# A Theory of Natural Philosophy

Roger Joseph Boscovich, S.J. (Venice: 1763)
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PART I

IN THE FIRST SIX ARTICLES, I state the time at which I evolved my Theory, what led me to it, & where I have discussed it hitherto in essays already published: also what it has in common with the theories of Leibniz and Newton; in what it differs from either of these, & in what it is really superior to them both. In addition I state what I have published elsewhere about equilibrium & the centre of oscillation; & how, having found out that these matters followed quite easily from a single theorem of the most simple & elegant kind, I proposed to write a short essay thereon; but when I set to work to deduce the matter from this principle, the discussion, quite unexpectedly to me, developed into a whole work of considerable magnitude.

From this until Art. 11, I explain the Theory itself: that matter is unchangeable, and consists of points that are perfectly simple, indivisible, of no extent, & separated from one another; that each of these points has a property of inertia, & in addition a mutual active force depending on the distance in such a way that, if the distance is given, both the magnitude & the direction of this force are given; but if the distance is altered, so also is the force altered; & if the distance is diminished indefinitely, the force is repulsive, & in fact also increases indefinitely; whilst if the distance is increased, the force will be diminished, vanish, be changed to an attractive force that first of all increases, then decreases, vanishes, is again turned into a repulsive force, & so on many times over; until at greater distances it finally becomes an attractive force that decreases approximately in the inverse ratio of the squares of the distances. This connection between the forces & distances, & their passing from positive to negative, or from repulsive to attractive, & conversely, I illustrate by the force with which the two ends of a spring strive to approach towards, or recede from, one another, according as they are pulled apart, or drawn together, by more than the natural amount.

From here on to Art. 16, I show that it is not merely an aggregate of forces combined haphazard, but that it is represented by a single continuous curve, by means of abscissae representing the distances & ordinates representing the forces. I expound the construction & nature of this curve; & I show how it differs from the hyperbola of the third degree which represents Newtonian gravitation. Finally, here too I set forth the scope of the whole work & the nature of the parts into which it is divided.

These statements having been made, I start to expound the whole of the analysis, by which I came upon a Theory of this kind, & from which I believe I have deduced the whole of it by a straightforward & perfectly rigorous chain of reasoning. I contend indeed, from here on until Art. 19, that, in the collision of solid bodies, either there must be compenetration, or the Law of Continuity must be violated by a sudden change of velocity, if the bodies come into immediate contact with unequal velocities. Now since the Law of Continuity must (as I prove that it must) be observed in every case, I infer that, before the bodies reach the point of actual contact, their velocities must be altered by some force which is capable of destroying the velocity, or the difference of the velocities, no matter how great that may be.

From Art. 19 to Art. 28 1 consider the artifice, adopted for the purpose of evading the strength of my argument by those who deny the existence of hard bodies; as a matter of fact this cannot be used as an argument against me by the Newtonians, or the Corpuscularians in general, for they assume that the elementary particles of solids are perfectly hard. Moreover, those who admit that all the particles of solids, however small they may be, are soft or elastic, yet do not escape the difficulty, but transfer it to prime surfaces, or points; & here a sudden change would be made & the Law of Continuity violated. . . .

7. The primary elements of matter are in my opinion perfectly indivisible & non-extended points; they are so scattered in an immense vacuum that every two of them are separated from one another by a definite interval; this interval can be indefinitely increased or diminished, but can never vanish altogether without compenetration of the points themselves; for I do not admit as possible any immediate contact between them. On the contrary I consider that it is a certainty that, if the distance between two points of matter should become absolutely nothing, then the very same indivisible point of space, according to the usual idea of it, must be occupied by both together, & we have true compenetration in every way. Therefore indeed I do not admit the idea of vacuum interspersed amongst matter, but I consider that matter is interspersed in a vacuum & floats in it.

8. As an attribute of these points I admit an inherent propensity to remain in the same state of rest, or of uniform motion in a straight line, (a) in which they are initially set, if each exists by itself in Nature. . . .

9. 1 therefore consider that any two points of matter are subject to a determination to approach one another at some distances, & in an equal degree recede from one another at other distances. This determination I call 'force'; in the first case 'attractive', in the second case 'repulsive'; this term does not denote the mode of action, but the propensity itself, whatever its origin, of which the magnitude changes as the distances change; this is in accordance with a certain definite law, which can be represented by a geometrical curve or by an algebraical formula, & visualized in the manner customary with Mechanicians. We have an example of a force dependent on distance, & varying with varying distance, & pertaining to all distances either great or small, throughout the vastness of space, in the Newtonian idea of general gravitation that changes according to the inverse squares of the distances: this, on account of the law governing it, can never pass from positive to negative; & thus on no occasion does it pass from being attractive to being repulsive, i.e., from a propensity to approach to a propensity to recession. Further, in bent springs we have an illustration of that kind of mutual force that varies according as the distance varies, & passes from a propensity to recession to a propensity to approach, and vice versa. For here, if the

two ends of the spring approach one another on compressing the spring, they acquire a propensity for recession that is the greater, the more the distance diminishes between them as the spring is compressed. But, if the distance between the ends is increased, the force of recession is diminished, until at a certain distance it vanishes and becomes absolutely nothing. Then, if the distance is still further increased, there begins a propensity to approach, which increases more & more as the ends recede further & further away from one another. If now, on the contrary, the distance between the ends is continually diminished, the propensity to approach also diminishes, vanishes, & becomes changed into a propensity to recession. . .

10. Now the law of forces is of this kind; the forces are repulsive at very small distances, & become indefinitely greater & greater, as the distances are diminished indefinitely, in such a manner that they are capable of destroying any velocity, no matter how large it may be, with which one point may approach another, before ever the distance between them vanishes. When the distance between them is increased, they are diminished in such a way that at a certain distance, which is extremely small, the force becomes nothing. Then as the distance is still further increased, the forces are changed to attractive forces; these at first increase, then diminish, vanish, & become repulsive forces, which in the same way first increase, then diminish, vanish, & become once more attractive; & so on, in turn, for a very great number of distances, which are all still very minute: until, finally, when we get to comparatively great distances, they begin to be continually attractive & approximately inversely proportional to the squares of the distances. This holds good as the distances are increased indefinitely to any extent, or at any rate until we get to distances that are far greater than all the distances of the planets and comets [see Fig. 8-1].
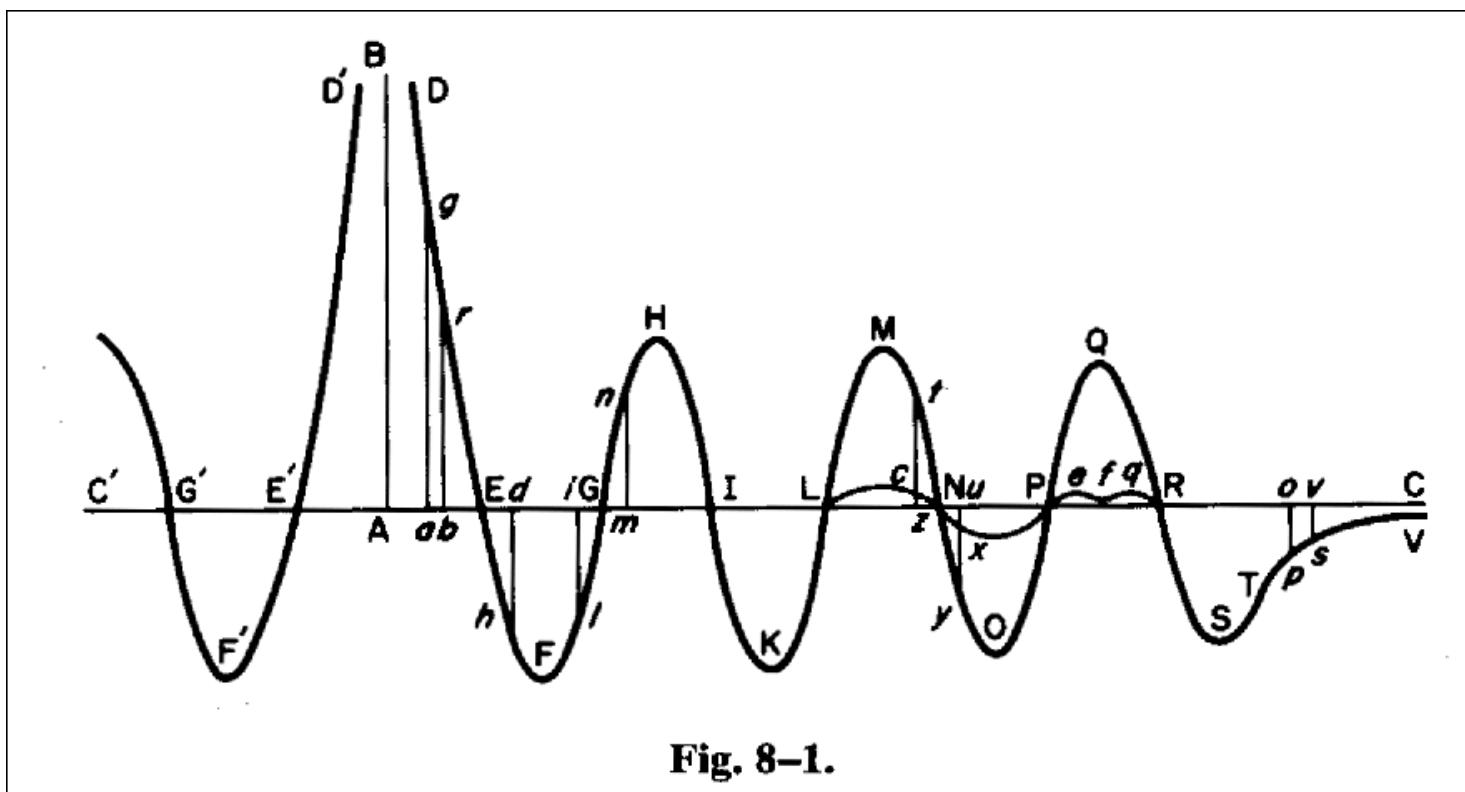


Fig. 8–1.

78. First of all, the gravitation of all bodies towards the Earth, which is an everyday experience, proves sufficiently that the repulsion that we found for very small distances does not extend to all distances; but that at distances that are now great there is a propensity for approach, which we have called an attractive force. Moreover the Keplerian Laws in astronomy, so skilfully employed by Newton to deduce the law of universal gravitation, & applied even to the comets, show perfectly well that gravitation extends, either to infinity or at least to the limits of the system including all the planets & comets, in the inverse ratio of the squares of the distances. Hence the curve will have an arc lying on the opposite side of the axis, which, as far as can be perceived by our senses, approximates to that hyperbola of the third degree, of which the ordinates are in the inverse ratio of the squares of the distances; & this indeed is the arc STV in Fig. 8-1. Now from this it is evident that there is some point E, in which a curve of this kind cuts the axis; and this is a limit-point for attractions and repulsions, at which the passage from one to the other of these forces is made.

79. The phenomenon of vapour arising from water, & that of gas produced from fixed bodies lead us to admit two more of these limit-points, i.e., two other intersections, say, at G & I. Since in these there would be initially no repulsion, nay rather there would be an attraction due to cohesion, by which, when one part is retracted, another generally followed it: & since in the former, repulsion is clearly evidenced by the greatness of the expansion, & by the force of its elasticity; it therefore follows that there is, somewhere or other, a passage from repulsion at very small distances to attraction, then back again to repulsion, & from that back once more to the attractions of universal gravitation. Effervescences & fermentations of many different kinds, in which the particles go & return with as many different velocities, & now approach towards & now recede from one another, certainly indicate many more of these limit-points & transitions. But the existence of these limit-points is perfectly proved by the case of soft substances like wax; for in these substances a large number of compressions are acquired with very different distances, yet in all of these there must be limit-points. For, if the front part is drawn out, the part behind will follow; or if the former is pushed inwards, the latter will recede from it, the distances remaining

approximately unchanged. This, on account of the repulsions existing at very small distances, which prevent contiguity, cannot take place in any way, unless there are limit-points there in all those distances between attractions & repulsions; namely, those that are requisite to account for the fact that one part will follow the other when the latter is drawn out, & will recede in front of the latter when that is pushed in.

80. Therefore there are a large number of limit-points, & a large number of flexures on the curve, first on one side & then on the other side of the axis, in addition to two arcs, one of which, ED, is continued to infinity & is asymptotic, & the other, STV, is asymptotic also, provided that universal gravitation extends to infinity. It approximates to the form of the hyperbola of the third degree mentioned above so closely that the difference from it is imperceptible; but it cannot altogether coincide with it, because, in that case it would never depart from it. For, of two curves of different nature, there cannot be any continuous arcs, no matter how short, that absolutely coincide; they can only cut, or touch, or osculate one another in an indefinitely great number of points, & approximate to one another indefinitely closely. Thus we now have the whole form of the curve of forces, of the nature that I gave at the commencement, derived by a straightforward chain of reasoning from natural phenomena, & sound principles. It only remains for us now to determine the constitution of the primary elements of matter, derived from these forces; & in this manner the whole of the Theory that I enunciated at the start will become quite clear, & it will not appear to be a mere arbitrary hypothesis. We can proceed to remove certain apparent difficulties, & to apply it with great profit to the whole of Physics in general, explaining some things fully &, to prevent the work from growing to an unreasonable size, merely mentioning others.

81. Now, because the repulsive force is indefinitely increased when the distances are indefinitely diminished, it is quite easy to see clearly that no part of matter can be contiguous to any other part; for the repulsive force would at once separate one from the other. Therefore it necessarily follows that the primary elements of matter are perfectly simple, & that they are not composed of any parts contiguous to one another. This is an immediate & necessary deduction from the constitution of the forces, which are repulsive at very small distances & increase indefinitely.

102. There are indeed certain things that relate to the law of forces of which we are altogether ignorant, such as the number & distances of the intersections of the curve with the axis, the shape of the intervening arcs, & other things of that sort; these indeed far surpass human understanding, & He alone, Who founded the universe, had the whole before His eyes. But truly there is no reason on that account, why a thing, whose existence we fully recognize, & many of the properties & results of which are readily understood, should not be accepted; although certainly there do remain many other things pertaining to it that are unknown to us. For instance, nobody would call gold an unknown & mysterious substance, & still less would deny its existence, simply because it is quite probable that many of its properties are unknown to us, to be discovered perhaps in the future, as so many others have been already discovered from time to time, or because it is not visually apparent what is the texture of the particles composing it, or why & in what way Nature adopts that particular composition. Again, as regards action at a distance, we amply guard against this by the same means; for, if this is admitted, then it would be possible for any point to act upon itself, & to be determined as to its direction of action & energy apart from another point, or that God should produce in either point a motion according to some arbitrary law fixed by Him when founding the universe. To my mind indeed it is clear that motions produced by these forces depending on the distances are not a whit more mysterious, involved or difficult of understanding than the production of motion by immediate impulse as it is usually accepted; in which impenetrability determines the motion, & the latter has to be derived just the same either from the nature of solid bodies, or from an arbitrary law of the founder of the universe.

450. Now those things, which are commonly called the Elements, Earth, Water, Air & Fire, are nothing else in my Theory but different solids & fluids, formed of the same homogeneous points differently arranged; & from the admixture of these with others, other still more compound bodies are produced. Indeed Earth consists of particles that are not connected together by any force; & these particles acquire solidity when mixed with other particles, as ashes when mixed with oils; or even by some change in their internal arrangement, such as comes about in vitrification; we will leave the discussion of the manner in which these transformations take place till the end. Water is a liquid fluid devoid of elasticity such as comes within the scope of the senses through a sensible compression; although there is a strong repulsive force exerted between its particles, which is sufficient to sustain the pressure of an external force or of its own weight without sensible diminution of the distances. Air is an elastic fluid, which in all probability consists of particles of very many different sorts; for it is generated from very many totally different fixed bodies, as we shall see when we discuss transformations. For that reason, it contains a very large number of vapours & exhalations, & heterogeneous corpuscles that float in it. Its particles, however, repel one another with a fairly large force; & this repulsive force of the particles lasts for a long while as the distances are diminished, & pertains to a space that bears a very large ratio to the so much smaller distance, to which it can be reduced by compression; & at this distance too the force still increases, the arc of the curve corresponding to it still receding from the axis. But after that, the curve must return very steeply, so that in the neighbourhood of the next limit-point there may yet be had in the space that remains great variations in the arcs & the limit-points. Further such great extension of the repulsive arc is indicated by the great compression induced by the pressure due to a large force; & this, in order that the compression may be proportional to the impressed force, shows, as we pointed out in Art. 352, that there must be repulsive forces inversely proportional to the distances of the particles from one another. Moreover it can pass into & through a fixed & solid body; & the reason of this also I will state when I deal with transformations towards the end. Fire is also a highly elastic fluid, which is agitated by the most vigorous internal motions; it excites fermentations, or even consists of this very fermentation; it emits light. . .

451. The principles of chemical operations are derived from the same source, namely, from the distinctions between particles; some of these being inert with regard to themselves & in combination with certain others, some attract others to themselves, some repel others continuously through a fairly great interval; & the attraction itself with some is greater, & with others is less, until when the distance is sufficiently increased it becomes practically nothing. Further, some of them with respect to others have a very great alternation of forces; & this can vary if the structure is changed slightly, or if the particles are grouped & intermingled with others; in this case there

follows another law of forces for the compound particles, which is different to that which we saw obeyed by the simple particles. If all these things are kept carefully in view, I really think that there can be found in this Theory the general theory for all chemical operations.