Robert Boyle, *Of the Excellency and Grounds of the Corpuscular or Mechanical Philosophy* (1674)[1]

Robert Boyle (1627–91) was one of the foremost experimental natural philosophers of his day. He was educated at Eton and then given private lessons in Geneva. Around 1656 he settled in Oxford and became a leading member of a circle of experimentalists who later formed the Royal Society of London (in 1660), though he turned down the presidency of the Society in 1680 because of his religious scruples against oath-taking. He debated with Hobbes over the existence of the vacuum and the nature of the "spring" of the air, and with Spinoza over the interpretation of experiments. Boyle was a prolific author; among his many works are New Experiments Physico-Mechanicall, Touching the Spring of the Air *(1660), in which he reports the results of his experiments with an air-pump that he constructed,* The Sceptical Chymist *(1661), in which he rejects Aristotelian and Paracelsian theories of matter, and* Certain Physiological Essays *(1661), in which he announces his mechanical and corpuscularian philosophy. This philosophy, of course, is the topic of the following essay.*[2]

By embracing the corpuscular or mechanical philosophy, I am far from supposing with the Epicureans that atoms accidentally meeting in an infinite vacuum were able, of themselves, to produce a world and all its phenomena; nor do I suppose, when God had put into the whole mass of matter an invariable quantity of motion, he needed do no more to make the universe, the material parts being able by their own unguided motions to throw themselves into a regular system. The philosophy I plead for reaches only to purely corporeal things; and distinguishing between the first origin of things and the subsequent course of nature teaches that God indeed gave motion to matter, but that in the beginning he so guided the various motion of the parts of it as to contrive them into the world he designed they should compose, and established those rules of motion and that order among corporeal things which we call the laws of nature. Thus the universe being once framed

1. From *The Philosophical Works of the Honourable Robert Boyle, Abridged* . . . ed. Peter Shaw (London, 1725), 3 vols., English, modified.

2. For more on Boyle, see Peter Alexander, *Ideas, Qualities and Corpuscles: Locke and Boyle on the External World* (Cambridge: Cambridge University Press, 1985), Steve Shapin and Simon Schaffer, *Leviathan and the Air Pump* (Princeton: Princeton University Press, 1985), or Rose-Mary Sargent, *The Diffident Naturalist: Robert Boyle and the Philosophy of Experiment* (Chicago: University of Chicago Press, 1995).

by God, and the laws of motion settled and all upheld by his perpetual concourse and general providence, the same philosophy teaches that the phenomena of the world are physically produced by the mechanical properties of the parts of matter, and that they operate upon one another according to mechanical laws. It is of this kind of corpuscular philosophy that I speak.

And the first thing that recommends it is the intelligibleness or clearness of its principles and explanations. Among the Peripatetics there are many intricate disputes about matter, privation, substantial forms, their eductions, etc. And the chemists are puzzled to give such definitions and accounts of their hypostatical principles, as are consistent with one another, and to some obvious phenomena; and much more dark and intricate are their doctrines about the Archeus, Astral Beings, and other odd notions,[3] which perhaps have in part occasioned the darkness and ambiguity of their expressions, that could not be very clear when the conceptions were obscure. And if the principles of the Aristotelians and chemists are thus obscure, it is not to be expected that the explications made by the help of such principles only should be intelligible. And, indeed, many of them are so general and slight, or otherwise so unsatisfactory, that, granting their principles, it is very hard to understand or admit their applications of them to particular phenomena. And, I think, even in some of the more ingenious and subtle of the Peripatetic discourses, the authors, upon their superficial and narrow theories, have acted more like painters than philosophers, and only shown their skill in making men fancy they see castles, cities, and other structures, that appear solid, magnificent, and extensive, when the whole piece is superficial, artificially made up of colors, and comprised within a frame. But, as to the corpuscular philosophy, men do so easily understand one another's meaning when they talk of local motion, rest, magnitude, shape, order, situation, and contexture of material substances; and these principles afford such clear accounts of those things that are rightly deduced from them alone, that even such Peripatetics or chemists, as maintain other principles, acquiesce in the explications made by these, when they can be had, and seek no further; though, perhaps, the effect is so admirable as to make it pass for that of a hidden form or an occult quality. Those very Aristotelians who believe the celestial bodies to be moved by intelligences have no recourse to any peculiar agency of theirs to account for eclipses; and we laugh at those East Indians who, to this day, go out in multitudes with some instruments to relieve the distressed luminary, whose loss of light, they fancy, proceeds from some fainting fit, out of which it must be roused. For no intelligent man, whether chemist or Peripatetic, flies to his peculiar principles after he is informed that the moon is eclipsed by the interposition of the earth between her and it, and the sun by that of the moon between him and the earth. And when we see the image of a man cast into the air by a concave spherical mirror, though most men are amazed at it, and some suspect it to be no less than an effect of witchcraft, yet he who is skilled enough in catoptrics will, without consulting Aristotle or Paracelsus or flying to hypostatical principles or substantial forms, be satisfied that the phenomenon is produced by rays of light reflected and made to converge according to optical and mathematical laws.

I next observe that there cannot be fewer principles than the two grand ones of our philosophy, matter and motion; for matter alone, unless it is moved, is wholly inactive, and, while all the parts of a body continue in one state without motion, that body will not exercise any action or suffer any alteration, though it may, perhaps, modify the action of other bodies that move against it.

Nor can we conceive any principles more primary than matter and motion; for either both of them were immediately created by God, or, if matter is eternal, motion must either be produced by some immaterial supernatural agent or it must immediately flow, by way of emanation, from the nature of the matter it appertains to.

There cannot be any physical principles more simple than matter and motion, neither of them being resoluble into any other thing.

3. The "chemists" referred to are followers of Paracelsus and van Helmont; hypostatical principles are essential principles or elements, and the Archeus is a vital spirit responsible for chemical and physiological reactions.

The next thing which recommends the corpuscular principles is their extensiveness. The genuine and necessary effect of the strong motion of one part of matter against another is either to drive it on in its entire bulk, or to break and divide it into particles of a determinate motion, figure, size, posture, rest, order, or texture. The two first of these, for instance, are each of them capable of numerous varieties; for the figure of a portion of matter may either be one of the five regular geometrical figures, some determinate species of solid figures, or irregular, as the grains of sand, feathers, branches, files, etc. And, as the figure, so the motion of one of these particles may be exceedingly diversified, not only by the determination to a particular part of the world but by several other things, as by the almost infinitely different degrees of celerity, by the manner of its progression, with or without rotation, etc. and more yet by the line in which it moves, as circular, elliptical, parabolic, hyperbolic, spiral, etc. For, as later geometers have shown that these curves may be compounded of several motions, that is, described by a body whose motion is mixed, and results from two or more simple motions; so, how many more curves may be made by new compositions and recompositions of motion is not easy to determine.

Now, since a single particle of matter, by virtue of only two mechanical properties that belong to it, may be diversified so many ways, what a vast number of variations may we suppose capable of being produced by the compositions and recompositions of myriads of single invisible corpuscles that may be contained and concreted in one small body, and each of them be endowed with more than two or three of the fertile universal principles above mentioned? And the aggregate of those corpuscles may be further diversified by the texture resulting from their convention into a body, which, as so made up, has its own magnitude, shape, pores, and many capacities of acting and suffering, upon account of the place it holds among other bodies, in a world constituted like ours; so that, considering the numerous diversifications that compositions and recompositions may make of a small number, those who think the mechanical principles may serve, indeed, to account for the phenomena of some particular part of natural philosophy, as statics, the theory of planetary motions, etc., but prove inapplicable to all the phenomena of things corporeal seem to imagine that by putting together the letters of the alphabet one may, indeed, make up all the words to be found in Euclid or Virgil, or in the Latin or English language, but that they can by no means supply words to all the books of a great library, much less to all the languages in the world.

There are other philosophers, who, observing the great efficacy of magnitude, situation, motion, and connection in engines, are willing to allow those mechanical principles a great share in the operations of bodies of a sensible bulk and manifest mechanism and, therefore, to be usefully employed in accounting for the effects and phenomena of such bodies, though they will not admit that these principles can be applied to the hidden transactions among the minute particles of bodies, and, therefore, think it necessary to refer these to what they call nature, substantial forms, real qualities, and the like unmechanical agents. But this is not necessary, for the mechanical properties of matter are to be found and the laws of motion take place, not only in the great masses and the middle-sized lumps, but in the smallest fragments of matter—a less portion of it being as much a body as a greater must as necessarily as the other have its determinate bulk and figure. And whoever views sand through a good microscope will easily perceive that each minute grain has its own size and shape as well as a rock or a mountain. Thus too, when we let fall a large stone and a pebble from the top of a high building, they both move conformably to the laws of acceleration in heavy descending bodies, and the rules of motion are observed, not only in cannon-bullets, but in small shot; and the one strikes down a bird according to the same laws as the other batters a wall. And though nature works with much finer materials and employs more curious contrivances than art, yet an artist, according to the quantity of the matter he employs, the exigency of the design he undertakes, and the magnitude and shape of the instruments he uses, is able to make pieces of work of the same nature or kind, of extremely different bulks where yet the like art, contrivance, and motion may

be observed. Thus a smith who, with a hammer and other large instruments, can forge great bars or wedges out of masses of iron to make strong and ponderous chains to secure streets and gates may, with lesser instruments, make smaller nails, and filings, almost as minute as dust, and with yet finer tools, make links wonderfully light and slender. And therefore, to say that though in natural bodies, whose bulk is manifest and their structure visible, the mechanical principles may be usefully admitted but are not to be extended to such portions of matter whose parts and texture are invisible, is like allowing that the laws of mechanism may take place in a town clock and not in a pocket watch, or, because the terraqueous globe is a vast magnetic body, one should affirm that magnetic laws are not to be expected manifest in a small spherical piece of lodestone; yet experience shows us that, notwithstanding the immense disproportion between these two spheres, the terella[4] as well as the earth has its poles, equator, and meridians, and in several other magnetic properties resembles the terrestrial globe.

When, to solve the phenomena of nature, agents are made use of which, though they involve no contradiction in their notions, as many think substantial forms and real qualities do, yet are such that we conceive not how they operate to produce effects—such agents I mean, as the soul of the world, the universal spirit, the plastic power, etc.—the curiosity of an inquisitive person who seeks not so much to know what is the general agent that produces a phenomenon, as by what means, and after what manner it is produced, is not satisfied hereby. Sennert and other physicians tell us of diseases which proceed from incantation; but surely, it is very trivial to a sober physician who comes to visit a patient reported to be bewitched, to hear only that the strange symptoms he meets with, and would have an account of, are produced by a witch or the devil; and he will never be satisfied with so short an answer, if he can by any means reduce those extravagant symptoms to any more known and stated diseases; as epilepsies, convulsions, hysteric fits, etc. and if he cannot, he will confess his knowledge of this distemper to come far short of what might be expected and attained in other diseases, in which he thinks himself bound to search into the morbific matter, and will not be satisfied, until he can, probably, deduce from that, and the structure of the human body, and other concurring physical causes, the phenomena of the malady. And it would be of little satisfaction to one who desires to understand the causes of the phenomena in a watch, and how it comes to point at and strike the hours to be told that a certain watchmaker so contrived it, or, to him who would know the true causes of an echo, to be answered that it is a man, a vault, or a wood, that makes it.

I come now to consider that which I observe most alienates other sects from the mechanical philosophy, namely, a supposition that it pretends to have principles so universal and mathematical that no other physical hypothesis can be tolerated by it.

This I look upon as an easy, indeed, but an important mistake, for the mechanical principles are so universal and applicable to so many purposes that they are rather fitted to take in, than to exclude any other hypothesis founded on nature. And such hypotheses, if prudently considered, will be found, as far as they have truth on their side, to be either legitimately deducible from the mechanical principles or fairly reconcilable to them. For such hypotheses will, probably, attempt to account for the phenomena of nature, either by the help of a determinate number of material ingredients, such as the *tria prima* of the chemists[5] or else by introducing some general agents, as the Platonic soul of the world and the universal spirit, asserted by some chemists, or by both these ways together.

Now, the chief thing that a philosopher should look after in explaining difficult phenomena is not so much what the agent is or does, as what changes are made in the patient to bring it to exhibit the phenomena proposed, and by what means, and after what manner those changes are effected. So that the mechanical philosopher being satisfied, one part of matter can act upon another only by virtue of local

4. A magnetic sphere or lodestone, described in William Gilbert's *De magnete* (1600).

5. The Paracelsian "elements" of salt, sulfur, and mercury.

motion or its effects and consequences; he considers if the proposed agent is not intelligible and physical, it can never physically explain the phenomena, and if it is intelligible and physical, it will be reducible to matter and some or other of its universal properties. And the indefinite divisibility of matter, the wonderful efficacy of motion, and the almost infinite variety of coalitions and structures that may be made of minute and insensible corpuscles being duly weighed, why may not a philosopher think it possible to make out, by their help, the mechanical possibility of any corporeal agent, however subtle, diffused, or active, that can be solidly proved to have a real existence in nature? Though the Cartesians are mechanical philosophers, yet their subtle matter which the very name declares to be a corporeal substance is, for all I know, little less diffused through the universe, or less active in it than the universal spirit of some chemists, not to say the world soul of the Platonists. But whatever is the physical agent, whether it is inanimate or living, purely corporeal or united to an intellectual substance, the above mentioned changes wrought in the body made to exhibit the phenomena may be brought about by the same or the like means, or after the same, or the like manner, as for instance, if corn is reduced to meal, the materials and shape of the millstones and their peculiar motion and adaptation will be much of the same kind; and, to be sure, the grains of corn will suffer various attritions and pulverizations in their passage to the form of meal, whether the corn is ground by a watermill, or a windmill, a horsemill, or a handmill, that is, a mill whose stones are turned by inanimate, by brute, or by rational agents. And if an angel himself should work a real change in the nature of a body, it is scarcely conceivable to men how he could do it without the assistance of local motion, since, if nothing were displaced or otherwise moved than before, it is hardly conceivable how it should be, in itself, different from what it was before.

But if the chemists or others who would deduce a complete natural philosophy from salt, sulfur, and mercury, or any determined number of ingredients of things, would well consider what they undertake, they might easily discover that the material parts of bodies can reach but to a few phenomena of nature, while these things are considered but as quiescent things; whence they would find themselves to suppose them active, and that things purely corporeal cannot but by means of local motion, and the effects that may result from it, be very variously shaped, sized, and combined parts of matter, so that the chemists must leave the greatest part of the phenomena of the universe unexplained by means of the ingredients of bodies, without taking in the mechanical and more comprehensive properties of matter, especially local motion. I willingly grant that salt, sulfur, and mercury, or some substances analogous to them, are obtainable by the action of the fire from a very great many bodies able to be dissipated here below. Nor do I deny that in explaining several phenomena of such bodies, it may be of use to a naturalist to know and consider that as sulfur, for instance, abounds in the body proposed, it may be, thence, probably argued that the qualities usually attending that principle, when predominant, may be also upon its account found in the body that so largely partakes of it. But, though chemical explications are sometimes the most obvious, yet they are not the most fundamental and satisfactory: for the chemical ingredient itself, whether sulfur or any other, must owe its nature and other qualities to the union of insensible particles in a convenient size, shape, motion, or rest, and texture, all which are but mechanical properties of convening corpuscles. And this may be illustrated by what happens in artificial fireworks. For, though in most of those sorts made either for war, or recreation, gun powder is a principal ingredient, and many of the phenomena may be derived from the greater or less proportion in which it enters the compositions, yet there may be fireworks made without gun powder, as appears by those of the ancient Greeks and Romans. And gun powder owes its aptness to fire, and to be exploded to the mechanical texture of more simple portions of matter, niter, charcoal, and sulfur. And sulfur itself, though it is mistaken for a hypostatical principle by many chemists, owes its inflammability to the union of still more simple and primary corpuscles, since chemists confess that it had an inflammable ingredient and experience shows that it very

much abounds with an acid and uninflammable salt and is not destitute of a terrestrial part. It may, indeed, be here alleged that the productions of chemical analyses are simple bodies, and, upon that account, irresoluble, but that several substances, which chemists call the salts, sulfurs, or mercuries of the bodies that afford them, are not simple and homogeneous is demonstrable. Nor is their not being easily dissipable or resoluble a clear proof of their not being made up of more primitive portions of matter. For compounded bodies may be as difficulty resoluble as most of those that chemists obtain by the fire: witness common greenglass, which is far more durable and irresoluble than many of those which pass for hypostatical substances. And some enamels will, for several times, even vitrify in the forge without losing their nature or often so much as their color, yet enamel consists of salt, powder of pebbles, or sand, and calcined tin, and, if not white, usually of some tinning metal or mineral. But however indestructible the chemical principles are supposed, several of the operations ascribed to them will never be made to appear without the help of local motion; were it not for this, we can but little better solve the phenomena of many bodies by knowing what ingredients compose them than we can explain the operations of a watch by knowing of how many and of what metals, the balance, the wheels, the chain, and other parts consist, or than we can derive the operations of a windmill from barely knowing that it is made up of wood, stone, canvas, and iron. And here let me add that it would not at all overthrow the corpuscularian hypothesis, though, either by more exquisite purifications or by some other operations than the usual analysis by fire, it should appear that the material principles of mixed bodies are not the *tria prima* of the vulgar chemists, but either substances of another nature or fewer in number, or if it were true that the Helmontians had such a resolving menstruum as their master's alkahest[6] by which he affirms that he could reduce stones into salt of the same weight with the mineral, and bring both that salt and all other mixed and tangible bodies into insipid water. For whatever is the number or qualities of the chemical principles, if they really exist in nature, it may very possibly be shown that they are made up of insensible corpuscles of determinate bulks and shapes, and by the various coalitions and textures of such corpuscles, many material ingredients may be composed or made to result. But though the alkahestical reductions newly mentioned should be admitted, yet the mechanical principles might well be accommodated even to them. For the solidity, taste, etc. of salt may be fairly accounted for by the stiffness, sharpness, and other mechanical properties of the minute particles of which salt consists; and if, by a further action of the alkahest, the salt or any other solid body is reduced into insipid water, this also may be explained by the same principles, supposing a further comminution of its parts and such an attrition as wears off the edges and points that enabled them to strike briskly upon the organ of taste; for as to fluidity and firmness, they principally depend upon two of our grand principles, motion and rest. And it is certain that the agitation or rest, and the looser contact or closer cohesion of the particles, is able to make the same portion of matter at one time a firm and at another a fluid body. So that, though future sagacity and industry of chemists should obtain from mixed bodies, homogeneous substances, different in number, nature, or both, from their vulgar salt, sulfur, and mercury, yet the corpuscular philosophy is so general and fertile as to be fairly reconcilable to such a discovery, and also so useful that these new material principles will, as well as the old *tria prima*, stand in need of the more universal principles of the corpuscularians, especially of local motion. And, indeed, whatever elements or ingredients men have pitched upon, yet if they do not take in the mechanical properties of matter, their principles are so deficient that I have observed both the materialists and chemists not only leave many things unexplained, to which their narrow principles will not extend, but even in the particulars they presume to give an account of, they either content themselves to assign such common and indefinite causes as are too general to be satisfactory, or if they venture to give particular causes, they

6. A "resolving menstruum" is a solvent, and the "alkahest" is a universal solvent.

assign precarious or false ones, liable to be easily disproved by circumstance or instances to which their doctrines will not agree. The chemists, however, need not be frightened from acknowledging the prerogative of the mechanical philosophy, since that may be reconcilable with the truth of their own principles, so far as they agree with the phenomena they are applied to; for these more confined hypotheses may be subordinate to those more general and fertile principles, and there can be no ingredient assigned that has a real existence in nature but may be derived either immediately or by a row of compositions from the universal matter, modified by its mechanical properties. For if with the same bricks, differently put together and ranged, several bridges, vaults, houses, and other structures may be raised merely by a various contrivance of parts of the same kind, what a great variety of ingredients may be produced by nature from the various coalitions and contextures of corpuscles that need not be supposed, like bricks, all of the same size and shape, but to have, both in the one and the other, as great a variety as could be wished for? And the primary and minute concretions that belong to these ingredients may, without opposition from the mechanical philosophy, be supposed to have their particles so minute and strongly coherent that nature of herself scarce ever tears them asunder. Thus mercury and gold may be successively made to put on a multitude of disguises, and yet so retain their nature as to be reducible to their pristine forms.

From hence it is probable if, besides rational souls, there are any immaterial substances, such as the heavenly intelligences and the substantial forms of the Aristotelians that are regularly to be numbered among natural agents, their way of working being unknown to us, they can only help to constitute and effect things, but will very little help us to conceive how things are effected, so that, by whatever principles natural things are constituted, it is by the mechanical principles that their phenomena must be clearly explained. For instance, though we grant with the Aristotelians that the planets are made of a quintessential matter and moved by angels or immaterial intelligences, yet to explain the stations, progressions and retrogradations, and other phenomena of the planets, we must have recourse either to eccentrics, epicycles, etc. or to motions made in elliptical or other peculiar lines, and in a word to theories in which the motion, figure, situation, and other mathematical or mechanical properties are chiefly employed. But if the principles proposed are corporeal, they will then be fairly reducible or reconcilable to the mechanical principles, these being so general and fertile that, among real material things, there is none but may be derived from or reduced to them. And when the chemists shall show that mixed bodies owe their qualities to the predominance of any one of their three grand ingredients, the corpuscularians will show that the very qualities of this or that ingredient flow from its peculiar texture and the mechanical properties of the corpuscles that compose it. And to affirm that because the chemical furnaces afford a great number of uncommon productions and phenomena, that there are bodies or operations among purely corporeal things not derivable from or reconcilable to the principles of mechanical philosophy is to say, because there are many and various hymns, pavanes, threnodies, courantes, gavottes, sarabands, etc. in a music book, many of the tunes or notes have no dependence on the scale of music, or as if because excepting rhomboids, squares, pentagons, chiliagons, and numerous other polygons, one should affirm there are some rectilinear figures not reducible to triangles, or that have properties which overthrow Euclid's doctrine of triangles and polygons.

I shall only add that as mechanical principles and explanations, where they can be had, are preferred by materialists themselves for their clearness, so the sagacity and industry of modern naturalists and mathematicians, having happily applied them to several of those difficult phenomena which before were referred to occult qualities, it is probable that when this philosophy is more scrutinized and further improved, it will be found applicable to the solution of still more phenomena of nature. And it is not always necessary that he who advances an hypothesis in astronomy, chemistry, anatomy, etc. be able, *a priori*, to prove it true or demonstratively to show that the other hypothesis proposed about the same subject must be false, for as Plato said that the world is God's

epistle to mankind and might have added in his own way that it was written in mathematical characters, so, in the physical explanations of the parts of the system of the world, I think there is somewhat like what happens when men conjecturally frame several keys to read a letter written in ciphers. For though one man by his sagacity finds the right key, it will be very difficult for him either to prove, otherwise than by trial, that any particular word is not such as it is guessed to be by others according to their keys, or to show *a priori* that theirs are to be rejected and his to be preferred, yet, if due trial being made, the key he proposes be found so agreeable to the characters of the letter as to enable one to understand them and make coherent sense of them, its suitableness to what it should decipher is, without either confutations or foreign positive proofs, alone sufficient to make it accepted as the right key of that cipher. Thus, in physical hypotheses, there are some that, without falling foul upon others, peaceably obtain the approbation of discerning men only by their fitness to solve the phenomena for which they were devised, without thwarting any known observation or law of nature; and therefore, if the mechanical philosophy shall continue to explain corporeal things, as it has of late, it is scarce to be doubted but that in time unprejudiced persons will think it sufficiently recommended by its being consistent with itself and applicable to so many phenomena of nature.