PHILOSOPHY OF MIND

Classical and Contemporary Readings

David J. Chalmers

New York Oxford
OXFORD UNIVERSITY PRESS
2002

Oxford University Press

Oxford New York
Auckland Bangkok Buenos Aires Cape Town Chennai
Dar es Salaam Delhi Hong Kong Istanbul Karachi Kolkata
Kuala Lumpur Madrid Melbourne Mexico City Mumbai Nairobi
São Paulo Shanghai Singapore Taipei Tokyo Toronto

and an associated company in Berlin

Published by Oxford University Press, Inc.
198 Madison Avenue, New York, New York, 10016
http://www.oup-usa.org

Library of Congress Cataloging-in-Publication Data

Chalmers, David John, 1966–
Philosophy of mind : classical and contemporary readings / David J. Chalmers.
p. cm.
Includes bibliographical references.
ISBN-13 978-0-19-514581-6
ISBN 0-19-514580-1 (hardback : alk. Paper)—ISBN 0-19-514581-X (pbk : alk.paper)
1. Philosophy of mind. I. Title.

BD418.3 .C435 2002
128'.2—dc21 2002072403

Printing number: 9 8 7 6 5

Printed in the United States of America
on acid-free papers

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Mechanism and Its Alternatives

C. D. Broad

The Ideal of Pure Mechanism

. . . Let us first ask ourselves what would be the ideal of a mechanical view of the material realm. I think, in the first place, that it would suppose that there is only one fundamental kind of stuff out of which every material object is made. Next, it would suppose that this stuff has only one intrinsic quality, over and above its purely spatio-temporal and causal characteristics. The property ascribed to it might, e.g., be inertial mass or electric charge. Thirdly, it would suppose that there is only one fundamental kind of change, viz., change in the relative positions of the particles of this stuff. Lastly, it would suppose that there is one fundamental law according to which one particle of this stuff affects the changes of another particle. It would suppose that this law connects particles by pairs, and that the action of any two aggregates of particles as wholes on each other is compounded in a simple and uniform way from the actions which the constituent particles taken by pairs would have on each other. Thus the essence of Pure Mechanism is (a) a single kind of stuff, all of whose parts are exactly alike except for differences of position and motion; (b) a single fundamental kind of change, viz, change of position. Imposed on this there may of course be changes of a higher order, e.g., changes of velocity, of acceleration, and so on; (c) a single elementary causal law, according to which particles influence each other by pairs; and (d) a single and simple principle of composition, according to which the behaviour of any aggregate of particles, or the influence of any one aggregate on any other, follows in a uniform way from the mutual influences of the constituent particles taken by pairs.

A set of gravitating particles, on the classical theory of gravitation, is an almost perfect example of the ideal of Pure Mechanism. The single elementary law is the inverse-square law for any pair of particles. The single and simple principle of composition is the rule that the influence of any set of particles on a single particle is the vector-sum of the influences that each would exert taken by itself. An electronic theory of matter departs to some extent from this ideal. In the first place, it has to assume at present that there are two ultimately different kinds of particle, viz., protons and electrons. Secondly, the laws of electro-magnetics cannot, so far as we know, be reduced to central forces. Thirdly, gravitational phenomena do not at present fall within the scheme; and so it is necessary to ascribe masses as well as charges to the ultimate particles, and to introduce other elementary forces beside those of electro-magnetics.

On a purely mechanical theory all the apparently different kinds of matter would be made of the same stuff. They would differ only in the number, arrangement and movements of their constituent particles. And their apparently different kinds of behaviour would not be ultimately different. For they would all be deducible by a single simple principle of composition from the mutual influences of the particles taken by pairs; and these mutual influences would all obey a single law which is quite independent of the configurations and surroundings in which the particles happen to find themselves. The ideal which we have been describing and illustrating may be called "Pure Mechanism."

When a biologist calls himself a "Mechanist" it may fairly be doubted whether he means to assert anything so rigid as this. Probably all that he wishes to assert is that a living body is composed only of constituents which do or might occur in non-living bodies, and that its characteristic behaviour is wholly deducible from its structure and components and from the chemi-

Excerpted from C. D. Broad, *The Mind and Its Place in Nature* (Routledge & Kegan Paul, 1925), pp. 43–72, with permission of the publisher.

cal, physical and dynamical laws which these materials would obey if they were isolated or were in non-living combinations. Whether the apparently different kinds of chemical substance are really just so many different configurations of a single kind of particles, and whether the chemical and physical laws are just the compounded results of the action of a number of similar particles obeying a single elementary law and a single principle of composition, he is not compelled as a biologist to decide. I shall later on discuss this milder form of "Mechanism," which is all that is presupposed in the controversies between mechanistic and vitalistic biologists. In the meanwhile I want to consider how far the ideal of Pure Mechanism could possibly be an adequate account of the world as we know it.

Limitations of Pure Mechanism

No one of course pretends that a satisfactory account even of purely physical processes in terms of Pure Mechanism *has* ever been given; but the question for us is: How far, and in what sense, *could* such a theory be adequate to all the known facts? On the face of it external objects have plenty of other characteristics beside mass or electric charge, e.g., colour, temperature, etc. And, on the face of it, many changes take place in the external world beside changes of position, velocity, etc. Now of course many different views have been held about the nature and status of such characteristics as colour; but the one thing which no adequate theory of the external world can do is to ignore them altogether. I will state here very roughly the alternative types of theory, and show that none of them is compatible with Pure Mechanism as a complete account of the facts. . . .

I will now sum up the argument. The plain fact is that the external world, as perceived by us, seems not to have the homogeneity demanded by Pure Mechanism. If it *really* has the various irreducibly different sensible qualities which it *seems* to have, Pure Mechanism cannot be true of the whole of the external world and cannot be the whole truth about any part of it. The best that we can do for Pure Mechanism on this theory is to divide up the external world first on a macroscopic and then on a microscopic scale; to suppose that the macroscopic qualities which pervade any region are causally determined by the microscopic events and objects which exist within it; and to hope that the latter, in their interactions with *each other* at any rate, fulfil the conditions of Pure Mechanism. . . .

If, on the other hand, we deny that physical objects have the various sensible qualities which they seem to us to have, we are still left with the fact that some things *seem* to be red, others to be blue, others to be hot, and so on. And a complete account of the world must include such events as "seeming red to me," "seeming blue to you," etc. We can admit that the ultimate physical objects may all be exactly alike, may all have only one non-spatio-temporal and non-causal property, and may interact with each other in such a way which Pure Mechanism requires. But we must admit that they are also cause-factors in determining the *appearance,* if not the *occurrence,* of the various sensible qualities at such and such places and times. And, in these transactions, the laws which they obey *cannot* be mechanical.

We may put the whole matter in a nutshell by saying that the appearance of a plurality of irreducible sensible qualities forces us, no matter what theory we adopt about their status, to distinguish two different kinds of law. One may be called "intra-physical" and the other "trans-physical." The intra-physical laws may be, though there seems no positive reason to suppose that they are, of the kind required by Pure Mechanism. If so, there is just one ultimate elementary intra-physical law and one ultimate principle of composition for intra-physical transactions. But the trans-physical laws cannot satisfy the demands of Pure Mechanism; and, so far as I can see, there must be at least as many irreducible trans-physical laws as there are irreducible determinable sense-qualities. The nature of the trans-physical laws will of course depend on the view that we take about the status of sensible qualities. It will be somewhat different for each of the three alternative types of theory which I have mentioned, and it will differ according to which form of the third theory we adopt. But it is not necessary for our present purpose to go into further detail on this point.

The Three Possible Ways of Accounting for Characteristic Differences of Behaviour

So far we have confined our attention to pure qualities, such as red, hot, etc. By calling these "pure qualities" I mean that, when we say "This is red," "This is hot," and so on, it is no part of the meaning of our predicate that "this" stands in such and such a relation to something else. It is *logically* possible that this should be red even though "this" were the only thing in the world; though it is probably not *physically* possible. I have argued so far that the fact that external objects seem to have a number of irreducibly different pure qualities makes it certain that Pure Mechanism cannot be an adequate account of the external world. I want now to consider differences of *behaviour* among external objects. These are not differences of pure quality. When I say "This combines with that," "This eats and digests," and so on, I am making statements which would have no meaning if "this" were the only thing in the world. Now there are apparently extremely different kinds of behaviour to be found among external objects. A bit of gold and a bit of silver behave quite differently when put into nitric acid. A cat and an oyster behave quite differently when put near a mouse. Again, all bodies which would be said to be "alive," behave differently in many ways from all bodies which would be said not to be "alive." And, among nonliving bodies, what we call their "chemical behaviour" is very different from what we call their "merely physical behaviour." The question that we have now to discuss is this: "Are the differences between merely physical, chemical, and vital behaviour ultimate and irreducible or not? And are the differences in chemical behaviour between Oxygen and Hydrogen, or the differences in vital behaviour between trees and oysters and cats, ultimate and irreducible or not?" I do not expect to be able to give a conclusive answer to this question, as I do claim to have done to the question about differences of pure quality. But I hope at least to state the possible alternatives clearly, so that people with an adequate knowledge of the relevant empirical facts may know exactly what we want them to discuss, and may not beat the air in the regrettable way in which they too often have done.

We must first notice a difference between vital behaviour, on the one hand, and chemical behaviour, on the other. On the macroscopic scale, i.e., within the limits of what we can perceive with our unaided senses or by the help of optical instruments, *all* matter seems to behave chemically from time to time, though there may be long stretches throughout which a given bit of matter has no chance to exhibit any marked chemical behaviour. But only a comparatively few bits of matter *ever* exhibit vital behaviour. These are always very complex chemically; they are always composed of the same comparatively small selection of chemical elements; and they generally have a characteristic external form and internal structure. All of them after a longer or shorter time cease to show vital behaviour, and soon after this they visibly lose their characteristic external form and internal structure. We do not know how to make a living body out of non-living materials; and we do not know how to make a once living body, which has ceased to behave vitally, live again. But we know that plants, so long as they are alive, do take up inorganic materials from their surroundings and build them up into their own substance; that all living bodies maintain themselves for a time through constant chemical change of material; and that they all have the power of restoring themselves when not too severely injured, and of producing new living bodies like themselves.

Let us now consider what general types of view are possible about the fact that certain things behave in characteristically different ways.

[Special Component Theories]

[These theories] hold that the characteristic behaviour of a certain object or class of objects is in part dependent on the presence of a peculiar component which does not occur in anything that does not behave in this way. . . .

The doctrine which I will call "Substantial Vitalism" is logically a theory of this type about vital behaviour. It assumes that a necessary factor in explaining the characteristic behaviour of living bodies is the presence in them of a peculiar component, often called an "Entelechy," which does not occur in inorganic matter or in bodies which were formerly alive but have now died. I will try to bring out the analogies and differences between this type of theory as applied to vital behaviour and as applied to the behaviour of chemical compounds. (i) It is not supposed that the presence of an entelechy is sufficient to explain vital behaviour; as in chemistry, the structure of the complex is admitted to be also an essential factor. (ii) It is admitted that entelechies cannot be isolated, and that perhaps they cannot exist apart from the complex which is a living organism. But there is plenty of analogy to this in chemistry. In the first place, elements have been recognised, and the characteristic behaviour of certain compounds has been ascribed to their presence, long before they were isolated. Secondly, there are certain groups, like CH_3 and C_6H_5 in organic chemistry, which cannot exist in isolation, but which nevertheless play an essential part in determining the characteristic behaviour of certain compounds. (iii) The entelechy is supposed to exert some kind of directive influence over matter which enters the organism from outside. There is a faint analogy to this in certain parts of organic chemistry. The presence of certain groups in certain positions in a Benzene nucleus makes it very easy to put certain other groups and very hard to put others into certain positions in the nucleus. There are well-known empirical rules on this point.

Why then do most of us feel pretty confident of the truth of the chemical explanation and very doubtful of the formally analogous explanation of vital behaviour in terms of entelechies? I think that our main reasons are the following, and that they are fairly sound ones. (i) It is true that some elements were recognised and used for chemical explanations long before they were isolated. But a great many other elements had been isolated, and it was known that the process presented various degrees of difficulty. No entelechy, or anything like one, has ever been isolated; hence an entelechy is a purely hypothetical entity in a sense in which an as yet unisolated but suspected chemical element is not. If it be said that an isolated entelechy is from the nature of the case something which could not be perceived, and that this objection is therefore unreasonable, I can only answer (as I should to the similar assertion that the physical phenomena of mediumship can happen only in darkness and in the presence of sympathetic spectators) that it may well be true but is certainly very unfortunate. (ii) It is true that some groups which cannot exist in isolation play a most important part in chemical explanations. But they are groups of known composition, not mysterious simple entities; and their inability to exist by themselves is not an isolated fact but is part of the more general, though imperfectly understood, fact of valency. Moreover, we can at least pass these groups from one compound to another, and can note how the chemical properties change as one compound loses such a group and another gains it. There is no known analogy to this with entelechies. You cannot pass an entelechy from a living man into a corpse and note that the former ceases and the latter begins to behave vitally. (iii) Entelechies are supposed to differ in kind from material particles; and it is doubtful whether they are literally in Space at all. It is thus hard to understand what exactly is meant by saying that a living body is a compound of an entelechy and a material structure; and impossible to say anything in detail about the structure of the total complex thus formed.

These objections seem to me to make the doctrine of Substantial Vitalism unsatisfactory, though not impossible. I think that those who have accepted it have done so largely under a misapprehension. They have thought that there was no alternative between Biological Mechanism (which I shall define a little later) and Substantial Vitalism. They found the former unsatisfactory, and so they felt obliged to accept the latter. We shall see in a moment, however, that there is another alternative type of theory, which I will call "Emergent Vitalism," borrowing the adjective from Professors Alexander and Lloyd Morgan. Of course positive arguments have been put forward in favour of entelechies, notably by Driesch. I do not propose to consider them in detail. I will merely say that Driesch's arguments do not seem to me to be in the least conclusive, even against Biological Mechanism, because they seem to forget that the smallest fragment which we can make of an organised body by cutting it up may contain an enormous number of similar microscopic structures, each of enormous complexity. And, even if it be held that Driesch has conclusively disproved Biological Mechanism, I cannot see that his arguments have the least tendency to prove Substantial Vitalism rather than the Emergent form of Vitalism which does not assume entelechies.

Emergent Theories

Put in abstract terms the emergent theory asserts that there are certain wholes, composed (say) of constituents A, B, and C in a relation R to each other; that all wholes composed of constituents of the same kind as A, B, and C in relations of the same kind as R have certain characteristic properties; that A, B, and C are capable of occurring in other kinds of complex where the relation is not of the same kind as R; and that the characteristic properties of the whole R(A, B, C) cannot, even in theory, be deduced from the most complete knowledge of the properties of A, B, and C in isolation or in other wholes which are not of the form R(A, B, C). The mechanistic theory rejects the last clause of this assertion.

Let us now consider the question in detail. If we want to explain the behaviour of any whole in terms of its structure and components we *always* need two independent kinds of information. (*a*) We need to know how the parts would behave separately. And (*b*) we need to know the law or laws according to which the behaviour of the separate parts is compounded when they are acting together in any proportion and arrangement. Now it is extremely important to notice that these two bits of information are quite independent of each other in every case. . . .

We will now pass to the case of chemical composition. Oxygen has certain properties and Hydrogen has certain other properties. They combine to form water, and the proportions in which they do this are fixed. Nothing that we know about Oxygen by itself or in its combinations with anything but Hydrogen would give us the least reason to suppose that it would combine with Hydrogen at all. Nothing that we know about Hydrogen by itself or in its combinations with anything but Oxygen would give us the least reason to expect that it would combine with Oxygen at all. And most of the chemical and physical properties of water have no known connexion, either quantitative or qualitative, with those of Oxygen and Hydrogen. Here we have a clear instance of a case where, so far as we can tell, the properties of a whole composed of two constituents could not have been predicted from a knowledge of the properties of these constituents taken separately, or from this combined with a knowledge of the properties of other wholes which contain these constituents.

Let us sum up the conclusions which may be reached from these examples before going further. It is clear that in no case could the behaviour of a whole composed of certain constituents be predicted *merely* from a knowledge of the properties of these constituents, taken separately, and of their proportions and arrangements in the particular complex under consideration. Whenever this *seems* to be possible it is because we are using a suppressed premise which is so familiar that it has escaped our notice. The suppressed premise is the fact that we have examined other complexes in the past and have noted their behaviour; that we have found a general law connecting the behaviour of these wholes with that which their constituents would show in isolation; and that we are assuming that this law of composition will hold also of the particular complex whole at present under consideration. For purely dynamical transactions this assumption is pretty well justified, because we have found a simple law of composition and have verified it very fully for wholes of very different composition, complexity, and internal structure. It is therefore not particularly rash to expect to predict the dynamical behaviour of any material complex under the action of any set of forces, however much it may differ in the details of its structure and parts from those complexes for which the assumed law of composition has actually been verified.

The example of chemical compounds shows us that we have no right to expect that the same simple law of composition will hold for chemical as for dynamical transactions. And it shows us something further. It shows us that, if we want to know the chemical (and many of the physical) properties of a chemical compound, such as silver-chloride, it is absolutely necessary to study samples of *that particular compound*. It would of course (on any view) be useless merely to study silver in isolation and chlorine in isolation; for that would tell us nothing about the law of their conjoint action. This would be equally true even if a mechanistic explanation of the chemical behaviour of compounds were possible. The essential point is that it would also be useless to study chemical compounds in general and to compare their properties with those of their elements in the hope of discovering a *general* law of composition by which the properties of any chemical compound could be foretold when the properties of its separate elements were known. So far as we know, there is no general law of this kind. It is useless even to study the properties of other compounds of silver and of other compounds of chlorine in the hope of discovering one general law by which the properties of silver-compounds could be predicted from those of elementary silver and another general law by which the properties of chlorine-compounds could be predicted from those of elementary chlorine. No doubt the properties of silver-chloride are completely *determined* by those of silver and of chlorine; in the sense that whenever you have a whole composed of these two elements in certain proportions and relations you have something with the characteristic properties of silver-chloride, and that nothing has these properties except a whole composed in this way. But the law connecting the properties of silver-chloride with those of silver and of chlorine and with the structure of the compound is, so far as we know, a *unique* and *ultimate* law. By this I mean (*a*) that it is not a special case which arises through substituting certain determinate values for determinable variables in a general law which connects the properties of *any* chemical compound with those of its separate elements and with its structure. And (b) that it is not a special case which arises by combining two more general laws, one of which connects the properties of *any* silver-compound with those of elementary silver, whilst the other connects the properties of *any* chlorine-compound with those of elementary chlorine. So far as we know there are no such laws. It is (c) a law which could have been discovered only by studying samples of silver-chloride itself, and which can be extended inductively *only* to other samples of the same substance.

We may contrast this state of affairs with that which exists where a mechanistic explanation is possible. In order to predict the behaviour of a clock a man need never have seen a clock in his life. Provided he is told how it is constructed, and that he has learnt from the study of *other* material systems the general rules about motion and about the mechanical properties of springs and of rigid bodies, he can foretell exactly how a system constructed like a clock must behave.

The situation with which we are faced in chemistry, which seems to offer the most plausible example of emergent behaviour, may be described in two alternative ways. These may be theoretically different, but in practice they are equivalent. (i) The first way of putting the case is the following. What we call the "properties" of the chemical elements are very largely propositions about the compounds which they form with other elements under suitable conditions E.g., one of the "properties" of silver is that it combines under certain conditions with chlorine to give a compound with the properties of silver-chloride. Likewise one of the "properties" of chlorine is that under certain conditions it combines with silver to give a compound with the properties of silver-chloride. These "properties" cannot be deduced from any selection of the other properties of silver or of chlorine. Thus we may say that we do not know all the properties of chlorine and of silver until they have been put in presence of each other; and that no amount of knowledge about the properties which they manifest in other circumstances will tell us what property, if any, they will manifest in these circumstances. Put in this way the position is that we do not know all the properties of any element, and that there is always the possibility of their manifesting unpredictable properties when put into new situations. This happens whenever a chemical compound is prepared or discovered for the first time. (ii) The other way to put the matter is to confine the name "property" to those characteristics which the elements manifest when they do not act chemically on each other, i.e., the physical characteristics of the isolated elements. In this case we may indeed say, if we like, that we know all the properties of each element; but we shall have to admit that we do not know the laws according to which elements, which have these properties in isolation, together produce compounds having such and such other characteristic properties. The essential point is that the behaviour of an as yet unexamined compound cannot be predicted from a knowledge of the properties of its elements in isolation or from a knowledge of the properties of their other compounds; and it matters little whether we ascribe this to the existence of innumerable "latent" properties in each element, each of which is manifested only in the presence of a certain other element; or to the lack of any general principle of composition, such as the parallelogram law in dynamics, by which the behaviour of any chemical compound could be deduced from its structure and from the behaviour of each of its elements in isolation from the rest.

Let us now apply the conceptions, which I have been explaining and illustrating from chemistry, to the case of vital behaviour. We know that the bits of matter which behave vitally are composed of various chemical compounds arranged in certain characteristic ways. We have prepared and experimented with many of these compounds apart from living bodies, and we see no obvious reason why some day they might not all be synthesised and studied in the chemical laboratory. A living body might be regarded as a compound of the second order, i.e., a compound composed of compounds; just as silver-chloride is a compound of the first order, i.e., one composed of chemical elements. Now it is obviously possible that, just as the characteristic behaviour of a first-order compound could not be predicted from any amount of knowledge of the properties of its elements in isolation or of the properties of other first-order compounds, so the properties of a second-order compound could not be predicted from any amount of knowledge about the properties of its first-order constituents taken separately or in other surroundings. Just as the only way to find out the properties of silver-chloride is to study samples of silver-chloride, and no amount of study of silver and of chlorine taken separately or in other combinations will help us; so the only way to find out the characteristic behaviour of living bodies may be to study living bodies as such. And no amount of knowledge about how the constituents of a living body behave in isolation or in other and non-living wholes might suffice to enable us to predict the characteristic behaviour of a living organism. This possibility is perfectly compatible with the view that the characteristic behaviour of a living body is completely determined by the nature and arrangement of the chemical compounds which compose it, in the sense that any whole which is composed of such compounds in such an arrangement will show vital-behaviour and that nothing else will do so. We should merely have to recognise, as we had to do in considering a first-order compound like silver-chloride, that we are dealing with an *unique* and *irreducible* law; and not with a special case which arises by the substitution of particular values for variables in a more general law, nor with a combination of several more general laws.

We could state this possibility about living organisms in two alternative but practically equivalent ways, just as we stated the similar possibility about chemical compounds. (i) The first way would be this. Most of the properties which we ascribe to chemical compounds are statements about what they do in presence of various chemical reagents under certain conditions of temperature, pressure, etc. These various properties are not deducible from each other; and, until we have tried a compound with every other compound and under every possible condition of temperature, pressure, etc., we cannot possibly know that we have exhausted all its properties. It is therefore perfectly possible that, in the very special situation in which a chemical compound is placed in a living body, it may exhibit properties which remain "latent" under all other conditions. (ii) The other, and practically equivalent, way of putting the case is the following. If we confine the name "property" to the behaviour which a chemical compound shows in isolation, we may perhaps say that we know all the "properties" of the chemical constituents of a living body. But we shall not be able to predict the behaviour of the body unless we also know the laws according to which the behaviour which each of these constituents *would have* shown in isolation is compounded when they are acting together in certain proportions and arrangements. We can discover such laws only by studying complexes containing these constituents in various proportions and arrangements. And we have no right to suppose that the laws which we have discovered by studying non-living complexes can be carried over without modification to the very different case of living complexes. It may be that the only way to discover the laws according to which the behaviour of the separate constituents combines to produce the behaviour of the whole in a living body is to study living bodies as such. For practical purposes it makes little difference whether we say that the chemical compounds which compose a living body have "latent properties" which are manifested only when they are parts of a whole of this peculiar structure; or whether we say that the properties of the constituents of a living body are the same whether they are in it or out of it, but that the law according to which these separate effects are compounded with each other is different in a living whole from what it is in any nonliving whole.

This view about living bodies and vital behaviour is what I call "Emergent Vitalism"; and it is important to notice that it is quite different from what I call "Substantial Vitalism." So far as I can understand them I should say that Driesch is a Substantial Vitalist, and that Dr J. S. Haldane is an Emergent Vitalist. But I may quite well be wrong in classifying these two distinguished men in this way.

Mechanistic Theories

The mechanistic type of theory is much more familiar than the emergent type, and it will therefore be needless to consider it in great detail. I will just consider the mechanistic alternative about chemical and vital behaviour, so as to make the emergent theory still clearer by contrast. Suppose it were certain, as it is very probable, that all the different chemical atoms are composed of positive and negative electrified particles in different numbers and arrangements; and that these differences of number and arrangement are the only ultimate difference between them. Suppose that all these particles obey the same elementary laws, and that their separate actions are compounded with each other according to a single law which is the same no matter how complicated may be the whole of which they are constituents. Then it would be theoretically possible to deduce the characteristic behaviour of any element from an adequate knowledge of the number and arrangement of the particles in its atom, without needing to observe a sample of the substance. We could, *in theory*, deduce what other elements it would combine with and in what proportions; which of these compounds would be stable to heat, etc.; and how the various compounds would react in presence of each other under given conditions of temperature, pressure, etc. And all this should be *theoretically* possible without needing to observe samples of these compounds.

I want now to explain exactly what I mean by the qualification "theoretically." (1) In the first place the mathematical difficulties might be overwhelming in practice, even if we knew the structure and the laws. This is a trivial qualification for our present purpose, which is to bring out the *logical* distinction between mechanism and emergence. Let us replace Sir Ernest Rutherford by a mathematical archangel, and pass on. (2) Secondly, we cannot directly perceive the microscopic structure of atoms, but can only infer it from the macroscopic behaviour of matter in bulk. Thus, in practice, even if the mechanistic hypothesis were true and the mathematical difficulties were overcome, we should have to start by observing enough of the macroscopic behaviour of samples of each element to infer the probable structure of its atom. But, once this was done, it should be possible to deduce its behaviour in macroscopic conditions under which it has never yet been observed. That is, if we could infer its microscopic structure from a selection of its observed macroscopic properties, we could henceforth *deduce* all its other macroscopic properties from its microscopic structure without further appeal to observation. The difference from the emergent theory is thus profound, even when we allow for our mathematical and perceptual limitations. If the emergent theory of chemical compounds be true, a mathematical archangel, gifted with the further power of perceiving the microscopic structure of atoms as easily as we can perceive hay-stacks, could no more predict the behaviour of silver or of chlorine or the properties of silver-chloride without having observed samples of those substances than we can at present. And he could no more deduce the rest of the properties of a chemical element or compound from a selection of its properties than we can.

Would there be any theoretical limit to the deduction of the properties of chemical elements and compounds if a mechanistic theory of chemistry were true? Yes. Take any ordinary statement, such as we find in chemistry books; e.g., "Nitrogen and Hydrogen combine when an electric discharge is passed through a mixture of the two. The resulting compound contains three atoms of Hydrogen to one of Nitrogen; it is a gas readily soluble in water, and possessed of a pungent and characteristic smell." If the mechanistic theory be true the archangel could deduce from his knowledge of the microscopic structure of atoms all these facts but the last. He would know exactly what the microscopic structure of ammonia must be; but he would be totally unable to predict that a substance with this structure must smell as ammonia does when it gets into the human nose. The utmost that he could predict on this subject would be that certain changes would take place in the mucous membrane, the olfactory nerves and so on. But he could not possibly know that these changes would be accompanied by the appearance of a smell in general or of the peculiar smell of ammonia in particular, unless someone told him so or he had smelled it for himself. If the existence of the so-called "secondary qualities," or the fact of their appearance, depends on the microscopic movements and arrangements of material particles which do not have these qualities themselves, then the laws of this dependence are certainly of the emergent type.

The mechanistic theory about vital behaviour should now need little explanation. A man can hold it without being a mechanist about chemistry. The minimum that a Biological Mechanist need believe is that, in theory, everything that is characteristic of the behaviour of a living body could be deduced from an adequate knowledge of its structure, the chemical compounds which make it up, and the properties which these show in isolation or in non-living wholes.

Logical Status of Emergence and Mechanism

I have now stated the two alternatives which alone seem worthy of serious consideration. It is not my business as a philosopher to consider detailed empirical arguments for or against mechanism or emergence in chemistry or in biology. But it is my business to consider the logical status of the two types of theory, and it is relevant to our present purpose to discuss how far the possibility of science is bound up with the acceptance of the mechanistic alternative.

(1) I do not see any a prior impossibility in a mechanistic biology or chemistry, so long as it confines itself to that kind of behaviour which can be completely described in terms of changes of position, size, shape, arrangement of parts, etc. I have already argued that this type of theory cannot be the whole truth about all aspects of the material world. For one aspect of it is that bits of matter have or seem to have various colours, temperatures, smells, tastes, etc. If the occurrence or the appearance of these "secondary qualities" depends on microscopic particles and events, the laws connecting the latter with the former are certainly of the emergent type. And no complete account of the external world can ignore these laws.

(2) On the other hand, I cannot see the least trace of self-evidence in theories of the mechanistic type, or in the theory of Pure Mechanism which is the ideal towards which they strive. I know no reason whatever why new and theoretically unpredictable modes of behaviour should not appear at certain levels of complexity, or why they must be explicable in terms of elementary properties and laws of composition which have manifested themselves in less complex wholes. . . .

Let us now sum up the theoretical differences which the alternatives of Mechanism and Emergence would make to our view of the external world and of the relations between the various sciences. The advantage of Mechanism would be that it introduces a unity and tidiness into the world which appeals very strongly to our aesthetic interests. On that view, when pushed to its extreme limits, there is one and only one kind of material. Each particle of this obeys one elementary law of behaviour, and continues to do so no matter how complex may be the collection of particles of which it is a constituent. There is one uniform law of composition, connecting the behaviour of groups of these particles as wholes with the behaviour which each would show in isolation and with the structure of the group. All the apparently different kinds of stuff are just differently arranged groups of different numbers of the one kind of elementary particle; and all the apparently peculiar laws of behaviour are simply special cases which could be deduced in theory from the structure of the whole under consideration, the one elementary law of behaviour for isolated particles, and the one universal law of composition. On such a view the external world has the greatest amount of unity which is conceivable. There is really only one science, and the various "special sciences" are just particular cases of it. This is a magnificent ideal; it is certainly much more nearly true than anyone could possibly have suspected at first sight; and investigations pursued under its guidance have certainly enabled us to discover many connexions within the external world which would otherwise have escaped our notice. But it has no trace of self-evidence; it cannot be the *whole* truth about the external world, since it cannot deal with the existence or the appearance of "secondary qualities" until it is supplemented by laws of the emergent type which assert that under such and such conditions such and such groups of elementary particles moving in certain ways have, or seem to human beings to have, such and such secondary qualities; and it is certain that considerable scientific progress can be made without assuming it to be true. As a practical postulate it has its good and its bad side. On the one hand, it makes us try our hardest to explain the characteristic behaviour of the more complex in terms of the laws which we have already recognized in the less complex. If our efforts succeed, this is sheer gain. And, even if they fail, we shall probably have learned a great deal about the minute details of the facts under investigation which we might not have troubled to look for otherwise. On the other hand, it tends to over-simplification. If in fact there are new types of law at certain levels, it is very desirable that we should honestly recognise the fact. And, if we take the mechanistic ideal too seriously, we shall be in danger of ignoring or perverting awkward facts of this kind. This sort of over-simplification has certainly happened in the past in biology and physiology under the guidance of the mechanistic ideal; and it of course reaches its wildest absurdities in the attempts which have been made from time to time to treat mental phenomena mechanistically.

On the emergent theory we have to reconcile ourselves to much less unity in the external world and a much less intimate connexion between the various sciences. At best the external world and the various sciences that deal with it will form a kind of hierarchy. We might, if we liked, keep the view that there is only one fundamental kind of stuff. But we should have to recognise aggregates of various orders. And there would be two fundamentally different types of law, which might be called "intra-ordinal" and "trans-ordinal" respectively. A trans-ordinal law would be one which connects the properties of aggregates of adjacent orders. A and B would be adjacent, and in ascending order, if every aggregate of order B is composed of aggregates of order A, and if it has certain properties which no aggregate of order A possesses and which cannot be deduced from the A-properties and the structure of the B-complex by any law of composition which has manifested itself at lower levels. An intra-ordinal law would be one which connects the properties of aggregates of the same order. A trans-ordinal law would be a statement of the irreducible fact that an aggregate composed of aggregates of the next lower order in such and such proportions and arrangements has such and such characteristic and non-deducible properties. . . .

There is nothing, so far as I can see, mysterious or unscientific about a trans-ordinal law or about the notion of ultimate characteristics of a given order. A trans-ordinal law is as good a law as any other; and, once it has been discovered, it can be used like any other to suggest experiments, to make predictions, and to give us practical control over external objects. The only peculiarity of it is that we must wait till we meet with an actual instance of an object of the higher order before we can discover such a law; and that we cannot possibly deduce it beforehand from any combination of laws which we have discovered by observing aggregates of a lower order. There is an obvious analogy between the trans-ordinal laws which I am now discussing and the trans-physical laws which I mentioned in considering Pure Mechanism and said must be recognised in any complete account of the external world. The difference is this. Trans-physical laws, in the sense in which we are using the term, are *necessarily* of the emergent type. For they connect the configurations and internal motions of groups of microscopic particles, on the one hand, with the fact that the volume which contains the group is, or appears to be, pervaded by such and such a secondary quality. Since there are many irreducibly different *kinds* of secondary quality, e.g. colour, smell, temperature, etc., there must be many irreducible laws of this sort. Again, suppose we confine our attention to one *kind* of secondary quality, say colour. The concepts of the various colours—red, blue, green, etc.—are not contained in the general concept of Colour in the sense in which we might quite fairly say that the concepts of all possible motions are contained in the general concepts of Space and of Motion. We have no difficulty in conceiving and adequately describing determinate possible motions which we have never witnessed and which we never shall witness. We have merely to assign a determinate direction and a determinate velocity. But we could not possibly have formed the concept of such a colour as blue or such a shade as sky-blue unless we had perceived instances of it, no matter how much we had reflected on the concept of Colour in general or on the instances of other colours and shades which we *had* seen. It follows that, even when we know that a certain kind of secondary quality (e.g., colour) pervades or seems to pervade a region when and only when such and such a kind of microscopic event (e.g., vibrations) is going on within the region, we still could not possibly predict that such and such a determinate event of the kind (e.g., a circular movement of a certain period) would be connected with such and such a determinate shade of colour (e.g., sky-blue). The trans-physical laws are then necessarily of the emergent type. . . .