

Galileo Galilei (1564-1642):

Letter to the Grand Duchess Christina of Tuscany (1615)

Adapted from the Internet Modern History Sourcebook (Excerpts)

To the Most Serene Grand Duchess Mother:

Some years ago, as Your Serene Highness well knows, I discovered in the heavens many things that had not been seen before our own age. The novelty of these things, as well as some consequences which followed from them in contradiction to the physical notions commonly held among academic philosophers, stirred up against me no small number of professors-as if I had placed these things in the sky with my own hands in order to upset nature and overturn the sciences. They seemed to forget that the increase of known truths stimulates the investigation, establishment, and growth of the arts; not their diminution or destruction.

Showing a greater fondness for their own opinions than for truth they sought to deny and disprove the new things which, if they had cared to look for themselves, their own senses would have demonstrated to them. To this end they hurled various charges and published numerous writings filled with vain arguments, and they made the grave mistake of sprinkling these with passages taken from places in the Bible which they had failed to understand properly, and which were ill-suited to their purposes.

These men would perhaps not have fallen into such error had they but paid attention to a most useful doctrine of St. Augustine's, relative to our making positive statements about things which are obscure and hard to understand by means of reason alone. Speaking of a certain physical conclusion about the heavenly bodies, he wrote: "Now keeping always our respect for moderation in grave piety, we ought not to believe anything inadvisedly on a dubious point, lest in favor to our error we conceive a prejudice against something that truth hereafter may reveal to be not contrary in any way to the sacred books of either the Old or the New Testament."

Well, the passage of time has revealed to everyone the truths that I previously set forth; and, together with the truth of the facts, there has come to light the great difference in attitude between those who simply and dispassionately refused to admit the discoveries to be true, and those who combined with their incredulity some reckless passion of their own. Men who were well grounded in astronomical and physical science were persuaded as soon as they received my first message. There were others who denied them or remained in doubt only because of their novel and unexpected character, and because

they had not yet had the opportunity to see for themselves. These men have by degrees come to be satisfied. But some, besides allegiance to their original error, possess I know not what fanciful interest in remaining hostile not so much toward the things in question as toward their discoverer. No longer being able to deny them, these men now take refuge in obstinate silence, but being more than ever exasperated by that which has pacified and quieted other men, they divert their thoughts to other fancies and seek new ways to damage me.

I should pay no more attention to them than to those who previously contradicted me-at whom I always laugh, being assured of the eventual outcome-were it not that in their new calumnies and persecutions I perceive that they do not stop at proving themselves more learned than I am (a claim which I scarcely contest), but go so far as to cast against me the imputations of crimes which must be, and are, more abhorrent to me than death itself. I cannot remain satisfied merely to know that the injustice of this is recognized by those who are acquainted with these men and with me, as perhaps it is not known to others.

Persisting in their original resolve to destroy me and everything mine by any means they can think of, these men are aware of my views in astronomy and philosophy. They know that as to the arrangement of the parts of the universe, I hold the sun to be situated motionless in the center of the revolution of the celestial orbs while the earth revolves about the sun. They know also that I support this position not only by refuting the arguments of Ptolemy and Aristotle, but by producing many counter-arguments; in particular, some which relate to physical effects whose causes can perhaps be assigned in no other way. In addition there are astronomical arguments derived from many things in my new celestial discoveries that plainly confute the Ptolemaic system while admirably agreeing with and confirming the contrary hypothesis. Possibly because they are disturbed by the known truth of other propositions of mine which differ from those commonly held, and therefore mistrusting their defense so long as they confine themselves to the field of philosophy, these men have resolved to fabricate a shield for their fallacies out of the mantle of pretended religion and the authority of the Bible. These they apply with little judgment to the refutation of arguments that they do not understand and have not even listened to.

First they have endeavored to spread the opinion that such propositions in general are contrary to the Bible and are consequently damnable and heretical. They know that it is human nature to take up causes whereby a man may oppress his neighbor, no matter how unjustly, rather than those from which a man may receive some just encouragement. Hence they have had no trouble in finding men who would preach the damnability and heresy of the new doctrine from their very pulpits with unwonted confidence, thus doing impious and inconsiderate injury not only to that doctrine and its followers but to all mathematics and mathematicians in general. Next, becoming bolder, and hoping (though vainly) that this seed which first took root in their hypocritical minds would send out branches and ascend to heaven, they began scattering rumors among the people that before long this doctrine would be condemned by the supreme authority. They know, too, that official condemnation would not only suppress the two propositions which I have mentioned, but would render damnable all other astronomical and physical statements and observations that have any necessary relation or connection with these.

In order to facilitate their designs, they seek so far as possible (at least among the common people) to make this opinion seem new and to belong to me alone. They pretend not to know that its author, or rather its restorer and confirmer, was Nicholas Copernicus; and that he was not only a Catholic, but a priest and a canon. He was in fact so esteemed by the church that when the Lateran Council under Leo X took up the correction of the church calendar, Copernicus was called to Rome from the most remote parts of Germany to undertake its reform. At that time the calendar was defective because the true measures of the year and the lunar month were not exactly known. The Bishop of Culm, then superintendent of this matter, assigned Copernicus to seek more light and greater certainty concerning the celestial motions by means of constant study and labor. With Herculean toil he set his admirable mind to this task, and he made such great progress in this science and brought our knowledge of the heavenly motions to such precision that he became celebrated as an astronomer. Since that time not only has the calendar been regulated by his teachings, but tables of all the motions of the planets have been calculated as well.

Having reduced his system into six books, he published these at the instance of the Cardinal of Capua and the Bishop of Culm. And since he had assumed his laborious enterprise by order of the supreme pontiff, he dedicated this book *On the celestial revolutions* to Pope Paul III. When printed,

the book was accepted by the holy Church, and it has been read and studied by everyone without the faintest hint of any objection ever being conceived against its doctrines. Yet now that manifest experiences and necessary proofs have shown them to be well grounded, persons exist who would strip the author of his reward without so much as looking at his book, and add the shame of having him pronounced a heretic. All this they would do merely to satisfy their personal displeasure conceived without any cause against another man, who has no interest in Copernicus beyond approving his teachings.

Now as to the false aspersions which they so unjustly seek to cast upon me, I have thought it necessary to justify myself in the eyes of all men, whose judgment in matters of religion and of reputation I must hold in great esteem. I shall therefore discourse of the particulars which these men produce to make this opinion detested and to have it condemned not merely as false but as heretical. To this end they make a shield of their hypocritical zeal for religion. They go about invoking the Bible, which they would have minister to their deceitful purposes. Contrary to the sense of the Bible and the intention of the holy Fathers, if I am not mistaken, they would extend such authorities until even in purely physical matters - where faith is not involved - they would have us altogether abandon reason and the evidence of our senses in favor of some biblical passage, though under the surface meaning of its words this passage may contain a different sense.

I hope to show that I proceed with much greater piety than they do, when I argue not against condemning this book, but against condemning it in the way they suggest - that is, without understanding it, weighing it, or so much as reading it. For Copernicus never discusses matters of religion or faith, nor does he use argument that depend in any way upon the authority of sacred writings which he might have interpreted erroneously. He stands always upon physical conclusions pertaining to the celestial motions, and deals with them by astronomical and geometrical demonstrations, founded primarily upon sense experiences and very exact observations. He did not ignore the Bible, but he knew very well that if his doctrine were proved, then it could not contradict the Scriptures when they were rightly understood and thus at the end of his letter of dedication, addressing the pope, he said:

“If there should chance to be any exegetes ignorant of mathematics who pretend to skill in that discipline, and dare to condemn and censure this hypothesis of mine upon the authority of some scriptural passage twisted to their purpose, I value

them not, but disdain their unconsidered judgment. For it is known that Lactantius - a poor mathematician though in other respects a worthy author - writes very childishly about the shape of the earth when he scoffs at those who affirm it to be a globe. Hence it should not seem strange to the ingenious if people of that sort should in turn deride me. But mathematics is written for mathematicians, by whom, if I am not deceived, these labors of mine will be recognized as contributing something to their domain, as also to that of the Church over which Your Holiness now reigns.”

Such are the people who labor to persuade us that an author like Copernicus may be condemned without being read, and who produce various authorities from the Bible, from theologians, and from Church Councils to make us believe that this is not only lawful but commendable. Since I hold these to be of supreme authority I consider it rank temerity for anyone to contradict them-when employed according to the usage of the holy Church. Yet I do not believe it is wrong to speak out when there is reason to suspect that other men wish, for some personal motive, to produce and employ such authorities for purposes quite different from the sacred intention of the holy Church.

Therefore I declare (and my sincerity will make itself manifest) not only that I mean to submit myself freely and renounce any errors into which I may fall in this discourse through ignorance of matters pertaining to religion, but that I do not desire in these matters to engage in disputes with anyone, even on points that are disputable. My goal is this alone; that if, among errors that may abound in these considerations of a subject remote from my profession, there is anything that may be serviceable to the holy Church in making a decision concerning the Copernican system, it may be taken and utilized as seems best to the superiors. And if not, let my book be torn and burnt, as I neither intend nor pretend to gain from it any fruit that is not pious and Catholic. And though many of the things I shall reprove have been heard by my own ears, I shall freely grant to those who have spoken them that they never said them, if that is what they wish, and I shall confess myself to have been mistaken. Hence let whatever I reply be addressed not to them, but to whoever may have held such opinions.

The reason produced for condemning the opinion that the earth moves and the sun stands still 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 a 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-whenver 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 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. Perhaps this is what Tertullian meant by these words:

“We conclude that God is known first through Nature, and then again, more particularly, by doctrine, by Nature in His works, and by doctrine in His revealed word.”

From this I do not mean to infer that we need not have an extraordinary esteem for the passages of holy Scripture. On the contrary, having arrived at any certainties in physics, we ought to utilize these as the most appropriate aids in the true exposition of the Bible and in the investigation of those meanings which are necessarily contained therein, for these must be concordant with demonstrated truths. I should judge that the authority of the Bible was designed to persuade men of those articles and propositions which, surpassing all human reasoning could not be made credible by science, or by any other means than through the very mouth of the Holy Spirit.

Yet even in those propositions which are not matters of faith, this authority ought to be preferred over that of all human writings which are supported only by bare assertions or probable arguments, and not set forth in a demonstrative way. This I hold to be necessary and proper to the same extent that divine wisdom surpasses all human judgment and conjecture.

But I do not feel obliged to believe that the same God who has endowed us with senses, reason and intellect has intended us to forego 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 other 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. Such is the opinion of the holiest and most learned Fathers, and in St. Augustine we find the following words: “It is likewise commonly asked what we may believe about the form and shape of the heavens according to the Scriptures, for many contend much about these matters. But with superior prudence our authors have forborne to speak of this, as in no way furthering the student with respect to a blessed life-and, more important still, as taking up much of that time which should be spent in holy exercises. What is it to me whether heaven, like a sphere surrounds the earth on all sides as a mass balanced in the center of the universe, or whether like a dish it merely covers and overcasts the earth? Belief in Scripture is urged rather for the reason we have often mentioned; that is, in order that no one, through ignorance of divine passages, finding anything in our Bibles or hearing anything cited from them of such a nature as may seem to oppose manifest conclusions, should be induced to suspect their truth when they teach, relate, and deliver more profitable matters. Hence let it be said briefly, touching the form of heaven, that our authors knew the truth but the Holy Spirit did not desire that men should learn things that are useful to no one for salvation.”

The same disregard of these sacred authors toward beliefs about the phenomena of the celestial bodies is repeated to us by St. Augustine in his next chapter. On the question whether we are to believe that the heaven moves or stands still, he writes thus:

“Some of the brethren raise a question concerning the motion of heaven, whether it is fixed or moved. If it is moved, they say, how is it a firmament? If it stands still, how do these stars which are held fixed in it go round from east to west, the more northerly performing shorter circuits near the pole, so that the heaven (if there is another pole unknown to us) may seem to revolve upon some axis, or (if there is no other pole) may be thought to move as a discus? To these men I reply that it would require many subtle and profound reasonings to find

out which of these things is actually so; but to undertake this and discuss it is consistent neither with my leisure nor with the duty of those whom I desire to instruct in essential matters more directly conducing to their salvation and to the benefit of the holy Church.”

From these things it follows as a necessary consequence that, since the Holy Ghost did not intend to teach us whether heaven moves or stands still, whether its shape is spherical or like a discus or extended in a plane, nor whether the earth is located at its center or off to one side, then so much the less was it intended to settle for us any other conclusion of the same kind. And the motion or rest of the earth and the sun is so closely linked with the things just named, that without a determination of the one, neither side can be taken in the other matters. Now if the Holy Spirit has purposely neglected to teach us propositions of this sort as irrelevant to the highest goal (that is, to our salvation), how can anyone affirm that it is obligatory to take sides on them, that one belief is required by faith, while the other side is erroneous? Can an opinion be heretical and yet have no concern with the salvation of souls? Can the Holy Ghost be asserted not to have intended teaching us something that does concern our salvation? I would say here something that was heard from an ecclesiastic of the most eminent degree: “That the intention of the Holy Ghost is to teach us how one goes to heaven. not how heaven goes.”

But let us again consider the degree to which necessary demonstrations and sense experiences ought to be respected in physical conclusions, and the authority they have enjoyed at the hands of holy and learned theologians. From among a hundred attestations I have selected the following:

“We must also take heed, in handling the doctrine of Moses, that we altogether avoid saying positively and confidently anything which contradicts manifest experiences and the reasoning of philosophy or the other sciences. For since every truth is in agreement with all other truth, the truth of Holy Writ cannot be contrary to the solid reasons and experiences of human knowledge.”

And in St. Augustine we read:

“If anyone shall set the authority of Holy Writ against clear and manifest reason, he who does this knows not what he has undertaken; for he opposes to the truth not the meaning of the Bible, which is beyond his comprehension, but rather his own interpretation, not what is in the Bible, but what he has found in himself and imagines to be there.”

This granted, and it being true that two truths cannot contradict one another, it is the function of expositors to seek out the true senses of scriptural texts. These will unquestionably accord with the

physical conclusions which manifest sense and necessary demonstrations have previously made certain to us. Now the Bible, as has been remarked, admits in many places expositions that are remote from the signification of the words for reasons we have already given. Moreover, we are unable to affirm that all interpreters of the Bible speak by Divine inspiration for if that were so there would exist no differences among them about the sense of a given passage. Hence I should think it would be the part of prudence not to permit anyone to usurp scriptural texts and force them in some way to maintain any physical conclusion to be true, when at some future time the senses and demonstrative or necessary reasons may show the contrary. Who indeed will set bounds to human ingenuity? Who will assert that everything in the universe capable of being perceived is already discovered and known? Let us rather confess quite truly that “Those truths which we know are very few in comparison with those which we do not know.”

We have it from the very mouth of the Holy Ghost that God delivered up the world to disputations, so that man cannot find out the work that God hath done from the beginning even to the end. In my opinion no one, in contradiction to that dictum, should close the road to free philosophizing about mundane and physical things, as if everything had already been discovered and revealed with certainty. Nor should it be considered rash not to be satisfied with those opinions which have become common. No one should be scorned in physical disputes for not holding to the opinions which happen to please other people best, especially concerning problems which have been debated among the greatest philosophers for thousands of years. One of these is the stability of the sun mobility of the earth, a doctrine believed by Pythagoras and all his followers, by Heraclides of Pontus (who was one of them), by Philolaus, the teacher of Plato, and by Plato himself according to Aristotle. Plutarch writes in his Life of Numa that Plato, when he had grown old, said it was absurd to believe otherwise. The same doctrine was held by Aristarchus of Samos, as Archimedes tells us; by Seleucus the mathematician, by Nicetas the philosopher (on the testimony of Cicero), and by many others. Finally this opinion has been amplified and confirmed with many observations and demonstrations by Nicholas Copernicus. And Seneca, a most eminent philosopher, advises us in his book on comets that we should more diligently seek to ascertain whether it is in the sky or in the earth that the diurnal rotation resides.

Hence it would probably be wise and useful counsel if, beyond articles which concern salvation and the establishment of our Faith, against the

stability of which there is no danger whatever that any valid and effective doctrine can ever arise, men would not aggregate further articles unnecessarily. And it would certainly be preposterous to introduce them at the request of persons, who, besides not being known to speak by inspiration of divine grace, are clearly seen to lack that understanding which is necessary in order to comprehend, let alone discuss, the demonstrations by which such conclusions are supported in the subtler sciences. If I may speak my opinion freely, I should say further that it would perhaps fit in better with the decorum and majesty of the sacred writings to take measures for preventing every shallow and vulgar writer from giving to his compositions (often grounded upon foolish fancies) an air of authority by inserting in them passages from the Bible, interpreted (or rather distorted) into senses as far from the right meaning of Scripture as those authors are near to absurdity who thus ostentatiously adorn their writings. Of such abuses many examples might be produced, but for the present I shall confine myself to two which are germane to these astronomical matters. The first concerns those writings which were published against the existence of the Medicean planets recently discovered by me, in which many passages of holy Scripture were cited. Now that everyone has seen these planets, I should like to know what new interpretations those same antagonists employ in expounding the Scripture and excusing their own simplicity. My other example is that of a man who has lately published, in defiance of astronomers and philosophers, the opinion that the moon does not receive its light from the sun but is brilliant by its own nature. He supports this fancy (or rather thinks he does) by sundry texts of Scripture which he believes cannot be explained unless his theory is true; yet that the moon is inherently dark is surely as plain as daylight.

It is obvious that such authors, not having penetrated the true senses of Scripture, would impose upon others an obligation to subscribe to conclusions that are repugnant to manifest reason and sense, if they had any authority to do so. God forbid that this sort of abuse should gain countenance and authority, for then in a short time it would be necessary to proscribe all the contemplative sciences. People who are unable to understand perfectly both the Bible and the science far outnumber those who do understand them. The former, glancing superficially through the Bible, would arrogate to themselves the authority to decree upon every question of physics on the strength of some word which they have misunderstood, and which was employed by the sacred authors for some different purpose. And the smaller number of understanding men could not dam up the furious torrent of such people, who would gain the majority

of followers simply because it is much more pleasant to gain a reputation for wisdom without effort or study than to consume oneself tirelessly in the most laborious disciplines. Let us therefore render thanks to Almighty God, who in His beneficence protects us from this danger by depriving such persons of all authority, reposing the power of consultation, decision, and decree on such important matters in the high wisdom and benevolence of most prudent Fathers, and in the supreme authority of those who cannot fail to order matters properly under the guidance of the Holy Ghost. Hence we need not concern ourselves with the shallowness of those men whom grave and holy authors rightly reproach, and of whom in particular St. Jerome said, in reference to the Bible:

“This is ventured upon, lacerated, and taught by the garrulous old woman, the dotting old man, and the prattling sophist before they have learned it. Others, led on by pride, weigh heavy words and philosophize amongst women concerning holy Scripture. Others—oh shame!—learn from women what they teach to men, and (as if that were not enough) glibly expound to others that which they themselves do not understand. I forbear to speak of those of my own profession who, attaining a knowledge of the holy Scriptures after mundane learning, tickle the ears of the people with affected and studied expressions, and declare that everything they say is to be taken as the law of God. Not bothering to learn what the prophets and the apostles have maintained, they wrest incongruous testimonies into their own senses—as if distorting passages and twisting the Bible to their individual and contradictory whims were the genuine way of teaching, and not a corrupt one.”

I do not wish to place in the number of such lay writers some theologians whom I consider men of profound learning and devout behavior, and who are therefore held by me in great esteem and veneration. Yet I cannot deny that I feel some discomfort which I should like to have removed, when I hear them pretend to the power of constraining others by scriptural authority to follow in a physical dispute that opinion which they think best agrees with the Bible, and then believe themselves not bound to answer the opposing reasons and experiences. In explanation and support of this opinion they say that since theology is queen of all the sciences, she need not bend in any way to accommodate herself to the teachings of less worthy sciences which are subordinate to her; these others must rather be referred to her as their supreme empress, changing and altering their conclusions according to her statutes and decrees. They add further that if in the inferior sciences any conclusion should be taken as certain in virtue of demonstrations or experiences,

while in the Bible another conclusion is found repugnant to this, then the professors of that science should themselves undertake to undo their proofs and discover the fallacies in their own experiences, without bothering the theologians and exegetes. For, they say, it does not become the dignity of theology to stoop to the investigation of fallacies in the subordinate sciences; it is sufficient for her merely to determine the truth of a given conclusion with absolute authority, secure in her inability to err.

Now the physical conclusions in which they say we ought to be satisfied by Scripture, without glossing or expounding it in senses different from the literal, are those concerning which the Bible always speaks in the same manner and which the holy Fathers all receive and expound in the same way. But with regard to these judgments I have had occasion to consider several things, and I shall set them forth in order that I may be corrected by those who understand more than I do in these matters—for to their decisions I submit at all times.

First I question whether there is not some equivocation in failing to specify the virtues which entitle sacred theology to the title of “queen.” It might deserve that name by reason of including everything that is included from all the other sciences and establishing everything by better methods and with profounder learning. It is thus, for example, that the rules for measuring fields and keeping accounts are much more excellently contained in arithmetic and in the geometry of Euclid than in the practices of surveyors and accountants. Or theology might be queen because of being occupied with a subject which excels in dignity all the subjects which compose the other sciences, and because her teachings are divulged in more sublime ways.

That the title and authority of queen belongs to theology in the first sense, I think, will not be affirmed by theologians who have any skill in the other sciences. None of these, I think, will say that geometry, astronomy, music, and medicine are much more excellently contained in the Bible than they are in the books of Archimedes, Ptolemy, Boethius, and Galen. Hence it seems likely that regal preeminence is given to theology in the second sense; that is, by reason of its subject and the miraculous communication of divine revelation of conclusions which could not be conceived by men in any other way, concerning chiefly the attainment of eternal blessedness.

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. This difference was well understood by the learned and holy Fathers, as proven by their having taken great pains in refuting philosophical fallacies. This may be found expressly in some of them; in particular, we find the following words of St. Augustine:

“It is to be held as an unquestionable truth that whatever the sages of this world have demonstrated concerning physical matters is in no way contrary to our Bibles, hence whatever the sages teach in their books that is contrary to the holy Scriptures may be concluded without any hesitation to be quite false. And according to our ability let us make this evident, and let us keep the faith of our Lord, in whom are hidden all the treasures of wisdom so that we neither become seduced by the verbiage of false philosophy

nor frightened by the superstition of counterfeit religion.”

From the above words I conceive that I may deduce this doctrine That in the books of the sages of this world there are contained some physical truths which are soundly demonstrated, and others that are merely stated; as to the former, it is the office of wise divines to show that they do not contradict the holy Scriptures And as to the propositions which are stated but not rigorously demonstrated, anything contrary to the Bible involved by them must be held undoubtedly false and should be proved so by every possible means.

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 at 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 these 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. And to prohibit the whole science would be to censure a hundred passages of holy Scripture which teach us that the glory and greatness of Almighty God are marvelously discerned in all his works and divinely read in the open book of heaven. For let no one believe that reading the lofty concepts written in that book leads to nothing further than the mere seeing of the splendor of the sun and the stars and their rising and setting, which is as far as the eyes of brutes and of the vulgar can penetrate. Within its pages are couched mysteries so profound and concepts so sublime that the vigils, labors, and studies of hundreds upon hundreds of the most acute minds have still not pierced them, even after the continual investigations for thousands of years. The eyes of an idiot perceive little by beholding the external appearance of a human body, as compared with the wonderful contrivances which a careful and practiced anatomist or philosopher discovers in that same body when he seeks out the use of all those muscles, tendons, nerves, and bones; or when examining the functions of the heart and the other principal organs, he seeks the seat of the vital faculties, notes and observes the admirable structure of the sense organs, and (without ever ceasing in his amazement and delight) contemplates the receptacles of the imagination, the memory, and the understanding. Likewise, that which presents itself to mere sight is as nothing in comparison with the high marvels that the ingenuity of learned men discovers in the heavens by long and accurate observation....

Your Highness may thus see how irregularly those persons proceed who in physical disputes

arrange scriptural passages (and often those ill-understood by them) in the front rank of their arguments. If these men really believe themselves to have the true sense of a given passage, it necessarily follows that they believe they have in hand the absolute truth of the conclusion they intend to debate. Hence they must know that they enjoy a great advantage over their opponents, whose lot it is to defend the false position; and he who maintains the truth will have many sense-experiences and rigorous proofs on his side, whereas his antagonist cannot make use of anything but illusory appearances, quibbles, and fallacies. Now if these men know they have such advantages over the enemy even when they stay within proper bounds and produce no weapons other than those proper to philosophy, why do they, in the thick of the battle, betake themselves to a dreadful weapon which cannot be turned aside, and seek to vanquish the opponent by merely exhibiting it? If I may speak frankly, I believe they have themselves been vanquished, and, feeling unable to stand up against the assaults of the adversary, they seek ways of holding him off. To that end they would forbid him the use of reason, divine gift of Providence, and would abuse the just authority of holy Scripture—which, in the general opinion of theologians, can never oppose manifest experiences and necessary demonstrations when rightly understood and applied. If I am correct, it will stand them in no stead to go running to the Bible to cover up their inability to understand (let alone resolve) their opponents' arguments, for the opinion which they fight has never been condemned by the holy Church. If they wish to proceed in sincerity, they should by silence confess themselves unable to deal with such matters. Let them freely admit that although they may argue that a position is false, it is not in their power to censure a position as erroneous - or in the power of any-one except the Supreme Pontiff, or the Church Councils. Reflecting upon this, and knowing that a proposition cannot be both true and heretical, let them employ themselves in the business which is proper to them; namely, demonstrating its falsity. And when that is revealed, either there will no longer be any necessity to prohibit it (since it will have no followers), or else it may safely be prohibited without the risk of any scandal.

Therefore let these men begin to apply themselves to an examination of the arguments of Copernicus and others, leaving condemnation of the doctrine as erroneous and heretical 'to the proper authorities. Among the circumspect and most wise Fathers, and in the absolute wisdom of one who cannot err, they may never hope to find the rash decisions into which they allow them selves to be

hurried by some particular passion or personal interest. With regard to this opinion, and others which are not directly matters of faith, certainly no one doubts that the Supreme Pontiff has always an absolute power to approve or condemn; but it is not in the power: of any created being to make things true or false, for this belongs to their own nature and to the fact. Therefore in my judgment one should first be assured of the necessary and immutable truth of the fact, over which no man has power. This is wiser counsel than to condemn either side in the absence of such certainty, thus depriving oneself of continued authority and ability to choose by determining things which are now undetermined and open and still lodged in the will of supreme authority. And in brief, if it is impossible for a conclusion to be declared heretical while we remain in doubt as to its truth, then these men are wasting their time clamoring for condemnation of the motion of the earth and stability of the sun, which they have not yet demonstrated to be impossible or false

From Isaac Newton, *The Mathematical Principles of Natural Philosophy*

DEFINITIONS

DEFINITION I.

The quantity of matter is the measure of the same, arising from its density and bulk conjunctly.

Thus air of double density, in a double space, is quadruple in quantity; in a triple space, sextuple in quantity. The same thing is to be understood of snow, and fine dust or powders, that are condensed by compression or liquefaction; and of all bodies that are by any caused whatever differently condensed. I have no regard in this place to a medium, if any such there is, that freely pervades the interstices between the parts of bodies. It is this quantity that I mean hereafter everywhere under the name of body or mass. And the same is known by the weight of each body; for it is proportional to the weight, as I have found by experiments on pendulums, very accurately made, which shall be shewn hereafter.

DEFINITION II.

The quantity of motion is the measure of the same, arising from the velocity and quantity of matter conjunctly.

The motion of the whole is the sum of the motions of all the parts; and therefore in a body double in quantity, with equal velocity, the motion is double; with twice the velocity, it is quadruple.

DEFINITION III.

The vis insita, or innate force of matter, is a power of resisting, by which every body, as much as in it lies, endeavours to persevere in its present state, whether it be of rest, or of moving uniformly forward in a right line.

This force is ever proportional to the body whose force it is; and differs nothing from the inactivity of the mass, but in our manner of conceiving it. A body, from the inactivity of matter, is not without difficulty put out of its state of rest or motion. Upon which account, this *vis insita*, may, by a most significant name, be called *vis inertiae*, or force of inactivity. But a body exerts this force only, when another force, impressed upon it, endeavours to change its

condition; and the exercise of this force may be considered both as resistance and impulse; it is resistance, in so far as the body, for maintaining its present state, withstands the force impressed; it is impulse, in so far as the body, by not easily giving way to the impressed force of another, endeavours to change the state of that other. Resistance is usually ascribed to bodies at rest, and impulse to those in motion; but motion and rest, as commonly conceived, are only relatively distinguished; nor are those bodies always truly at rest, which commonly are taken to be so.

DEFINITION IV.

An impressed force is an action exerted upon a body, in order to change its state, either of rest, or of moving uniformly forward in a right line.

This force consists in the action only; and remains no longer in the body when the action is over. For a body maintains every new state it acquires, by its *vis inertiae* only. Impressed forces are of different origins as from percussion, from pressure, from centripetal force.

DEFINITION V.

A centripetal force is that by which bodies are drawn or impelled, or any way tend, towards a point as a centre.

Of this sort is gravity, by which bodies tend to the centre of the earth; magnetism, by which iron tends to the load-stone; and that force, whatever it is, by which the planets are perpetually drawn aside from the rectilinear motions, which otherwise they would pursue, and made to revolve in curvilinear orbits. A stone whirled about in a sling, endeavours to recede from the hand that turns it; and by that endeavour, distends the sling, and that with so much the greater force, as it is revolved with the greater velocity, and as soon as ever it is let go, flies away. That force which opposes itself to this endeavour, and by which the sling perpetually draws back the stone towards the hand, and retains it in its orbit, because it is directed to the hand as the centre of the orbit, I call the centripetal force. And the thing is to be understood of all bodies, revolved in any orbits. They

all endeavour to recede from the centres of their orbits; and were it not for the opposition of a contrary force which restrains them to, and detains them in their orbits, which I therefore call centripetal, would fly off in right lines, with a uniform motion. A projectile, if it was not for the force of gravity, would not deviate towards the earth, but would go off from it in a right line, and that with an uniform motion, if the resistance of the air was taken away. It is by its gravity that it is drawn aside perpetually from its rectilinear course, and made to deviate towards the earth more or less, according to the force of its gravity, and the velocity of its motion. The less its gravity is, for the quantity of its matter, or the greater the velocity with which it is projected, the less will it deviate from a rectilinear course, and the farther it will go. If a leaden ball, projected from the top of a mountain by the force of gunpowder with a given velocity, and in a direction parallel to the horizon, is carried in a curve line to the distance of two miles before it falls to the ground; the same, if the resistance of the air were taken away, with a double or decuple velocity, would fly twice or ten times as far. And by increasing the velocity, we may at pleasure increase the distance to which it might be projected, and diminish the curvature of the line, which it might describe, till at last it should fall at the distance of 10, 30, or 90 degrees, or even might go quite round the whole earth before it falls; or lastly, so that it might never fall to the earth, but go forward into the celestial spaces, and proceed in its motion *in infinitum*. And after the same manner that a projectile, by the force of gravity, may be made to revolve in an orbit, and go round the whole earth, the moon also, either by the force of gravity, if it is endued with gravity, or by any other force, that impels it towards the earth, may be perpetually drawn aside towards the earth, out of the rectilinear way, which by its innate force it would pursue; and would be made to revolve in the orbit which it now describes; nor could the moon without some such force, be retained in its orbit. If this force was too small, it would not sufficiently turn the moon out of a rectilinear course: if it was too great, it would turn it too much, and draw down the moon from its orbit towards the earth. It is necessary, that the force be of a just quantity, and it belongs to the mathematicians to find the force, that may serve exactly to retain a body in a given orbit, with a given velocity; and *vice versa*, to determine the curvilinear way, into which a body projected from a given place, with a given velocity, may be made to deviate from its natural rectilinear way, by means of a given force.

The quantity of any centripetal force may be considered as of three kinds; absolute, accelerative, and motive.

DEFINITION VI.

The absolute quantity of a centripetal force is the measure of the same proportional to the efficacy of the cause that propagates it from the centre, through the spaces round about.

Thus the magnetic force is greater in one load-stone and less in another according to their sizes and strength of intensity.

DEFINITION VII.

The accelerative quantity of a centripetal force is the measure of the same, proportional to the velocity which it generates in a given time.

Thus the force of the same load-stone is greater at a less distance, and less at a greater: also the force of gravity is greater in valleys, less on tops of exceeding high mountains; and yet less (as shall hereafter be shown), at greater distances from the body of the earth; but at equal distances, it is the same everywhere; because (taking away, or allowing for the resistance of the air), it equally accelerates all falling bodies, whether heavy or light, great or small.

DEFINITION VIII.

The motive quantity of a centripetal force, is the measure of the same, proportional to the motion which it generates in a given time.

Thus the weight is greater in a greater body, less in a less body; and, in the same body, it is greater near to the earth, and less at remoter distances. This sort of quantity is the centripetency, or propension of the whole body towards the centre, or, as I may say, its weight; and it is always known by the quantity of an equal and contrary force just sufficient to hinder, the descent of the body.

These quantities of forces, we may, for brevity's sake, call by the names of motive, accelerative, and absolute forces; and, for distinction's sake, consider them, with respect to the bodies that tend to the centre; to the places of those bodies; and to the centre of force towards which they tend; that is to say, I refer the motive force to the body as an endeavour and propensity of the whole towards a centre, arising

from the propensities of the several parts taken together; the accelerative force to the place of the body, as a certain power or energy diffused from the centre to all places around to move the bodies that are in them; and the absolute force to the centre, as endued with some cause, without which those motive forces would not be propagated through the spaces

round about; whether that cause be some central body (such as is the load-stone, in the centre of the magnetic force, or the earth in the centre of the gravitating force), or anything else that does not yet appear. For I here design only to give a mathematical notion of those forces, without considering their physical causes and seats.

AXIOMS, OR LAWS OF MOTION

each other are always equal, and directed to contrary parts.

LAW I.

Every body perseveres in its state of rest, or of uniform motion in a right line, unless it is compelled to change that state by forces impressed thereon.

PROJECTILES persevere in their motions, so far as they are not retarded by the resistance of the air, or impelled downwards by the force of gravity. A top, whose parts by their cohesion are perpetually drawn aside from rectilinear motions, does not cease its rotation, otherwise than as it is retarded by the air. The greater bodies of the planets and comets, meeting with less resistance in more free spaces, preserve their motions both progressive and circular for a much longer time.

LAW II.

The alteration of motion is ever proportional to the motive force impressed; and is made in the direction of the right line in which that force is impressed.

If any force generates a motion, a double force will generate double the motion, a triple force triple the motion, whether that force be impressed altogether and at once, or gradually and successively. And this motion (being always directed the same way with the generating force), if the body moved before, is added to or subtracted from the former motion, according as they directly conspire with or are directly contrary to each other; or obliquely joined, when they are oblique, so as to produce a new motion compounded from the determination of both.

LAW III.

To every action there is always opposed an equal reaction; or the mutual actions of two bodies upon

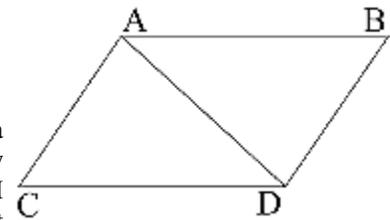
Whatever draws or presses another is as much drawn or pressed by that other. If you press a stone with your finger, the finger is also pressed by the stone. If a horse draws a stone tied to a rope, the horse (if I may so say) will be equally drawn back towards the stone: for the distended rope, by the same endeavour to relax or unbend itself, will draw the horse as much towards the stone as it does the stone towards the horse, and will obstruct the progress of the one as much as it advances that of the other.

If a body impinges upon another, and by its force change the motion of the other, that body also (because of the quality of, the mutual pressure) will undergo an equal change, in its own motion, towards the contrary part. The changes made by these actions are equal, not in the velocities but in the motions of bodies; that is to say, if the bodies are not hindered by any other impediments. For, because the motions are equally changed, the changes of the velocities made towards contrary parts are reciprocally proportional to the bodies. This law takes place also in attractions, as will be proved in the next scholium.

COROLLARY I.

A body by two forces conjoined will describe the diagonal of a parallelogram, in the same time that it would describe the sides, by those forces apart.

If a body in a given time, by the force M impressed apart in the place A, should with an uniform motion be



carried from A to B; and by the force N impressed apart in the same place, should be carried from A to C; complete the parallelogram ABCD, and, by both forces acting together, it will in the same time be carried in the diagonal from A to D. For since the force N acts in the direction of the line AC, parallel to BD, this force (by the second law) will not at all alter the velocity generated by the other force M, by which the body is carried towards the line BD. The body therefore will arrive at the line BD in the same time, whether the force N be impressed or not; and therefore at the end of that time it will be found somewhere in the line BD. By the same argument, at the end of the same time it

will be found somewhere in the line CD. Therefore it will be found in the point D, where both lines meet. But it will move in a right line from A to D, by Law 1.

COROLLARY II.

And hence is explained the composition of any one direct force AD, out of any two oblique forces AC and CD; and, on the contrary, the resolution of any one direct force AD into two oblique forces AC and CD: which composition and resolution are abundantly confirmed from mechanics.

RULES OF REASONING IN PHILOSOPHY

RULE I.

We are to admit no more causes of natural things than such as are both true and sufficient to explain their appearances.

To this purpose the philosophers say that Nature does nothing in vain, and more is in vain when less will serve; for Nature is pleased with simplicity, and affects not the pomp of superfluous causes.

RULE II.

Therefore to the same natural effects we must, as far as possible, assign the same causes.

As to respiration in a man and in a beast; the descent of stones in *Europe* and in *America*; the light of our culinary fire and of the sun; the reflection of light in the earth, and in the planets.

RULE III.

The qualities of bodies, which admit neither intensification nor remission of degrees, and which are found to belong to all bodies within the reach of our experiments, are to be esteemed the universal qualities of all bodies whatsoever.

For since the qualities of bodies are only known to us by experiments, we are to hold for universal all such as universally agree with experiments; and such as are not liable to diminution can never be quite taken away. We are certainly not to relinquish the evidence of experiments for the sake of dreams and vain fictions of our own devising; nor are we to recede from the analogy of

Nature, which uses to be simple, and always consonant to itself. We no other way know the extension of bodies than by our senses, nor do these reach it in all bodies; but because we perceive extension in all that are sensible, therefore we ascribe it universally to all others also. That abundance of bodies are hard, we learn by experience; and because the hardness of the whole arises from the hardness of the parts, we therefore justly infer the hardness of the undivided particles not only of the bodies we feel but of all others. That all bodies are impenetrable, we gather not from reason, but from sensation. The bodies which we handle we find impenetrable, and thence conclude impenetrability to be an universal property of all bodies whatsoever. That all bodies are moveable, and endowed with certain powers (which we call the *vires inertiae*) of persevering in their motion, or in their rest we only infer from the like properties observed in the bodies which we have seen. The extension, hardness, impenetrability, mobility, and *vis inertiae* of the whole, result from the extension hardness, impenetrability, mobility, and *vires inertiae* of the parts; and thence we conclude the least particles of all bodies to be also all extended, and hard and impenetrable, and moveable, and endowed with their proper *vires inertiae*. And this is the foundation of all philosophy. Moreover, that the divided but contiguous particles of bodies may be separated from one another, is matter of observation; and, in the particles that remain undivided, our minds are able to distinguish yet lesser parts, as is mathematically demonstrated. But whether the parts so distinguished, and not yet divided, may, by the powers of Nature, be actually divided and separated from one another, we cannot certainly determine. Yet, had we the proof of but one experiment that any undivided particle, in breaking a hard and solid body, offered a division, we might by virtue of this rule conclude that the undivided as well as the divided particles may be divided and actually separated to infinity.

Lastly, if it universally appears, by experiments and astronomical observations, that all bodies about the earth gravitate towards the earth, and that in proportion to the quantity of matter which they severally contain, that the moon likewise, according to the quantity of its matter, gravitates towards the earth; that, on the other hand, our sea gravitates towards the moon; and all the planets mutually one towards another; and the comets in like manner towards the sun; we must, in consequence of this rule, universally allow that all bodies whatsoever are endowed with a principle of mutual gravitation. For the argument from the appearances concludes with more force for the universal gravitation of all bodies than for their impenetrability; of which, among those in the celestial regions, we have no experiments, nor any manner of observation. Not that I affirm gravity to be essential to bodies: by their *vis insita* I mean nothing but their *vis inertiae*. This is immutable. Their gravity is diminished as they recede from the earth.

RULE IV.

In experimental philosophy we are to look upon propositions collected by general induction from phænomena as accurately or very nearly true, notwithstanding any contrary hypotheses that may be imagined, till such time as other phænomena occur, by which they may either be made more accurate, or liable to exceptions.

This rule we must follow, that the argument of induction may not be evaded by hypotheses.

from **The New Organon**
by

Francis Bacon

<http://www.earlymoderntexts.com/pdf/bacno.pdf>

Aphorisms Concerning the Interpretation of Nature, Book 1

[In 86 below, Bacon explains ‘aphorisms’ as meaning ‘short scattered sentences, not linked by any method’. His ‘aphorisms’ vary from three lines to sixteen pages, but his label ‘aphorism’ will be allowed to stand.]

1. Man, being nature’s servant and interpreter, is limited in what he can do and understand by what he has observed of the course of nature - directly observing it or inferring things from what he has observed. Beyond that he doesn’t know anything and can’t do anything.

2. Not much can be achieved by the naked hand or by the unaided intellect. Tasks are carried through by tools and helps, and the intellect needs them as much as the hand does. And just as the hand’s tools either give motion or guide it, so in a comparable way the mind’s tools either point the intellect in the direction it should go or offer warnings.

3. Human knowledge and human power meet at a point; for where the cause isn’t known the effect can’t be produced. The only way to command nature is to obey it; and something that functions as the cause in thinking about a process functions as the rule in the process itself.

7. If we go by the contents of books and by manufactured products, the mind and the hand seem to have had an enormous number of offspring. But all that variety consists in very fine-grained special cases of, and derivatives from, a few things that were already known; *not* in a large number of fundamental propositions.

8. Moreover, the works that have already been achieved owe more to chance and experiment than to disciplined sciences; for the sciences we have now are merely pretty arrangements of things already discovered, not ways of making discoveries or pointers to new achievements.

11. Just as the sciences that we now have are

useless for devising new inventions, the logic that we now have is useless for discovering new sciences. [Bacon here uses *inventio* in two of its senses, as = ‘invent’ and as = ‘discover’.]

12. The logic now in use serves to fix and stabilize errors based on the ideas of the vulgar, rather than to search for truth. So it does more harm than good.

13. The syllogism isn’t brought to bear on the basic principles of the sciences; it *is* applied to intermediate axioms, but nothing comes of this because the syllogism is no match for nature’s subtlety. It constrains what you can *assent* to, but not what can *happen*.

14. A syllogism consists of propositions, which consist of words, which are stand-ins [*tesserae*, literally = ‘tickets’] for notions. So the root of the trouble is this: If the notions are confused, having been sloppily abstracted from the facts, nothing that is built on them can be firm. So our only hope lies in true induction.

18. The discoveries that have been made in the sciences up to now lie close to vulgar notions, scarcely beneath the surface. If we are to penetrate into nature’s inner and further recesses, we’ll need a safer and surer method for deriving notions as well as axioms from things, as well as an altogether better and more certain way of conducting intellectual operations.

19. There are and *can be* only two ways of searching into and discovering truth. **(1)** One of them starts with the senses and particular events and *swoops* straight up from them to the most general axioms; on the basis of these, taken as unshakably true principles, it proceeds to judgment and to the discovery of intermediate axioms. This is the way that people follow now. **(2)** The other derives axioms from the senses and particular events in a gradual and unbroken ascent, going *through* the intermediate axioms

and arriving *finally* at the most general axioms. This is the true way, but no-one has tried it.

22. Both ways set out from the senses and particular events, and come to rest in the most general propositions; yet they are enormously different. For one of them (1) merely glances in passing at experiments and particular events, whereas the other (2) stays among them and examines them with proper respect. One (1) proceeds immediately to laying down certain abstract and useless generalities, whereas the other (2) rises by step by step to what is truly better known by nature. [In calling something 'known to nature' Bacon means that it is a general law of nature; 'better known by nature' could mean 'a more general law of nature' or 'a generality that is more completely lawlike'.]

23. There is a great difference between the *idols* of the human mind and the *ideas* of God's mind - that is, between certain empty beliefs and the true seals [= 'signs of authenticity'] and marks that we have found in created things.

24. There's no way that axioms established by argumentation could help us in the discovery of new things, because the subtlety of nature is many times greater than the subtlety of argument. But axioms abstracted from particulars in the proper way often herald the discovery of new particulars and point them out, thereby returning the sciences to their active status.

25. The axioms that are now in use are mostly made so that they *just* cover the items from which they arise, namely thin and common-or-garden experiences and a few particulars of the commonest sorts, so it is no wonder if they don't lead to new particulars. And it's not only the axioms, but also the way they are handled, that is defective. If some unexpected counter-example happens to turn up, the axiom is rescued and preserved by some frivolous distinction, rather than (the truer course) being amended.

26. To help me get my ideas across, I have generally used different labels for human reason's two ways of approaching nature: the customary way I describe as *anticipating nature* (because it is rash and premature) [see note on 'anticipation' on page 3 above]; and the way that draws conclusions from facts in the right way I describe as *interpreting nature*.

36. There remains for me only one way of getting

my message across. It is a simple way, namely this: I must lead you to the particular events themselves, and to the order in which they occur; and you for your part must force yourself for a while to lay aside your notions and start to familiarize yourself with facts.

38. The idols and false notions that now possess the human intellect and have taken deep root in it don't just occupy men's minds so that truth can hardly get in, but also when a truth *is* allowed in they will push back against it, stopping it from contributing to a fresh start in the sciences. This can be avoided only if men are forewarned of the danger and do what they can to fortify themselves against the assaults of these idols and false notions.

39. There are **four classes of idols that beset men's minds**, and to help me in my exposition I have given them names. I call the first class **idols of the tribe**, the second **idols of the cave**, the third **idols of the market place**, and the fourth **idols of the theatre**.

40. The proper way to keep idols at bay and to drive them off is, no doubt, to form ideas and axioms by true induction. But it is very useful just to point the idols out; for the truth about the idols serves the interpretation of nature in the way that the truth about argumentative fallacies serves ordinary logical argumentation.

41. The **idols of the tribe** have their foundation in human nature itself - in the tribe known as 'mankind'. It is not true that the human senses are the measure of things; for all perceptions - of the senses as well as of the mind - reflect the perceiver rather than the world. The human intellect is like a distorting mirror, which receives light-rays irregularly and so mixes its own nature with the nature of things, which it distorts.

42. The **idols of the cave** are the idols of the individual man. In addition to the errors that are common to human nature in general, everyone has his own personal cave or den that breaks up and corrupts the light of nature. This may come from factors such as these: his own individual nature, how he has been brought up and how he interacts with others, his reading of books and the influence of writers he esteems and admires, differences in how his environment affects him because of differences in his state of mind - whether it is busy thinking

about something else and prejudiced against this intake or calm and open-minded. So that the human spirit is distributed among individuals in ways that make it variable and completely disorderly - almost a matter of luck. Heraclitus was right: men look for sciences in their own individual lesser worlds, and not in the greater world that they have in common.

43. There are also idols formed by men's agreements and associations with each other (·I have in mind especially the agreements that fix the meanings of words·). I call these **idols of the marketplace**, because that is where men come together and do business. ·Such transactions create idols because men associate by talking to one another, and the uses of words reflect common folks' ways of thinking. It's amazing how much the intellect is hindered by wrong or poor choices of words. The definitions or explanations that learned men sometimes use to protect themselves against such troubles· don't at all set the matter right: words plainly force and overrule the intellect, throw everything into confusion, and lead men astray into countless empty disputes and idle fancies.

44. Lastly, there are idols that have come into men's minds from various philosophical dogmas and from topsy-turvy laws of demonstration. I call these **idols of the theatre**, because I regard every one of the accepted systems as the staging and acting out of a fable, making a fictitious staged world of its own. I don't say this only about the systems that are currently fashionable, or only about the ancient sects and philosophies; many other fables of the same kind may still be written and produced, seeing that errors can be widely different yet have very similar causes. And I'm saying this not only about whole systems but also about a good many principles and axioms in individual sciences - ones that have gathered strength through tradition, credulity, and negligence. But these various kinds of idols will have to be discussed more clearly and at greater length if the human intellect is to be adequately warned against them....

49. The human intellect doesn't burn with a dry [here = 'uncontaminated'] light, because what the person *wants* and *feels* gets pumped into it; and that is what gives rise to the 'please-yourself sciences'. For a man is more likely to believe something if he would like it to be true. Therefore he rejects difficult things because he hasn't the

patience to research them, sober and prudent things because they narrow hope, the deeper things of nature, from superstition, the light that experiments can cast, from arrogance and pride (not wanting people to think his mind was occupied with trivial things), surprising truths, out of deference to the opinion of the vulgar. In short, there are countless ways in which, sometimes imperceptibly, a person's likings colour and infect his intellect.

[Bacon's many uses of the word *schematismus* show that for him a body's *schematismus* is its fine-grained

structure. This version will always use 'microstructure', but be aware that Bacon doesn't use a word with the prefix 'micro'. Also, here and throughout, 'spirits' are extremely finely divided gases or fluids, *not* mental items of any kind.]

50. But what contributes most to the blockages and aberrations of the human intellect is the fact the human senses are dull, incompetent and deceptive. The trouble is this: things that strike the senses outweigh other things - more important ones - that don't immediately strike them. That is why people stop *thinking* at the point where their *eyesight* gives out, paying little or no attention to things that can't be seen - for example, all the workings of the spirits enclosed in tangible bodies. Nor do they pay attention to all the subtler changes of microstructure in the parts of coarser substances (which are vulgarly called 'alterations' though they are really extremely small-scale movements). And yet unless these two things - ·the workings of spirits, and subtle changes of form in bodies· - can be searched out and brought into the light, nothing great can be achieved in nature in the way of practical applications. A third example: the essential nature of our common air, and of all the many bodies that are less dense than air, is almost unknown. For the senses by themselves are weak and unreliable; and instruments for extending or sharpening them don't help much. All the truer kind of *interpretation* of nature comes about through instances and well-designed experiments: the senses pass judgment on the experiment, and the experiment passes judgment on nature, on the facts.

51. The human intellect is inherently prone to make abstractions, and it feigns an unchanging essence for things that are in flux. But better than abstracting from nature is dissecting it; which is

what Democritus and his followers did, getting deeper into nature than anyone since. What we should be attending to is *matter*, its microstructures and changes of microstructure, and simple action, and the laws of action or motion. 'The alternative to studying *matter* is to study *forms*, but forms are fabrications of the human mind, unless you want to call the laws of action 'forms'.

52. Those, then, are the **idols of the tribe**, as I call them - the idols that arise from human nature as such. More specifically, they arise from the human spirit's regularity of operation, or its prejudices, or its narrowness, or its restlessness, or input from the feelings, or from the incompetence of the senses, or from the way the senses are affected.

53. The **idols of the cave**...arise from the particular mental and physical make-up of the individual person, and also from upbringing, habits, and chance events. There are very many of these, of many different kinds; but I shall discuss only the ones we most need to be warned against - the ones that do most to disturb the clearness of the intellect.

54. A man will become attached to one particular science and field of investigation either because he thinks he was its author and inventor or because he has worked hard on it and become habituated to it. But when someone of this kind turns to *general* topics in philosophy and science he wrecks them by bringing in distortions from his former fancies. This is especially visible in Aristotle, who made his natural science a mere bond-servant to his logic, rendering it contentious and nearly useless. The chemists have taken a few experiments with a furnace and made a fantastic science out of it, one that applies to hardly anything. . . . [In this work 'chemists' are alchemists. Nothing that we would recognize as chemistry existed.]

59. The **idols of the market place** are the most troublesome of all - idols that have crept into the intellect out of the contract concerning words and names [Latin *verborum et nominum*, which could mean 'verbs and nouns'; on the contract, see **43**]. Men think that their reason governs words; but it is also true that words have a power of their own that reacts back onto the intellect; and this has rendered philosophy and the sciences sophistical and idle. Because words are usually adapted to the abilities of the vulgar, they follow the lines of

division that are most obvious to the vulgar intellect. When a language-drawn line is one that a sharper thinker or more careful observer would want to relocate so that it suited the true divisions of nature, words stand in the way of the change. That's why it happens that when learned men engage in high and formal discussions they often end up arguing about words and names, using definitions to sort them out - thus ending where, according to mathematical wisdom and mathematical practice, it would have been better to start! But when it comes to dealing with natural and material things, definitions can't cure this trouble, because the definitions themselves consist of words, and those words beget others. So one has to have recourse to individual instances

60. The idols imposed by words on the intellect are of two kinds. (1) There are names of things that don't exist. Just as there are things with no names (because they haven't been observed), so also there are names with no things to which they refer - these being upshots of fantastic theoretical suppositions. Examples of names that owe their origin to false and idle theories are... 'prime mover', and... 'element of fire'. This class of idols is fairly easily expelled, because you can wipe them out by steadily rejecting and dismissing as obsolete all the theories that beget them. (2) 'Then there are names which, though they refer to things that do exist, are confused and ill-defined, having been rashly and incompetently derived from realities. Troubles of this kind, coming from defective and clumsy abstraction, are intricate and deeply rooted. Take the word 'wet', for example. If we look to see far the various things that are called 'wet' agree with one other, we'll find that 'wet' is nothing but than a mark loosely and confusedly used to label a variety of states of affairs that can't be unified through any constant meaning.... So that it is easy to see that the notion has been taken by abstraction only from water and common and ordinary liquids, without proper precautions.

61. The **idols of the theatre**...are not innate, and they don't steal surreptitiously into the intellect. Coming from the fanciful stories told by philosophical theories and from upside-down perverted rules of demonstration, they are openly proclaimed and openly accepted. Things I have already said imply that there can be no question of *refuting* these idols: where there is no agreement on premises or

on rules of demonstration, there is no place for argument.... This at least has the advantage that it leaves the honour of the ancients untouched -because I shall not be *arguing against* them. I shall be *opposing* them, but- there will be no disparagement of them in this, because the question at issue between them and me concerns only *the way*. The course I propose for discovery in the sciences leaves little to the acuteness and strength of intelligence, but puts all intelligences nearly on a level.... But though particular counter-arguments would be useless, I should say something about the classification of the sects whose theories produce these idols, about the external signs that there is something wrong with them, and lastly about the causes of this unhappy situation, this lasting and general agreement in error. My hope is that this will make the truth more accessible, and make the human intellect more willing to be cleansed and to dismiss its idols.

62. There are many idols of the theatre, or idols of theories, and there can be and perhaps will be many more. For a long time now two factors have militated against the formation of new theories in philosophy and science. Men's minds have been busied with religion and theology. Civil governments, especially monarchies, have been hostile to anything new, even in theoretical matters; so that men have done that sort of work at their own peril and at great financial cost to themselves - not only unrewarded but exposed to contempt and envy. If it weren't for those two factors, there would no doubt have arisen many other philosophical sects like those that once flourished in such variety among the Greeks. Just as many hypotheses can be constructed regarding the phenomena of the heavens, so also - and even more! - a variety of dogmas about the phenomena of philosophy may be set up and dug in. And something we already know about plays that poets put on the stage is also true of stories presented on the philosophical stage - namely that fictions invented for the stage are more compact and elegant and generally liked than true stories out of history! What has gone wrong in philosophy is that it has attended in great detail to a few things, or skimpily to a great many things; either way, it is based on too narrow a foundation of experiment and natural history, and decides on the authority of too few cases....So there are the triplets born of error and false philosophy: philosophies that are **(1)** sophistical, **(2)** empirical, and **(3)** superstitious.

95. Those who have been engaged in the sciences divide into *experimenters* and *theorists*. The experimenters, like ants, merely collect and use -particular facts-; the theorists, like spiders, make webs out of themselves. But the bee takes a middle course: it gathers its material from the flowers of the garden and the field, but uses its own powers to transform and absorb this material. A true worker at philosophy is like that: he doesn't rely solely or chiefly on the powers of the mind -like a theorist = spider-, and he doesn't take the material that he gathers from natural history and physical experiments and store it up in his memory just as he finds it -like an experimenter = ant-. Rather, he stores the material in his intellect, altered and brought under control. So there is much to **hope** for from a closer and purer collaboration between these two strands in science, experimental and theoretical - a collaboration that has never occurred before now.