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Real Dispositions in the Physical World

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ABSTRACT

The role of dispositions in the physical world is considered. It is shown that not only can classical physics be reasonably construed as the discovery of real dispositions, but also quantum physics. This approach moreover allows a realistic understanding of quantum processes.

I INTRODUCTION

It is a common belief that modern science does away with those obscure notions of 'disposition' and 'potentiality', in favour of an analysis of the component structure of the things concerned, and their functional relationships. Science, it is often said, cannot long accept an explanation of an object breaking in terms of just its 'fragility', or of a plant seeking light in terms of just its 'phototropism'. Dispositions, so popular opinion has it, are regarded by the scientist as merely a sign that he has to work harder, to find the underlying structural forms and their relations. Talk of 'dispositions', 'powers', and 'capacities' is somehow not seen as sufficiently *definite* for a hard-nosed scientific explanation. There seems to be something intrinsically unsatisfactory and vague about a property that *may or may not* operate, and in particular it seems uncertain how to describe them rigorously and mathematically.

Suppose we do follow the above proposal, and analyse observed dispositions in terms of constituents. Presumably the parts are to have the *abilility to interact*. But this means at the microscopic level of explanation we again have to accept some kinds of dispositional properties: of the parts this time. This is because 'to be able' signals a dispositional property. Thus I will argue (somewhat controversially) that in fact dispositional properties, though perhaps explained, are never explained away. However much we may dislike them, they are never found to be illusory, and cannot be completely replaced by talk of functional relationships, differential equations, and probability calculus.

At the microscopic level we *might* hope that the constituents have *many* definite properties (e.g. mass, shape, position, velocity, energy etc.), and only a *few* of those peculiar dispositional properties (e.g. perfect elasticity, gravitational attraction, and electric charge). In that way there might be a minimum number of these inexplicable 'occult powers'. Such would be the case if Newtonian physics were true, as seen in section 4.

Quantum phenomena show, however, that this hope is not satisfied. Section 5 will describe how in quantum physics there are *more* kinds of dispositions than in Newtonian physics. For the properties of position and velocity, previously thought quite definite, now behave like dispositional properties that may or may not have definite values. I will be describing the 'propensity interpretation' of quantum physics, and it will be seen that in the quantum world there are very few *non*-dispositional properties, i.e. very few properties that always have perfectly definite values. In particular, it will turn out that there is no such thing as a definite corpuscle: following Maxwell [1985], this concept is replaced by that of a 'packet of propensity' or 'propensiton'. Indeed, relativistic quantum field theory goes on to describe how even the *existence* of such an ultimate constituent is itself a probabilistic notion.

2 GENERAL ANALYSIS OF DISPOSITIONS

I will be using the terms 'power', 'potential', 'capability', 'capacity', 'propensity' and 'cause' as examples within the category of 'dispositional properties of objects'. The ascription of properties in this category is typically, adapting a definition of Harre and Madden [1975, 1970], of the form

> 'Object S has the dispositional power P to do action A'
> if and only if
> 'if S is in some circumstance C, C depending on P and A, then there will be a non-zero likelihood of S doing A, in virtue of the constitution of S'.

Here, the 'circumstance C' is usually defined by multiple spatial relations to other objects, and the 'action A' can either be a change in S itself or an interaction with other objects. Harre and Madden [1975] designed the phrase 'in virtue of the constitution of S' to exclude 'changes' to certain properties of S that are changes in purely external relations that may come about completely independently of whatever S is actually like. Thus, for example, no disposition of Socrates is necessary to explain his becoming smaller than Theaetetus, if it is the latter who is growing.

Note that we are not with these ascriptions assuming a permanent 'nature' of the object from which all its powers can be always deduced, only that at any given time there is 'something about the object', a 'real internal constitution' (to use Locke's phrase) that explains all the dispositions it in fact has at that time.

A distinction[1] is thus made between the 'Principal Cause' (that disposition which operates), and the 'Instrumental Cause' (that circumstance by means of which dispositions operate). Principal causes operate according to instrumental causes. Both are necessary for any action, for example, when a stone is let fall: the principal cause is the earth's gravitational attraction, and the instrumental cause is our action of letting go. Its hitting the ground is thus caused by our letting go, but only as an instrumental cause. Many common uses of 'cause' refer to instrumental causes rather than principal causes, as it is only in the instrumental sense that *events* can be said to be causes.

The next point to note is that dispositional properties can only be explained or reduced to other dispositions, *not* to entirely static or structural properties. That is, dispositions have a 'categorical irreducibility', as it is impossible to explain them away in terms of other categories such as space, time, form, process, material, property etc. For suppose that the exact shape and size of an object were known, the shapes and sizes of all its constituents, along with a list of these facts at every time. We would still know nothing about *how* or *why* the object would change with time or on interactions. Still less could we predict how it would respond to a new experimental test. In fact, if it and its parts had no dispositional properties, as Hume would argue, then we have his conclusion that any actions or changes (apart perhaps from uniform motion) would be entirely inexplicable: there would be nothing about the object that could lead to these changes rather than to any others. This categorical irreducibility was seen clearly by Aristotle and Leibniz, as discussed by Leclerc [1972], and has been explained at some length recently by Weissmann [1965], Mellor [1974], Harre & Madden [1970, 1975], and Emmet [1984], among others (see Tuomela [1978]). According to Shoemaker [1979], the continued identity of objects also depends on their causal properties.

An opposing view has recently been argued by Prior [1985], who claims that a disposition must ultimately be reducible to a non-dispositional *basis*. She claims for example that, since the laws of physics are contingent, we can imagine possible worlds where, say, a body with inertial mass would not experience finite acceleration under any applied force (i.e. it would not satisfy the usual subjunctive for inertial mass). This would appear to indicate that inertial mass could not be identified with the dispositional property of being such that the subjunctive is always true, but must instead have (or be) a non-dispositional basis. In this latter account, inertial mass is whichever property is

[1] However, this distinction does *not* simply match Aristotle's distinction of material, efficient, formal and final causes.

responsible (in just this world, *or* in all worlds) for being such that the subjunctive conditional holds.

The difficulty with this argument is that I cannot see how, in *any* possible world, a purely non-dispositional basis can ever be *responsible* for a dispositional property, in the sense of *implying* the disposition. The (very weak) sense of 'responsibility' she has invoked is practically 'by stipulation', this being apparently the nature of physical contingency. That is, physical law 'just says' that a certain static property called inertial mass is (somehow) 'responsible' for a certain subjunctive condition. This, however, appears to make physical law essentially arbitrary, and makes realistic interpretations difficult. I believe that a more satisfactory account of physical contingency is given by Maxwell's [1968, 1985] 'conjectural essentialism' (see also Harre & Madden [1975]). In this account, dispositional properties such as inertial mass necessarily have their associated conditional property, but it is a completely contingent and empirical question whether any given body (or any body at all) has that kind of inertial mass. Maxwell's account (by having bases that are intrinsically dispositional themselves) gives fundamental bases a much stronger sense of 'responsibility' for observed dispositions. It is precisely because there are such weak connections between purely static and dispositional properties that Prior's purely non-dispositional bases are unsatisfactory, as dispositions cannot be properly explained by static properties. Inertial mass, for example; must be either implied by or identical with a subset of the basic and fundamental *dispositional* properties.

3 ARE DISPOSITIONS REAL?

There seems no way to avoid *some* kind of irreducibly dispositional properties of physical objects unless we find force in one or more of the following objections: (a) that one should deny the subjunctive in the power ascription as anything more than hypothetical, (b) science should be content with finding only the regularity of effects, and not try to discover causes and determining constitutions, or (c) the world should be considered as a 'Zeno universe' that has only successive states and no proper changes.

Taking approach (a), Ryle [1949] denies that dispositional ascriptions 'assert extra matters of fact' and claims that they are *only* 'inference-tickets, which licence us to predict, retrodict, etc.'. That is, he would omit the 'in virtue of the constitution of S' phrase in section 2. Since then, there is no property of S which makes the ascription true, that truth cannot be explained by properties of S. Thus Ryle (quite explicitly) denies that one should even look for either causal or mechanistic explanations of the dispositions. Even, presumably, in cases in physics and chemistry where there are quite obviously explanations in terms of constituents and their propensities to attract and repel each other. His restriction on looking for explanations in terms of internal dynamics is largely disregarded in scientific practice.

Concerning injunction (b), I accept that all observations are of effects rather than of causes, but that does not mean we cannot conceive of causes and of the way they might lead to effects. It seems to me quite legitimate for causes to be postulated in a Popperian fashion, and the consequences deduced for the production of effects. The reverse *in*duction is quite different: obviously we cannot deduce precise causes from observable effects (as Hume has long pointed out), but that does not mean that there no causes. It should not be necessary to accept Hume's [1739] conclusion that 'the distinction, which we often make between a power and the exercise of it, is without foundation'.

To consider (c) the world as a 'block universe' or 'Zeno universe', as recently pointed out by Emmet [1984], is to see only different states of affairs at successive times, and not to see the changes that lead to these differences. Since the rise of Einsteinian relativity, it has become popular to see all of time and space in one 'block continuum' of four dimensions, and to see change as only the difference between successive 'time slices' of this continuum. In this world there is only what actually happens, and as in (a) above, what 'might have happened' is purely hypothetical. The only sense of 'might happen' that can be invoked is to imagine an entirely new possible world, e.g. one with different initial conditions or different physical laws. This world view thus does not base power ascriptions on any real features of this particular universe.

If we reject the 'block universe', we are also rejecting the account of time in which the future is 'already formed' and perfectly definite in advance of its happening, if indeed on this account anything happens at all. (In extreme versions of this theory, time and real change are both completely illusory.) I admit that these accounts have an internal consistency that makes them difficult to refute, but despite their being advocated by many philosophers and physicists, I do not believe that they should be the only coherent metaphysical systems on offer. I believe that alternatives can be devised that not only have more explanatory power (e.g. for quantum physics, see section 5), but also more practical use (see below, end of this section). Once these alternatives have been formulated, we should be able to decide in which way our world is more adequately described.

Rejecting the objection (c), however, does *not* mean rejecting all talk of the spacetime continuum. One alternative approach (following Maxwell [1968, 1985 sections 5 & 6]) says that it is facts about objects, rather than objects themselves, that are (or can construed to be) spread out in time. Spatial relations are between objects, but temporal relations are between facts about objects. Another view follows Whitehead in regarding the spacetime continuum as giving the ordering of possible events (even before they are actual).

Reitdijk [1966, 1973] and Maxwell [1985 sections 1–4] have claimed that special relativity is *in*compatible with the real actualisation of dispositions, as a global account cannot be given of which dispositions are actual and which are not, at any single (metric) time. But that there is no 'global metric time' does *not* mean that we cannot conceive of a 'process time' that counts actualising changes where ever they may be occurring.[2]

It does in any case seem very odd to deny that objects have dispositional properties that relate what might happen as well as what actually happens. To deny causes apart from their manifestations, Mellor [1974 p173] shows, leds to some bizarre consequences, for then dispositions could not be ascribed when their displays are impossible. Taking precautions to avoid the conditions in which nuclear fuel would explode, to use his example, should not mean that the fuel was not explosive. 'It is ridiculous to say that their success robs the fuel of its explosive disposition and thus the precautions of their point.'

Furthermore, a theory that only predicted what actually happens, and not what might happen, would be useless as an engineering planning tool. For it would not be able to predict the consequences of a plan that we might consider employing, but in the end did not actually use. Such a theory could not tell us, for example, what would have happened if one of the *unsuccessful* channel-tunnel designs had been chosen. These questions are of great practical (and political) importance, and real physical theories are of course most useful here.

4 DISPOSITIONS IN CLASSICAL PHYSICS

In this section, we show first that dispositions (of kinds to be determined) have an essential role in physics, and secondly that mathematical physics is an attempt to relate forms and dispositions in a regular manner. Physics need not be concerned with the ultimate nature of dispositions, but only with knowing that they *do* exist, and then with investigating their properties, locations, interactions, effects, changes with time, etc. in as much detail as possible. We will see that dispositions are important in almost all kinds of Newtonian physics.

Dispositions first appear in physics as the macroscopic features of observable objects that we wish to explain. Dispositional properties are largely those which cannot be explained purely by the location and shape of these objects, but require *causal* kinds of ascriptions and analyses, as explained in section 2, in terms of causal powers. Thus, if we wanted, one way to deny causal powers would be to deny the reality of *all* dispositional properties, as discussed in the previous section, by denying the reality of the subjunctive in the power ascription. On this account, what *might* happen to objects is completely irrelevant to what *really* happens. If a glass is never going to be hit, for example,

[2] For the concept of 'process time' as a 'universal passage of nature' see for example Capek [1961], pp. 205 *et seq.* What has to be done now is to understand how process time is an 'extensive becoming' (Capek [1961], p. 220). This 'extension' is necessary to explain the 'reduction of the wavepacket' in relativistic space, and is the subject of further investigation.

it is purely hypothetical whether it is ever able to break. In physics, as in politics, hypothetical questions need not be answered. They need not be, but they usually are: we would hardly be satisfied with a physical theory, however true, that only holds for laboratory test cases. And if they are answered, on the basis of which real properties are the answers correct, if not dispositional properties?

Another way in which the reality of causes could perhaps be denied is to say that physics is *only* the discovery of laws that relate events, not the explanation of the properties of things that lead to these events: that is, that physics is (or should be) only concerned with effects, not with causes. It is agreed that all observations are effects of interactions, but it does seem an unnecessarily severe restriction not to permit physicists to speculate on the causal properties of what they are examining, nor to permit them to postulate, for example, potential energy apart from kinetic energy. Without potential energy, as in a coiled spring, we could not even have the conservation of energy.

A mathematical physicist might argue that what is objective and essential about a physical theory is a certain differential equation and its family of solutions in phase space. I agree that it would be a significant scientific achievement to have devised such an equation that correctly predicts events and movements etc. But if we are not satisfied with a purely instrumentalist account of scientific theories, we can still ask 'what is it about the physical world that makes this theory a correct description?'. Why does the differential equation correctly predict the world? Perhaps because it describes correctly the time evolution of dispositions such as forces, potentials, or quantum wave functions, in which case it can be construed as a good description of these real dispositions. Perhaps, however, it cannot be simply interpreted in this way, yet still gives good predictions of what actually happens. I would then ask whether the equation can also describe what particular objects or particles *might do* if put in new situations. If it cannot, then it clearly falls short of the tasks physicists set themselves, and it would be useless for planning in engineering. If it does answer hypothetical questions, I ask: which properties of the objects involved determine the parameters of the equation? How, for example, is the equation set up with the correct strengths of couplings to the gravitational, electromagnetic and/or nuclear fields? I claim that it is precisely these dispositional properties of the objects that are needed to set up hypothetical test cases, with purely structural properties being inadequate. That is, it would appear that any mathematical description can answer all hypothetical questions correctly *only* if it has embedded within it (explicitly or implicitly) a description of causes and their operations. The equation, for example, would have different structures if vector influences combined in different ways (e.g. by vector sum, or by largest effect dominating, or by random selection of effects from different sources).

A fourth kind of physical theory that appears to avoid real dispositions is

Einstein's general theory of relativity, and its modern variant, geometrodynamics. Both of these theories are usually interpreted in terms of a 'block universe' with time as if spatially extended, as they reduce all dynamics to the geometric properties of spacetime. As however both theories can and have been used to answer hypothetical questions (e.g. what would happen to the solar system should the sun suddenly become deformed), they can both be reformulated as sets of rules for deriving the state of the universe (along some spacelike hypersurface) at some time t′, given its state at some earlier time $t < t'$. In a realistic interpretation of this time-dependent formulation, it turns out that dispositions (or something very similar) reappear. For now general relativity describes how the mass-energy tensor causes spacetime curvature, and the curvature itself in turn describes how objects *would* move in spacetime *if* they were present. That is, matter can be regarded as influencing the dispositions of objects to move in straight or curved paths.

Geometrodynamics (assuming the theory can be worked out in adequate detail) has a similar 'thick sandwich' time-dependent interpretation, but is different from general relativity in that now physical objects are not *in* spacetime (as we have always imagined), but simply *are* regions of spacetime with certain patterns of curvature. In the time evolution from t to t′, these patterns interact in a non-linear fashion, and attract and repel each other as do physical objects. But this means that implicit in the non-linear field equations are rules for determining how a given pattern of curvature would interact in various circumstances, on the basis of its nature as a pattern. That is, these patterns do have dispositional properties. I agree that in this theory the nature of objects would be a set of structural properties of spacetime curvature, and not a set of dispositional properties. But since these structural patterns only have significance in conjunction with the field equations, and because this conjunction results in true dispositions, the theory is not incompatible with reality of dispositions. It is just that, if geometrodynamics were correct, the dispositions would be properties of spacetime itself, not of physical objects in spacetime (as there are no such things).

A significant part of ordinary physics is the explanation of macroscopic dispositional properties in terms of the dispositional properties of the components and the configuration of these components in the whole. Thus the elasticity of a solid, for example, is explained in terms of the attractions between the electrons and their neighbouring atoms. Note that it is *not* enough to say that the elasticity can be explained simply in terms of the 'electronic structure', as purely structural properties cannot explain dispositional features without assuming some dispositions (such as charge, mass etc.) inherent in the electrons themselves.

There have been very few attempts in physics to deny that the constituent parts *do* have causal properties—i.e. that electrons do not really have electric charge, mass, and spin. Even the proposed quarks have these dispositional properties, along with 'colour charge', 'strangeness', 'charm', etc. It is an empirical question *which* causal properties are basic, but physicists nearly always rely on some causal properties being fundamental. The form of the postulated basic causal powers (nuclear and electric fields, etc.) may be constrained by mathematical laws of symmetry, so that for example there are only discrete values for charge, spin etc., but the *existence* of these causal powers is something that *must* be assumed in order to provide a basis for physical accounts of the dispositions evident in nuclear, chemical, and biochemical systems.

The task of physics must therefore be to relate causal properties to what is known about the actual forms of the objects under investigation. Mathematical physics describes the numerical features of natural objects, and simply assumes that there are dispositional properties that exist according to the described forms. For example, the attribution of electric charge is purely formal until it is assumed either that there is a real dispositional property (e.g. a force) with corresponding features, or that there is a corresponding coupling to a potential-energy field. ('Forces' and 'potentials' are equivalent descriptions of the same disposition, as forces are spatial gradients of potential energy field.)

In Newtonian physics the mechanical corpuscules had the dispositional properties of impenetrability, durability, and perfect elasticity according to their spatial shape. These causal properties cannot, however, be logically derived from the shape alone, as Descartes was forced to acknowledge. Newton also realised that other causal powers must be attributed to the atoms, in order for example to explain gravity and the tensile strength of materials. Gravitational attraction could be made according to mass and distance, but the short-range attractions could not be attributed according to any form known at that time. The fact that the attribution of gravitational powers was in strict accordance to some known form may have contributed to the impression that gravity was satisfactorily explained, but this attribution does not remove the need for a dispositional category. For Newton's law of gravitation does not say what always *does* happen, but only what *would* happen in suitable circumstances (e.g. no interference from outside influences: in Newton's case, no nuclear or electromagnetic forces). This fact was one of Nancy Cartwright's [1983] objections to the reality of physical laws, but is understandable when laws, even Newton's law, are regarded as laws of causes, not simply as laws of effects.

5 DISPOSITIONS IN QUANTUM PHYSICS

Position and velocity were also spatial properties in Newtonian physics. That is, they were definite and actual features of the elementary corpuscules, and could be called 'definite' rather than 'dispositional'. This belief changed with the advent of quantum mechanics, which showed that position and velocity are not continuously definite, but only have specific values in suitable situations such as measurement interactions of certain kinds. That is, position and velocity values are now not 'primary qualities' which exist continuously in all situations, but are more akin to 'secondary qualities' which are only specific in some suitable (i.e. not all) situations. In fact, the circumstances for positions being definite are *incompatible* with the circumstances for velocity being definite: this is part of the content of Heisenberg's 'Uncertainty Principle'. If we take an ontological (rather than epistemological) view of what this principle means, then position and velocity values can only be real if they are features of actions by dispositions, and not definite 'primary' forms themselves.

This shows that position and velocity should now be related *not* to spatial properties or actual shapes, but to *propensities* (Popper [1967], Whiteman [1971] and Maxwell [1982, 1985 appendix]). Quantum mechanics uses the 'propensity' type of disposition, as this type displays its effects probabilistically: see Popper [1959]. If we then ask what must the world be like in order that quantum mechanics describes it correctly, we arrive at the existence of real propensities. It is sometimes thought that talk of propensities can be reduced to talk of conditional probabilities etc., but as Humphreys [1985] shows, this cannot be carried through as propensities have for example a time asymmetry not shared by conditional probabilities.

If we look at what definite forms natural things *do* have in quantum physics, these, I believe,[3] are

1) the set of 'quantum numbers' (for charge, spin etc.) of the quantum systems, and
2) the set of definite past interactions (by measurement or other events)[4] which determine the current quantum state.

Thus in quantum theory, 'what is actual' refers not to spatial shapes, but to combinations of numbers and past events. Within this scheme, quantum objects have propensities according to these definite numbers and events. It is from those corresponding propensities (not the events etc. themselves) that both the subsequent spatial shapes and later behaviour of the objects can be derived. Note that quantum objects do *not* behave as if they had a *definite* spatial shape, because the spatial distribution of propensities varies with time. They are like 'wave packets' of variable extent. Their extension can even have temporary gaps in it, as in the two-slit diffraction experiment.

Quantum mechanics itself would describe the subsequent development of a

[3] I am not yet allowing for theories of 'spontaneous symmetry breaking' which, if wholly successful, would account for quantum numbers in terms of actual events in the early stages of the 'big bang'.

[4] There have been several proposals for how events (other than measurement events) can give definite selections, or 'reduction of the wave packet'. See e.g. Maxwell [1982, 1985], or D. Bedford and D. Wang [1975].

dispositional state in terms of an evolving Schrodinger wave function, or in terms of an Heisenberg transition operator from the previous definite interactions to the range of possible interactions in the future. These quantum-mechanical procedures are thus an attempt to describe the time evolution of the propensities of natural objects.

Because of this variation of shape with time, and because the 'actual particle' *never* appears (neither in propagations nor in interactions), it is now best to regard quantum objects as essentially just *distributions of propensity over spacetime*. Such objects Maxwell [1985] has called 'propensitons'. The propensities involved are not arbitary dispositions, but are propensities *for* interactions: for localised actual events.[5] This means that *during interactions* the 'propensitons' behave almost as if they were particles, but not at intermediate times. Between interactions, a propensiton does have a spatial extent, but in a probabilistic and variable, not definite, manner.

Of course, many physicists have continued using the term 'particle' for these propensity distributions. The meaning of the word 'particle' has thus changed. Kaempffer [1965], for example, after pointing out the 'erosion of naive pictures of particles', goes on to suggest that the word 'particle' stand for a quantum mechanical state characterised by a set of quantum numbers, which is associated, in principle, with an identifiable event such as a momentum transfer in a collision. Note how this concept is similar to that of a distribution of propensity associated, in principle, with an actual event such as a collision.

In quantum field theory (a more complete form of quantum physics), even the *existence* of objects is a dispositional property that may or may not be manifested, as, for example, pairs of particles and anti-particles may or may not be formed. Quantum field theory furthermore replaces the 'potential energy fields' of ordinary quantum mechanics with the 'virtual exchange of particles'. Both of these are dispositional: virtual exchange is the propensity of generating short-lived particles that may or may not interact with others in their vicinity, and that can also form what physicists often call a 'cloud of possibilities' if they do not interact.

6 CONCLUSIONS

By means of the arguments presented above, I hope to have shown that the notion of a 'real disposition' is an essential part of both our theoretical and practical understanding of the physical world. Not only this, but that the notion is likely to be fundamental to a realistic and non-paradoxical account of quantum physics. For at least these reasons it is thus important to resist certain interpretations of physics and of the physical world that render dispositions impossible.

[5] A more complete account of the concepts of 'actuality' and 'potentiality' involved here is in preparation.

In particular, it is necessary to reject the 'block universe' account of time which sees the future as 'already formed', only waiting for us to 'come across it'. That in the future some event is going to happen does *not* imply that there 'now' exists some event that in the future is going to happen. Until events happen, they need not even exist.

Equally importantly, it is necessary to reject the account of physical processes as the mere succession of events, without their being in any sense caused or produced or generated by appropriate previous event(s). This Humean account of process removes by definition the possibility of any rationally coherent account of *how* events are caused.

I recognise that in rejecting the above two accounts, I am also rejecting the simplest interpretation of Einsteinian relativity theory: the interpretation in terms of a single spacetime of fixed events. Since Minkowski, relativity theory is often taken as *implying* this view of spacetime, but I intend to show in subsequent papers that there are more plausible interpretations.

Often allied to the Humean account, and hence also to be rejected, is the conception of physics as finding only the *laws or regularities* that describe the succession of events, or of states of the world. That is, physics is seen as finding functional relationships between events, and *not* the causes of events. Physicists may say that their laws 'govern' the succession of events, but, once the 'block universe' account of time is rejected, it is quite mysterious *how* this can occur. (They may also say that they are 'iron laws', but there is no iron hand of the law to enforce them.)

Such difficulties are avoided if physics is seen as discovering the dispositional properties of objects, so that the above event laws are *consequences* of the way things are, not *fiats* to be enforced. On this construal physics, even Newtonian physics, can realistically describe what 'would happen' in different possible worlds, not just the (simpler) knowledge of what 'does happen' in the present world: it can predict for example what *would* happen in various experiments, even if those experiments are never in fact performed. It tries to do this on the basis of describing the real dispositions of physical objects, and how these dispositions lead to various effects in different circumstances.

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