The Origin of forms and Qualities (according to the corpuscular philosophy) illustrated by (1) considerations and (2) experiments 1. The Theoretical Part

Robert Boyle

1666

[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 text is (1) 'the theoretical part' of Boyle's *Origin of Forms and Qualities*; the somewhat shorter (2) 'experimental part' is not presented here.—Some of the divisions and section-titles are Boyle's, but most have been added in this version.

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Contents

Glossary

affection: An affection of a thing is a state or property or quality or attribute of the thing. The word will be left unchanged throughout this work, because there seems to be no systematic replacement for it.

chemist: For Boyle's objection to the 'chemistry' of his time, see 'Can we hope for help. . . ' on page 9.

history: Boyle uses this word as we still use it in the phrase 'natural history'. In this sense, a 'history of. . . heat' (page 10) is an assemblage of observed facts about heat, organised or classified in some useful way.

modification: A thing's 'modifications' are its non-relational properties—whatever can be attributed to or predicated of the thing. What makes it the case that (for example) *This lump of brass is spherical*? Answer **(a)**: The brass somehow contains a thing-like item, its sphericalness. Answer **(b)**: The brass is laid out in space in a certain way. Boyle regularly uses 'modification' as a way of opting for **(b)**.

motion: In this version, 'motion' often replaces Boyle's 'local motion' = 'motion involving change of place'. For us, all motion is local motion; but there is a long tradition of using 'motion' (and its conventional equivalents in other languages) to mean 'change'; and 'local motion' served to narrow that. We don't need it.

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 Boyle's topic throughout is science, specifically physics, though issues that are 'philosophical' in our sense sometimes come into it.

physical: In Boyle's time, 'physical' had a broader meaning than it has 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 to do with what is really out there in the world'.

principle: In the early modern period 'principle' (like its kin 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 source, a cause, a generating factor. (Hume's *Enquiry into the Principles of Morals* doesn't discuss any moral propositional principles; it's an enquiry into the *sources in human nature* of our moral beliefs and feelings.) Boyle uses 'principle' a lot in each of those senses: through pages 1–8 in our sense of it; but then on page 9 he speaks of the chemists' 'three principles', referring (old sense) to three *kinds of matter*—salt, sulphur and mercury—which the chemists credited with having special causal powers. Then in the same paragraph he speaks (our sense) of 'a system of theoretical principles of philosophy'.

school: The 'schools' to which Boyle frequently alludes were, roughly speaking, heavily Aristotelian philosophy departments; the cognate adjective is 'scholastic'.

second cause: For those with certain theological views, God is the first cause of everything that happens in the world; a 'second cause' is an ordinary down-to-earth cause such as heat causing butter to melt. It is a 'second' cause because God causes the butter to melt *through* bringing heat to bear on it.

The publisher addresses the intelligent reader

Audendum est, & veritas investiganda; quam etiamsi non assequamur, omnino tamen propius,
quam nunc sumus ad eam perveniemus.
We must be daring, and search for the truth; for even if we don't reach it we'll come nearer to it than we are now. (Galen)

• • •

In this curious and inquisitive age, when men have become thoroughly tired of the wrangling and idle theory-spinning of the schools, and are now searching earnestly for a more solid, rational, and useful philosophy [for 'schools' and 'philosophy' see Glossary], it may turn out to be good useful work to help and guide them in their studies and researches—hanging out a light to them as the Egyptians used to do from their famous ·lighthouse· Pharos, to guide sailors in those dangerous seas near Alexandria. The aim is to get better results as they steer their course through the vast ocean of learning, and make more complete discoveries of previously unknown philosophical truths. This has been the main purpose of. . . .the most excellent and incomparable author of the work now presented to your view. You won't find here the sort of thing that has happened in the past, namely:

> Principles were •shoved under the world's nose because of a great name; or else they were •involved in cloudy and mystical notions that put the understanding on the rack, and yet when all this brain-labour was done the principles turned out to be irrelevant and useless for giving even *fairly* satisfactory accounts of ordinary everyday natural phenomena [see Glossary].

What you will get here, instead, are principles built on the firm and unshakable foundation of reason, the senses, and experience; plain and obvious to the eye as well as to the understanding, and just as satisfactory in their application. And although the author here mainly accepts atomism (corrected and purged from its original inventors' wild fancies and extravagances concerning the origin of the universe, fancies that are still embraced so lovingly by some atomists. . . .), given the many alterations and additions ·to atomism· that his penetrating judgment has led to, I don't hesitate to say that what this work presents is *a new hypothesis* that is *his*, based on daily observations, on familiar proofs and experiments, and on exact and easily practicable chemical processes; a hypothesis by which one of the most abstruse parts of natural philosophy—the origin of forms and qualities, which so greatly troubled and puzzled the ancients [and, he rather laboriously adds, Descartes]—is now completely cleared up and made obvious. From this very essay, therefore, we can take hope, and joyfully expect to see the noble project of the famous Bacon (hitherto classed among the desiderata [meaning that there was a need for Bacon's project, it filled a gap]) brought to completion in a real, useful, experimental physiology established and grounded on easy, true, and generally accepted principles. But rather than forestalling your judgment about the excellence of the author, or his subject. . . .I shall refer you to the Work itself, after I have given you these few preliminary notices.

[The rest of the publisher's letter is mainly concerned with a question about one experiment in the second part of the present work [not presented here], which was also described in

a roughly contemporaneous work by another writer. The publisher gives reasons for his confidence that Boyle thought this up for himself, and did the experiment; and he comments on Boyle's decency in defending the other person (whose name we are not given) against a charge of plagiarism.

[He says that Boyle honestly confronts genuine criticism that seems to show he has gone wrong somewhere, but that he follows his own bent and the advice of his friends in not picking quarrels or chasing down everything that has been published in opposition to his views. He says that the defence of Boyle against all this will come from such of his intellectual allies as have 'more leisure than he has for writing polemical books'.

[He winds up thus:] In the meantime I am sure that everyone who has any regard for the great concerns of learning will eventually read and accept this challenging and excellent piece with the pleasure, delight, respect, and esteem that it so highly merits.

The author informally addresses the reader

Just as it is the job of a mineralist both •to discover new mines and •to work ones that have already been discovered, extracting perfect metal from the ore, so I think it is fitting for a naturalist [= 'natural scientist'] not only •to develop hypotheses and experiments but also •to examine and improve ones that have already been discovered. This was one of several reasons why I was invited to make the following attempt [Boyle's phrase].

Because its results will now be seen by people other than those for whom they were written, I should tell you a little about the occasion, the scope, and some of the circumstances. I am all the more willing to do this because it will involve me in giving you •reasons for writing in the way I do about the Aristotelian philosophy, and •those may be of some use to some sorts of readers (especially gentlemen); and if you relate •them to most of the other things I have written about the school philosophy, they may do you some service and save you and me the trouble of repetitions. [Why 'especially gentlemen'? For one or more of these reasons: (i) They are most likely readers to have the Aristotelian assumptions that Boyle is challenging. (ii) This document is partly practical-experimental, and gentlemen should be encouraged to get their hands dirty or at least to work with artisans who will do so. (iii) There are among gentlemen conventions of trust that are essential to progress in empirical science. —This note owes everything to J. J. MacIntosh.]

[Boyle goes on to express his growing conviction that there is need for an introduction to corpuscularianism = mechanistic physics; certain previous writings of his were most apt for people who already knew their way around corpuscularianism; they might make others interested to learn about it, but they didn't themselves provide the needed introduction. He continues:]

At about that time I also had some thoughts of writing a history [see Glossary] of qualities. I wrote on loose pages

some observations and experimental reports that would help in that plan, and I also wrote a discussion of which some parts could introduce some of the particular experimental items while other parts could serve as a *General Preface* to •the history of qualities, if I ever had time and inclination to write •it. I had been writing to Pyrophilus [a pseudonym for a nephew of Boyle's] some kind of introduction to the mechanical philosophy; and I thought I would now present to him, as far as my thoughts and experiments would let me, a brief account of what the corpuscularian view is about the nature and origin of qualities and forms. ·It was especially important to do this for my young protégé because· this topic takes one into the most basic and important part of natural philosophy.

[What followed was a time of some confusion, Boyle explains [referring to the turbulent time when the Cromwell regime was collapsing and King Charles II wasn't yet on the throne] during which much of his written material was scattered through the various places where he had lived. However, a person in whose care he had left some of his papers made clean copies of many of them, including nearly all the notes on qualities and forms and the Preface addressed to Pyrophilus. Other friends read these, and urged Boyle to publish, which after some enforced delays, he is now doing. He goes on:]

The way the scholastic [see Glossary] philosophers deal with

forms and qualities, and

generation and corruption and alteration

is usually so obscure, tangled and unsatisfactory, and their discussions of these subjects consist so much more of logical and metaphysical notions and hair-splitting than of observations and reasonings about the real world, that it's difficult for a reader of average intelligence to know what they mean, and equally difficult for any intelligent and unprejudiced reader to accept that they teach. [Most readers, even the very intelligent ones, Boyle says, are scared off issues in general physics by the 'darkness and difficulties' of the scholastic = Aristotelian treatments of them; and he predicts that these people will be glad] to be offered intelligible notions of things that as usually expressed are not usually understood. I believe that the subjects themselves are among the noblest and most important topics in physical science, the most delightful to work on, and (if handled rightly) the most useful.

[Boyle notes that many able people have been drawn to •this way of scientific thinking (which is often now called 'corpuscularianism', the name *he* first gave it) by their pleasure in certain experimental results. Some of them have gone on to devise experiments of their own, but haven't first been instructed in •its basic concepts.] Our Pyrophilus, for whom these notes were written, used to be in some ways like these ·untutored· scientific practitioners; and he was glad to receive the notes, and perhaps others will be also. Although the chief business of the notes is to give an account of the nature and origin of forms and qualities, that topic connects with so many other parts of general physics that I have had to bring in so many other important points that this present work can serve as. . . .an introduction to the elements of the corpuscularian philosophy.

Readers who have had the curiosity to look at what is commonly taught in the schools regarding

forms and generation and corruption

and other such topics have usually turned away in disgust from those unrewarding intricacies. Perhaps they will be pleased to find in my notes explanations of those matters that at least make them intelligible; and they may like seeing those topics—the ones the schools had so interwoven with Aristotle's doctrines—reconciled to and handled in terms of corpuscularian physics.

[Boyle anticipates the criticism that he has neglected various topics that the Aristotelians 'solemnly and eagerly'

deal with. He responds rather stiffly that he knows the literature of scholasticism, and ignores most of it in the present work because he thinks it is useless and would only bring needless obscurity. After saying sharp things about the intellectual conduct of some scholastics, he continues, crescendo:]

Many questions and controversies arising within the Aristotelian philosophy are hotly and loudly debated there, but it would have been tedious and irrelevant for me to include them here. That is because they

- •presuppose the truth of doctrines of theirs that we ·corpuscularians· reject, or
- •depend on technical terms that we have no use for.

As for the great disputes over questions such as these:

(1) Do the four elements [see note on page 38] have distinct substantial forms, or are they distinguished only by their separate qualities?

(2) Do the elements remain in mixed bodies according to their forms or according to their qualities?

(3) Are their forms refracted or not? Are their qualities refracted or not?

These and other such questions are irrelevant to—out of place in—the philosophy of anyone who doesn't accept •that there are four elements, •that cold, heat, dryness and moisture are in the Aristotelian sense 'first qualities', •that the real natural world contains any such things as substantial forms. [Boyle adds that he is further deterred by the slippery ambiguities in the language of recent scholastic writers. He contrasts the bad habit of meaning different things by the same word with his own healthy practice:] When ·in these notes· I sometimes use a variety of words and phrases to express the same thing, I do it deliberately, perhaps harming my own reputation, in the interests of Pyrophilus. I am not the only person to have noticed that when a single unobvious notion can be expressed in several different ways, readers—even clever ones—may differ in which of the expressions gives them the best grasp of it.

[Boyle goes on at some length about anti-Aristotelian writings that he also doesn't bring into his own work. He distinguishes two kinds of these. **(a)** There are works that depend on claiming that Aristotle has contradicted himself. Boyle says that to evaluate such a claim one would have to establish what Aristotle *did* say, and that this is often surprisingly difficult (although Aristotle is often clearer than his followers). Also, he adds, accusations of inconsistency are mere point-scoring and don't serve in the pursuit of truth. Suppose that Aristotle really did in one place say P, which is inconsistent with Q which he said in another; one of the two may still be true. **(b)** Let Boyle speak for himself:] For reasons I have given elsewhere, I have deliberately left unread many treatments of general hypotheses—ones that are admired, rightly, for all I know—and it may be that they had things to teach me. But there are others that I make no use of, though I *have* read them, because some of them could be useful only to someone who adopted some hypothesis or theory that I am not sure is true and that I have no need of in what I aim to do. So I haven't used any arguments that are based on or presuppose

- •indivisible corpuscles called 'atoms',
- •any innate motion belonging to them,
- •the thesis that the essence of bodies consists in extension,
- •the thesis that vacuum is impossible, or
- •celestial globules, or subtle matter

such as the Cartesians employ to explain most natural phenomena. Writing for corpuscularians in general, and not for any party of them, I decided not to bring in any of the above notions or various others: they would **(1)**

create needless difficulties when I was discoursing •against theorists for whom these things appear as disputable as the Aristotelian doctrines seem to me, and **(2)** prevent me from getting through to able readers who would think it unfair for me to try to convince them of anything while using notions that I did not myself think proper.

For similar reasons I have stayed away from arguments purporting to show that the inanimate parts of nature involve intentions and passions that really belong only to living beings, and perhaps only to thinking beings. [There may be some tiny pockets of truth in all this, Boyle says, but he isn't going to present them because it would be hard to make clear how limited they are. Also, this and some related topics would get him into battles with theologians, which he prefers to avoid. 'My whole business in this tract is to discourse of natural things as a naturalist, without invading the province of theologians.'. . . .]

Don't think I am censuring or decrying the whole Aristotelian philosophy, let alone despising Aristotle himself. His writings sometimes make it surprising to me that absurdities are so confidently attributed to him by his scholastic interpreters. I regard him as one (though *only* one among many) of the famous ancients who ennobled Greece around the time of Alexander; and I freely grant him most of the praises that are due to great intellects except for those that belong to clear-headed naturalists. Let me say this here, once and for all: When I speak against 'Aristotle's doctrine', referring to it in that vague general way, all I am talking about is his physical science, or rather the theoretical part of it (for I greatly admire his natural history of animals). . . .

Aristotelian nit-picking led me to digress. Coming back to what I was saying before that: I don't mean anything that I have said to disparage the excellent authors—especially the modern ones—who have declared their opposition to Aristotelian physics, such as

Lucretius
Bacon
Basso
Arnold and Gerald Boate
Descartes and his followers
Gassendi
Magnenus
Pemble
Helmont;

and I don't want to be thought to have made no use of their ideas and arguments. [He goes on to explain that he wasn't able to get some of their books, and with the ones he could obtain 'the weakness of my eyes' stopped him reading any but the parts dealing with the subject he was working on. He hopes he benefited from what he did read, he says, and adds that he might have learned more from Gassendi's small, intelligent *Syntagma Philosophiae Epicuri* ['Treatise on the Epicurean Philosophy'] if he had known of it earlier.]

I willingly leave it to you to judge whether, in the first or theoretical part of this work, I have

—treated the nature and origin of forms and qualities more comprehensively than others have done,
—made it more intelligible than others have done, by new and appropriate comparisons and examples,
—added any considerable number of notions and arguments, furthering the completion and confirmation of the proposed ·corpuscularian· hypothesis,
—rightly dismissed arguments that aren't fit to be relied on,
—presented some arguments so warily [Boyle's word] that they are not liable to the troubles that have beset them in others' presentation of them.

But I invite you to agree that in the second or experimental

[Boyle says 'historical'] part I have done some little service to the part of physics that I have been dealing with. [Boyle continues at some length about the second part [which is not offered on the website where you found the present version].]

Some scientifically active people who are perhaps more in touch with things than with books may think that the Aristotelian philosophy is retreating everywhere as much as it is in England; and this may lead them to think that a doctrine that is so near to death needn't have been so carefully refuted. But others who know better won't be surprised that I think that a doctrine with the advantages of Aristotelianism, though too erroneous to be feared, is too considerable to be ignored. ·When I speak of 'knowing better' and of this doctrine's 'advantages' I am referring to the following facts·:

—Aristotelian has struck down deep roots, especially (but not only) in the universities, where it has flourished for many ages; in some of them it is watered and fenced [Boyle's phrase] and taught to the exclusion of the mechanical philosophy. . . .

—Some clever people (ones who are more subtle than honest) find it easier to give a plausible defence of an error than to confess it honestly.

Some of our opponents (led astray only by education and morally harmless prejudices) deserve a better cause than one that •needs all their argumentative cunning without being •worthy of it. They deserve this *so much* that I'll think that the trouble I have taken was worthwhile if my arguments and experiments have the good fortune to undeceive them. . . .and lead them to achieve considerable things by using as much skill expounding the riddles of nature as they do solving the riddles of the schoolmen, spending their intellect and industry on overcoming the obscurity of nature's works rather than the obscurity of Aristotle's. . . .

[Boyle closes this chat with the reader by giving advance notice that some of the 'Notes' that comprise this work are presented as though they were notes on a work by someone else. [The work in question is 'Essay on Saltpetre', included in Boyle's *Certain Physiological Essays* (1661).] He gives two complicated reasons for this: one having to do with his plans to make the work easy to revise and correct, the other concerning his wish to present corpuscularian ideas without dogmatically asserting corpuscularian propositions.]

Preface

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The origin and nature of the qualities of bodies, Pyrophilus, is a subject that I have long regarded as one of the most important and useful that the natural scientist can choose to study. What we know about bodies outside us is mostly derived from information the mind gets through the senses; bodies act on our senses only by virtue of their qualities; so what we know about bodies is pretty much confined to those qualities. What about the 'substantial forms' that

some people imagine to be in all natural bodies? Well, it's not obvious that there *are* any such; it's much more obvious that the wisest of those who do believe in them admit that they don't know them well. And just as it is by their qualities that bodies act immediately on our senses, so also it is by virtue of those attributes that they act on other bodies, and by that action produce in the other bodies and often in themselves the changes that sometimes we call **(2)** alterations, and sometimes **(1)** generation or **(3)** corruption. [•Boyle is here thinking of changes in which something **(1)** comes into existence or **(3)** goes out of existence or **(2)** alters in some manner in the interim. It could be the birth or death of an organism, but we'll see that that's not the whole story. •The equation of 'qualities' with 'attributes' is Boyle's.]

The limited knowledge that experience has given us of these differing qualities of bodies is what enables us. . . .to exercise the limited control that we have acquired or re-acquired over the created things ·in question·. But the study of qualities is no more •noble and useful than it is (for me at least) •difficult. What the schools teach us about qualities is so slight and flimsily supported that it's an open question whether they have •obscured rather than •illustrated the things they should have explained. I soon stopped expecting to learn much from the schools about the nature of various particular qualities when I found that they derive most qualities from bodies' *forms*, whose particular natures (the wisest of them admit) they can't comprehend. (The only exceptions are a few qualities of bodies that can be deduced from the four qualities that they choose to call 'primary'—or so they say, but without saying *how* this deduction goes, leaving it to us to guess.) And Aristotle himself ·is doubly at fault in this matter·. **(1)** As I shall show later on, his definition of *quality* is as obscure as qualities themselves are (though it seems to me that *quality* is far more easily definable than many of the particular qualities are. **(2)** Surprisingly, in his eight Books of Physics, where he claims to discuss the general affections [see Glossary] of natural things, he leaves out the doctrine of qualities, as have. . . .various later writers on Aristotelian science. I can't help seeing this as an *omission*, because qualities seem to belong to natural bodies generally considered just as much as do place, time, motion, and the other things that are usually dealt with in the general part of natural philosophy.

The most ingenious Descartes says a little about •some qualities; but although (for reasons I have given elsewhere) I have deliberately refrained from studying his system of philosophy, I have flipped through his pages and found that he has left most of the •other qualities undiscussed; and regarding the ones that are more properly called 'sensible' he speaks very briefly and generally, attending to how they affect the sense-organs rather than to what changes happen in the objects themselves to make them cause in us a perception sometimes of one quality and sometimes of another. Besides, many of his explanations depend on his special notions of 'subtle matter', 'globes of the second element' and the like; and as befits such a great person he has interwoven these with the rest of his system, to such an extent that they can seldom be made use of without adopting his whole philosophy. Epicurus and his expositor Lucretius have given some good hints regarding the nature of a few qualities. But even these explanations include many that are either doubtful or imperfect or both, and many other qualities are left for others to deal with. This brings up the second and main difficulty that I find in investigating the nature of qualities, namely:

> Whatever should be thought of the general theories of Aristotle or other philosophers concerning qualities, we obviously don't have an experimental history of them, which is needed as a foundation for any such

> theory if it is to be solid and useful. And we so completely lack this that I don't know of any single quality of which any author has given us a competent ·experimental· history.

(The only exceptions are mathematicians' work on sounds, and our illustrious Bacon's observations (rather than experiments) regarding heat in his essay *The form of cold*.) There's something I want to explain here:

> The nature of qualities is so beneficial a topic of theory that my labours may be regarded as not wholly useless, even if I can contribute only a little to clearing it up. Given that it is such an abstruse subject, I hope to be pardoned if I sometimes go wrong and leave various things uncompleted—that being what great philosophers have done before me.

·*That* is why I mentioned faults in the work of some of my predecessors·. I wasn't aiming to disparage those great men, whose aim seems to have been to present principles and summaries of philosophy rather than to insist on particulars; all I wanted was to show that if my work on this topic is faulty, I am in good company!

But, Pyrophilus, before I give you my notes on this part of our author's Essay [see bracketed passage just before the Preface on page 6], I need to give you advance notice of four things, so that you'll understand what I intend in doing this.

(1) Whenever I speak indefinitely of 'substantial forms', I will always mean to exclude from the range of what I'm talking about the reasonable soul that is said ·by the Aristotelians· to be the form of the human body. Please note: *always*.

(2) I am not willing to discuss the origin of qualities in beasts [= 'in animals other than humans']; partly because •I don't want to commit myself to examining what the nature of their souls is, and partly because •it is difficult in most cases—at least for someone who is compassionate enough—either to make experiments on living animals, or to judge what influence their life may have on the change of qualities produced by such experiments. [Boyle did have things to say about physical transactions whose outcome differs according to whether one of the items is alive. But his reference to being 'compassionate enough' suggests that he may have meant to write: '. . . what influence the change of qualities produced by such experiments may have on their life'.]

(3) My only reason for writing these notes is that our author in the part of his Essay about saltpetre briefly conveys some notions about the nature and origin of qualities; you mustn't expect that I, whose method leads me to write only some *notes* on this and some other parts of the Essay in question, will write solemnly or elaborately about the nature of particular qualities, or that I will fully exhibit my own views on those subjects. For. . . .in these first notes I write as a corpuscularian, and set down only things that seem to have a tendency to illustrate or confirm the notions. . . .implied in our author's Essay. So I must here tell you that I don't have the time, and don't claim to have the skill, to present a full ·natural· history ·of the qualities· or to explain the nature of each separate quality in detail.

(4) In recent years the schools have created confusion by their way of 'explaining' all natural effects in terms of entities that they call 'real qualities'. [Here 'real' means 'thing-like', from Latin *res* = 'thing'.] In line with that label for them, the schoolmen attribute to these 'qualities' a nature quite different from the states of the matter they belong to; ·the crucial difference is that a 'real quality' is said to be capable of moving from one piece of matter to another·, and in some cases ·'real qualities are held to be· separable from all matter whatsoever. Anyone who accepts this doctrine will think it needless or hopeless for men to explore the nature of particular qualities, and their effects. Example:

We ask: how does it come about that snow dazzles the eyes?
the 'real qualities' theorist answers: It happens by a quality of whiteness that is in it; which makes all very white bodies produce the same effect.

We ask: What is this whiteness?
his answer boils down to: It is a real entity that makes 'white' the right word for any portion of matter to which it is joined.

We ask: What *is* this real entity that you call a quality?
his answer: (It will be about the same as what he says about his 'substantial forms'. . . .or at any rate it won't be any more intelligible.)

We ask: How does it come about that white bodies in general do produce *this* effect of dazzling the eyes rather than effects of green or blue?
What he *ought to* answer: It's because white bodies reflect outwards—and so reflect onto the eye—far more of the incident light than green and blue ones do.
What he probably *will* answer: It's because of the natures of white, green and blue bodies that they have these different effects.

This approach makes it very *easy* to 'explain' all of nature's phenomena •in general, while making men think that it's *impossible* to explain almost any of them •in particular.

·Can we hope for help from the chemists?· What has led many learned men, especially physicists, to accept the chemists' three principles [see Glossary] is a desire to escape from the unsatisfactoriness and barrenness of the school philosophy; and I do have a very good opinion of chemistry itself considered as a •practical art [= 'a system of skills']. But the chemists claim to have a system of •theoretical principles of philosophy, and I'm afraid it won't give much satisfaction to any serious enquirer into the nature of qualities. For one thing, many qualities can't with any probability be derived from any of the ·chemists'· three principles; also, those that are ascribed to one or other of them can't intelligibly be explained without help from the more comprehensive principles of the corpuscularian philosophy. Suppose we are told that *all solidity comes from salt*, and let's suppose that we find this plausible: still, all it tells us is what material principle or ingredient solidity resides in, not **how solidity is produced**. It doesn't tell us, for example, how water even in tightly sealed containers comes to be frozen into ice, i.e. changed from a fluid to a solid body, without acquiring any salty ingredient. . . . So, Pyrophilus, I thought it might help us greatly in understanding the nature of qualities to show **how they are generated**; and that same procedure might, I hoped, lessen the obstacle to the advancement of solid and useful philosophy that is posed by these dark and narrow theories of the Aristotelians and chemists. What I am chiefly aiming at is to make it probable to you by experiments. . . .that

> almost all sorts of qualities—most of which the schools have either left unexplained or else 'explained' in terms of I-know-not-what incomprehensible 'substantial forms'—can be produced *mechanically*.

I mean: they can be produced by corporeal agents that seem **(a)** to work purely by virtue of the motion, size, shape, and inner structure of their own parts (I call these attributes 'mechanical' affections of matter because they are what we willingly turn to when explaining the various operations of mechanical engines), and **(b)** to produce the new qualities exhibited by the bodies they act on purely by changing the texture, or motion, or some other mechanical affection of the bodies in question. [Boyle adds, rather unclearly, that he doesn't expect to present a complete corpuscularian explanation of everything that we might want it for, but he hopes to make a good enough job of a big enough part of it

to] have done a useful service to natural philosophy, partly by arousing you and your learned friends to search for more intelligible and satisfactory ways of explaining qualities, and partly by making a start on the history [see the Glossary] of the qualities that I shall emphasize most, including heat, colours, fluidity and firmness. I want this start to invite you and other able men to contribute ·your and· their experiments and observations to this useful work, thus laying a foundation on which you, and perhaps I, may build a more distinct and explicit theory of qualities than I shall at present try for. I know that some of the things that **(a)** my experiments tend to confirm are also confirmed by **(b)** more obvious natural phenomena; but I presume you won't mind my choosing to direct your attention to **(a)**. . . .because

•the changes of qualities that **(a)** our experiments make will mostly be faster and more conspicuous ·than those of **(b)**·, and

•it will be easier for us to judge in **(a)** than in **(b)** what the agents doing the work *are* and to estimate what ·exactly· they are doing; that is because in **(a)** it is we who have applied the agents and often we who have prepared them.

Section 1: Introductory points 1–3

Before I get down to details, Pyrophilus, I'll try to give you a general sense of the doctrine (or rather the hypothesis) that is to be checked against the historical [see Glossary] truths that I'll present concerning particular qualities (and forms)—checked against them and either confirmed or disproved by them.

I will cast myself in the role of a corpuscularian. And here at the entrance I'll give you (in a general way) a brief account of the hypothesis itself in its bearing on the origin of qualities (and forms); and in the interests of clarity I'll put it into eight particular points. ·I want this to be as brief as possible· so as to enable you to grasp the whole scheme better, taking it in in a single view, so to speak; so I'll do little more than barely state some of my points—the ones that either •seem evident enough by their own light or •can harmlessly have their various proofs reserved for proper places later on in this treatise. Others of my points ·can't be dealt with in such a summary fashion: they are ones· that concern important topics and suffer from almost universal prejudices against them; so I have to say something about them right away, so as to clear their names and justify them. . . .

1. I agree with most philosophers about this: there is one catholic or universal matter [Boyle's adjectives] that is common to all bodies—meaning by 'matter' a substance that is extended, divisible and impenetrable.

2. Because this matter all has the same intrinsic nature, the qualitative variation we see in bodies *must* arise from something other than the matter they consist of. And since we don't see how matter could change if all the parts that it is or could be divided into were perpetually at rest among

themselves, it follows •that the universal matter can sort itself out into a variety of natural bodies only if it has motion in some or all its distinguishable parts; and •that this motion must have various tendencies, with one portion of matter tending to move one way and another portion in another way. . . .

That there is motion in many portions of matter is obvious to the senses, but there is an old and still continuing dispute about how matter came to have this motion. The ancient corpuscularian philosophers didn't believe in an Author of the universe, so they had to make motion congenite to matter [meaning that matter came into existence moving; we might say that it 'hit the ground running']. . . . I don't agree. I tend to agree with the ancient corpuscularians about most things, but not this one. It is just not true that the nature of matter includes motion or an endeavour at motion: matter is as much *matter* when it is stationary as when it moves, and we see that a single portion of matter can first move and then be brought to rest and then, by external agents, be set a moving again. [Boyle is silently assuming that if motion were 'congenite' to matter it would also be essential to matter.] I think that a man can be a good natural scientist without being an atheist; and I have no qualms about saying that the origin of motion in matter is from God. (In this I agree with an eminent philosopher of old, and with the excellent Descartes who has revived this opinion among us.) But we should *not* believe that this beautiful and orderly world of ours resulted simply from matter's being set moving and then left to itself. I think that the wise Author of things, by establishing the laws of motion among bodies and guiding the first motions of the small portions of matter, •brought them to come together in the way needed to constitute the world, and •constructed those fascinating and elaborate engines, the bodies of living creatures, giving most of them a power to propagate their species. But though these are my convictions, I don't have to rely on them here, where I'm not claiming to present a complete discussion of the principles of natural philosophy, but only to touch on notions that are needed to explain the origin of qualities and forms. So I'll move on to the remainder of my topic as soon as I have pointed out that motion seems to be the chief second cause [see Glossary], and the grand agent of everything that happens in nature. It's true that size, shape, rest, location, and texture do have a role in natural phenomena, but in comparison with motion they seem to be in many cases *effects*, and in many others little more than *conditions* or *requirements* which have an effect on how one portion of matter affects another through its motion. Example: a watch's ability to tell the time depends on the number, the shape, and the mutual fit of the wheels and other parts; but until these parts are actually put into motion, all their other affections are without any causal relevance. [He gives two more examples: a key and a knife. Then:] Similarly with brimstone: however favourable its structure of parts is to its burning, it won't catch fire unless some actual fire—or some other portion of vigorously and variously agitated matter—puts its sulphurous corpuscles into a very brisk motion.

3. These two grand and most universal principles [see Glossary] of bodies, matter and motion, being thus established, two things follow: **(i)** Matter must be actually divided into parts, that being the natural effect of motions with different directions and speeds; **(ii)** Each of the basic fragments, or other separate and whole masses of matter, must have two attributes—its own size and its own shape. Experience shows us (especially experience of chemical operations, in many of which matter is divided into parts that are too small to be separately perceptible) that matter is often divided into imperceptible corpuscles or particles, and from this we can

infer that the tiniest fragments of the universal matter, as well as the biggest masses of it, are each endowed with its particular size and shape. Why? Well, being a finite body it must have dimensions that are terminated and measurable; and though it may change its shape, it must necessarily. . . .have some shape or other. So now we have uncovered and must accept three essential properties of each whole or undivided portion of matter, perceptible or not:

size
shape
motion or rest (there is no intermediate case!).

The first two may be called *inseparable accidents* of each separate portion of matter: •inseparable because the portion, being extended but finite, *must* have some size or other and some shape or other; and yet •accidents because the thought of a portion's changing its shape or being subdivided does not interfere with the thought of its still being *matter*—whether or not either of those changes can be actually brought about by physical agents.

Whether these accidents can conveniently be called the 'modes' or primary affections [see Glossary] of bodies, to distinguish them from the less simple qualities such as colours, tastes and odours that bodies have because of them. . . .I shan't now stay to consider; but ·I do have to consider· one thing that the modern schools usually teach regarding accidents—something that clashes so completely with the position I am advocating that I can't ignore it entirely. (·I have in fact already mentioned it on page 8·. I am referring to the view that natural bodies have a store of 'real qualities' and other 'real accidents' which, so far from being modes ·or states· of matter are real entities that •are distinct from it, and—according to many modern schoolmen—•can exist separate from all matter whatsoever. [Boyle starts his long and learned discussion by distinguishing two traditional senses of 'accident'. **(1)** In one sense, an 'accident' of x is a property or quality or attribute that x has *contingently*. Whereas your human nature is something you necessarily have (you couldn't lose it while remaining the human being that you are), your good health is in that sense an **(1)** 'accident' of you, because you could fall ill yet still be a human being and indeed be the same human being. The term in this sense belongs to the contrast **necessary/contingent**, and Boyle rightly says that it is irrelevant to his present topic, which is entirely concerned with **(2)** the other sense of 'accident'. In this sense, 'accidents' include all the things that can be true of a substance; the term in this sense belongs to the contrast **substance/accident**; and everything that can be true of a substance over and above its being-a-substance counts as an accident. Now Aristotle and others have distinguished substances from **(2)** accidents by saying that a substance exists 'of itself', unaided 'by any created being', whereas an accident can't exist except *in* a substance. According to Aristotle and his early followers, an accident is in a substance not as a part of it and not as something that could exist independently of it. This wall's whiteness isn't a part of the wall, and can't exist except in that wall, i.e. as the whiteness *of that wall*. Boyle continues:] In the light of this, it won't be hard to see the falsity of the scholastic opinion about real qualities and accidents: this doctrine seems to me to be either unintelligible or outright self-contradictory. In maintaining that. . . .

> an accident is not a mere mode of a portion of matter x—·a mere *way* that x is·—such as being hot, being white, etc., but rather is an entity really distinct from x, ·so that it can exist separated from x· and in some cases can exist separated from all matter,

they are giving it the name 'accident' but are describing it in a manner that fits only the notion of substances. The

·essential· nature of a substance is just this, that it can exist on its own, without being 'in' anything else in the way whiteness can be 'in' a wall; so that when the schoolmen tell us that a quality or other accident can exist without being in that way 'in' anything, they are in fact treating it as a substance while calling it an accident. And I have never found an intelligible account of what these 'real qualities' *are*, given that they are said not to be matter or modes of matter or immaterial substances. When a bowling ball runs along, its motion—like its spherical shape—is not *nothing*, and yet it is not any part of the ball, whose whole substance would remain even if it stopped moving or was forced into the shape of a cube. And making them real and physical entities (we are doing physical science here, not logic or metaphysics) seems to be on a par with holding that because we can think of a man as sitting, standing, running, thirsty, hungry, weary etc., we should make each of these a distinct entity, as we do give some of them (e.g. hunger, weariness) distinct names.

The subject of all these qualities is the same man, considered with details that make him appear different in one case from how he appears in another. And it may be useful to my present topic to remark that a single entity may have different names, and even different definitions. A simple example: one man can be a father, a husband, a master, a prince, etc., and in each of these capacities or relations he will fall under an appropriate definition, while through all this he is one and the same man. Well, the same thing happens with many of the physical attributes of a body.

Section 2: Detour regarding the relative nature of physical qualities

This notion is of some importance as an aid to avoiding the grand mistake that people have been making about the nature of qualities; so I think it will be worthwhile to illustrate it a little further. Let us suppose that the first locksmith made the first lock before making a key to it (it wouldn't affect the point I am making if we supposed the key to come first). That lock was only a piece of iron x worked into a certain shape; and when the key was made it too was nothing but a piece of iron y with a certain shape; but because of the fit between x's shape and y's, it became the case that the main fact about x was that it was a lock that could opened by y, and the main fact about y was that it was a key that could open x. Yet these new attributes didn't add any real or physical entity to either the lock or the key; each of them remained nothing but the same piece of iron shaped exactly as it was before. And when our smith made other keys of various sizes or with various internal shapes, the first lock came to have a new power, namely a power to resist those other keys; but this, again, wasn't a new *feature of the lock* but only a new relationship between it and certain other things.

Now let me carry this comparison a little further. Someone who defined the first lock and the first key would have given them distinct definitions relating each to the other; but these

definitions wouldn't imply that these two iron instruments were physically unlike in any way except the shape, size and structure of the iron that each consisted of. In line with this, I don't see why we can't think of the qualities. . . .that we call 'sensible' in the following way:

> A body may be said to have a certain quality—·e.g. being yellow·—by virtue of some facts about how its shape, texture and other mechanical attributes make it relate to our sense-organs; but this quality isn't a real entity *in* the body. All we have here is *the body*, with its particular size, shape, and other mechanical modifications. [See Glossary.]

Modern goldsmiths and refiners count as a principal way of distinguishing gold, by which men can be sure that they have a portion of true gold and not some counterfeit, that gold is easily soluble in *aqua regia* and insoluble in *aqua fortis*; but these attributes aren't something in the gold other than its special structure; and the gold we have now has exactly the same nature as gold in Pliny's time, when *aqua fortis* and *aqua regia* were utterly unknown to the Roman goldsmiths. I have selected this example because it gives me an opportunity to make the point that if the doctrine I have been proposing is wrong then we must accept that a body may have an almost infinite number of new real entities attached to it without there having been any physical change in the body itself. [He develops this point with examples that are hardly needed; the point is clear enough in itself.] There are some materials that don't cause vomiting or sweating on their own, but do so when some gold is joined to them. In short,

> **nature** produces so many new things with new relations to other things—doing this sometimes by chance and sometimes not; and
>
> **art**, especially assisted by chemistry, can make such a host of new products, each having new operations on our sense-organs, either •immediately or •by making perceptible changes in other bodies—doing this by chemically pulling natural bodies apart in various ways, or compounding them or their constituent parts with one another,

that for all you know to the contrary the most familiar bodies may have multitudes of qualities that you have never dreamed of; and no thoughtful person will come anywhere near to accepting that such a crowd of real physical entities can get attached to a body while it remains in itself exactly as it was before, so far as our senses can tell.

To clarify this a little further, led me add that powdered glass is commonly classified as a poison, and. . . .I remember a story of Cardan's. In a cloister where he had a patient who seemed near to death from torments in the stomach, two other nuns had been already killed by a mad woman who, having accidentally been allowed to go free, had mixed powdered glass with peas that were eaten by these three, and by several other sisters (who escaped unharmed.) Now, the powers of poisons are not only regarded as real qualities, but are counted among the most hidden ones—·ones that are somehow tucked away there inside the substance·. Yet this harmful power, which is supposed to be a special added entity in the powdered glass, is really nothing distinct from the glass itself. . . ., whose parts have been ground into definite sizes and shapes. These glassy fragments are numerous and rigid and fairly small (but not as small as dust), and equipped with sharp points and cutting edges; and these mechanical affections enable them to pierce or wound the tender membranes of the stomach and guts, and cut the little blood-vessels they meet with there; from which it naturally follows that there are great gripings and contortions of the injured parts, and often discharges of

blood caused by the perforation of the tiny arteries, and the great irritation of the excretory system; and sometimes horrid convulsions by consent of [here = something like 'triggered by'] the brain and cerebellum along with some of the nervous or membranous parts that happen to be hurt. . . . Powdered glass has at various times been observed to have done no harm to animals that have swallowed it, and that fact fits very well with the conjecture I have just offered ·concerning *how* ground glass does its harm·. For there is no reason why it should do harm if the corpuscles of the powder happen to be too small to wound the guts, which are usually lined with a slimy substance in which very small ·grains of· powders can be sheathed, so to speak, and thus prevented from hurting the guts. [Boyle goes on to give anecdotal support for the thesis that apart from variations in size of grains there is also variation in how well defended people are against such dangers by the strength of their stomachs and the thickness of the slimy lining of their guts. So Cardan's story presents no great problem: three nuns died of eating the peas-and-glass mixture; others didn't; but we have a good hypothesis about what made the difference. Boyle continues:]

This reminds me of something that I ought to add here. some people reject the opinion I have been defending, on the ground that:

> the qualities of a body can't come from the bare texture and other mechanical affections of its matter, because a single natural body can have a great variety of different qualities ·at different times·.

This is wrong. We must consider each body not barely •as it is in itself, a separate and delimited portion of matter, but •as it is a part of the universe, and consequently placed among a great number and variety of other bodies which it may act on, and by which it may be acted on, in many ways; ·and the error in the above indented sentence comes from· thinking of each kind of causal interaction as a distinct power or quality in the body in question. If we consider things rightly, we shan't be very surprised that a portion of matter that

- •has only a very few mechanical affections–e.g. its particular texture and motion—but
- •is placed among a multitude of other bodies that differ in those respects both from it and from one another,

should be capable of having a great number and variety of ·causal· relations to those other bodies. The only people who will think of these as distinct inherent qualities are those who regard those relations or respects a body x may have to other bodies as real and distinct entities implanted within x itself.

When an intricate watch is going, its spring is the source of all the motion of its parts. But we don't think (as an Indian or Chinese person might) that this spring contains one faculty [= power] to move the minute-hand uniformly around the face, another to strike the hours, and perhaps a third to give an alarm or show the age of the moon or the tides. The spring is just a flexible piece of steel, forcibly coiled together, and *all* that it does—its entire action—is merely its effort to unwind itself; and the rest of its effects (·hands, alarm, tides, moon etc.·) depend on the various relations that the spring has to the other parts of the watch and their relations to one another.

·Then consider the powers of the sun·. We all know that the sun has a power to

> harden clay,
> soften wax,
> melt butter,
> thaw ice,
> turn water into steam,
> make air expand itself in weather-glasses,

help to blanch linen,
make the white skin of the face swarthy,
make mowed grass yellow,
ripen fruit,
hatch the eggs of silk-worms, caterpillars etc.,
and perform I don't know how many other things.

Some of these seem to be opposite effects, but they aren't separate powers or faculties in the sun but only the productions of its heat, diversified by the differing textures of the bodies that it chances to work on, and the condition of the other bodies that are concerned in the operation. (·Don't think that the heat itself is a difficulty for mechanism·: a body's heat is merely the brisk and confused motion of its minute parts.)

Those examples of the sun's powers could all be produced, with some careful management, by an ordinary kitchen fire. A few years ago in the course of some experiments that I did concerning the propagation of motion, I did something that illustrates a quite different power of the sun. [He had made some perfectly spherical and superbly polished iron balls; these acted as mirrors, showing the reflected object reduced in size and apparently behind the surface of the mirror; and there were other fine effects also, though Boyle doesn't describe them. He goes on:] And yet the globe that had all these properties and affections was nothing but the iron itself which had been given a spherical shape—the mirroring surface wasn't something added; it was just the outer surface of the iron. You can easily make small mirrors of this kind by breaking a large drop of mercury into several little ones, each of which will mirror objects placed pretty near it. The smaller drops will be nearer to spherical. . . ., and you can have a good time looking at the reflections in one of them through a good microscope. ·But look at what has happened·! You started with a quantity of stagnant mercury which behaved much like an ordinary flat mirror, and you turned it into a number of these little spherical mirrors, whose properties are so different from those of flat ones, and you did this by a slight movement which in the twinkling of an eye changed the shape of the portion of matter you started with.

You may wonder, Pyrophilus, why I have gone on such length in this attack on the mistaken view that everything that is ordinarily called a 'quality' must be a real and physical entity [those four words are Boyle's]. It is because of the importance of the subject. I have omitted some things that would have been relevant, partly so that I can bring them in later on, and partly because I didn't want to make this detour any longer. But I can't end it right here, because first I have to add this brief announcement.

I have chosen to declare what I mean by *qualities* by giving examples rather than definitions, for two reasons. **(1)** Because qualities are. . . .objects of the senses, men generally understand one another pretty well when they talk about them ('That tastes salty/sour/etc/', 'That sound is melodious/shrill/jarring/etc.'), especially when we speak of a sensible quality with help from a list of particular things that notably have the quality. You can make yourself understood •in this way as well as by •setting out to give a logical definition of the quality you are talking about. **(2)** [The second reason is that so far there *aren*'t any acceptable and helpful definitions of the needed kind. Boyle offers some remarks about Aristotle's endeavours to define *quality*—remarks that are technical, very hard to follow, and probably not needed for the parts of this work that lie ahead. The passage ends thus:] Some of the modern logicians, being aware of ·the defects in Aristotle's attempt·, have tried to rescue the matter with certain cautions and limitations; but these displays of ingenuity still leave us, so far as I can see, lacking a correct right and intelligible definition of *quality in general*. And

yet it is probably easier to provide *that* than to define many *particular qualities* such as saltiness, sourness, green, blue, and many others. Everyone knows what these mean when he hears them, but so far as I know no-one has been able to give accurate definitions of them.

Section 3: Introductory points 4–6

4. Suppose that the entire universe were annihilated except for just one whole undivided corpuscle of the sort discussed in point **3.** above. It's hard to say what could be attributed to it apart from

its being matter,
its being in motion (or at rest),
bulk, and
shape.

(Notice, incidentally, that although 'bulk' is usually meant in a •comparative sense it is in my sense •an absolute thing, because a body would have it even there were no other body in the world.) But now the universe actually contains great multitudes of corpuscles mixed together, and that makes it possible to attribute two new accidents or events to any distinct portion of matter made up of a number of corpuscles: **(1)** One relates the item in question to the really or supposedly stable bodies in its vicinity, namely its **posture**—its being upright, tilted, or horizontal. **(2)** When two or more of such bodies are placed together, their particular placement—one beside the other, one behind the other, etc.—can be called their **order**. . . . When many corpuscles come together so as to constitute a distinct body—e.g. a stone, a piece of metal—then from their other accidents (or modes) together with these last two, posture and order, there emerges a certain disposition or structure of parts in the whole, which we may call its **texture**.

5. If all the universe were annihilated except for one such body—a piece of metal or a stone—it would be hard to show that there is physically [see Glossary] anything more in it than matter and the accidents I have already named. But now let us take account of some actual facts:

•The world contains certain sensing and thinking beings that we call *men*.

•The body of each man has several external parts—the eye, the ear, etc.—each with its own particular texture that enables it to receive impressions from bodies in its vicinity, it is called a sense-organ.

•The sense-organs can be acted on by the shape, motion, and texture of external bodies in many different ways.

•Some of those external bodies are fitted to affect the eye, others the ear, others the nostrils, etc.

•To these operations of the objects on the sense-organs the human mind (which perceives them because of its union with the body) gives distinct names, calling the one 'light' or 'colour', another 'sound', another 'odour', etc..

•Because each organ of sense—the eye, the palate, or whatever—can be affected in different ways by external objects, the mind likewise gives different names to the objects of one sense, calling one colour 'green', another 'blue', one taste 'sweet' and another 'bitter' and so on.

•This has led men to generate a long catalogue of such things, which we call 'sensible qualities' because of how they relate to our senses.

And because •we have been familiar with these sensible qualities since before we had the use of reason, and •the human mind is given to conceiving almost everything (even privations such as blindness, death, etc.) as a true entity or substance as the mind itself is, we have from our infancy been apt to imagine that these sensible qualities are real [= 'thing-like'] beings in the objects that have them, and that they have the power to produce such-and-such results—that gravity, for example, has the power to •stop the motion of a bullet shot upwards and •carry that solid globe of matter toward the centre of the earth. Whereas the fact is (according to what I have abundantly shown above) that the body to which these sensible qualities are attributed contains nothing real and physical except the size, shape, and motion or rest of its component particles, together with the texture of the whole thing, which results from the particles' being put together as they are. There's no need for them to have in them anything more that is *like* the ideas they occasion in us. Those are either •the effects of our prejudices or thoughtlessness or else derived from the relation that happens to obtain between those primary accidents of the sensible object and the texture of the organ that it affects. For example, when I suffer pain from a pin's being run into my finger, there is no distinct quality in the pin corresponding to what I am apt to fancy *pain* to be. It's just that the pin is slender, stiff, and sharp, and by those qualities happens to make a break in the continuity of my organ of touch; and this, because of the structure of the body and its intimate union with the soul, gives rise to the troublesome kind of perception that we call 'pain'. I'll say more later to show in detail how much that ·upshot· depends on the special structure of the body.

6. But I foresee here a difficulty that may be the main one we'll have to confront in defending the corpuscular hypothesis, so that it ought to be attended to before we go any further. It is this:

> We ·corpuscularians· explain colours, odours, and other such sensible qualities by a relation to our senses, but it seems evident that those qualities have an absolute existence without relation to us; snow (for instance) would be white and a glowing coal would be hot even if there were no man or any other animal in the world. And it is obvious that bodies by their qualities work not only on our senses but on other bodies, inanimate ones; the glowing coal will not only heat or burn a man's hand if he touches it but would also heat wax to the melting point and thaw ice into water, even if all the men and sensitive beings in the world were annihilated.

To deal with this difficulty, I have five things to say.

(1) I don't say that the only accidents in bodies are colours, odours, and the like. I have indeed already taught that there are simpler and more primitive affections of matter on which these **secondary qualities**, if I may so call them, depend; and we'll see in due course that the operations of bodies on one another depend on them too. [In this version, 'primitive' is usually replaced by 'basic', but it is left untouched here because of its closeness to **primary**, the significance of which is obvious.]

(2) I don't say either that all qualities of bodies are directly sensible; but I remark that when one body acts on another,

our knowledge of their operation comes either •from some sensible quality or from •some more universal affection of matter such as changes in motion or texture in one ·or both· of them; for it's hard to conceive how else we could come to discover what goes on between them.

(3) We mustn't look on every distinct body that acts on our senses as a bare lump of matter with a certain apparent size and outward shape. Many bodies have parts that are intricately structured and many (perhaps most) of them are in motion too. [In the next sentence, in a complex clause that is hard to fit smoothly into the sentence, Boyle inserts a statement about *why* the universe is like 'a great engine': it's because so far as we know there is no vacuum, no empty space, between bodies—or at any rate 'none that is considerable'. [He is presumably thinking of cases where x affects y without directly touching it. But even then, the remark seems not to be relevant to his clock example.]] We mustn't look on the universe we inhabit as a motionless and undifferentiated heap of matter, but rather as a great engine in which the actions of particular bodies on one another mustn't be thought of abstractly as though portions of matter of their size and shape were placed in some imaginary space *beyond* the world, but rather as being situated *in* the world, constituted as it now is, and consequently as having their action on each other liable to be helped or hindered or modified by the actions of other bodies besides them. **(i)** An example is what happens in a clock, where a small force applied to move the hour-hand to the numeral 12 will make the hammer strike often and forcibly against the bell, making a much greater commotion among the wheels and weights than a far greater force would do if the clock's structure didn't abundantly contribute to the production of this great effect. **(ii)** When we agitate water into froth, that motion would never produce whiteness if it weren't for the fact that the sun or some other source of light shines on that aggregate of small bubbles, enabling them to reflect confusedly a great store of little. . . .light-images to the eye. **(iii)** Giving a concave shape to a large metal mirror would never enable it to set wood on fire—let alone to melt metals—if it weren't for the fact that the sun's beams, which on a cloudless day. . . .seem to fill the air, are thrown together to a point with the help of that concavity. **(iv)** For a perfect example of how a single action by a natural agent can produce very different effects because of differences in the dispositions of the bodies it works on, consider this: In two eggs, one fertile and the other not, our senses may be unable to detect any difference at all before they are hatched; and yet these bodies, outwardly so alike, differ in the internal lay-out of their parts in such a way that if they are both exposed to the same degree of warmth (whether of a hen or an artificial oven) this warmth will change the one into a rotted and stinking substance, and the other into a chick equipped with a great variety of organic parts with different consistencies and different intricate textures.

(4) I don't deny that there's a very good sense in which it's true that bodies could have the qualities we call 'sensible' ·or 'secondary'· even if there were no animals in the world. [Boyle explains this through a series of examples, all handling the matter in terms of counterfactual conditionals. If all sensing disappeared from the world, this body x that is now *red* would still be different from this other body y which is white, because the following would be true of x but not of y:

> If there were animals of such-and-such kinds, it would produce through their eyes a state of the kind we call 'seeing something red'.

This difference between x and y comes from difference in 'the dispositions of their constituent corpuscles'. Another example: the following conditional:

> If this were firmly pressed, end-on, against the skin of an animal of such-and-such a kind, the animal would feel pain

would be true of a needle in a world where in fact there were no animals, and it wouldn't be true of, for example, a bullet; the difference in this case coming purely from differences in shape. Similarly with snow in the dark, and a lute when it is not being played. In all these cases, Boyle says:] If there were no sensitive beings, the bodies that are now the objects of our senses would be only **conditionally** endowed with colours, tastes, ·being-in-tune·, and the like; all they would **actually** have would be the more universal affections of bodies—·the ones that all bodies have always·—such as shape, motion, texture, etc. [In that sentence, 'conditionally' replaces Boyle's 'dispositively, if I may so speak'.]

To illustrate this a little further: suppose that a man beats a drum outside a cave that is conveniently situated to return the drum's noise; men will immediately conclude that the cave has an echo, and will be apt to imagine that there must be some *real property* in the place to which the echo is said to belong; and it's true that in many other nearby places the drum's noise wouldn't be reflected to the ear, showing that those places don't 'have echoes'. But to speak physically of things, this special quality or property that we imagine in the cave is nothing but the hollowness of its shape, which disposes it when the air beats against it to reflect the motion towards the place the motion came from; and what *happens* on this occasion is just this:

- •The drum-stick impinges on the drum, which
- •makes a percussion of the air, which
- •puts that fluid body (·the air·) into an undulating motion, and
- •the air-waves thrust on one another until
- •they arrive at the interior surface of the cave, where
- •its resistance and shape make the waves bounce back
- •towards the place where the drum was when it was struck.

So all that is making any difference here consists in •the shape of one body and •the motion of another. If a man's ear happens to be in the way of these to-and-fro motions of the air, it gives him a perception of them, which he calls 'sounds'; and because these perceptions. . . .occur at distinct times one after another, the hollow body from which the second sound is conceived to come is imagined to have a special 'faculty', on account of which men are accustomed to saying that such a place 'has an echo'.

(5) It's true that qualities of the sort we call 'sensible' often seem to be produced in one body by another body; this is a body-to-body action, and our senses seem not to come into it. But I hold that when one inanimate body x acts on another y, the only change that x makes in y is some motion of its parts or some change of texture as a result of that motion; so if y comes to have any sensible quality that it didn't have before, it has it in the same way that other bodies do; it's purely a result of the mechanical change of y's texture; we attribute this or that sensible quality to y because of its effects on our sense-organs. [Boyle now repeats his earlier examples, slightly adapted to fit his present point, which is (abstractly stated): When

> inanimate body x causes inanimate body y to acquire a sensible quality,

all that is really, basically going on is that

> x changes y's texture and/or internal motions in such a way that a conditional of the form
>
> > when it relates thus and so to a sense-organ of a certain kind, the mind of the organ's owner has an experience of kind K
>
> becomes true of y whereas previously it was false.

Example: Something heavy falls on transparent ice, making it white. The sun shines on the cloudy ice, restoring its transparency. A piece of rough silver is polished to smoothness. With each example, Boyle states explicitly what the motion-and-texture underlay is of the change, but we hardly need these details in order to get his point. Something he says about heat, however, should be included, if only because Berkeley later made it famous:] Heat is so wholly relative to the sense-organs that experience it that the following can happen:

> A man with a cold left hand and a hot right hand plunges both hands into a bowl of lukewarm water—i.e. water whose corpuscles are moderately agitated by the fire—and it will appear hot to the left hand and cold to the right.

Same water; same man. In brief:. . . . It isn't easy to conceive •how one body x can act on another body y except by moving itself, or sending out moving parts, or •how that motion can do anything to y except set its parts moving too, thereby producing a change of situation and texture or of some other of y's mechanical affections [see Glossary] . Because y is placed among other bodies in a world constituted as ours now is, and comes to act on the most intricately contrived sense-organs of animals, it may for both these reasons exhibit many different sensible phenomena. However ·insistently· we regard these as distinct qualities, they are only the effects of the universal affections of matter that I have referred to so often, and are derived from the size, shape, motion (or rest) posture, order, and the resulting texture of the insensible parts of bodies. For brevity's sake I shan't hesitate to speak of 'qualities', since the word is already so generally accepted, but I want this to be understood in a sense that conforms to the doctrine I have presented. . . . If I say that heat melts metals, I will mean that this fusion is brought about by fire, or some other body that feels hot to us because of the various and vehement motion of its insensible parts. . . .

Section 4: Introductory point 7: the nature of a form

7. Moving on now to a new topic: When men noticed that certain conspicuous accidents were grouped together in some bodies, and other combinations of accidents in other bodies, they found it convenient and time-saving to agree to distinguish bodies into several *sorts*. A given sort could be called **(a)** a 'genus' when it is being thought of in relation to a narrower sort or to individuals, or **(b)** a 'species' when it is being thought of in relation to a more comprehensive sort. For example, observing many bodies to agree in being fusible, malleable, heavy etc. they gave to that sort of body the name 'metal', which is **(a)** a genus in reference to gold, silver and lead, but only a **(b)** species in reference to the sort of mixed bodies they call *fossilia* [= 'dug out of the ground'], a higher **(a)** genus that includes metals, stones, and various other concretions; though the *fossilia* themselves constitute a mere **(b)** species in relation to *mixed bodies*. Now, when

a body is placed within a species ('It's a bit of metal', 'It's a stone' or the like) because men have for their convenience agreed to use that one name to signify the group of accidents that are required for a body to be of that sort, most writers on physics [see Glossary] have tended to think that ·any given· body has the common matter that all bodies have and just •*one other thing* that distinguishes it from other kinds ·of body· and makes it what it is. For brevity's sake they call •this a *form*; and because all the qualities and other accidents of the body must depend on it, they imagine this 'form' to be a genuine •substance, indeed a kind of •soul, which unites with the gross matter to constitute a natural body, causing it to have its various qualities. . . .

My comment on that is this: Suppose you ask a man 'What is gold?', if he can't show you a piece of gold and tell you '*This* is gold', he will describe gold to you as a body that

> is extremely heavy,
> is very malleable and ductile,
> can be melted but not evaporated by fire,
> ·is not dissolved by *aqua fortis*·, and
> has a yellowish colour.

And if you try to get him to accept a piece of brass as a piece of gold, he'll refuse it on the spot, and if he understand metals he'll tell you that although your brass is coloured like gold, it is not as heavy or as malleable as gold, and it won't (as gold does) resist the utmost brunt of the fire, or resist *aqua fortis*. And if you ask men what they mean by 'a ruby' or 'saltpetre' or 'a pearl', their answers will show you clearly that for all their **theoretical talk** about 'substantial forms', what they **actually go by** in distinguishing one body from others and saying what species it belongs to is nothing but a cluster or combination of accidents—the ones men think to be necessary or sufficient to make a portion of common matter belong to this or that genus or species of natural bodies. (·How do they come to think that F and G and H are necessary for something to count as gold·? They *agree* that those accidents are to count as essential to gold; this business ·of sorting· is more arbitrary [= 'more dependent on people's decisions'] than we are aware of.)

Now, many people (most of the chemists and also various philosophers and even some of the schoolmen) maintain that it's possible to transmute the less noble metals into gold; which implies that if a man could cause any portion of matter to become yellow, malleable and heavy, indissoluble in *aqu fortis* and (in short) to have all the accidents by which men tell true gold from false, everyone would confidently take this matter to be true gold. If that happened, the learned schoolmen might dispute whether this artificial material, made by the chemists' art, had the substantial form of gold; but most people would leave them arguing, and would go ahead treating the new stuff as *gold* because it passed all their careful tests for gold—more careful than their tests for anything else!—meaning that it was found to have *all* the accidents that had been agreed to be jointly sufficient for something to count as gold. [Boyle comments on the 'all'. What qualifies a body as belonging to a certain species is its having a *group* of accidents, he says, so that it is usually not hard to spot an impostor by its lack of just one of the group. He gives •the example of *luna fixa* [= literally 'fixed silver', i.e. silver-coloured metal that can't be volatilised by heat], which the chemists say is exactly like gold except that it isn't yellow; and •another example having to do with the classification of geometrical figures. It would be a stupid person who couldn't tell a needle from a file, or a key from a pair of scissors, Boyle says; but these items are all made of iron, and differ only in size and shape; whereas most differences between kinds of natural bodies involve far more than two accidents, and should therefore be even easier to detect. He continues:]

·AN ASIDE: TWO POINTS ABOUT ESSENCES·

(a) It is tempting but wrong to think: 'qualities can't be *essential* to natural bodies because they are merely *accidents*.' I pointed out earlier [on page 12] that 'accident' has two senses: there is accident$_1$ which is opposed to **(1)** essence, and there is accident$_2$ which is opposed to **(2)** substance. ·In my discussion of 'forms' I have been using 'accident$_2$' to cover everything that could be predicated of a substance—every quality or property or affection or state; and its meaning in this sense has nothing to do with the accident/essence = contingent/necessary distinction.· **(b)** ·The distinction between accidental$_1$ and essential is *sort-relative* in a way that I shall now explain·. An accident$_2$ must be merely accidental$_1$ to matter considered just as a substantial thing but it can also be essential to this or that particular body. Roundness is accidental$_1$ to brass but essential to a brazen sphere: the brass could become cubic, but it couldn't do so while still remaining a sphere.

·END OF ASIDE·

A group or combination of qualities is enough to make the portion of matter that has it *what it is* and to classify it as belonging to this or that specific **sort** of bodies; and we have seen that those qualities proceed from the more primary and universal affections of matter—size, shape, motion or rest, and the texture resulting from these; so it is clearly all right for us to say that the **form** of a body, being made up of those qualities united in one subject, also consists in a combination of the newly named mechanical affections of matter that is necessary to constitute a body of that determinate kind. [In that sentence, the shift from 'proceed from' to 'consists in' is Boyle's, not an artifact of this version.] So when for brevity's sake I use the word 'form', please understand me to mean by it (not a real substance distinct from matter, but only) a natural body's *matter*, thought of in terms of its particular manner of existence—·i.e. thought of as textured and shaped and moved etc. in such-and-such a way·. This could conveniently be called its •specific or denominating state, or its •essential modification. . . .

[•Regarding the **nouns** in that sentence: The so-called 'form' of a dog (say) is a complex set of separately humdrum features of that mass of matter; in calling them its **state** or **modifications**, Boyle is emphasizing that the 'form' isn't an extra ingredient in the dog's matter; it is merely *how that matter is arranged*. •Regarding the **adjectives**: the set of features is **specific** because it entitles the dog to be included in the species *dog*; it is **denominating** because it entitles the dog to be called 'a dog'; and it is **essential** because an animal *must* have these features if it is to qualify as a dog. You may want to ask:

> What about properties or features or qualities that are just plain essential to a thing—not essential-considered-as-an-F or essential-*qua*-F but simply essential *period*?

Boyle's answer, as given in the recent 'Aside', is that there aren't any.]

Such a combination of accidents is sufficient to play the role that a so-called 'form' is supposed to play: it makes the body. . . .belong to this or that determinate species of bodies, and distinguishes it from all bodies belonging to other species. [Boyle illustrates this by repeating what he has already said about the essential features of gold. Then:] Some say that the form of a body ought to be the principle [see Glossary] of its operations. Later on I'll discuss whether and in what sense that is to be accepted or rejected; but all I need just now is to point out that even in the vulgar philosophy—·i.e. the Aristotelian physics that vaguely inhabits the minds of most people who have any views about these matters·—it is accepted that natural things mostly operate through their qualities: snow dazzles the eyes by its whiteness, and water scattered into drops of rain falls from the clouds on the account of its gravity [Boyle's phrase]. ·That testifies to the causal fertility of 'qualities' (in my sense of that term), and thus to their ability to play the role assigned to 'forms'; but much stronger testimony is also available·. The

power that a body can exercise by virtue of a single quality ·goes far beyond those little one-effect examples that I have just given; and· can appear in various and often prodigious effects. Fire's single quality *heat* enables it to melt metals, pulverise stones, destroy whole forests and cities etc. Even greater things may be brought about by a *group* of active qualities combined in one body,. . . .and we can guess at the scope of this by considering the strange things that some engines do; just because they are engines, i.e. artifacts, no-one thinks that they have substantial forms, so there is no escaping the conclusion that the amazing things they do must arise from those accidents—the shape, size, motion, and organisation of their parts. . . .

Section 5: Introductory point 8: Generation, corruption, and alteration

8. It now remains for me to say what, in the spirit of my hypothesis, is to be meant by 'generation', 'corruption', and 'alteration'—three names that have greatly puzzled and divided philosophers. To get to grips with this issue we have first to be clear about five points.

(1) The world contains a great store of particles of matter, each of which

- is too small to be perceptible on its own;
- (being entire, undivided) has a definite shape, and
- is very solid [here = 'hard', 'resistant to being broken'.]

Such particles, because they are so small and solid, are hardly ever broken up by any natural process, so we can in this sense call them 'minima naturalia'. Such a natural minimum can be divided mentally—·i.e. we have the thought of (say) *half of it*·—and God can split any of them.

(2) There are also multitudes of corpuscles each of which is made up of a group of the natural minima I have spoken of. Each of these corpuscles—these little primitive concretions or clusters (if I may so call them)—is so small that on its own it is below the threshold of sense-perception; and the binding-together of its parts is so tight and strong that, although it isn't absolutely indivisible by nature into the natural minima that compose it (or perhaps into other little fragments), it is extremely unlikely to be dissolved or broken. . . . These corpuscles remain entire in a great variety of perceptible bodies under various forms or disguises. [Boyle now reminds the reader of a recent example—omitted from this version—concerning a laxative that a woman passes on, through her breast-milk, to the child she is nursing. Then:] Even larger and more complex corpuscles can have such a permanent texture [i.e. can retain their structure through many changes in their immediate surroundings]: liquid mercury, for instance, can be turned into

> a red powder,
> a body that can be melted and hammered,
> a cloud of smoke that can be blown away, and
> I don't know how many other things,

and yet ·through all this· remain true and recoverable

mercury. These corpuscles are the immediate principles of many sorts of natural bodies, such as earth, water, salt, etc. [Why 'immediate'? See the last half-page of this section, page 29, for the distinction Boyle has in mind here.] And these corpuscles, not singly detectable by the senses, can be perceived when a number of them come together. Here's an example of this that I tried for myself: Put good camphor into pure spirit of wine [i.e. pure alcohol] and leave it there for a while; this will break it up into such little parts that they disappear entirely, leaving the solution looking as clear as pure water; then pour a suitable amount of water into this mixture, and in a moment the scattered corpuscles of the camphor will come together and become white, and thus visible, just as they were before being scattered by dissolving.

(3) ....When natural minima come to adhere to one another to form a corpuscle, this will **always** affect the size of the corpuscle, will **often** affect the corpuscle's shape, and will **fairly often** affect the speed or direction of the motion of either the minimum or the corpuscle or both. And the same thing holds when the corpuscles composing a cluster of particles are separated from one another.... And any change in the matter composing a corpuscle—whether by adding or removing—its size must necessarily be altered, and usually its shape will be altered too; and these changes will •make it fit the pores of some bodies (perhaps including our sense-organs) and •stop it from fitting the pores of others; and this will alter the range of situations in which the corpuscle is able to operate. I'll expand on this later.

(4) When many of these imperceptible corpuscles come together to form one visible body, if many of them are set moving (never mind how), that alone may produce great changes and new qualities in the body they compose. Motion can do a great deal even when it makes no visible difference: when air is sped up by being blown out of bellows, it gets a new name ('wind') and feels much colder than the same air when it is not formed into a stream; and when iron is briskly rubbed against wood or other iron, its small parts become so agitated that they feel hot. And this motion ·of corpuscles· often visibly alters the texture of the body in question. That is because the moved parts try to communicate some of their motion to other parts that were not moving or were moving differently, and often those same moved parts pull apart or break some of the corpuscles they collide with, thereby changing their size or shape or both...., from which it follows that the texture is—for a while at least....and sometimes permanently—very much altered. [Boyle gives examples: water loses much of its transparency by being frozen into ice; hard rubbing together of two pieces of resinous wood can turn their surfaces into a kind of coal; milk in hot weather separates out into •a thinner sort of liquor and •cream; when cream is churned it turns into butter and thin, fluid, sour butter-milk; an apple when bruised undergoes a change in colour, taste, smell, and consistency. He continues:] All this illustrates what I have already said, namely that motion has a greater share in altering a portion of matter than have any of the matter's other affections. It is not only the grand agent or cause among second causes [see the Glossary], but is also often one of the principal things that constitute the form of bodies. For example when two sticks are set on fire by rubbing one hard against the other, motion is the cause not only of •the fire but also of •the stream of shining matter that bears the name and nature of flame....

(5) We have seen that the size, shape, motion and organization of small portions of matter are the source of the colour, odour, taste, and other qualities of the body of which they are parts; and we are of course well aware that such changes can't happen in a body without greatly varying its nature; so we shouldn't sneer at the ancient atomists for

putting their supposed 'atoms' to work by trying to derive

- •generation from atoms' coming together; ·moving **in**·;
- •corruption from atoms' moving apart, ·moving **out**·;
- •alterations from atoms' moving around **within** the body in question.

. . . .If (as is probable) they meant this only as an account of the kind of motion that is *usually* uppermost in each of the three kinds of event, I shan't much oppose this doctrine; though I think that the motion of parts within a portion of matter plays a large role in generation and corruption as well as in alteration. We see this when milk or meat or fruit, with no great addition or loss of parts, turns into maggots or other insects; and we see it even more obviously in the vitrification of metals [i.e. making them glass-like by heating them], when mercury is precipitated without anything being added, and in other chemical experiments that I shall discuss later.

·GENERATION·

After those preliminaries, it won't be hard now to state fairly briefly a doctrine about the generation, corruption, and alteration of bodies that is suitable to my hypothesis and to what I have been saying here. ·I shall express what comes next in terms of one species of body, namely *stones*; but what I say is to be understand as applying to every other species as well.· Let x be a group of accidents which includes (perhaps along with others) the set y that men have tacitly agreed to be necessary and sufficient to qualify a thing as a *stone*; now, if a portion of matter happens to acquire (never mind how) all the members of x, we express this by saying that 'a stone has been generated' or 'a new stone has been produced'. Nothing substantial has been produced. What has happened, rather, is that portions of matter that were already in existence but were either scattered and shared among other bodies or inter-related in some other way, are now brought together and inter-related in the way required for the resultant body to count as 'a stone', making it belong to that determinate species. [Boyle may seem to have changed the subject, switching from (a) 'A portion of matter acquires a group of accidents' to (b) 'A number of grains come together to form a stone', but the switch is innocent. In (a), the relevant portion of matter is the matter distributed through all those grains; the accident that that portion acquires is a complex one along the lines of *having parts that are (in a certain sense) together*'; and that is (b).] In generation, then, no new substance is produced; it's merely that something already existing acquires a new modification or manner of existence. [Boyle illustrates this with the coming-into-existence of a watch by the appropriate assembly of the already-existing spring, wheels, balance, and so on; with the generation of glass by melting sand and ashes together and then letting the mixture cool; and with the following:] When butter and butter-milk are generated by the churning of cream, we don't find any *new* substance produced in either of them; what has happened is just that the serum and the fat corpuscles, being set moving, have through their frequent collisions extricated themselves from each other and come to be inter-related in the new manner that qualifies them as butter-milk and butter respectively.

·CORRUPTION·

Just as a body is said to be 'generated' when it first appears clothed with all the qualities that make men count it as a stone (a piece of metal, a portion of salt, whatever—·let's say "K" for short·), so when a body comes to lose any of the accidents that are essential. . . .to its being K it is said to be 'corrupted' or 'destroyed'—it's no longer a body of kind K, having lost its title to its former name. Nothing corporeal or substantial goes out of existence in this change; all that is destroyed is the essential modification of the matter—the modification ·or set of accidents· that it needed to qualify a thing as being of kind K. The body is still a body—no natural agent can annihilate matter. [Boyle illustrates this with

examples: smashing a watch, destroying cream by churning it into butter and butter-milk, destroying ice by melting it. He continues:] Examples like these can teach us to understand rightly the common axiom of natural scientists:

> —*corruptio unius est generatio alterius & è contra*;
> —The corruption of one thing is the generation of another, and vice versa.

·To see what truth there is in this, think about the following three points·. **(a)** Everyone agrees that matter can't be annihilated. **(b)** Some properties—size, shape, and motion (or rest)—are inseparable from actual portions of matter. **(c)** The coming together of any large enough number of these portions is sufficient to constitute a natural body equipped with various sensible qualities. Given these three facts, it is *almost* certain that when the texture of one body is destroyed the resultant fragments will be reshuffled and come to be inter-related in such a way as to constitute some new sort of body. For example, burning destroys wood while generating flame, soot, and ashes. But I don't accept the axiom as holding true universally; I don't agree that *every* corruption must generate a body belonging to some particular species, unless we take *powders* to constitute a species of natural bodies and *fluids* to constitute another. Some kinds of plants when they rot turn into worms, but we know that many of them merely turn into some slimy or watery substance or (more often) crumble into a kind of dust or powder. That dust or powder may be regarded ·by some people· as being the earth that ·all· rotten bodies eventually break down into, ·with this being thought of as utterly simple and basic, one of the four so-called 'elements': earth, air, fire, and water. But even if there *were* such an elemental earth·, this dust or powder isn't it—indeed it is very far from being of an elementary nature; it is a compound body that retains some, if not many, of the qualities that can make the dust of one sort of plant or animal differ greatly from the dust of another. And this will supply me with the following argument *ad hominem* [see note on page 38]:

> **(1)** In the violent corruptions of bodies that occur when outward agents shatter the bodies into pieces, the fragments that arise from this must, according to the axiom, be really natural bodies. . . .that have been generated according to the course of nature (as when wood is destroyed by fire and turned into flame, soot, coals, and ashes).

From this we ought to be allowed to conclude that:

> **(2)** The chemical productions that so many people think are merely artificial are actually natural ones, and regularly generated.

Given that it's same agent (the fire) that operates on bodies, whether in closed glasses or in chimneys, I see no good reason to deny that the chemical oils and volatile salts and other things that chemists obtain from mixed bodies are natural bodies, along with the soot, ashes, and charcoal that are obtained from kindled wood by the same fire.

Before we leave the topic of the corruption of bodies we should have a look at what is called their *putrefaction*. This is just a special kind of corruption that is brought about *slowly* in bodies (which distinguishes it from destruction by fire and other fast-moving agents). What usually happens in putrefaction is this:

> The air. . . .penetrates the body's pores and by its agitation in them it brings out some of the more agile and less entangled parts of the body, loosening and dislocating the parts in general. This changes the body's texture, and perhaps also the shape of the corpuscles that compose it, giving it qualities that are unsuitable to its former nature and usually offensive to our senses, especially of smell and taste.

I add that last clause so as to exclude the change of an egg into a chick, which is ordinarily regarded not as a corruption of the egg but as its perfection [here = 'the completion of its process']. And there's ·a more general reason for including the 'offensiveness' clause in the account of what putrefaction is·: If a body lost its former nature slowly, making this event a candidate for the label 'putrefaction', I think we probably wouldn't call it putrefaction if in the course of it the body in question came to smell and taste *better* than it did before. The meaning of 'putrefaction' includes 'a change for the worse'; so we might disagree about what should be called 'putrefaction' if the texture of the organs of tasting and smelling of some of us were to change through nature or custom or any other cause. [Boyle remarks that the change in medlars which in other fruit would be called 'going rotten' is called 'ripening' because we like the flavor of the medlar in that condition. [The Shorter Oxford Dictionary says that the medlar 'is eaten when half-rotten'.] After another example, from the animal kingdom, Boyle continues:] And we see that some men whose appetites are gratified by rotten cheese don't think of it as having gone bad but rather as having reached its best state, when having lost its former colour, smell, and taste—and being in great part turned into those insects called 'mites'!—it is 'corrupted' in a philosophical sense and putrid in the opinion of most men.

·ALTERATION·

It very seldom happens that a body of kind K in being generated acquires only the qualities that are absolutely necessary for it to count as belonging to the species K; therefore in most K bodies there are various other qualities—·i.e. qualities other than the K-making ones·—that may be present or absent without the thing's K status being changed. Water can be clear or muddy, fragrant or stinking, and still remain water; and butter can be white or yellow, sweet or rancid, firm or melted, and still be called 'butter'. When a portion of matter acquires or loses a quality that isn't essential to it, that acquisition or loss is marked off as an 'alteration' or 'mutation'. When something acquires only the qualities that are absolutely necessary to constitute its essential and specific difference, or when it loses any of those qualities, this mustn't be called mere 'alteration' but must have the more specific name 'generation' or 'corruption'. It seems from this that generation and corruption are merely different kinds of alteration, when 'alteration' is understood in a broad sense, though they are distinguished from it in a more strict and limited meaning of that word.

I should comment here on the fruitfulness and scope of the mechanical hypothesis. According to this doctrine:

- our world is not a static or unprocessed mass of matter, but a self-moving engine in which at any time most of the matter is moving (though not always the same matter);
- bodies are so close to one another that (except in some very rare and extraordinary cases) they have either no empty spaces between them, or only very small ones dotted around here and there;
- the different ways in which corpuscles can come together into one visible body is enough to give them a peculiar texture, and thereby fit them to exhibit various sensible qualities and to become sometimes a K_1 body and sometimes. . . .a K_n one.

From all this it naturally follows that from the various collisions of those innumerable swarms of little bodies that are moved to and fro in the world there will be many that are fitted to stick to one another and thus compose concretions, while in other places many will be uncoupled from one another and agitated separately; and many that will be driven to associate themselves now with one body and then with

another. If we bear in mind **(1)** that

> the sizes of the small particles of matter may be very various, their shapes almost innumerable, and if a portion of matter merely *happens* to stick to one body it may chance to make it of kind K_1, whereas if it adheres to (or hits against some of the parts of) another body it may constitute a body of kind K_2; and if a portion of matter is knocked off from a body it may leave it and become itself of another nature than it was before;

while also bearing in mind **(2)** that

> the innumerable multitude of words contained in all the languages of the world are made from combinations of some of the 24 letters of the alphabet

(I borrow that comparison from Lucretius), we won't find it hard to conceive that there may be a bewildering variety of associations and textures of the minute parts of bodies, and consequently a vast multitude of portions of matter that have enough differentiating qualities to deserve separate species-names, though men haven't attended to them enough to sort them as they deserve and give them distinct and proper names. ·What follows from this?· I wouldn't say that anything can **immediately** be made out of anything, e.g. that a gold ring can immediately be made out of a lump of gold, or that oil or fire can immediately be made out of water. But given that

> bodies have only one common matter and are differentiated from one another only by accidents, which seem all to be the effects of motion,

I don't see why it should be absurd to think that (at least among inanimate bodies) almost anything could **at length** be made out of anything, by an orderly process of adding and subtracting matter. . . .and gradually transforming the matter one is working on. ·Here is a trivially easy example of the difference between 'immediately' and 'at length'·: You can't immediately make a ring out of a lump of gold; but if you gradually draw the lump out into wire, or melt it and put some of it into a mould, *then* you can easily make a ring out of it. ·Here's a less trivial one·: Water can't be immediately transmuted into oil, still less into fire; but if you nourish certain plants with water alone (as I have done), until they have assimilated a great deal of water into their own nature, you can distill this transmuted water—which you can distinguish and separate from the part of the plant that you had under water—in a suitable retort and obtain, among other things, a true oil and a black combustible coal (and consequently fire). [Boyle doesn't at first say *how* 'you can distinguish and separate' etc., i.e. how you can know that you are dealing with altered water rather than with a mixture of water and materials from the plant. But he addresses the question right at the end of his account of this experiment:] . . . true oil and a black combustible coal; and there can be so much of these as to leave no good reason to suspect that they could come anywhere near to being products of any little spirituous parts that may be presumed to have been communicated ·to the water· by that part of the plant that was first immersed in the water.

Section 6: Summary of everything up to here

I can see, Pyrophilus, that the difficulty and fruitfulness of my topic have made me write at greater length than I intended—so much so that it would be as well for me now to shrink the summary of my hypothesis, briefly presenting its main points with little or no illustration, and without particular proofs, Here, then, is what I teach (but without flatly asserting it).

(1) The matter of all natural bodies is the same, namely an extended and impenetrable substance.

(2) All bodies thus agreeing in the same common matter, differences among them come from the accidents that diversify that matter.

(3) Motion, not belonging to the essence of matter (which retains its whole nature when it isn't moving), and not being an upshot of other accidents as they upshots of it, can be regarded as the first and chief mode or affection of matter.

(4) Motion, going in various directions and at various speeds, naturally divides the moving matter into actual fragments or parts; and this division is made into parts that are very tiny and often too small to be singly perceivable by our senses—we know this from obvious experience and even better from chemical operations.

(5) It follows strictly from this that each of these minute parts or natural minima (as well as every particular body composed of any number of them) must have a definite size and shape. And these three—size, shape, and motion or rest—. . . .are the three primary and most universal modes or affections of the imperceptible portions of matter considered individually.

(6) When different ones are considered together, there will necessarily follow here on this planet a certain orientation or posture in relation to the horizon (upright, tilted, horizontal), and a certain order. (Compare this with a company of soldiers: one stands upright, another stoops, a third lies on the ground; and they are placed beside one another in ranks and behind one another in files.) And when many of these small portions are brought together into one body with their various primary affections, and their lay-out with regard to posture and order, the result of this is what by one comprehensive name we call the *texture* of that body. . . . And these are the affections that belong to a body considered in itself and without relation to perceivers or to other natural bodies.

(7) Because there are men in the world whose sense-organs are structured in such different ways [this is the difference between eyes and ears, for example, not between you and me] that one organ is fitted to receive impressions from some external objects and another to receive them from others. (An external body may act on the senses as an entire body (·touch·) or by sending corpuscles across (·smell·) or by propagating some motion to the sense-organ (·hearing·).) Men give different names to the perceptions of these impressions–'heat', 'colour', 'sound', 'smell' etc.—and most men imagine that these come from certain distinct and particular qualities in the external object, qualities that have some resemblance to the ideas their action on the senses arouses in the mind. In fact, though, all these sensible qualities. . . .are merely effects of the above-mentioned primary affections of matter. . . .

(8) When a portion of matter happens to acquire a combination of all the qualities that men commonly agree to be necessary and sufficient for the body that has them to count as 'metal' or 'stone' or the like, and to qualify as a member of

some determinate species of bodies, then we say that a body of that species has been 'generated'. This can happen when a portion of matter gains some corpuscles, and/or loses some, and/or re-shuffles the ones it already has.

(9) When a combination of accidents jointly (not separately) constitute the essence of some named kind K of body, demarcating all bodies of that kind from bodies of every other kind, that group of accidents is thought of as a single collective thing which is called the 'form' of the body that has it. . . . Such a form or accident-group can be called an •essential •modification of the body that has it: a •modification because it is indeed ·not a thing, but· merely the body's way of existing; and •essential because it is essentially necessary to the particular body which without it wouldn't be a body of kind K (wouldn't be metal, wouldn't be a stone, or whatever)—but not essential to the body just considered as a material thing, because that matter could lack those accidents while still being matter.

(10) A body can have many qualities other than the ones that jointly serve to make up its form; and the gaining or losing of any of those other qualities is what natural scientists, using the word in a stricter sense ·than the man in the street does·, call *alteration*. Examples: oil freezes, changes colour, or becomes rancid. If any of the qualities that are regarded as essential to such a body are lost or destroyed, that notable change is called *corruption*. When boiling oil catches fire it isn't said to be 'altered' in the former sense, but to be 'corrupted' or 'destroyed', and the emergent [Boyle's word] fire is said to be 'generated'. And when a body is slowly corrupted, and thereby also acquires qualities offensive to our senses (especially of smell and taste). . . .that kind of corruption is given the more restricted name 'putrefaction'. Nothing substantial is destroyed in this or any other kind of corruption, just as no substantial thing is produced in generation; everyone agrees that matter itself is incorruptible. . . .