and unfit choice of words wonderfully obstructs the understanding. Nor do the definitions or explanations wherewith in some things learned men are wont to guard and defend themselves, by any means set the matter right. But words plainly force and overrule the understanding, and throw all into confusion, and lead men away into numberless empty controversies and idle fancies.

XLIV.

Lastly, there are Idols which have immigrated into men's minds from the various dogmas of philosophies, and also from wrong laws of demonstration. These I call Idols of the Theatre; because in my judgment all the received systems are but so many stage-plays, representing worlds of their own creation after an unreal and scenic fashion. Nor is it only of the systems now in vogue, or only of the ancient sects and philosophies, that I speak; for many more plays of the same kind may yet be composed and in like artificial manner set forth; seeing that errors the most widely different have nevertheless causes for the most part alike. Neither again do I mean this only of entire systems,

but also of many principles and axioms in science, which by tradition, credulity, and negligence have come to be received....

8.4 Robert Hooke, Preface, *Micrographia*, 1665 (New York: Dover Publications, 1961)

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 priviledge of humane Nature in general, so is it capable of being so far advanced by the helps of Art, and Experience, as to



By the Council of the ROYAL SOCIETY of *London* for Improving of Natural Knowledge.

Ordered, That the Book written by Robert Hooke, M.A. Fellow of this Society, Emituled, Micrographia, or some Phyfiological Descriptions of Minute Bodies, made by Magnifying Glaffes, with Obfervations and Inquiries thereupon, Be printed by John Martyn, and James Allestry, Printers to the said Society.

Novem. 23.

1664.

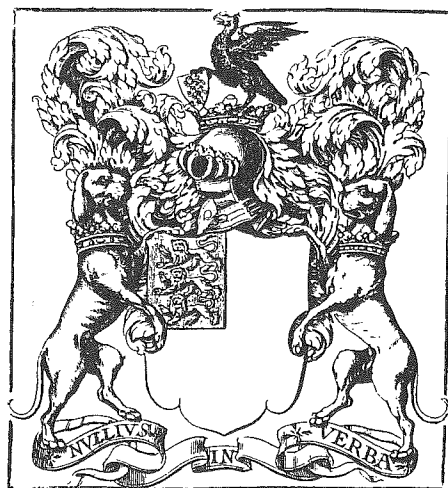
BROUNCKER. *P. R. S.*



MICROGRAPHIA:
OR SOME
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MADE BY
MAGNIFYING GLASSES.
WITH
OBSERVATIONS and INQUIRIES thereupon.

By *R. HOOKE*, Fellow of the **ROYAL SOCIETY**.

*Non possis oculo quantum contendere Linceus,
Non tamen idcirco contemnas Lippus inungi.* Horat. Ep. lib. 1.



LONDON, Printed by *Jo. Martyn*, and *Ja. Allestry*, Printers to the
ROYAL SOCIETY, and are to be sold at their Shop at the *Bell* in
S. Paul's Church-yard. M DC LX V.

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 is 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 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 antient 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 antient 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. [...]

And I beg my Reader, to let me take the boldness to assure him, that in this present condition of knowledge, a man so qualified, as I have indeavoured to be, only with resolution, and integrity, and plain intentions of imploying his Senses aright, may venture to compare the reality and the usefulness of his services, towards the true Philosophy, with those of other men, that are of much stronger, and more acute speculations, that shall not make use of the same method by the Senses.

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. [...]

The Indeavours of Skilful men have been most conversant about the assistance of the Eye, and many noble Productions have followed upon it; and from hence we may conclude, that there is a way open'd for advancing the operations, not only of all the other Senses, but even of the Eye it self; that which has been already done ought not to content us, but rather to incourage us to proceed further, and to attempt greater things in the same and different wayes.

'Tis not unlikely, but that there may be yet invented several other helps for the eye, as 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 improbable also, but that the sense of feeling may be highly improv'd, for that being a sense that judges of the more gross and robust motions of the Particles of Bodies, seems capable of being improv'd and assisted very many wayes. Thus for the distinguishing of Heat and Cold, the Weather-glass and Thermometer, which I have describ'd in this following Treatise, do exceedingly perfect it; by each of which the least variations of heat or cold, which the most Acute sense is not able to distinguish, are manifested. This is oftentimes further promoted also by the help of Burning-glasses, and the like, which collect and unite the radiating heat. Thus the roughness and smoothness of a Body is made much more sensible by the help of a Microscope, then by the most tender and delicate Hand. Perhaps, a Physitian might, by several other tangible proprieties, discover the constitution of a Body as well as by the Pulse. [...]

8.5 Robert Boyle, *Some Considerations Touching the Usefulness of Experimental Natural Philosophy, the Second Tome*, 1671, in M. Hunter and E. Davis (eds), *The Works of Robert Boyle*, vol. 6 (London: Pickering & Chatto, 1999), pp. 396–400 (vols 1–14 1999–2000)

[...] If it be ask'd why I did not forbear to make use of some Practises of tradesmen and other known, and perhaps seemingly triviall, Experiments. These things may be replied,

1. That since on divers occasions it was requisite, that my discourse should tend rather to convince than barely to inform my reader, it was proper, that I should imploy at least Some instances, whose truth was generally enough known, or easy to be known (by making inquiry among Artificers) even by such as out of lasiness, or want of Skill, or accommodation cannot conveniently make themselves the tryals.

2. But yet, I have taken care, that these should not be the only, nor yet the most numerous instances, I make use of: it being in this Tome, as well as in my other Physiologicall writings, my main businesse, to take all just Occasions to contribute as much, as without indiscretion I can, to the history of Nature and Arts.

3. As to the Practices and observations of Tradesmen, the two considerations already alledged, may both of them be extended to the giving of an account of the mention I make of them. Of the truth of divers of the Experiments I alledge of theirs, one may be easily satisfied by inquiring of Artificers about it, and the particular or more circumstantial accounts I give of some of their experiments, I was induc'd to set down by my desire to contribute toward an experimental History. For I have found by long and unwelcome experience, that very few Tradesmen will and can give a man a clear and full account of their own Practices; partly out of Envy, partly out of want of skill to deliver a relation intelligibly enough, and partly (to which I may add chiefly) because they omitt generally, to express either at all or at least clearly some important circumstance, which because long use hath made very familiar to them, they presume also to be known to others: and yet the omission of such circumstances, doth often render the Accounts they give of such practices, so darke and so defective, that, if their experiments be any thing intricate or difficult (for if they be Simple and easy, they are not so liable to produce mistakes) I seldom thinke my self sure of their truth, and that I sufficiently comprehend them, till I have either tryed them at home, or caused the Artificers to make them in my presence.

They that have given themselves the trouble of endeavouring to make the experiments of Tradesmen, to be met with in the writings of Cardan, Weckar, and Baptista Porta for instance, and have thereby discovered (what is not usually obvious upon a transient reading) how lamely and darkely, (not to add unintelligibly) severall things are written, will probably afford me their Assent, having found upon tryal the instructions of such learned and ingenious men, to be often obscure and insufficient for practice.