# The Grounds for and Excellence of the Corpuscular or Mechanical Philosophy

Robert Boyle

1674



[Brackets] enclose editorial explanations. Small ·dots· enclose material that has been added, but can be read as though it were part of the original text. Occasional •bullets, and also indenting of passages that are not quotations, are meant as aids to grasping the structure of a sentence or a thought. Every four-point ellipsis . . . . indicates the omission of a brief passage that seems to present more difficulty than it is worth. Longer omissions are reported between brackets in normal-sized type.—This short piece by Boyle opens and closes in the form of a letter; there is no known addressee; and most of the thing reads as though it wasn't really addressed to any individual.—The section-breaks and -headings are not Boyle's.

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# Glossary

***a priori*:** When Boyle uses this phrase on page 11 he isn't using it in the sense that Kant made famous 80 years later. That is, he isn't talking about proving *independently of all experience* that your theory is true. He seems to mean something along those lines, but less strenuous, namely proving *in advance of thorough and protracted testing* that your theory is true.

**chemist:** In Boyle's day there wasn't much of the science called 'chemistry' today: no atoms had been isolated, the periodic table hadn't been discovered, and so on. Boyle's frequent mentions of 'chemists' refer to *alchemists*. Reading this text will tell you what his basic complaints against them were. Text-books and encyclopedias will tell you that Boyle *was* a chemist. That is a long story.

**phenomenon:** Boyle regularly uses this word to mean 'particular event or state of affairs'.

**philosophy:** In Boyle's time 'philosophy' covered science as well as the discipline called 'philosophy' today. The word will be left untouched in this version, but all through the discussion Boyle's topic is science, specifically physics, though some of his arguments bring in issues that are 'philosophical' in our sense.

**physical:** In Boyle's time, 'physical' had a broader meaning than it does today. It came from an ancient trilogy:

logic, physics, ethics,

having to do with

what must be, what is, what ought to be.

Roughly speaking, Boyle's 'physical' means 'having do with what is really out there in the world'. See for example the paragraph beginning 'I shall start. . . ' on page 6.

**principle:** Throughout the early modern period 'principle' (like its cousins in French and Latin) **sometimes** meant, as it does today, a proposition that has some privilege of basicness or certainty; but **more often** it meant something totally different: a 'principle' was a source, a cause, a generating factor. (Hume's *Enquiry into the Principles of Morals* doesn't discuss any moral propositional principles; it is, as Hume explicitly says, an enquiry into the *sources in human nature* of our moral beliefs and feelings.) Most of Boyle's uses of the word in the present work have this once dominant and now obsolete sense. For example: some 'chemists' held that many facts about how a bit of matter behaves depend on what proportions it contains of salt, sulphur, and mercury; and Boyle repeatedly credits them with regarding those three substances as 'principles'. See also, especially, the note on page 9.

# Introduction

The importance of the question you put to me would ·ordinarily· lead me to refer you to my *Dialogue about a Good Hypothesis* [a work that is now lost] and some other papers of that kind, where you could find my thoughts about the advantages of the mechanical hypothesis set down and discussed pretty fully. But all you want from me is a brief account not of •what I am firmly convinced of but of •what I think is *probably* true that can be said in support of preferring and valuing the corpuscular philosophy above Aristotle's and the chemists'. So you'll have to settle for getting from me a really short sketch of some of the chief advantages of the hypothesis that you and I favour, with no

> introductory remarks,
> exact method, or
> full discussion,

or anything else that would take many words. I'm willing to satisfy your curiosity on this occasion because I have often seen you alarmed and upset when you hear of any book that claims to uphold or repair the decaying philosophy of the schools [= 'the scholastics', the Aristotelians], or when some bold chemist who gives to the chemists the title of 'philosophers' and claims to build wholly upon experience, with the implication that the chemists are the only scientists who have had any experience!

Some of those writers applaud things that they don't understand (as when the Aristotelians praise 'substantial forms'); others criticise things that they don't understand (as when the chemists condemn mechanical explications of nature's phenomena). I don't want you to be tempted to despair by the confidence or reputation of these people, so I'll offer you some considerations that I hope will not only •keep you on good terms with the philosophy you have embraced, but perhaps also (by some considerations that you haven't yet met with) •make you think it probable that any new attacks on it that you hear of will fail—either being turned back by the corpuscularian philosophy or found to be reconcilable to it.

When I speak ·approvingly· of the corpuscular or mechanical philosophy, I am far from endorsing the view of the Epicureans that

> atoms, meeting together by chance in an infinite vacuum, are able unaided to produce the world and all its phenomena;

or the view of some modern philosophers that

> God put into the whole mass of matter such an invariable quantity of motion that that was all he needed to do to make the world, the material parts being able by their own unguided motions to work themselves into what we recognise as a *system*,

All I'm defending is a philosophy that **(1)** deals only with purely corporeal things [i.e. deals only with bodies, and has nothing to say about minds]; and **(2)** distinguishes **(a)** the ultimate origins of things from **(b)** the subsequent course of nature, and teaches concerning **(a)** that God not only gave motion to matter but also at the outset •guided the various motions of its parts in such a way that he contrived them into the world he planned for them to compose—a world supplied with seminal principles [see Glossary] and structures or models of living creatures—and •established the rules of motion and the order amongst bodies that we ordinarily call 'the laws of nature'. And having said this about **(a)**, the corpuscular philosophy may be allowed to teach regarding **(b)** that once the universe had been constructed by God, and with the laws of motion being settled and then upheld by his unceasing concourse [i.e. his unceasingly allowing, consenting to, going along with, them] and his general providence, the phenomena of

the world thus constituted are physically produced by the mechanical states of the parts of matter, and the effects they have on one another according to mechanical laws.

And now having shown what kind of corpuscular philosophy I am talking about, I proceed to the considerations that I thought give it the best support.

## Four points

**1.** Firstly, there is the fact that mechanical principles and explanations are intelligible, *clear*. I needn't tell you that the Aristotelians have complex quarrels among themselves regarding matter, privation, substantial forms. . . .and so on; and I have shown ·in my book *The Sceptical Chemist*· that the chemists are sufficiently puzzled to define and describe their 'hypostatical principles' in a way that makes them consistent with one another and also consistent with some obvious phenomena. [From now on this version will replace 'hypostatical' by 'elemental', meaning 'incapable of being analysed into simpler and more basic kinds of matter. For 'principles', see Glossary.] And their doctrines about the 'archeus', 'astral beings', 'gas' [a new word at that time], blas, and other odd notions are even darker and more intricate. That may have contributed to the darkness and ambiguity of what the chemists say, because their speech can't be very clear when their conceptions are far from being so. And if the principles of the Aristotelians and the chemists are thus obscure, we can't expect clarity in explanations that are given in terms of them and them alone. And indeed many of those explanations are either so general and slight—or so unsatisfactory in other ways—that even if we grant the chemists their principles, it is very hard to understand or accept their applications of them to particular phenomena. And in some of the Aristotelians' discussions of their shallow and narrow theories—though more ingenious and subtle ·than those of the chemists·—they strike me as having behaved more like painters than philosophers: they have presented only the *skin*, like drawers of landscapes who make men imagine they are seeing castles and towns and other structures that appear solid and magnificent and widely spread out, when really the whole thing is just a *surface* made up of colours and art and held within a frame that may be barely a yard long.

With the corpuscular philosophy, on the other hand, •men **easily** understand one another's meaning when they talk of motion, rest, size, shape, order, situation, and contexture [here = 'microstructure'] of material substances; and •these principles provide **clear** accounts of the things that are rightly derived purely from them—so **easily** and so **clear** that when such corpuscularian explanations are available they are accepted even by the Aristotelians and chemists whose own principles are quite different. ·It seems that they *really* accept them: they· don't look for any further explanation, even when the phenomenon being explained is so remarkable that it might well be thought to be the effect of a hidden form or an occult quality! The very same Aristotelians who think that the stars and planets are moved by intelligences can't explain eclipses in terms of their own theoretical apparatus. Even today there are East Indians who swarm out with instruments that they use to relieve the distressed moon, whose loss of light they think is due to a fainting fit out of which it must be aroused; and we ·*all*· laugh at them, because no intelligent man, whether chemist or Aristotelian, brings his own special principles into the story after he is informed that the moon is eclipsed by the earth's coming between it and the sun, and the sun by the moon's coming between it and the earth. And when we see the image of a man projected into the air by a concave

spherical looking glass, though most men are amazed at it (and some suspect it to be outright witchcraft), anyone who knows enough of the mathematical theory of mirrors will be satisfied that this phenomenon is produced by the beams of light reflected and thereby made convergent according to optical (and therefore mathematical) laws; he won't need to consult Aristotle, or Paracelsus [an influential 'chemist'], or bring in elemental principles and substantial forms.

Philosophers of various sects have rejected corpuscular principles, even when they think our explanations as clear as, or even clearer than, theirs; because they imagine that our explanations can be given for only a few things and consequently are insufficient. But I mustn't now repeat what I say elsewhere to show this.

**2.** There can't be *fewer* principles than the two grand ones of mechanical philosophy, matter and motion. For matter alone, if it isn't moved, is altogether inactive, and while all the parts of a body continue in one state without any motion at all, that body won't undergo any alteration and it won't act on anything else, though it may perhaps alter the action of other bodies that bump into it.

**3.** We can't conceive any principles more basic than matter and motion. Either

> both of them were immediately created by God

or, if matter is eternal and thus was never created (as some hold to be the case) it must be the case that

> •motion was produced by some immaterial supernatural agent, or •motion is something that the moving matter just naturally produces itself.

**4.** There can't be any physical principles that are simpler than matter and motion, because there's no truthful or even reasonably plausible way of representing either of them as compounded out of two or more simpler items.

## One more: the versatility of mechanism

**5.** Corpuscular principles are enormously comprehensive. If one part of matter x collides strongly enough with another y, the necessary effect of this is either •to drive y on as a whole or else •to break or divide y up into particles that have determinate motions, shapes, sizes, postures, orders and textures. ·To get a sense of the range of possibilities here, consider just· the first two of these, ·motion and shape·. Each of these is capable of numerous varieties. The shape of a portion of matter may be

- •one of the five regular shapes treated of by geometricians: or
- •some determinate three-dimensional shape such as those of a cone, a cylinder, etc.; or
- •an irregular shape such as those of grains of sand, hoops, feathers, branches, forks, files, etc. (we have names for some of these, but not for all).

And the great variety of shapes is matched by the variety of motions that one of these particles may have. As well as •the direction in which a particle is moving, there are many other factors—especially •the almost infinitely varying speeds, •whether in moving it is also rotating or not, •whether the line along which it is moving is straight, circular, elliptical, parabolical, hyperbolical, spiral, and I don't know how many others. ·Why do I suspect that there are countless others? Well·, later geometricians have shown that those crooked lines can be compounded of several ·simpler· motions,. . . .so that it is anyone's guess how many more curves can. . . .be made by new compositions and decompositions of motions.

Now, given that a single particle of matter can be diversified in so many ways simply through its shape and motion, think what a vast number of variations could be produced by the compositions and decompositions of myriads of single

invisible corpuscles that may be contained and organised in one small body! ·And don't think of those tiny particles as having nothing but shape and motion·; each of them may have others of the always-causally-relevant features that I have mentioned—·size, order, situation, contexture and so on·. Especially since a collection of those corpuscles may be gathered together into a single body which, because of the way its parts have been put together, •is further diversified by its size and shape, and pores (perhaps very many, and of various shapes and sizes), and also •has many capacities of acting and being acted on because of its place among other bodies in a world constituted as ours is. So bearing in mind the almost endless variety that can come from different ways of putting together a small number of things (e.g. fewer than twenty things), when I think about those who believe this:

> Mechanical principles may indeed serve to explain the phenomena of this or that particular part of natural philosophy (statics, hydrostatics, the theory of the planetary motions, or whatever), but they can never be applied to corporeal phenomena,

I am apt to regard those otherwise learned men as I would someone who asserted this:

> By putting together the letters of the alphabet one can indeed make up all the words to be found in one book (e.g. in Euclid or Virgil) or in one language (e.g. in Latin or English), but that they can't possibly suffice to provide words for all the books of a great library, much less to all the languages in the world.

And there's another sort of philosopher who •sees the great causal power of

> size, shape, location, motion, and connection

in *engines*, and •is led by this to grant that those mechanical principles may have a large role in the operations of bodies that are big enough to be seen and felt, but who •won't admit that these principles can be applied to the hidden interactions among the minute particles of bodies, and who therefore •thinks we have to explain these ·hidden interactions· in terms of what he calls 'nature', 'substantial forms', 'real qualities', and other such unmechanical principles and agents. [In his edition of this work, J.J.MacIntosh remarks that 'This somewhat blithely ignores the problem corpuscularians had with cohesion', i.e. with the question of what makes the difference between a pebble and a handful of dust.]

But we *don't* have to ·resort to any of those unmechanical notions·, because the mechanical states of matter occur and the laws of motion operate not only in great masses and middle-sized lumps of matter, but also in the smallest fragments. A smaller portion of matter is as much *a body* as a larger one, so it must necessarily have its particular size and shape, just as a larger one must. Look at sand through a good microscope and you'll easily see that each tiny grain of sand has its own size and shape just as a rock or a mountain has. And when we drop a big rock and a pebble from the top of a high building, we find that the pebble as well as the rock moves in conformity with the laws of acceleration-of-heavy-falling-bodies. And the rules of motion are kept to not only by cannon-balls but also by small shot; the laws by which the former batters down a wall are also in play when the other strikes down a bird. And although

> **nature** (or rather its Divine Author) usually works with much finer materials, and employs more intricate contrivances than **art** (so that the structure of even the most complex watch is incomparably inferior to that of a human body),

still a ·human· artist [here = 'craftsman'] can make pieces of work of the general kind ·as nature's· though very different in size, and in these works we can see skill and complexity *like* nature's though not *equal to* it, and often we see motions

like those of certain works of nature. In all this, of course, the human artist is constrained by the amount of the matter he employs, the demands of his design, and the size and shape of the instruments he employs. Think for instance of a smith who uses a hammer and other large instruments to turn masses of iron into great bars or wedges, or into the strong and heavy chains that used to be employed to load down malefactors. . . .; with smaller instruments he could make smaller nails and filings, almost as tiny as dust; and the time may come when with even finer tools men will make links of a strange slenderness and lightness—so that ·even now· good authors report a chain with several links that was fastened to a flea which could move it. I seem to remember seeing something like this, and I have had the pleasure of seeing how human skill can produce extremely small things of kinds that are usually made much bigger. So if someone says that

> the mechanical principles can usefully be brought into our account of big natural bodies whose structure is visible, they shouldn't be applied to portions of matter whose parts and texture are invisible ·because they are so small·,

he will sound to some ·of us· like someone who says that

> the laws of mechanism can explain what happens in a town-clock, but don't apply to a pocket-watch.

[Boyle then gives the example of a terrella [from Latin meaning 'little earth', an artificial magnetised sphere], which he says obeys the same 'magnetic laws' as the whole earth does.]

Those who 'explain' natural phenomena in terms of 'agents' that are such that we have no conception of how they operate to make those effects happen—people who tell us about such vague agents as 'the soul of the world', 'the universal spirit', 'the plastic power' and so on—may in some cases tell us something, but they don't tell us anything that will satisfy the curiosity of an inquisitive person who is not asking 'What is the general agent that produces phenomenon x?' so much as 'By what means and in what manner is x produced?'. ·In saying that they sometimes tell us something·, I am conceding that the notions they are working with *are not* internally self-contradictory, which many judicious people think that 'substantial forms' and 'real qualities' *are*.

The famous Sennertus and some other learned physicians tell us about diseases that are caused by incantations. But ·that is a useless account of them·. If a competent physician comes to visit a patient who is reported to be bewitched, asks about the strange symptoms, and is given the cool reply 'They are produced by a witch or the devil', he won't settle for such a short and uninformative account as that if he •can somehow trace those extravagant symptoms back to some better known and more published disease such as epilepsy, convulsions, hysterical fits, or the like. And if he •can't do that, he'll admit that he knows much less about this illness than might be expected and attained with other diseases; and that will make him think that he ought to search into the nature of the diseased matter, and he won't be satisfied until that search, along with what he knows of the structure of the human body and other concurring physical causes, enables him to formulate at least a *probable* explanation of this malady. The account he was initially given would satisfy him as much as someone who asks 'How does it happen that this watch marks and strikes the hours?' would be satisfied by being told 'It was made to do that by watchmaker Smith'. . . .

And now at last I come to the matter that in my experience does most to alienate other sects from the mechanical philosophy. It is that they think

> The mechanical philosophy claims to have principles that are so universal and so mathematical that no other physical hypothesis can square with it or be tolerated by it.

I look on this as an easy mistake but an important one [easy to make? easy to correct?]. It is important because the very fact that the mechanical principles are so universal, and therefore applicable to so many things, fits them to include (rather than forcing them to reject) any other hypothesis that is grounded in nature. . . . When any such hypothesis is prudently considered by a skilful and moderate person who is more interested in uniting sects than in multiplying them, whatever is true in it will be found to be •legitimately (though perhaps not immediately) deducible from mechanical principles, or ·at least· to be •consistent with them.

Why is that so? Well, such ·non-mechanistic· hypotheses will probably try to explain natural phenomena either **(1)** with the help of a specified list of material ingredients, such as the Top Trio of the chemists [Boyle uses the Latin *tria prima*; the trio in question are salt, sulphur and mercury], which ·are supposed to· give other bodies their qualities by being ingredients in them, or else **(2)** by introducing some general agent such as the Platonic 'soul of the world' or the 'universal spirit' asserted by some Spagyrists [= 'chemists'], or **(3)** by both of these together.

## The world's soul etc.

I shall start with **(2)**. When an inquiring natural scientist wants to explain some difficult phenomenon, what he's after is not so much •what the **agent** is or does as •what changes are made in **the thing that is acted on** that bring it to exhibit the phenomena that are under examination, and how and by what means those changes are brought about. Now, the mechanical philosopher ·who aims to evaluate some proposal that a certain agent A explains a certain phenomenon· believes at the outset that the only way one bit of matter can act on another is through motion or its effects; which leads him to the view that if the proposed agent A isn't intelligible and physical [see Glossary], it can never physically explain the phenomenon; and that if it *is* intelligible and physical it will be reducible to *matter, and some of the universal states or qualities of matter* that I have already often mentioned. And in the light of

- •the indefinite divisibility of matter,
- •the wonderful efficacy of motion, and
- •the almost infinite variety of combinations and structures that can be made out of minute and insensible corpuscles,

a philosopher can reasonably think it possible, given these resources, to show how any corporeal agent is mechanically possible—*any* corporeal agent, whatever its name or disguise is, however subtle or diffused or active it may be, as long as it can be solidly proved to be really existent in nature.

(The Cartesians are mechanical philosophers, but their 'subtle matter'—the very name of which proclaims it as a corporeal substance—may for all I know be nearly as widespread and active in the universe as the 'universal spirit' of some chemists or the 'world soul' of the Platonists. But this is by the way.) [Two points about this tricky little aside of Boyle's. •For matter to be 'subtle' is for it to be so finely divided that it is more rarefied and easily pushed around than air. (In Descartes's physics it often seems to stand in for the empty space that Descartes wouldn't allow.) •When Boyle implies that subtle matter may be almost as *helpful* in physical explanations as the universal spirit or the world soul, that is his sarcastic way of saying that it may be almost as *useless*. The point of

the aside is to say that the Cartesians' lip service to mechanism doesn't do them any good as scientists.]

·Here's an example, which I shall follow with the general point of which it is an example·. Whenever corn is ground down to meal, the materials and shape of the millstones will be similar, and so will their special way of moving and engaging with other things; and even if these were quite different in a particular case, that would affect only *how* the grains of corn were squeezed and pulverised; ·the result would still be corn-meal, and—this being the main point—·it wouldn't make the slightest difference whether the millstones were turned by water or wind, or a horse, or human hands, i.e. by inanimate or brute or rational agents. ·Now the general point:· When a body exhibits some phenomenon [see Glossary], the physical cause of this

> —whether inanimate or living,
> whether purely corporeal, or united to a thinking substance—

will bring it about by making in the body the kinds of changes I have mentioned. Even if *an angel* caused a real change in the nature of a body x, it is hardly humanly conceivable how he could do this without the aid of *motion*: if nothing was dislodged, and no change was made in *how* x or anything related to it was moving, it's hard for us to conceive how x would come out of this changed in any way.

## The top trio

But now let us come to the other sort of hypotheses that I mentioned [item **(1)** on page 6]. If the chemists or others who want to derive a complete natural philosophy from salt, sulphur, and mercury—or any other set list of ingredients—would think about what they're trying to do, they could easily discover that when portions of matter are regarded as merely quiescent things, they can't explain the vast majority of natural phenomena; so they would find that they had to suppose them—·i.e. their salt and sulphur and mercury, or whatever·—to be active; ·to which we can add· that purely corporeal things can't be active except by means of •motion and •the effects of motion in combination with facts about shapes, sizes and textures. So that when the chemists and other materialists (if I may call them that) restrict themselves to their ·favoured· ingredients of bodies—whether two or three or more—they have to (and usually *do*) leave most of the phenomena of the universe unexplained. What they need is to bring in·to their explanations· the mechanical and more comprehensive states of matter, especially how material things move. I willingly grant that salt, sulphur, and mercury—or some substances like them—can be obtained by the action of the fire from a great many kinds of matter, scatterable matter, here below. [Boyle uses 'here below' sometimes to mean 'in this life (as distinct from the life in heaven)' and sometimes to mean 'on this planet (as distinct from the heavens)'. Context usually disambiguates, but here—the only occurrence in the present work—it doesn't. The entire content of this note was supplied by J. J. MacIntosh.] Nor would I deny that in explaining various facts about the behaviour of such bodies it may be useful to a skilful natural scientist to know and take into account the fact that this or that ingredient (sulphur, say) is a major ingredient in the body he is studying; from which it can be inferred that the qualities that usually accompany that ingredient when it predominates will probably be found in this present body that contains so much of it. But I have shown elsewhere [in his work *The Sceptical Chemist*] that there are many phenomena to the explanation of which this knowledge will contribute little or nothing; to which I would add here that chemical explanations, although they are sometimes the most obvious

and readily available, are not the most fundamental and satisfactory.

Why not? Because the chemical ingredient itself (sulphur or whatever) must owe its qualities to the union of invisibly small particles in a suitable size, shape, motion or rest, and texture, and all of these are merely *mechanical features* of the gathered-together corpuscles. This can be illustrated by what happens in fireworks. It's true that in most of the many different sorts ·of explosion· that are made either in war or for recreation gunpowder is a main ingredient, and much of the variety comes from differences in how much gunpowder is used. But fireworks can be created without gunpowder (as we learn from the ones made in ancient times by the Greeks and Romans); ·and there is a deeper reason than that why the facts about gunpowder don't really provide much support for the chemists' kind of approach to natural phenomena. It is that· gunpowder can be fired and exploded only because of how it is mechanically structured out of simpler portions of matter—saltpetre, charcoal, and sulphur. And sulphur itself, though many chemists mistake it for an elemental principle, owes its flammability to the assemblage ·in it· of even simpler and more basic corpuscles; because chemists admit that it has a flammable ingredient, and experience shows that it contains a great deal of an acid and inflammable salt, and isn't quite devoid of earthy matter.

I know it may be here alleged, that

> what chemical analyses produce are simple bodies, which means that they can't be analysed in their turn.

But it has been sufficiently proved elsewhere [in *The Sceptical Chemist*] that various substances that chemists like to call the 'salts' or 'sulphurs' or 'mercuries' of the bodies that they come from are not simple and homogeneous; and their not being easily scatterable or analysable is not a clear proof of their not being made up of more basic portions of matter. [Boyle almost certainly meant: '. . . of portions of more basic kinds of matter'. His word, incidentally, was not 'basic' but 'primitive'.] Some bodies that are ·certainly· composed of simpler kinds of matter—and even some whose components can be analysed in their turn into even simpler ones—are as *difficult* to resolve into their components as are most of those that chemists get as products of their so-called 'analysis by fire'. Common green glass, for example, is far more durable and resistant to analysis than many of those that are regarded as elemental substances; ·but nobody thinks that such glass is itself elemental·. [Boyle adds the example of 'some enamels' that resist great heat, though we know that they aren't elemental because we know what their ingredients are.]

## Challenges that mechanisms could survive

But even supposing the chemical principles to be utterly elemental, utterly incapable of analysis into simpler constituents, the •various operations ascribed to them will never be made plausible without the help of motion (•various different motions). If we don't bring motion into the story, and are 'explaining' the behaviour of a body merely by listing its ingredients, we'll do about as well as we do if we 'explained' the operations of a watch by saying what metals its various parts are made of, or 'explained' the operations of a windmill by saying that it is made up of wood, stone, canvas and iron.

And I should add this: even if it turned out, through . . . .delicate operations other than the usual analysis by fire, that the material principles of elements of mixed bodies were not the top trio of the common run of chemists, but either •substances of a quite different kind or fewer than three or more than three, that would not at all overthrow the corpuscularian hypothesis. (Regarding 'more than three':

some chemists claim that the right number is *five*: all mixed bodies can be analysed into exactly five simple elements; I could never find that this is true.) Nor would it be fatal to corpuscularianism if van Helmont's followers had the all-powerful solvent by which he claimed to be able to reduce a rock into salt with the same weight as the rock, and to turn both that salt and every other kind of mixed and tangible bodies into tasteless water. For whatever the number or qualities of the chemical principles, if they really exist in nature it may very possibly be shown [those six words are Boyle's] that they are made up of invisibly small •corpuscles with definite sizes and shapes, and that various combinations and arrangements of •these may constitute or cause three or five or more material ingredients. Even if van Helmont's great solvent did exist, mechanical principles might well be made to fit even them [i.e. even the outputs of reductions by the solvent]. The solidity, taste etc. of salt may be fairly accounted for by the stiffness, sharpness, and other mechanical qualities of the minute particles that salt is made up; and if a further action by the solvent reduced the salt or any other solid body to tasteless water, this may also be explained by the same ·mechanical· principles: it could be that. . . .the reduction process wears down the edges and points that had previously enabled the particles them to strike briskly on the organ of taste. ·And there's no problem for mechanism in the alleged Helmontian switch from solid to fluid, because· I have thoroughly shown elsewhere [in his *The History of Fluidity and Firmness*] that a single portion of matter can be liquid at one time because its constituent particles are agitated or loosely assembled, and solid at another time because the particulars are at rest or are more tightly crammed together; which means that the difference between *fluid* and *solid* mainly depends on two of our grand principles, motion and rest. [Notice that Boyle, for whom a 'principle' can be anything that plays a central part in explaining a particular fact or event (see Glossary), says that the two principles highlighted by mechanism are **qualities or states of bodies**, motion and rest, to which he would add shape and size etc., whereas the principles highlighted by the chemists are **kinds of matter**, salt, sulphur and mercury.]

Thus, if the further cleverness and hard work of the chemists (which I don't in the least want to discourage) were to lead to analyses of mixed bodies into homogeneous substances that differed—in number or nature or both—from their routine salt, sulphur and mercury, ·that would be a blow to their theoretical position, whereas· •the mechanistic philosophy is so general and fertile that it could take such a discovery in its stride [Boyle's words are: . . . that it would 'be fairly reconcilable to such a discovery'.] And •it would go on being useful, because these new material principles will—just as the old top trio did—need the more universal principles of the corpuscularians, especially motion. And that holds for all the elements or ingredients that men have fixed on as •principles (or anyway all that I know of): if the mechanical states and qualities of matter aren't brought into the account, these •principles have been so deficient that I have usually noticed that the materialists (including the chemists) don't merely leave unexplained many things that their narrow principles don't cover, but give poor 'explanations' of the particular phenomena that they do offer to give an account of. [Boyle seems here to be using 'materialist' in a special sense of his own. Note '. . . materialists, if I may call them that' on page 7. It seems that a 'materialist' in this sense is someone whose scientific thinking is dominated by the notion of *kinds of matter*. Who would be a materialist but not a chemist? Boyle doesn't say.] They either **(i)** settle for assigning common and indefinite causes that are too •general to satisfy anyone who really wants to understand what has been going on; or they do venture to give •particular causes, and assign shaky or false ones that are open to being easily

disproved by states of affairs or episodes that their doctrine doesn't square with (I have often elsewhere had occasion to show this).

## Mechanism isn't scary

The chemists needn't be afraid to admit the privilege of the mechanical philosophy, because it may be reconcilable with the truth of their own principles insofar as these agree with the phenomena they are applied to. For these more limited hypotheses ·of the chemists· can be subordinated to the more general and fertile principles ·of mechanism·. *Any* ingredient that has a real existence in nature can be derived—either immediately or through a series of decompositions —from universal matter and its mechanical states and qualities. [Boyle's phrase 'universal matter' makes clear something that may have been a little hidden up to here, namely his view that *there is only one basic kind of matter*; any qualitative differences between two portions of matter are upshots of difference in motion, structure, and so on. This comes up again in 'common matter that they diversify' on page 12.] For if different *arrangements* of the very same bricks could generate various kinds of walls, houses, furnaces, vaults, bridges, pyramids, etc., how much more could a great variety of ingredients be produced by. . . .the various combinations and structures of corpuscles which—unlike bricks that are all roughly the same size and shape—may be unlike one another in both respects in unimaginably many different ways! And the mechanical philosophy doesn't have to deny that the primary little lumps that belong to these ingredients may have particles that are so minute and strongly bound together that unaided nature hardly ever tears them apart; we see this in the cases of mercury and gold, which can successively made to put on a multitude of disguises and yet retain their nature so that they can be brought back to their pristine forms. ['pristine' meant 'original', and *still does* except in the speech of semi-literate people.] And I recently mentioned to you that common glass and good enamels, though both of them are artifacts, and are not only compounds but are compounds of compounds, have their component parts so strictly bound together by the skill of illiterate tradesmen that they stay together in the vitrifying [= 'glass-making'] violence of the fire. And common glass isn't affected by *aqua fortis* that will dissolve mercury, or by *aqua regia* that will dissolve gold. [The former of those is nitric acid; the latter is a mixture of that with hydrochloric acid.]

One at-least-probable upshot of all this is that if the following were the case:

> In addition to rational souls there are some other immaterial substances (such as the heavenly intelligences and substantial forms of the Aristotelians) that regularly function as natural *agents*, though we don't know *how* they do their work,

these agents might help us to •constitute and •effect things [i.e. to •create (new) kinds of matter as combinations of previously known kinds, and to •cause certain events], but they won't help us much to conceive how things are brought about. Thus, whatever principles natural things are constituted by, it is by the mechanical principles that their phenomena must be clearly explained. Here is an example: Even if we accept the Aristotelian view that

> the planets are made of a special kind of matter that only they have, and are moved by angels or immaterial intelligences,

we still won't be able to explain planetary phenomena—the planets' appearing to move forward, stand still, move backwards—unless we bring in theories in which the motion, shape, situation, and other mathematical or mechanical

states of bodies play the dominant role. [Boyle gives examples of the motions that might be involved—including candidates from pre- and from post-Copernican astronomy.] But if the principles proposed are corporeal things, there will be legitimate ways of reducing them to—or anyway reconciling them with—the mechanical principles, because these are so general and so fertile that there is nothing real among corporeal things that can't be derived from or subordinated to them. (Notice that I said 'nothing *real*; I don't have anything to say about *chimerical* [here = 'purely fantastical'] things such as some of Paracelsus's.) And when •the chemists show that mixed bodies owe their qualities to the predominance of this or that of their three grand ingredients, •the corpuscularians will show that the qualities of that ingredient flow from its structure and the mechanical qualities of the corpuscles it is made up of. ·Some people seem to think· that

> because chemists' furnaces present many uncommon productions and phenomena, there are bodies or corporeal operations that can't be derived from or reconciled with the comprehensive and fertile principles of the mechanical philosophy.

That is on a par with thinking that

> because there are a great number and variety of anthems, hymns, pavanes, threnodies, courantes, gavottes, sarabandes, jigs, and other (grave and sprightly) tunes in the books and practices of musicians, there are in them a great many tunes—or at least notes—that don't in any way depend on the musical scale.

Or with thinking that:

> because there are rhombuses, rhomboids, trapeziums, squares, pentagons, chiliagons, myriagons, and innumerable other regular and irregular polygons, there are among them some rectilinear shapes that aren't reducible to triangles, or have qualities that will overthrow what Euclid has taught regarding triangles and polygons.

## Decoding the world

I have only one thing to add. ·In the background of it is this·:

- •The clarity of mechanical principles and explanations leads to their being retained (where they can be had) even by materialists [see note on page 9] and others; and
- •The intelligence and hard work of modern scientists and mathematicians have successfully applied them to several difficult phenomena (in hydrostatics, the practical part of optics, gunnery, etc.)—phenomena that previously might well have been 'explained' in terms of occult qualities.

·Against that background·, I say that when this philosophy is more deeply searched into and further improved, it will probably turn out to solve more and more of nature's phenomena. And let me add that it isn't always necessary—even if it is always desirable—that someone who is presenting an hypothesis in astronomy, chemistry, anatomy, or other part of physics [see Glossary] be able to prove *a priori* [see Glossary] that his hypothesis is true, or rigorously prove that the other hypotheses proposed about the same subject must be false. I think it was Plato who said that the world is God's epistle written to mankind (and he could have added, in line with another saying of his, that it was written in mathematical letters); so what is happening when men offer physical explanations of the parts and system of the world is rather like (I think) what happens when men conjecturally develop several different keys to enable us to understand a document written in code. One man may have been smart

enough to discover the right key, but the only way he can prove that he has it right—i.e. to prove that this or that word is not what others guess it to be on the basis of their keys—is by *trial*. He can't show *a priori* that their keys should be rejected and his preferred. But if when his key is tried out it is found to fit the letters of the document well enough to enable us to understand them and make a coherent sense of them, that is enough for it be accepted as the right key of that cipher; there's no need for any further proofs, whether positive ones in favour of this key or negative ones against other keys that have been proposed. [The clause 'to understand them, and make a coherent sense of them' is verbatim Boyle; his point would have been stronger, it seems. if he had written 'to understand it and make coherent sense of it', where 'it' refers to the whole document.]

Sometimes a physical hypothesis peacefully wins the approval of discerning men purely through its fitness to explain the phenomena for which it was devised, doing this without conflicting with any known observation or law of nature. ·I say *peacefully*·—without noise, and without picking quarrels with rivals.

Thus, if the mechanical philosophy goes on explaining corporeal things at the same rate it has in recent years, it can hardly be doubted that eventually unprejudiced persons will think it sufficiently recommended by its internal consistency and the range of natural phenomena that it applies to.

## Recapitulation

Looking back over what I have written, I see that the difficulty and importance of the subject has seduced me into spending many more words on it than I at first planned; so I should now give you a short summary of what came into my mind to recommend the mechanical philosophy to you and remove your fears of seeing it supplanted. All of this ·has a triple underlay·: •I take for granted the creation and general providence of God; •in this paper I claim only to deal with corporeal things, and set aside immaterial beings (which otherwise I very willingly admit); and •I also set aside all agents and operations that are miraculous or supernatural.

**(1)** Corporeal things can't be explained on the basis of fewer than two principles, and no principles can be more basic than matter and motion.

**(2)** The natural and genuine effect of motions in various directions and at various speeds in a portion of matter is to divide it into parts of differing sizes and shapes, moving them in different ways. And in a world like ours the consequences that flow from these are differences in •the orientation, order and location of individual fragments, and in •the structures and textures resulting from their coming together.

**(3)** The parts of matter endowed with these universal qualities are by various interactions turned into natural bodies of various kinds—the kind depending on the abundance of the matter, and on the various compositions and decompositions of the the principles, all of which presuppose the common matter they diversify [see note on page 10.] And these various kinds of bodies, by virtue of their mechanical states and qualities (motion, rest etc.) which enable them to act on and be acted on by one another, come to have the various kinds of qualities, of which some are called 'manifest' [= easily perceptible'] and some 'occult' [= 'hidden']. Some of them act on

the specially constructed organs of sense, and when they are perceived through the soul's capacity for *noticing*, the perceptions are sensations.

**(4)** Because these principles—

matter,
motion (to which rest is related),
size,
shape,
orientation,
texture

—are so simple, clear, and comprehensive, they are applicable to all the real phenomena of nature, which seem not to be explainable by any other ·set of principles· that is a rival to mechanism. If anyone tries to invoke an immaterial principle or agent, it may be downright unintelligible, and in any case it won't enable us to *explain* the phenomena, because its way of working on material things would probably be more •harder to be physically made out than would a mechanical account of the phenomena. [Boyle means something like •'harder to describe and explain as something actually happening in the world'.] And even in the case of an *immaterial* created agent, we can't conceive of how it could produce changes in a body without the help of mechanical principles, especially motion. That is why the reasonable human soul can't produce whatever changes it pleases in the body, but is confined to ones it can produce by determining or guiding the motions of the spirits and other parts of the body that are subservient to voluntary motion.

[This refers to the 'animal spirits'—a supposed system of super-fluid matter that could move around the body—notably through the nerves—at astonishing speed and get into the smallest cracks and hollows. The theory, popularized by Descartes and accepted by Boyle, implied that when you voluntarily raise your arm the events that *immediately* precede your arm's going up are movements of the animal spirits; because these are portions of matter, those transactions are of the kind that Boyle has been saying are intelligible to us. He has of course a problem about the first part of the sequence from •your act of the will (your setting yourself to raise your arm) and •the first movements of the animal spirits. But he has said that in the present work he won't get into that (see 'All I'm defending. . . ' on page 1) .]

**(5)** And any ·supposedly rival· agents or active principles that are not immaterial, and are of a corporeal nature, must either •boil down to being the same as the corporeal principles I have listed or •be less general than mine because mine are so universal and so simple. . . . The fear that whatever truth there is in a new physical hypothesis will overthrow the mechanical principles or make them useless is on a par with the fear that a language will be proposed that is inconsistent with, or not reducible to, the letters of the alphabet.