Metaphysical Foundations of Natural Science

Immanuel Kant

1786

[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 on, between [brackets], in normal-sized type. Numerals in the margins refer to the pages in the Akademie edition of the work; these numbers are also supplied in both the existing English translations, which can thus easily be correlated with the present version.

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Metaphysical Foundations of Dynamics

Definition 1

496 **Matter** is whatever is movable and fills a space. To **fill** a space means to resist every ·other· movable thing that tries to move into that space. A space that is not filled is an *empty* space.

Remark

This is, now, the dynamical definition of the concept of matter. This definition presupposes the phoronomic one [page 7] but adds to it a causal property, namely the capacity to resist a motion within a certain space. This property couldn't have any role in phoronomy, even when we were dealing with the motions of a single point in opposite directions. This *filling* of space keeps a certain space free from the intrusion of any other movable thing, whatever direction it is coming from. Now we must investigate what matter's all-around resistance is based on and what it *is*. Definition 1 makes it clear that we aren't talking about matter's resistance to •being pushed from one place to another (that's a mechanical phenomenon,
497 ·to be dealt with in chapter 3·), but only its resistance to •being squeezed into a smaller amount of space. The phrase 'occupying a space', i.e. being immediately present at every point in the space, is used merely to indicate the extension of a thing in space; and this concept of a thing's spatial extension or presence-in-space implies nothing about what if anything the thing does to resist other things that try to force their way into that space. It doesn't even rule out the possibility that something present in a given space acts causally to *attract* other movable things *into* that space. The concept might also apply to something that, rather than being an instance of matter *in* a space, is itself a space; because every space is an assemblage of smaller spaces, ·and one of them could be said to be *in* the larger space·. . . . Because it leaves all these possibilities open, the concept of *occupying* a space is broader and less determinate than the concept of *filling* a space.

Proposition 1

Matter **fills** a space not by its mere existence but by a special moving force.

Proof

Penetration into a space is motion. The cause of motion's becoming less, or even changing into immobility, is *resistance* to it. Now, the only thing that can be combined with a motion in such a way as to lessen or destroy it is another motion, in the opposite direction, of the same movable thing. [Kant adds '(phoronomic proposition)'; but what he has just said doesn't come from the Proposition on page 14. Perhaps it comes from the various proofs and comments relating to that Proposition.] Consequently, when a portion of matter x fills a space and thus resists all intrusion into that space by another portion of matter y, the resistance that it puts up against y's coming into the space is a cause of y's moving in the opposite direction. But our label for any cause of motion is 'moving force'. Consequently, matter fills its space not by merely being there but by ·exerting· moving force. [At the start of this paragraph, Kant says that the very first instant of a thing's movement is called *Bestrebung*, which can mean 'attempt' or 'endeavour' or the like. Like other early modern philosophers he used that term (or its equivalent in other languages) to stand for an *active tendency* that a body may have to move in a certain way. To say that thing has a *Bestrebung* to enter a given space is *not* to say •that it is consciously *trying* to move in, but it is to say more than merely •that it is in a state such that it will move in unless something stops it. From now on in this version, 'endeavour' will be used for *Bestrebung* (and not for anything else), but remember that it isn't a psychological term.]

Remark

Lambert and others used the rather ambiguous word 'solidity' to name the property of a portion of matter by which it fills a space; and they maintained that solidity must be possessed by every thing that exists (every substance), or at least by every thing in the external sensible world. According to their
498 way of thinking, a real thing x in a region of space must *by its very concept* carry with it this resistance: *the principle of contradiction* rules out there being anything else in the space containing x. But a portion of matter that is moving towards penetrating a space that already contains another portion of matter isn't pushed back by the principle of contradiction! The only way I can make sense of the suggestion that

> a contradiction is involved in a space's containing one thing x and being penetrated by another y

is by attributing to x a force through which *it* pushes back an external movable thing that approaches it. Here the mathematician (·Lambert·) has assumed, as an initial datum in constructing the concept of matter, something that doesn't admit of being further constructed. Well, he can indeed begin his construction with any datum he pleases, treating the datum as unanalysed; but he isn't entitled to block the route back to the first principles of natural science by analysing this datum as something wholly incapable of any mathematical construction.

Definition 2

Attractive force is the moving force through which a portion of matter can be the cause of another portion's moving towards it (or, equivalently, through which it resists another portion's moving away from it).

Repelling force is the moving force through which a portion of matter can be the cause of another portion's moving away from it (or, equivalently, through which it resists another portion's moving towards it).

[In English we have the verb 'move' both as transitive (as in 'She moved the jar to the end of the shelf') and intransitive as in 'You spoiled the picture: just as I clicked, you moved'. In the phrase translated as 'moving force' Kant is referring not to a force that moves-intransitive but rather to a force that moves-transitive; not a force that roams, but one that shoves. In fact, German doesn't have a verb that exactly matches the English intransitive 'move'. In the present version of this work, Kant is often translated as saying of some item that it 'moves'; but he does this with a German expression which would be mechnically translated as 'is moved'.]

Note

These are the only two moving forces that can be thought of, ·as I shall now prove·. In the context of questions about one portion of matter impressing some motion on another, the two portions must be regarded as *points*; so any transaction of that kind must be regarded as happening between two points on a single straight line. Now, there are only two ways for two points to move ·relative to one another· on a single straight line: either

- •they approach one another, caused to do so by an attractive force; or
- •they recede from one another, caused to do so by a repelling force. 499

Consequently, these two kinds of forces are the only ones we can make sense of; and all the forces of motion in material Nature must come down to them.

Proposition 2

(a) Matter fills its space by the repelling forces of all its parts, i.e. by its own *force of extension*, and **(b)** this ·repelling force· has a definite degree that can be thought of as smaller or greater to infinity. [This use of 'degree' translates what is almost the first occurrence of *Grad* in the original. From here on, *Grad*/degree will occur often; in Kant's usage it is firmly linked to the notion of *intensive* magnitude [see note on page 16]. We'll later see him writing about the degree to which a given portion of space is filled; this doesn't mean (extensive) *how much of* the space is filled but (intensive) *how strongly* the space is filled.]

Proof

(a) Matter fills a space only through moving force (Proposition 1), specifically by a moving force that resists the penetration, i.e. the approach, of other matter; and this is a repelling force (Definition 2). So matter fills its space only through repelling forces, and indeed through the repelling forces of all its parts. (Why '*all* its parts'? Well, try to suppose that some part x of a portion of matter doesn't exert repelling force. That means that the portion of space assigned to x is not *filled*, which means that that x isn't a portion of matter after all, but only a region of space contained within a portion of matter.) And the force of something that is extended by virtue of the repulsion of all its parts is a force of extension. [Kant adds in brackets that this is 'expansive' force—the first time this word has occurred in the work. We'll see a lot of it from now on.] Therefore, matter fills its space only by its own force of extension. **(b)** Given any particular force, it is conceivable that there should be a greater one. If for a given force F it was inconceivable that there should be a greater force, that would mean that F was the greatest conceivable force, which could make something travel an infinite distance in a finite length of time; which is impossible. ·Why 'an infinite distance'? Well, suppose that the best F can do is to make something travel N miles in a year, where N is a finite number; then it is conceivable that some force F+ should make a thing travel N+1 miles in a year, so that F+ would be greater than F. Where there's room for the thought 'greater distance' there's room for the thought 'greater force'·. Also, given any particular force, it is conceivable that there should be a lesser one. If that weren't so, there could be a force F such that a weaker force was inconceivable, which implies that the distance F could make a thing travel in a year was *zero*; meaning that it couldn't make anything move at all; meaning that F isn't a force of movement after all. (·The explanation of *zero* in this half of the proof of **(b)** can easily be worked out from the explanation of *infinity* in the first half·.) Putting **(a)** and **(b)** together: The force of extension through which every portion of matter fills its space has a degree that is never the greatest or smallest, but beyond which greater as well as smaller degrees can always be found. [Kant presumably means 'can be found in the realm of possibilities' = 'can be conceived', not 'can be found in the material world'. His later uses of 'can be found' will be translated without comment.]

Note 1

The expansive force of matter is also called *elasticity*. This 500
force is the basis for the filling of space as an essential property of all matter, so it is *basic*, not a consequence of any other property of matter. So all matter is basically elastic.

Note 2

Given any extensive force there can be found a greater moving force that can work against it and diminish the space that the extensive force is trying to expand. In this case the latter force is called a 'compressive' one. Thus, for any given portion of matter a compressive force can be found that can squeeze this matter into a smaller space than the one it is currently occupying.

Definition 3

A portion of matter x in its motion **penetrates** another portion y when by compression it completely abolishes the space of y's extension. [Kant's verb *aufhebt* apparently has to mean 'abolishes' in this context. But we'll see in a moment that what he means is that x *takes over* the space through which y was extended, depriving y of it.]

Remark

When an air-pump's piston is pushed ever closer to the bottom of the cylinder, the air-matter is compressed. If this compression could be carried so far that the piston came flat against the bottom with no air escaping, then the air-matter would be penetrated ·in the sense laid down in Definition 3·. For it is between two portions of matter that leave no space for it, so that it's to be met with between the bottom of the cylinder and the piston without occupying a space. This penetrability of matter by external compressive forces would be called 'mechanical', if there were such a thing—or indeed if such a thing were conceivable. I distinguish this impossible penetrability of matter from another kind of penetrability which is perhaps equally impossible. I may need to say a little about this second kind of penetrability later on. [We'll see that in this second kind of penetrability, which Kant will call 'chemical', x penetrates y by coming to share all y's space with y (see page 44). This is a much more natural meaning for 'penetrate' than the present 'mechanical' one.]

Proposition 3

501 **(a)** Matter can be •compressed to infinity, but **(b)** it can never be •penetrated by other matter, however great the latter's pressing force may be.

Proof A basic force through which a portion of matter tries to extend itself all through the space that it occupies must be greater when enclosed in a smaller space, and must be infinite when compressed into an infinitely small space. **(a)** Now, for any given extensive force that a portion of matter has, there can be found a greater compressive force that squeezes this matter into a smaller space, and so on to infinity. But **(b)** penetrating the matter would require its compression into an infinitely small space, and thus would require an infinitely strong compressive force; but such a force is impossible. Consequently, a portion of matter cannot be penetrated by the compression of any other portion of matter.

Remark

I have assumed at the start of this proof that the more an extensive force is constricted the more strongly it must resist. This might not hold for a •derivative elastic force, but it can be postulated of ·any •basic elastic force, i.e.· any elastic force that a portion of matter has essentially, just because it is matter filling a space. Expansive force exercised from all points toward all sides constitutes the very concept of elasticity. And the smaller the space in which a given amount of expanding force has to exercise itself, the more strongly the force must exercise itself at every point in the space.

Definition 4

The impenetrability of matter that comes from its resistance ·to being squeezed·—impenetrability that increases proportionally to the degree of compression—I call '**relative**'.
The impenetrability that comes from the assumption that 502
matter as such can't be compressed at all is called '**absolute**' impenetrability. The filling of space with absolute impenetrability can be called 'mathematical'; that with merely relative impenetrability can be called 'dynamical'.

Remark 1

According to the merely mathematical concept of impenetrability (which doesn't assume that any moving force is basically inherent in matter), no matter can be compressed except to the extent that it contains empty spaces within itself. So matter, just *as matter*, resists all penetration unconditionally and with absolute necessity. According to my discussion of it, however, impenetrability has a physical basis; for the extensive force makes matter itself, as something extended filling its space, first of all possible. But this force has a degree that can be overcome, so the space occupied by a portion of matter can be diminished, i.e. its space can be somewhat penetrated by a given compressive force; but complete penetration is impossible, because it would require an infinite compressive force. Because of all this, the filling of space must be regarded only as relative impenetrability.

Remark 2

In fact absolute impenetrability is nothing more or less than a *qualitas occulta.* [Kant here refers (in Latin) to the 'occult (= hidden) qualities' that were postulated by various mediaeval philosophers to 'explain' certain phenomena; by Kant's time, everyone agreed that these explanations were no good. There were two basic complaints about them: **(i)** They weren't derived from anything deeper or more general; they were always treated as basic, fundamental. **(ii)** Their 'explanations' were always slam-bang one-sentence affairs, with no complexity that might enable them to connect fruitfully with other explanations of other phenomena.] We ask '*Why* can't portions of matter penetrate one another in their motion?' and are given the answer 'Because they are *impenetrable*'! The appeal to *repelling force* is not open to this complaint. It is true that **(i)** this force also can't be shown to be possible through our giving a further analysis of it, so that we have to accept it as a fundamental force; but it doesn't **(ii)** lack helpful complexity, because it involves the concept of an •active cause and of •the laws of this cause in accordance with which the strength of the force can be measured by how strongly the space in question resists penetration.

Definition 5

Material substance is whatever it is in space that is movable on its own, i.e. separated from everything else existing outside it in space. The motion of a portion of matter whereby 503
it ceases to be a part ·of some larger portion of matter· is **separation.** The separation of the parts of a portion of matter is physical division.

Remark

The concept of substance signifies the ultimate subject of existence, i.e. everything that doesn't exist merely as a predicate [here = 'property'] of some other existing thing, ·in the way a blush exists merely as a property of a face, or a storm exists merely as a property of some wind and water·. Now, matter is the subject of everything *existent* in space; for besides matter no other spatial subject can be thought of except space itself; and the concept of space hasn't any content relating to existence, and merely contains the necessary conditions for things we can perceive through the external senses to have external relations to one another. So •matter—as what is movable in space—is •substance in space. Similarly every part of a portion of matter will also be a substance, because it too is itself a subject and not merely a predicate of other portions of matter; so every part of any portion of matter is itself a portion of matter. . . .

Proposition 4

Matter is divisible to infinity, and indeed into parts each of which is again matter.

Proof

Matter is impenetrable because of its basic force of extension (Proposition 3 [page 22]), but this force of extension is only the consequence of the repelling forces of each point in a space filled with matter. Now, the space that matter fills is mathematically divisible to infinity, i.e. its parts can be differentiated to infinity; although they can't be moved and so can't be pulled apart. . . . Now, in a space filled with matter every part of the space contains repelling force to hold at bay on all sides all the parts surrounding it, and hence to repel them and be repelled by them, i.e. to be moved to
504 a distance away from them. Hence every part of a space filled by matter is movable and is therefore separable by physical division from any of the other parts that are material substances. Consequently, every mathematical division of a region of space has corresponding to it a possible physical division—a pulling apart—of the substance that fills the region of space; and such mathematical divisions can be continued to infinity, so all matter is physically divisible to infinity—divisible indeed into parts each of which is itself also a material substance.

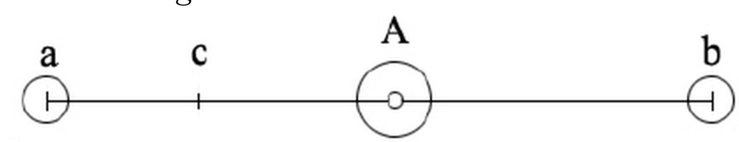
Remark 1

Proving the infinite divisibility of space is *far* from proving the infinite divisibility of matter unless one first shows that in every part of space there is material substance, i.e. separately movable parts. ·To see the need for this further premise, consider this position, which· a monadist might adopt:

> 'Matter consists of physical *points*, each of which—just because it *is* a point—has no separately movable parts, but nevertheless fills a region of space by mere repelling force. The region containing such a physical point is divided, but the substance acting in it—the physical point—is not divided.'

Thus, this monadist can have matter made up of physically indivisible parts while still allowing it to occupy space in a dynamical way, ·i.e. to occupy space by exerting force throughout it·.

But the proof I have given completely undermines this monadist dodge. My proof makes it clear that *every* point in a filled space must push back against whatever pushes in upon it. This •can be the case if the point contains a reacting subject that is separately movable and distinct from every other repelling point; and it's clear that it •can't be the case if all you have is a mere driving force exerting itself through a region of space. To get an intuitive grasp of this (and, therefore, of the proof I have given for Proposition 4), consider this diagram:



A is stipulated to be a monad whose sphere of repulsive force has the line aAb as a diameter. Then penetration of A's sphere of influence is resisted at the point a. But now consider a point c that is within the sphere, between a and A (there must be such a point, because space is infinitely divisible); and ask yourself what the state of affairs is at c. The answer is that *there must be at c something that holds A apart from a*:

> A force emitted from A can't make itself felt at a unless ·the contents of· those two points are kept apart; without that, they would penetrate one another ·so that the entire sphere would condense into a point·. 505

So something at c resists penetration by a and by A; so it repells the monad A at the same time as being repelled by it. And repelling is a kind of *motion*. So we get the result that c is something movable, ich means that it is matter. This shows that the filling of that sphere can't consist merely in a repelling force's being exerted throughout it by a one-point monad in its centre. On the contrary, the sphere must be filled with matter. (We are assuming, of course, that the argument about the point c could be repeated for *any* point within the sphere.)

Mathematicians represent the repelling forces of the parts of elastic portions of matter. . . .as increasing or decreasing in proportion to their distances from one another. The smallest parts of air, for instance, repel each other in inverse proportion to the distance between them, because their elasticity is inversely proportional to the spaces that they are squeezed into. Don't misunderstand the thought and mistake the language of the mathematicians by taking •something that necessarily belongs to *the process of constructing* the concept to be •something that applies to *the object* of the concept. ·Here's why they are different·. In the construction process, two things' being in contact can be represented as their being an infinitely small distance apart; and indeed the construction *has to* handle contact in that way in cases where a single quantity [*Quantität*] of matter, i.e. a single quantum of repelling forces, is represented as *completely* filling spaces of different sizes ·at different times·. For us to •have an intuitive sense of the expansion of a portion of matter to fill a larger space—·•that being what constructions are for·—we have to make use of the idea of an infinitely small distance. [See the note on 'idea' on page 9.] But if matter is infinitely divisible, there can't be any actual distance between any two ·nearest· parts; however much a portion of matter expands, it is still a continuum.

Remark 2

When mathematicians are just doing mathematics, they can ignore the tricks played by mistaken metaphysics. They can be sure of the obvious mathematical truth that space is infinitely divisible, without caring about objections that may be brought against this by foolish nit-pickers. But when they are ·not merely doing mathematics but· taking mathematical propositions that are valid for *space* and applying them to *substance filling space*, they have to submit what they are saying to purely conceptual tests, which means that they have to attend to metaphysics. Proposition 4 [page 24] is already a proof of this. For although matter is infinitely divisible *mathematically*, it doesn't follow that matter is *physically* divisible to infinity. Granted that every part of space is also a space, so that every part of space includes within itself parts that are external to one another, it doesn't follow that in every possible part of this filled space there is substance, which is separated from everything else and is independently movable. [Notice that Kant says 'filled space'—a phrase that he uses quite often to mean 'space filled with matter'. So the mathematicians' account of space as infinitely divisible stands firm even if the space in question is thought of as 'full of matter', provided (Kant warns) that this is left unexplained and (in particular) is not understood as meaning that every part of space contains *a material substance*. To the proposition that he is allowing the mathematicians to assert he might give the label 'the mathematical proposition of the infinite divisiblity of matter', setting this off against (a phrase that he *does* use) 'the physical proposition of the infinite divisibility of matter'.] So there has always been something missing from mathematical proof ·of the infinite divisibility of matter·, and there has been no guarantee that that proof could be securely applied in natural science. This gap has now been filled—by ·my proof of· Proposition 4 above. Now we have the *physical* proposition 506
of the infinite divisibility of matter; and when it comes to

metaphysical attacks on *that*, the mathematician must ·back off and· leave them entirely to the philosopher. When the philosopher tries to deal with these attacks, he ventures into a labyrinth that is hard enough to get through when he just approaches it philosophically; he can do without interference from mathematician! ·Here's a sketch of the labyrinthine problem· (stated for portions of matter, though it applies equally to regions of space):

> **(a)** A whole must already contain within itself all the parts into which it can be divided. Therefore **(b)** if matter is infinitely divisible, then it consists of infinitely many parts. But **(c)** a portion of matter can't possibly have infinitely many parts, because **(d)** the concept of *infiniteness* is the concept of *something that can't ever be wholly complete*, from which it follows that 'There are infinitely many of them, and they are all there, complete, settled' is self-contradictory.

That is the difficulty as it presents itself to the dogmatic metaphysician, who is thinking of wholes as *things in themselves*, the crucial point being that proposition **(a)** is true only of wholes considered as things in themselves. So we have to choose between two options:

- •Defy the geometer by denying **(1)** that space is divisible to infinity.
- •Annoy the metaphysician by denying **(2)** that •matter is a thing in itself and •space a property of a thing in itself, saying instead that matter is a mere appearance of our external senses and that space is just the essential form of matter, ·i.e. of that appearance·.

The philosopher is now squeezed between the horns of a dangerous dilemma. It's no use denying **(1)** that space is divisible to infinity; that's a mathematical result, and you can't get rid of it by tricky argument! But regarding matter as a thing in itself, and thus regarding space as a property of things in themselves, *is* denying **(1)**. So the philosopher sees himself as forced to depart from the assertion **(2)** that matter is a thing in itself and space a property of things in themselves—maintaining instead that space is only the *form* of our external sensible intuition [see note on page 8], so that matter and space are not things in themselves but only subjective modes of representation of objects that are *in themselves* unknown to us. Proposition **(2)** is common and commonsensical; the philosopher denies it only on the understanding that this will get him out of the difficulty about matter's being infinitely divisible yet not consisting of infinitely many parts. That matter consists of infinitely many parts can indeed be thought by reason, though this thought can't be constructed and made intuitable [see note on page 2]. If something x is •actual only by •being given in a representation, all you are given ·when you think of it· is what's met with in the representation, i.e. as far as the sequence of representations reaches. If something is an appearance that can be divided to infinity, what can we say about *how many* parts it has? Only that it has as many parts as we give it, i.e. as many as result from whatever division of it we choose to make. That's because the parts of something 507
that is merely an appearance exist only in thought, i.e. only in ·the thought of· the division itself. The division does indeed go on to infinity, but it is never *given* as infinite; so we can't infer that the divisible item contains within itself infinitely many parts ·that are things· in themselves existing independently of our representation of them. Why can't we? Because the division that can be infinitely continued is the division not •of the thing but only •of its representation. . . . A great man who perhaps contributes more than anyone else to the reputation of mathematics in Germany has several times rejected the impudent metaphysical claim to overturn what geometry teaches concerning the infinite divisibility of space.

[Who? Leibniz is a good guess (see below), except that the tenses in the foregoing sentence don't seem right for someone who had been dead for 70 years when Kant wrote this work.] His basis for this rejection was the reminder that space belongs only to the appearance of external things; but his readers didn't understand him. They took him to mean:

> **M:** Space is a thing in itself or a relation amongst things in themselves; but it appears to us, and the mathematicians ·aren't vulnerable to metaphysical attack because they· are talking only about space as it appears, ·not about actual space itself·.

What they should have understood him to mean is this:

> Space isn't a property of anything outside of our senses; it is only the subjective form of our sensibility. Objects of our external senses appear to us under this form, and we call this appearance *matter*. As for what these objects are like ·in themselves·—we know nothing about that.

According to the misinterpretation **M**, space was always thought of as a quality that things have independently of our power of representation, and the mathematicians ·were being criticised because they· thought of this quality only through common concepts (i.e. thought of it confusedly, for appearance is commonly thought of confusedly). This meant that according to **M** the geometricians had used a •confused representation of space as their basis for a mathematical proposition—asserting the infinite divisibility of matter—which presupposes the highest •clarity in the concept of space. Thus the door was left open for the **M**-accepting metaphysicians to bring clarity into this concept of space (they thought!) by supposing that space is made up of points and matter is made up of simple parts, ·i.e. parts that did not in their turn have parts·. This error was based on another misinterpretation—namely a misunderstanding of the monadology of Leibniz, which they saw as trying to explain natural appearances whereas really it is a platonic concept of the world. There's nothing wrong with Leibniz's concept ·of the world as a system of sizeless monads·, as long as the world is being regarded not as •an object of the *senses* but as •a thing in itself, i.e. as merely an object of the *understanding*, though it is the foundation of the appearances of the senses. [From here down to the next mention of Leibniz, this version expands on Kant's words in ways that the ·small dots· convention can't easily signify.] Now, any composite thing made up of things in themselves must certainly consist of *simple* things, because a composite *thing in itself* can't exist except as an upshot of the existence of its parts, *all* its parts, right down to the smallest ones that don't *have* parts. But a composite thing that is *an appearance* doesn't consist of 508
simple things, because its parts exist only as upshots of a division of the thing; so that they, rather than existing independently of the composite thing of which they are parts, exist only *in* that composite thing. For a thing in itself x:

> x exists as an upshot of the putting together of its parts;

whereas for an appearance y:

> y's parts exist as upshots of the division of y.

So it seems to me that Leibniz didn't intend to explain space in terms of an order of simple entities side by side, but rather to claim that this order *corresponds to* space while still belonging to a merely intelligible world that is unknown by us. And this is to assert just what I said elsewhere [in the *Critique of Pure Reason*], namely that space along with matter . . . . doesn't make up the world of things in themselves but only the appearance of such a world, and that what space itself *is* is only the form of our external sensible intuition.

Proposition 5

The possibility of matter requires a force of attraction, as the second essential basic force of matter.

Proof

Impenetrability, as the fundamental property of matter through which it first reveals itself as something real in the space of our external senses, is nothing but matter's power of extension (Proposition 2). Now, an essential moving force by which parts of matter pull away from one another cannot

> **(1)** be limited by itself, because such a force works on matter to drive it towards continuously expanding the space that it occupies;

and it cannot

> **(2)** be kept within limits by space itself. Why not? Because the most that space can do is to bring it about that when the volume of a portion of matter is increasing the extensive force becomes correspondingly weaker; such weakenings can go on to infinity—·the strength of a force is continuous·—but they can't reach zero, which is to say that space can't bring it about that the extensive force stops.

Therefore, if matter were driven only by its repelling force (the source of its impenetrability), with no other moving force counteracting this repelling one, there would be nothing to limit matter's extension; every portion of matter would disperse itself to infinity, so that no assignable quantity [*Quantität*] of matter would be found in any assignable ·region of· space. Consequently, if there were only repelling forces in matter, all regions of space would be empty—so that strictly speaking there wouldn't *be* any matter! [The thought is this: Let R be a region of space measuring a billion cubic kilometers, and let M be a portion of matter weighing a billionth of a gram: if matter expanded *infinitely*, there wouldn't be as big a portion of matter as M in a space as small as R, because that amount of matter would have been spread still more thinly through a still larger region of space. Repeat the argument, making M ever smaller and R ever larger; you will *always* have too much matter for that amount of space.] For matter to exist, therefore, it must have compressive forces opposed to the extensive 509
forces. 'Might not the force that keeps material portion x within limits be the ·expansive· force of a different portion y?' No, that can't be the basic account of the situation, because this 'different portion y' can't exist as matter unless some compressive force is acting upon *it*. So we have to assume that matter has a basic force acting in an opposite direction to the repelling force; this force must tend to bring things closer to one another, which is to say that it must be an *attractive* force. Now, this attractive force is needed for any matter to be possible, so it is more basic than any differences between kinds of matter; and therefore it must be attributed not merely to some one species of matter but to all matter. Thus, a basic attraction belongs to all matter as a basic force that is part of its essence.

Remark

We need to look more closely into what happens in our thinking when when we move from •one property ·that is *contained in*· the concept of matter to •a radically different property that equally *belongs to* the concept of matter without being contained in it. If attractive force is basically required for matter to be possible, why don't we use it, along with impenetrability, as the primary sign of matter? Impenetrability is given immediately with the concept of matter, while attraction isn't thought *in* the concept but only associated with it by inference—what's going on here? You might think: 'Well, our senses don't let us perceive attraction as immediately as repulsion and the resistance of impenetrability'—but that doesn't properly answer the

question. Suppose that we *could* perceive attraction as easily as repulsion: our understanding would still choose to differentiate space from matter—i.e. to designate substance *in* space—in terms of the *filling* of space (otherwise known as *solidity*). Attraction, however well we perceived it, ·couldn't do the job. It· would never reveal to us any portion of matter with a definite volume and shape. All it could reveal to us would be our perceiving organ's being tugged towards a point outside us, namely the central point of the attracting body. [Translated more strictly, Kant speaks not of the organ's being tugged but of its 'endeavouring' to reach that external point. Either way, it is initially surprising, but it is not unreasonable. How do we perceive repelling forces? By feeling ourselves being pushed away from things. So how would we (if we could) perceive attractive forces? By feeling ourselves being pulled towards things! This interpretation presupposes that the 'perceiving organ' is the perceiver's body, the 'organ' of the sense of touch.] That experience wouldn't reveal to us any material things with definite sizes and shapes, because the only way the attractive force of all parts of the earth could affect us is exactly the same as if that force were concentrated entirely in the centre of the earth and this point alone were tugging us; similarly with the attraction of a mountain, or of a stone, etc.—the pull would always be to the central point, and would give no sense of the relevant body's shape or
510 size of even its location. (·Why not its location? Because· although we would be able to perceive the *direction* of the attraction, as it is perceived in our experience of weight, we wouldn't know how far away it was in that direction.) The attracting point would be unknown, and I don't see how it could even be discovered through inferences unless we already had perceptions of matter as filling space, ·i.e. as having repelling force·. This makes it clear that our first application of our concepts of *size* to matter. . . .is based only on matter's space-filling property. Through our sense of touch this property tells us the size and shape of an extended thing, thus creating the concept of a determinate object in space—a concept that underlies everything else that can be said about this thing. No doubt this is what explains the fact that although there are very clear proofs that attraction must belong to the basic forces of matter just as much as repulsion does, there are people who strenuously reject attractive forces and won't allow matter to have any forces except those of impact and pressure (both by means of impenetrability). 'What space is filled by is substance', they say; and this is correct enough, ·but its correctness has led these people astray·. The substance that they talk about reveals its existence to us through the sense by which we perceive its impenetrability, namely the sense of touch; so it reveals its existence only through the contact of one portion of matter with another—a process that starts with *collision* and continues with *pressure*. And because of this it seems as though the only way for one material thing to act immediately on another is by colliding with it or putting pressure on it—these being the two influences that we can immediately perceive. Whereas it's very hard for us to think of *attraction* as a basic force, because it doesn't give us any sensation at all, or anyway no definite object of sensation.

Proposition 6

Matter isn't made possible by mere attraction, without repulsion.

Proof

Attractive force is the moving force of matter whereby one material thing gets another to approach it. If every part of the material world exercises such a force, all those parts are led to cluster together, thus shrinking the region of space that they jointly occupy. Now, the only thing that can block the action of a moving force is a moving force opposed to it; and the force that is opposite to attraction is the force of repulsion. If *that* didn't exist, there would be nothing to stop the force of attraction from pulling portions of matter together closer and closer, constantly shrinking the region of space containing matter. There would be no such thing as

> two material things so close together that repelling forces block them from coming even closer,

so that the force of attraction would eventually pull material things closer and closer together until they shrank into a mathematical point; and at that stage space would be empty, i.e. wouldn't contain any matter. So matter is impossible through mere attractive forces without repelling ones. [Notice the elegant shape of Kant's arguments about the two kinds of force. Allow only repulsion/expansion and matter is spread so widely and thus thinly that it disappears; allow only attraction/contraction and matter is packed so densely that it is all contained in a single point and disappears from all space except that point.]

Note

Any property that is required for something to be intrinsically possible (·whether or not possible in relation to other things·) is itself an essential element of that intrinsic possibility. So repelling force belongs to the essence of matter as much as attractive force does—the two can't be separated in the concept of matter.

Remark

I had first to consider the forces of repulsion and attraction •separately, in order to see what each on its own could contribute to the presentation of matter. The upshot was an *a priori* proof that they are both present, •united, in the general concept of *matter*. We found that space remains empty, with no matter to be found in it, unless *both* these forces are at work in it. ·Why only these two forces—why
511 only repulsion and attraction?· Because they are the only ones that are thinkable.

Definition 6

Contact in the physical sense is the immediate action and reaction of impenetrability. The action of one portion of matter on another when there is no contact between them is **action at a distance**. When this action at a distance occurs without the mediation of matter lying between the
two portions of matter it is called **unmediated** action at a 512
distance, or the action of portions of matter on one another through empty space. [Kant's word *unmittelbar* is usually translated as 'immediate'; and that is not incorrect. But it's natural for us to think of x's 'immediate' influence on y as ruling out not only **(a)** any mediating *thing* between them but also **(b)** any distance between x and y as well. Therefore, in cases where Kant is ruling out **(a)** and emphatically *not* ruling out **(b)**, 'unmediated' will be used instead.]

Remark

Contact in the mathematical sense of the word is the shared boundary of two regions of space—so it isn't *in* either of them. So straight lines can't be in contact (in this sense) with one another: when two straight lines have a point in common, that is because they *intersect*, and their common point belongs to each of them. But a circle and a straight line can be in contact at a point, and so can a circle and another circle; two planes can be in contact at a line, and two solids can be in contact at a plane. Mathematical contact lies at the basis of physical contact, but it doesn't *constitute* it. To get from the concept of mathematical contact to that of physical contact you have to add the thought of a dynamical relation—not that of the attractive forces but the relation of the repelling ones, i.e. of impenetrability. Physical contact is the two-way interaction of repelling forces at the common boundary of two portions of matter.

Proposition 7

The attraction that is essential to all matter is an unmediated action through empty space of one portion of matter on another.

Proof

The possibility of matter as *the thing that fills a space in a determinate degree* depends on the basic attractive force, and so the possibility of physical contact between portions of matter also depends on it. [Until now Kant hasn't spoken explicitly of regions as being filled to a greater or lesser degree, more or less *intensively* filled; but he has done so implicitly, by saying that the repelling force that constitutes space-filling is a matter of degree, i.e. can be more or less strong at a given point. This concept of *the degree to which a given region of space is filled* will be crucially important in what follows.] Thus, physical contact presupposes the attractive force, so the force can't depend on there being physical contact. Now, the action of a moving force that •doesn't depend on any contact •doesn't depend either on the filling of space between the moving thing and the thing moved, ·because 'the space between x and y is filled' is equivalent to 'from x to y there is a series of portions of matter, each in contact with the next'·. This means that such action must occur without the intervening space being filled, and so it's action that operates through empty space. Therefore the basic essential attraction of all matter is an unmediated action of portions of matter upon one another through empty space.

Remark 1

513 It is completely impossible to make any basic force *conceivable*, i.e. to present one or more other forces that somehow give rise to it. Just because it is a *basic* force it can't be derived from anything.

[This use of 'conceivable' may seem odd. It comes from the fact that Kant is running the proposition

> The concept of attraction can't be analysed into simpler or more basic concepts

in the same harness as the proposition

> The attractive force can't be shown to be derived from and dependent on some more basic forces.

On page 40 we shall find Kant inferring from propositions of the type

> The. . . force can't be shown to be derived from and dependent on some more basic forces

the corresponding propositions of the form

> It isn't possible for us to comprehend the possibility of the. . . force.

He regards this as an inevitable drawback of any theory that postulates basic forces; but we'll see that it's a drawback he is willing to put up with because of the advantages of that kind of theory.] But the basic attractive force isn't even slightly *more* inconceivable than the basic force of repulsion. The difference is merely that the basic attractive force doesn't offer itself so *immediately* to our senses as impenetrability—the repelling force—does in giving us concepts of determinate objects in space. Because it's not •felt but only •inferred, the attractive force gives the impression of being ·not a •basic force but· a •derived one, as though repulsion were the upshot of a hidden play of ·more basic· moving forces. But when we take a closer look at attraction, we see that it can't be derived from any source, least of all from the moving force of portions of matter through their impenetrability, because its action is exactly the opposite of impenetrability. The most common objection to unmediated action at a distance is the claim that *a portion of matter can't directly act at a place if it isn't there*. ·But· when the earth directly influences the moon to come closer, it is acting *unmediatedly* on a thing thousands of miles away; and the space between the earth and the moon might as well be regarded as entirely empty, because even if there is matter there it has no effect on the attraction. So the earth acts directly in a place without itself being there. That may *seem* to be self-contradictory, but it isn't. The truth of the matter in fact is that whenever *anything* in space acts on anything else, it acts in a place without itself being in it! If something were to act in the same place where it itself is present, then it wouldn't be acting on anything outside it, but only on itself. For a thing x to be 'outside' a thing y is for x to be in a place that doesn't have y in it. If the earth and the moon touched each other, the point of contact would be a place that has neither the earth nor the moon in it. . . . It wouldn't even have anyI *part* of either the earth or the moon in it, because this point lies at the boundary of the two filled regions, and this boundary isn't a part of either of them. It follows from this that the ·widely accepted· proposition that

> •portions of matter cannot unmediatedly act on each other at a distance

amounts to the proposition that

> •portions of matter can't unmediatedly [*unmittelbar*] act on each other without the intervention [*Vermittelung*] of the forces of impenetrability.

This amounts to saying that repelling forces are the only ones by which portions of matter can be active, or at least that they must be involved when portions of matter act on one another; which implies that the force of attraction is either •impossible or •always dependent on the action of repelling forces; and there is no basis for either of those assertions. The ·widespread· misunderstanding of this matter is a result
514 of confusing •the mathematical contact of regions of space with •their physical contact through repelling forces. [The rest of this paragraph expands Kant's words in ways that the ·small dots· convention can't easily signal.] For x to attract y unmediatedly and without contact is for this to be the case:

> **(1)** x and y come closer together in accordance with a constant law of the form 'If two portions of matter have relation R_1 between them, they move towards one another'.

And for x to repel y unmediatedly and without contact is for this to be the case:

> **(2)** x and y move away from one another in accordance with a constant law of the form 'If two portions of matter have relation R_2 between them, they move away from one another'.

Now, there is not the slightest difficulty about supposing that repelling force doesn't come into R_1 and that attractive force doesn't come into R_2. These two moving forces are wholly different in kind, and there's not the slightest basis for claiming, of either of them, that it depends on the other and isn't possible without the intervention of the other.

Remark 2

Attraction between two things that are in contact can't result in any motion. Why not? Because for two bodies to be in contact is for the impenetrability of each to act against the impenetrability of the other, and that impedes all motion. So there must be *some* unmediated attraction without contact, i.e. unmediated attraction at a distance. To see why, suppose that it is not so, and see where you get. We have two bodies that are approaching one another, without unmediated attraction being at work. In that case, the situation must be that they are being *pushed* towards one another by forces of pressure and impact. This is only apparent attraction, as against true attraction in which repelling forces have no role at all. But even such an apparent attraction must, deep down, involve true attraction, because the portions of matter whose pressure or impact is at work wouldn't even *be matter* if they didn't have attractive forces (Proposition 5 [page 28]). So the attempt to ·get rid of true attraction and· explain all phenomena of approach in terms of apparent attraction moves in a circle.

There is a view about Newton that is widely accepted, namely:

> He didn't see any need for his system to postulate unmediated attraction of portions of matter. Behaving strictly like a pure mathematician, he •kept right out of this issue, •left the physicists completely free to explain the possibility of such attraction in whatever way they thought best, and •avoided mixing up his propositions with their play of hypotheses.

But how could he establish the proposition that *the universal attraction of bodies—across a given distance—is proportional to the quantity* [*Quantität*] *of matter in the bodies* if he didn't assume that it's an essential feature of matter as such, ·matter simply *qua* matter·, that it exercises this motive force? For when one body pulls another, their approach to one another (according to •the law of the equality of
515 reciprocal action) must always occur in inverse proportion to ·the quantity of· the matter in those bodies—and it makes no difference what *kinds* of matter are involved. Still, •this law is not

> a principle of •dynamics, i.e. a law about the distribution of attractive forces,

but rather

> a law only of •mechanics, i,e, a law about the motions that attractive forces cause.

And not just *attractive* forces; it is valid for moving forces generally, of whatever kind. ·Here is an illustrative example·:

> A magnet x is attracted by an exactly similar magnet y on two occasions: on one occasion there are just the two magnets, on the other occasion magnet y is enclosed in a wooden box that weighs twice as much as y does. On the second occasion, y-plus-box will impart more relative motion to x than y alone did on the first occasion, despite the fact that the wood, which contributes to the quantity [*Quantität*] of the matter in y-plus-box, adds nothing at all to y's attractive force and exerts no magnetic attraction.

Newton ·regarded attraction as something that all matter, of whatever kind, must have. He· wrote:

> 'If the ether or any other body had no weight, it would differ from any other portion of matter only in its *form*, so that it could be transformed little by little through a gradual change of this form into a portion of matter of the heaviest kind on earth; and conversely the heaviest kind could become weightless through a change of its form. This is contrary to experience' and so on. [Newton's *Principia* II.vi.cor.2]

Thus he didn't exclude even the ether (much less other kinds of matter) from the law of attraction. If Newton held that the approach of bodies to one another was a case of mere apparent attraction, created ·somehow· by impact, what kind of matter would he be left with to provide the impact? So you can't claim this great founder of the theory of attraction as your predecessor, if you take the liberty of replacing the •true attraction that he did maintain by an •apparent attraction that forces you to explain the appproach of bodies in terms of impact. 'What causes the universal attraction of matter?' Newton declined to get into any hypotheses to answer this question; and he was right to do so, because the question belongs to physics or metaphysics, not mathematics. It's true that in the preface of the second edition of his *Optics* he says: 'And to show that I do not take gravity to be an essential property of bodies, I have added one question concerning its cause' and so on [Kant quotes this in Newton's Latin]. Well, perhaps he shared his contemporaries' shock at the concept of *basic attraction*, and was led by this to be at variance with himself. ·There can be no question of taking that remark from the *Optics* as his most fundamental and most considered view, because· he held that the attractive forces that two planets. . . .exercise on their satellites (mass unknown), when at the same distance from those satellites, are proportional to the quantity [*Quantität*] of the matter in the two planets; and he absolutely could not say this unless he assumed that *just by being matter* they had attractive force, in which case all matter must have it.

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Definition 7

A **superficial force** is a moving force by which portions of matter can directly act on one another only at the common surface of their contact; a **penetrating force** is a moving force by which one portion of matter can directly act on the parts of another that are not at the surface of contact.

Note

The repelling force through which matter fills a space is a mere superficial force. That is because the parts touching each other limit one another's sphere of action; the repelling force can't move any more distant part except by means of those lying between. . . . On the other hand, no intervening matter limits an attractive force. That kind of force enables a portion of matter to •occupy a region of space without filling it [see Remark on page 20]; and to •act through empty space upon other distant portions of matter, without this action's being limited by any intervening matter. That is how we must think of the basic ·force of· attraction that makes matter itself possible. So it's a penetrative force, and for that reason alone it is always proportional to the quantity [*Quantität*] of the matter.

Proposition 8

The basic attractive force, on which the very possibility of matter depends, reaches out directly from every part of the universe to every other part, to infinity.

Proof

Because the basic attractive force. . . .is essential to matter, every portion of matter has it. Now, suppose there were a distance beyond which the force of attraction didn't reach: 517
what could explain this limitation of the sphere of its efficacy? It would have to be explained either **(a)** by the matter lying within this sphere or **(b)** by the sheer size of the sphere. It couldn't be **(a)**, because this attraction is a penetrative force, which acts unmediatedly at a distance; it goes across every region of space as though the space were empty, unaffected by any intervening portions of matter. And **(b)** can't be right either. Every case of attraction involves a moving force that has a degree ·of strength·, given any such degree a smaller one is thinkable, and then one smaller than that. . . and so on to infinity. Now, the great distance between two portions of matter would reduce the strength of the attraction between them—reducing it in inverse proportion to the amount of the diffusion of the force—but it wouldn't destroy the attractive force between them completely. So there is nothing that could bring about a limit to the sphere of efficacy of the basic attraction of any part of matter, so this attraction reaches throughout the universe to infinity.

Note 1

We have here a basic attractive force—a *penetrating* force—which is exercised

- •by every portion of matter (in proportion to its quantity [*Quantität*] of matter), •upon all portions of matter, •across any possible distance.

From this force, in combination with the opposing repelling force, it must be possible to derive the limitation of the repelling force and hence the possibility of the filling of a region of space to a determinate degree. And in this way the dynamical concept of matter as *what is movable, and fills a region of space to some determinate degree* can be constructed. This construction requires a law governing how basic attraction and basic repulsion relate to one another at various distances. Finding this relation is a purely mathematical problem, because the relation rests solely on •the opposite directions of these two forces (one drawing points together, the other pushing them apart) and on •the size of the space into which each force diffuses itself at various distances; metaphysics has nothing to do with this. If the attempt to construct matter in this way meets with failure, that won't be the fault of metaphysics. Its only responsibility
518 is for the correctness of the elements of the construction that reason leads us to; it isn't responsible for the insufficiency and limitedness of our reason in doing the construction.

Note 2

Each portion of matter succeeds in being a determinate material thing only by filling a region of space with a determinate degree of repelling force; and such a filling of a determinate region of space can happen only through a conflict between a basic attraction and the basic repulsion. Now, the attraction involved in this filling of a determinate region of space may arise either ·internally· from •the attractions that the parts of the compressed matter exert on one another or ·externally· from •the attraction exerted upon this compressed matter by all the matter of the world. The basic attraction is proportional to the quantity [*Quantität*] of matter, and it reaches to infinity. So the only way a determinate region of space can be filled by matter is through matter's infinitely-reaching attraction; such a determinate degree of the filling of space can then be imparted to every portion of matter in accordance with the degree of its repelling force. The action of universal attraction—exercised by all matter directly on all matter and at all distances—is called *gravitation*; the endeavour [see long note on page 19] to move in the dominant gravitational direction is *weight*. The action of the universal repelling force of the parts of each portion of matter is called its basic *elasticity*. Weight involves an external relation, while elasticity is internal. These two are the only *a priori* comprehensible universal characteristics of matter; ·they are *a priori* graspable because· they are the foundations on which rests the very possibility of matter. When *cohesion* is explained as the reciprocal attraction of portions of matter that are in contact with one another, it doesn't belong to the possibility of matter in general and therefore can't be known *a priori* to be bound up with matter. This property ·of cohesion through contact· would be physical, not metaphysical, so it wouldn't belong to our present considerations.

Remark 1

I can't forbear adding a small preliminary remark for the sake of any attempt that may be made toward such a possible construction.

(1) Let F be some force—*any* force—that acts unmediatedly at different distances, with the amount of moving
force that it exerts at any given point being limited only 519
by how far it had to travel to reach that point. However much or little space F is spread through, the total amount of it is the same; but the intensity of its action upon a given point x will always be inversely proportional to the space F had to get through to reach x. Think of light being propagated from a point P, surrounded by a series of spheres each with P as its centre. The total amount of light falling on any sphere is the same as the total amount falling on

any other; but the amount of light falling on (say) a square inch of one sphere will be greater than the amount falling on a square inch of a larger sphere. And that's how it is with all other forces, and the laws according to which these forces must diffuse themselves, either in two dimensions or in three, in order to act according to their nature upon distant objects. If you want to do a drawing of the diffusion of a moving force from one point, it is better *not* to do it in the ordinary way (as in optics, for example), namely by means of straight-line rays diverging from a central point. However many lines you put into such a diagram, they'll get further apart the further they get from the central point; so they can never *fill* the space through which they pass or (therefore) fill the surface that they reach. This makes them a source of troubles that can be avoided if we ·get rid of straight-line rays, and· think of the situation merely in terms of the size of the whole spherical surface that is to be uniformly illuminated by the same quantity [*Quantität*] of light, so that—quite naturally—the intensity of illumination of any given area of a surface is inversely proportional to the size of the whole surface; and similarly with every other diffusion of a force through spaces of different sizes.

(2) If the force is an unmediated *attraction* at a distance, the lines of the direction of the attraction must be represented as rays not •diverging from the attracting point but, rather •converging at the attracting point from all points of the surrounding spherical surface. Why? Because the line of direction of the motion to this point—a point that *causes* the motion and *is its goal*—assigns the points *from* which the lines must begin, namely from all points of the surface. These lines get their direction from this surface to the attracting centre ·of the sphere·, and not vice versa. For only the size of the surface determines how many lines there are; the centre leaves this undetermined.[2]

(3) If the force is an unmediated repulsion by which a 520
point. . . .fills a space dynamically, and if the question is

> What law of infinitely small distances (here = *contacts*) governs how a basic repelling force acts at different distances?. . . .

then it is even further from being correct to represent this force by diverging rays of repulsion coming from the repelling point, even though the direction of the motion has this point as its starting-point. That's because the space in which the force must be diffused in order to act at a distance is a corporeal space that is to be thought of as filled. There's no way of mathematically representing how a point can dynamically fill a space; and the repelling force of a corporeally filled space can't possibly be represented by diverging rays coming from a point. What we must do, rather, is to assign a value to the repulsion at various infinitely small distances of
these mutually repelling points simply in inverse proportion 521
to the ·volumes of the· corporeal spaces that each of these points dynamically fills, so that the value will be in inverse

[2] It's impossible to represent surfaces at given distances as wholly filled with the action of lines spreading out from a point like rays, whether the action is illumination or attraction. Draw the situation in that way and you make it look as though the inferior illumination of a distant spherical surface consists in its having relatively large *un*illuminated and widely spaced illuminated ones! Euler's hypothesis ·that light consists of waves, not streams of particles· avoids this inconvenience, but at the cost of making it harder to get a conception of the rectilinear motion of light. [The footnote goes on at some length, recommending that we think of light as consisting not of waves or of straight-line streams of particles but rather an infinitely divisible *fluid*. Kant seems to acknowledge that there is no convenient way to *draw* this account of the matter; and recommends that we resort to the device of straight-line rays but only after getting firmly and clearly in mind what the truth is, so as not to be misled by the lines.]

proportion to the cube of the distances of these points from one another. . . .

(4) So the basic attraction of matter would act in inverse proportion to the square of the distance—*any* distance—while the basic repulsion would act in inverse proportion to the cube of the infinitely small distances. It's that action and reaction of the two fundamental forces that make ·a portion of· *matter* possible, by filling its space to a determinate degree. The point is that as parts move closer together the •repulsion between them increases faster than the •attraction does; and that sets a limit to the approach—the limit at which the available attractive force loses out to the available repelling force—and that limit determines *how* intensely the space is filled.

Remark 2

I'm well aware of the difficulty about this way of explaining the possibility of *a portion of matter* ·considered as separate from other portions of matter·. It consists in the fact that if a point can't unmediatedly [see note on page 30] drive another point by repelling force without at the same time filling the whole intervening corporeal space with its force, then it seems to follow that this ·intervening· space must contain several driving points. That conflicts with the hypothesis ·of the discussion, namely that we are talking here about action *at a distance*·, and it was ruled out above through the label 'sphere of repulsion of the simple in space'. [Ruled out *where*? Kant cites Proposition 4, but that seems wrong. Definition 6 is better, though neither there nor anywhere else has he spoken of 'the repulsion of *the simple*'.] But we should distinguish •the *concept* of an actual region of space, which could exist, from •the mere *idea* of

> a region of space that •is entertained in thought only for the purpose of determining how various given regions are inter-related, but •isn't in fact a region of space.

[See note on *Idee* on page 9.] In the case cited of a supposed physical monadology, there were to be actual spaces that were filled by a point dynamically, i.e. through repulsion; for they existed as points before any possible production of matter from these points, and through the proper sphere of their activity they *fixed* the part of the space to be filled that could belong to them. In this physical monadology, therefore, matter can't be regarded as infinitely divisible and as a continuous quantum, because the parts that unmediatedly repel one another are at a determinate distance from one another (the sum of the radii of their spheres of repulsion); whereas the thought of matter as a continuous quantity [*Größe*] doesn't allow for *any* distance between the unmediately repelling parts, or, therefore, for any increase or decrease of the spheres of their unmediated activity. However, portions of matter can expand or be compressed (like the air), and ·within the framework of the physical monadology· this can be represented in terms of increase and decrease of the distance between their nearest parts. But ·in actual fact· the closest parts of a continuous portion of matter touch one another, even when it is being expanded or compressed; so their distances from one another have to be thought of 522
as infinitely small, and this infinitely small space must be understood to be filled in a greater or lesser *degree* [see note on page 21] by their force of repulsion. But two things' •having an infinitely small space between them is their •being in contact. Hence it is only the idea of space that enables us to intuit [= 'see in our mind's eye'] the expansion of matter as a continuous quantity [*Größe*], although it can't actually be conceived in this way. Thus, when it is said that the repelling forces that two parts of matter unmediatedly exercise on one another are

•in inverse proportion to the cube of the distance between them,

this means only that they are

•in inverse proportion to the corporeal spaces that one thinks of between the parts,

though in fact the parts are immediately in contact (which is why we have to call the distance between them 'infinitely small' so as to distinguish it from every actual distance). We mustn't raise any objection to a concept itself because of difficulties in the construction of it or rather in the misinterpretation of the construction of it. . . .

The universal law of dynamics would in both cases be this:

•The action of the moving force that one point exerts on each other point external to it is inversely proportional to •the space through which that moving force has had to spread in order to act unmediatedly upon the other point at the given distance.

From the law that the parts of matter basically repel one another in inverse cubic proportion to their infinitely small distances, there must necessarily follow a law of the expansion and compression of these parts that is entirely different from Mariotte's law regarding the air. Mariotte's law proves that the forces causing the closest parts of the air to move away from one another are in inverse proportion to the distances between parts (Newton proves this in the scholium to Proposition 23 of Book II of the *Principia*). But the expansive force of the parts of the air can't be an example of the action of *basic* repelling forces. Why not? Because this expansive force comes from *heat*, which compels the proper parts of the air (which, incidentally, are at *actual* distances from each other) to move away from one another, doing this, apparently, by *vibrations*. . . . But the laws of the communication of motion through the vibration of elastic portions of matter make it easy to conceive that these ·heated-air· vibrations give to the air's parts a force that •causes them to move away from one another and •stands in inverse proportion to the distances between the parts. [The phrase 'communication of motion' is a common translation of the German *Mitteilung der Bewegung*. It would be closer to the German to put 'sharing of motion', but we would have to remember to liken this to 'thank you for sharing that news with me' rather than to 'thank you for sharing your cake with me'. Or we might use 'the passing on of motion'; but on page 60 Kant writes about those who thought of the *Mitteilung der Bewegung* as a literal passing over of some motion, from one body that loses it to another that gains it. That is one *theory about* this phenomenon; so terminology that strongly suggests it can't be used as a *neutral name for* the phenomenon.] But let me explain: I do *not* want my exposition of the law of basic repulsion to be seen as essential to the aim of my metaphysical treatment of matter. All I needed for that 523
treatment was to present the filling of space as a dynamic property of matter; and I don't want that to be mixed up with the disputes and doubts that might arise from ·further details of· my exposition.

GENERAL NOTE ON DYNAMICS

Looking back over everything I have said about the metaphysical treatment of matter, we find that the treatment has dealt with

(1) what is real in space (otherwise known as what is 'solid') in its filling of space through repelling force;

(2) what relates in a negative way to the real in space . . . ., namely, attractive force, ·which negates the real in space in the sense that· if this attractive force were left to itself it would permeate the whole of space and completely abolish everything solid;

(3) the limitation of **(1)** by **(2)**, yielding an empirically accessible degree of the **filling of space.**

So we see that the quality of matter has been completely dealt with under the headings of *reality*, *negation*, and *limitation*. When I say 'completely dealt with', I mean that the treatment contains everything needed for a metaphysical dynamics. [The terms 'reality' etc. are Kant's labels for the categories of Quality in his *Critique of Pure Reason*.]

GENERAL REMARK ON DYNAMICS

In what I am about to say, I use 'real' [German *real*, from Latin *res* = 'thing'] to apply only to *things* and not to mere *states* or *qualities*; for example a thing's location and size and shape are not real because they are not themselves things but are spatial qualities of things. Now, the universal principle of the dynamics of material Nature is this:

> Everything that is real in the objects of our external senses must be regarded as a moving force.

This principle banishes from natural science the empty concept of the so-called solid, i.e. the concept of absolute impenetrability, and replaces it by the concept of repelling force. On the other hand, the true and unmediated attraction is •defended against all the bad arguments of a metaphysics that misunderstands itself, and •is explained as a fundamental force that is necessary for the very possibility of the concept of matter. One consequence of this is that we can if necessary think of space as filled throughout but in varying degrees, ·so that we can think of a portion of matter as light or soft or undense· without having to suppose that it has pockets of empty space scattered through it. To understand this, consider these two:

(1) The basic repelling forces of matter, which are the basis for matter's first property, namely the filling of space;

(2) The basic attraction of matter—the attraction that every portion of matter exerts on every other and also the attraction that holds the portion together as a unit. 524

Now, **(1)** doesn't run in harness with **(2)**; on the contrary, we can think of their relationship to one another as infinitely diverse. This is because **(2)** rests on the amount [*Menge*] of matter in a given space, while **(1)** matter rests on the degree to which the space is filled—and this degree can vary enormously (as the same quantity [*Quantität*] of air in the same volume exhibits more or less elasticity according to its temperature). The underlying difference is this:

(2) in true attraction all particles of matter act directly on all other particles of matter; whereas

(1) by expansive force there is only action between the particles at the surface of contact between the two portions, and it makes no difference what the state of affairs is—whether there is much or little of this matter—behind this surface.

All this brings a *great* advantage to natural science, by relieving it of the burden of imagining a world built up out of full ·parts of space· and empty ones, allow it instead to think of all regions of space as full, but filled in varying measure [= 'in different degrees']. This at least deprives empty space of its status as *necessary*. It used to be thought of as *required* to explain differences in the weight or density etc. of different portions of matter, but now the thesis that there is absolutely empty space is reduced to the status of an *hypothesis*. [From here to the end of this chapter Kant will repeatedly contrast two different accounts of the fundamental nature of the physical world. To make it easier to keep the thread, the two will be given numerical labels within curly brackets, which aren't used for any other purpose in this document.]

[Kant begins his next paragraph by speaking of the advantage that {2} 'a methodically employed metaphysics' has over

{1} 'principles that are also metaphysical but haven't been subjected to the test of criticism'. That last word translates *Kritik*, which occurs in the German title of the *Critique of Pure Reason*. Its appearance here is sudden and surprising; it hasn't occurred earlier in this work except as part of that title; but Kant evidently expects us to gather that the difference between

> {1} the common atomist metaphysic that deals in basic solidity, absolute impenetrability, and empty space

and

> {2} his metaphysic of basic forces and degrees of intensity of fullness of space

is the difference between {1} a metaphysic that •hasn't been subjected to the kind of criticism that is central to the *Critique of Pure Reason* and {2} a metaphysic that •has. He says that the advantage of {2} over {1} is 'apparently only negative'. (Perhaps his thought is that {2} seems at first sight to do nothing but stop {1} from saying some of the things it is saying.) Anyway, {2} does in an indirect way enlarge the scope of the investigator of Nature, Kant continues:] because the conditions by which he previously limited his field, and by which all basic moving forces were philosophized away, now lose their validity, ·so that he has at his disposal some good concepts that he had thought were illegitimate; and *that* advantage is not 'only negative'·. But he—·this liberated investigator of Nature·—must be careful not to go beyond what makes the •universal concept of matter in general possible by trying to explain *a priori* any •specific facts about kinds of matter, let alone facts about •particular material things. The concept of matter is reduced to nothing but moving forces; that was to be expected, because in space the only activity, the only change, that is conceivable is motion. But who would claim to comprehend the possibility of fundamental forces? [See note on 'conceivable' on page 31.] They can only be *assumed*; ·and it is all right to assume them· if they inseparably belong to a concept that is provably basic and not further derivable from any other (such as the concept of the filling of space). These basic forces are the •repelling forces in general and the counteracting •attractive forces in general. We can quite well form *a priori* judgments concerning their inter-relations and consequences; the investigator is free to think up any relations he likes among these forces, provided he doesn't contradict himself. But he mustn't assume either of them as *actual*, because he is flatly not entitled to set up a hypothesis unless the *possibility* of what is assumed in it is entirely certain; and the possibility of the basic forces can never be comprehended ·and so can never be entirely certain·. And this points to an advantage that {1} the mathematico-mechanical kind of definition has over {2} the metaphysico-dynamical kind, namely: Starting 525
with

> **(a)** a single completely homogeneous basic kind of material

—·namely absolutely solid matter·—this {1} mathematico-mechanical mode can provide for a great variety of sorts of matter that differ in density and (if it adds forces from outside the basic material) different modes of action. To do this, it needs the help of

> **(b)** the different shapes that matter can have, and
>
> **(c)** empty spaces between the portions of matter,

·But the addition of those two doesn't weaken the system in any way·, because the possibility of **(b)** the shapes and of **(c)** the empty intermediate spaces can be proved with mathematical evidentness. In contrast with this, if {2} the basic •material is transformed into basic •forces, then we don't have the means for constructing this concept or for presenting as possible in intuition what we thought universally. Why not? Because there's no secure way of explaining different sorts of matter in terms of different patterns of the basic forces; indeed, we can't even determine *a priori* what the laws are that govern those forces. But {1} a merely mathematical physics pays a high price for that advantage, because •it has to base itself on an empty concept (absolute impenetrability), and because •it must forgo all matter's own forces, ·and make do with forces from outside·. ·And in addition to those two defects, {1} also runs a risk·: Employing its basic patterns of portions of solid matter interspersed with empty spaces, it is required to provide explanations ·of the variety in sorts of matter·, and this requires it to allow—and to insist on its right to—a greater freedom of imagination than is prudent.

Starting with {2} basic forces I can't adequately show the possibility of matter or explain the different sorts of matter. But all that variety can be brought *a priori* under a few intermediate headings, and I do hope to present a complete account of those. (Not that this will provide a way of conceiving the possibility of matter.). . . . ·This material will be presented in four groups·.

(i) A body in the physical sense of the word is a portion of matter that has determinate boundaries and therefore has a shape. The size of the space within these boundaries is the body's **volume**. The degree to which a space is filled is called **density**. . . . The {1} system of absolute impenetrability provides for something to have *absolute* density, by having a portion of matter that has absolutely no empty spaces inside it. Using this concept of the filling of space, one portion of matter counts as less dense than another if it contains less empty space than the other, the extreme case being that of a portion of matter that is called *perfectly dense* because there is no empty space within its boundaries. The phrase 'perfectly dense' has a use in the context of {1} the merely mathematical concept of matter, and *only* there. In {2} the dynamical system, which has only *relative* impenetrability, there is no maximum or minimum of density. In that context any portion of matter can be called 'fully dense' if it has no empty spaces within its boundaries. i.e. if it is a continuum 526
and not an interruptum; and this implies nothing about how thin—·airy, light, etc.·—it is. And one portion of matter counts as 'less dense', in {2} the dynamical sense, than another if it entirely fills its space but not to the same degree as the other. But even in the dynamical system it's not satisfactory to make a 'density' comparison between two portions of matter unless they are homogeneous with one another, ·i.e. of the same kind·, so that one can be produced from the other by mere compression. Now, it doesn't appear to be essential to the nature of matter as such that any portion of it could be made indistinguishable from any other by compression, we shouldn't make density comparisons between heterogeneous portions or kinds of matter, as people customarily do when they say that water is less dense than mercury. [The {1}/{2} labelling will turn up again on page 46.]

(ii) Attraction when considered as acting between things that are in contact is called **cohesion**.

(It's true that some very good experiments have shown that the force that is called 'cohesion' when it operates between things that are in contact with one another is also active at a very small distance. But attraction across small distances is hardly perceivable; so when we speak of 'cohesion' we are thinking of things that are in contact. Cohesion is commonly taken to be a property that all matter has—not •derivable from the concept of matter but •shown by experience to be a feature of all matter. This universality mustn't be misunderstood as meaning **(a)** that every portion of matter is constantly exerting this kind of attraction on every other portion of matter —like gravitation—but rather as meaning **(b)** that every portion of matter acts in this way on any other portion of matter that comes into contact with it. [Kant describes these two versions of the force's universality as 'collective' (he could have said 'conjuctive') and 'disjunctive' respectively: in **(a)** a portion x acts in the relevant way on y **and** z and w and. . . etc, while in **(b)** it acts on y **or** w or z or. . . and so on, depending on which of these comes into contact with it.] For that reason, and also because this attraction is not a penetrating force but only a superficial one (there's plenty of evidence for that), its strength isn't always proportional to the density ·of the matter involved·. What is needed for two portions of matter to cohere with full strength is for them to be *first* fluid and *then* rigid; . . . . when a looking-glass has a crack across it, the portions of glass on the two sides of the crack are nowhere near to being as strongly attracted as they were when they became solid after being fluid. For all these reasons I regard this attraction-in-contact as only a derivative force of nature, not a fundamental one. But more of this later.)

A portion of matter is **fluid** if any moving force, however small, is sufficient to re-arrange its parts. The parts of a portion of matter are **re-arranged** when they are made to
527 switch places while remaining completely in contact with one another. Portions of matter—including the parts of a portion of matter—are **separated** if they lose all contact with one another or the amount of contact is lessened. A rigid body is one whose parts can't be re-arranged by any force—so these parts must be resisting re-arrangement by a certain degree of force ·of their own·. The resistance to the re-arrangement of portions of matter is **friction**. The resistance to the separation of portions of matter that are in contact is **cohesion**. So fluid portions of matter don't undergo friction when they divide; and where friction is found the portions of matter are assumed to be more or less rigid, at least in their smaller parts. . . . A rigid body is **brittle** if its parts can't be re-arranged without its breaking, so that the way its parts cohere can't be changed without its losing cohesion altogether. It is quite wrong to say (·as some do·) that •the difference between fluid and solid portions of matter comes from the •difference in the degree to which their parts cohere. When we call a portion of matter 'fluid', we aren't talking about •how resistant it is to being broken apart, but only about •how resistant it is to being re-arranged. Its •cohesion can be as strong as you like, but its •resistance to re-arrangement equals zero. Consider a drop of water. If a particle within the drop is drawn to one side by a very strong attraction of the parts touching it on that side, then it will be drawn just as strongly to the opposite side; and since the attractions cancel out, the particle is as easily movable as if it were in empty space. That's because any force that might move it has no cohesion to overcome; the only resistance to it would be the matter's so-called *inertia*, and that has to be overcome in making *any* matter move, even matter that doesn't cohere at all. Therefore, a microscopic bug will move as easily within this drop as if there were no cohesion to overcome. For in fact it *doesn't* have to lessen the water's cohesion—to pull particles of the water apart from one another—but only to re-arrange them. [Kant goes on to explain that if the bug tries to escape from the drop, then it does now have to overcome the water's cohesion, but not in a way that lessens the strength of the water's holding together as a cohering drop. He continues:] So it is clear that an increase of the cohesion of the parts of a portion of matter hasn't the slightest effect on its fluidity. Water coheres in its parts much more strongly than is commonly thought. . . . 528
What is quite decisive with regard to our concept of fluidity is this: fluid portions of matter can be defined as those in which the forces exerted by or acting upon each point are the same in every direction. The first law of hydrostatics is based

on the property of fluidity; and it can't be a property of an aggregation of smooth solid particles . . . . The considerations we are in among here enable us to show that fluidity is a *basic* property. ·If it were not basic but derivative, there would be portions of matter that were *very* but not *perfectly* fluid, and there aren't any·. If in a fluid portion of matter there was a tiny hindrance to re-arrangement and hence a tiny amount of friction, this friction would grow with the strength of the pressure with which the portion's parts are pressed against one another, and a strong enough pressure would have the effect that the parts of this portion of matter couldn't be re-arranged by any small force, ·i.e. the effect that the portion would no longer be fluid·. ·Here is a concrete example·:

> Take a U-shaped tube, of which one arm is very wide and the other very narrow (but not as narrow as a capillary, ·because that would have effects that would cloud our result·). Let both arms be a few hundred feet high. According to the laws of hydrostatics, the fluid in the narrow arm would reach exactly the height of the fluid in the wide arm (they are arms of a single tube). But now let us keep adding fluid to the tube, steadily increasing the pressure on the matter at the bottom of the tubes. It there were the tiniest potentiality for friction there, then at *some* height-of-fluid the movement of matter between the arms would stop: adding a small quantity of water to the narrower tube wouldn't affect the height of the water in the wider
> 529 tube; so that the narrow arm's column of fluid could be made to rise higher and higher above the wider arm's column.

And this is contrary to experience and even to the concept of fluidity. The same thing holds if, instead of unlimited pressure by weight, we postulate unlimited cohesion of the parts. I have presented two definitions of fluidity:

> **(a)** A portion of matter is **fluid** if any moving force, however small, is sufficient to re-arrange its parts.
> **(b)** **Fluid** portions of matter can be defined as those in which the forces exerted by or acting upon each point are the same in every direction.

We can derive **(b)** from the conjunction of **(a)** and the **(c)** principle of general dynamics saying that *all matter is basically elastic*, as follows: A portion of matter that is **(c)** elastic will resist, by stretching, any force of compression to which it is subjected; and if it is **(a)**-fluid, its force of recovery will equal the force of compression (nothing will be lost to friction); which is to say that the forces at work in it will be the same in every direction, i.e. that this portion of matter is **(b)**-fluid. So friction, properly so-called, can be had only by rigid portions of matter. . . . Some portions of matter that may have no more force of cohesion than some fluids nevertheless *strongly* resist the re-arrangement of their parts, so that they can't be pulled apart except by destroying the cohesion of all parts in a given surface, thus creating an illusion that they do have more cohesion. ·An example would be a cake of chocolate: you can *break* it in two, but you can't *pull* the two halves of it apart·. Such portions are *rigid* bodies. But why this is so, i.e. how rigid bodies are possible, is still an unsolved problem, though the ordinary doctrine of Nature [see note on page 1] thinks it has easily solved it.

(iii) A portion of matter may be able, after it has been deformed by an external force, to regain its original size and shape when the deforming force is removed; that ability is **elasticity**. When something can return to its previous size after being compressed, that is expansive elasticity; something that returns to its previous size after being stretched has attractive elasticity. The elasticity that consists only in the recovery of the previous shape is always attractive—e.g.

with a bent sword in which the parts on the convex surface have been pulled away from one another and try to resume their former closeness to one another. . . . (Attractive elasticity . . . . is obviously •derivative. An iron wire stretched by a weight springs back into its original size when the weight is removed. The attraction we have here is the cause of the cohesion of the wire. . . . Expansive elasticity, on the other
530 hand, may be either •basic or •derivative. Every portion of matter must, just because it is matter, have basic elasticity, but some also have derived elasticity. [Kant cites the example of hot air, which he thinks has—in addition to its basic elasticity—a further elasticity from being hot. He thinks that air's being hot is its being mixed with a special fluid, and that the elasticity of *this*—which may be basic—is passed on to or shared by the air. Finally:] It isn't always possible to know for sure whether a given instance of elasticity is basic or derived.

(iv) When moving bodies collide and alter one anothers' motion, that is called **mechanical** action. When a body is at rest [= 'motionless'] as a whole though its parts are moving around within it and interacting, their action is called **chemical**. When this chemical influence has the effect of pulling apart the parts of a portion of matter ·and inserting between them parts of another portion·, it is called **dissolving**. When the influence has the effect of separating out two portions of matter that have been dissolved in one another, it is called **chemical analysis**. . . . Absolute dissolving is the dissolving-in-one-another of two portions of matter of different kinds—·call them X and Y·—in such a way that *every* part of the X portion is united with a part of the Y portion in the same proportion as that of the solution as a whole. ·For example, if 5 units of X matter are merged into 10 units of Y matter, and this is 'absolute' dissolving, then in the resultant solution *every* part, however small, consists of one third X and two thirds Y.· This could also be called chemical penetration. (Whether the dissolving forces that actually occur in Nature are capable of bringing about a complete ·or absolute· dissolving doesn't have to be decided here. Here the question is only whether such a solution can be thought of.) Obviously if the parts of a dissolved portion of matter are still *particles*, it is as possible for •them to be dissolved as it was for •the larger parts to be dissolved; and if the dissolving force continues, it's not merely possible but inevitable that the dissolving will continue until *every* part of the solution is composed of X matter and Y matter in the same proportion as they have in the solution as a whole. Because in this case every part of the solution contains a part of the X matter, this matter must *completely fill* the volume in a continuous way. And the same holds for the Y matter. And when *each* of two portions of matter entirely fill a single space, they penetrate one another. That is why a perfect ·or absolute· chemical dissolving would involve penetration of the portions of matter. This chemical penetration would be entirely different from mechanical penetration. In the latter, the thought is that as ·two· portions of matter approach one another the repelling force of one could entirely outweigh that of the other, so that the extent of one or both of these portions of matter is reduced to nothing. In contrast with
that, in chemical penetration each portion of matter retains 531
its extent, but the portions are not outside one another but within one another. . . . It's hard to see any objection to the thesis that such perfect dissolving is possible, and thus that chemical penetration is possible. It does involve a completed division to infinity, ·and that seems to clash with the thesis that an infinite such-and-such is one that 'can't ever be wholly complete'· [see page 26], but:

(a) There there is no contradiction in *this* case of infinite division, because the dissolving takes place continuously throughout a period of time, i.e. through an infinite series of ever-shorter moments.

(b) Moreover, as the division proceeds the sums of the surfaces of the not-yet-divided portions of matter increase; and since the dissolving force acts continuously, the whole dissolving can be completed in a specifiable time.

If you think you can't conceive of such a chemical penetration of two portions of matter, that will be because *the divisibility to infinity of every continuum in general* really *is* inconceivable. If you won't accept this complete dissolving ·of one kind of matter in another· then you'll have to settle for an account that ends with certain small particles of the dissolved matter swimming around in the solvent at fixed distances from one another; these are still divisible portions of matter but ·according to you· they aren't also dissolved, and you won't be able to give the slightest explanation of *why*! It may be true in Nature, as far as our experience goes, that the solvent goes a certain distance and doesn't act further, ·but that is beside my present point·. My question concerns the *possibility* of a dissolving force that acts on smaller and smaller particles until the dissolving is completed. The volume of the resultant solution can be equal to the sum of the volumes of the two portions of matter before the mixture, or it can be smaller than this sum, or even larger than it, depending on how the attractive forces relate to the repelling forces, These mutually dissolving portions of matter constitute in solution, each of itself and both combined, an elastic medium. This elasticity provides the only sufficient reason why the dissolved X matter doesn't by its weight pull itself out from the Y solvent; it's because the solvent Y's attraction, since it occurs equally strongly toward all sides, destroys the resistance of the X dissolved matter. . . . [The next sentence and a half expands Kant's words in ways that the convention of ·small dots· can't easily indicate.] You might want to suggest that chemical dissolving will never be complete because the Y solvent will always be somewhat viscous, i.e. a bit thick and sticky. But that thought rests on the assumption that all dissolving consists in some X matter's coming apart and allowing some more fluid Y matter to flow between the parts; and this view of what dissolving is doesn't fit with the great force that the more solvent fluids exert on dissolved portions of matter—e.g. the action of dilute acids on metals. They don't merely touch the metallic bodies, which is what would happen if the particles of metal merely swam in the acid; rather, the acids exert great attractive force to pull these bodies apart and disperse them throughout the entire space of the containing flask. And another point: Even if •our knowledge and skills didn't put at our disposal any chemical forces of dissolving that could bring about a complete dissolving, •Nature might exhibit such forces in the operations of plants and animals, perhaps producing portions of matter that were products of complete or absolute dissolving though we had no way of separating the components out again. [Kant sketches 532
two possible examples of this, one involving heat and the other magnestism. They are hard to follow, and rest on now-exploded theories about those two phenomena. Then:] Our present search, though, is not for •hypotheses to explain particular phenomena but for •the principle according to which such hypotheses are all to be judged. Everything that frees us from the necessity of invoking empty spaces is an actual gain for natural science. Why? Because empty spaces leave the imagination far too free to invent fictions to make up for the lack of real knowledge of Nature. In the doctrine of Nature, absolute emptiness and absolute density play about the same role that blind chance and blind fate play in metaphysics, namely that of a bar to reason's dominance—either replacing it with fictions or lulling it to

sleep on the pillow of occult qualities!

The chief problem in natural science is to explain how there can be an infinite variety of kinds of matter. There are just two ways in which this can be attempted: {1} the **mechanical** way, by combinations of the absolutely full with the absolutely empty; and in opposition to that there is {2} a **dynamical** way in which all the varieties of matter are explained merely through combinations of the basic forces of repulsion and attraction. {1} The raw materials of the first are atoms and the void. An atom is a small portion of matter that is physically indivisible. A portion of matter is physically indivisible if its parts cohere with a force that can't be overcome by any existing moving force in Nature. An atom marked off from other atoms by its shape is called a primary particle. A body (or particle) whose moving force depends on its shape is called a machine. The **mechanical** natural philosophy is the process of explaining the variety of kinds of matter in terms of the nature and composition of their smallest parts, considered as machines. {2} And we can label as 'the **dynamical** natural philosophy' the explanation of the variety of kinds of matter not in terms of

- •particles considered as machines, i.e. as mere implements used by external moving forces,

but rather in terms of

- •the moving forces of attraction and repulsion that are inherent in these particles.

The {1} mechanical kind of explanation is very convenient for
533 mathematics, which is why it has—under the label 'atomism' or 'the corpuscular philosophy'—always maintained its authority over and influence on the principles of natural science, with little change from Democritus to Descartes and even to our own times. Its essentials consist in the assumption of

- •the absolute impenetrability of the basic matter,
- •the absolute homogeneity of this matter, with no differences except in shape, and
- •the absolute unconquerability of the cohesion of the matter in these basic particles.

Those were the materials for generating different kinds of matter in a manner that ·has two seemingly attractive features; it· •avails itself of a single basic kind of matter, varied only by the shapes of its portions; and •it explains Nature's various actions mechanically, as arising from the shape of these basic parts considered as machines that only needed an externally impressed force. But the claim of this system to be accepted depended, first and foremost, on the supposedly unavoidable necessity of explaining the different densities of kinds of matter in terms of *empty spaces*, which were assumed to be distributed among the particles and within each particle. . . . {2} A dynamical mode of explanation is far better suited to experimental philosophy [here = 'science'], because it leads directly to the discovery of •the moving forces that are inherent in portions of matter and •the laws of those forces, but doesn't freely allow the assumptions of empty intermediate spaces and fundamental particles with fixed shapes, neither of which can be discovered and determined by any experiment. To go to work in {2} this way we don't have to devise new hypotheses; all we need is to refute {1}'s postulate that it's impossible to think of different kinds of matter in any way except through the intermixture of portions of matter and empty spaces. And we *can* refute it, simply by showing how the different densities of kinds of matter can be consistently thought of without bringing in empty spaces. . . . This move rests on the fact that matter does not fill its space by *absolute* impenetrability but by repelling force; this force is a matter of *degree*, which can be different in different portions of matter. The attractive force 534
of a portion of matter is proportional to the amount$_q$ of matter

in it, and is not correlated with its degree of repelling force; so the proportions of repelling to attractive force in different portions of matter can vary greatly. So there is no difficulty in the thought of a portion of matter that entirely fills its space without any empty parts and yet with only a tiny amount$_q$ of matter—so little that we can't detect it experimentally. This is one way to think about the ether. . . . The only reason for assuming an *ether* is to counter the claim that 'rarefied' matter can't be thought of except in terms of empty spaces. ·The outright assertion· that *there is ether* should not be made *a priori*, nor should any ·supposed· law about attractive or repelling forces. *Everything* must be concluded from data of experience—and that includes •the thesis that universal attraction is the cause of gravity, and •the laws of gravity. Still less will conclusions regarding chemical affinities be tested in any way except experimentally. Why? Because it lies right outside the scope of our reason to come at basic forces *a priori*. What natural philosophy [here = 'science'] does is to explain the variety of empirically encountered forces in terms of a smaller number of forces and powers; but these explanations go only as far as the fundamental forces—our reason can't get further down than that. Metaphysical investigation into the underpinnings of the empirical concept of matter is useful only for the purpose of leading natural philosophy as far as possible in the investigation of the dynamical grounds of explanation, because they provide our only hope of finding determinate laws and a system of explanations that hangs together in a rational way.

That is all that metaphysics can ever do for •the construction of the concept of matter, and thus on behalf of •the application of mathematics to the part of natural science dealing with •the properties by which a portion of matter fills a region of space in determinate measure. All metaphysics can do is to regard •these properties as dynamical and not as unconditioned basic *givens* such as a purely mathematical treatment would postulate.

I end this chapter with some remarks about the familiar question of the admissibility of empty spaces in the world. The possibility of such spaces can't be disputed. All forces of matter *presuppose* space; the laws governing the spread of these forces have the form 'If a region of space is. . . , then. . . ', so space is necessarily presupposed *before* all matter. Thus, attractive force is attributed to matter because matter occupies a space around itself by attraction, yet 525 without filling the space. So a region of space can be thought of as empty even when matter is active in it, so long as the activeness doesn't involve repelling forces, i.e. doesn't involve the matter's being *in* the space. But no •experience, •inference from experience, or •necessary hypothesis for explaining empty spaces can justify us in assuming that they are actual. Experience presents us only with *comparatively* empty spaces; and these can be perfectly explained in terms of the strength of the expansive force with which a portion of matter fills its space—·the *whole* of its space·—a strength that can be thought of as lesser and lesser to infinity, through all possible degrees, without requiring ·absolutely· empty spaces.