Pragmatic Ontology I:
Identifying Propensity as Substance

In a pragmatic approach to ontology, what is necessary and sufficient for the dispositional causation of events is interpreted realistically, and postulated to exist. This leads to a concept of 'generic substance' (Aristotle's underlying 'matter') as being constituted by dispositions, not just being the 'bare subject' for those dispositions. If we describe the forms of objects according their spatiotemporal range, then this form is best viewed as a field, and substances themselves are best conceived as 'fields of propensity'.

With the help of such a concepts, we can try to understand some of the more mysterious quantum features of nature, such as the nature of measurement interactions and non-localities, not as well as the duality of wave and particle descriptions.

1 What is Substance?

Questions about the nature of substance have traditionally been at the heart of philosophical and scientific enquiry, but over the last century, we find we know even less about its nature than we did before.

The Aristotelian position is that everything is matter in some form, but, while forms could be known by the intellect, the nature of matter (*hyle*, the underlying substance) as 'that potency which could receive form' is distinctly difficult to conceive intellectually. This hylomorphic position was developed by Aquinas and others in medieval times, and held in contrast to the Platonic position whereby 'pure forms' could exist in their own right. In the present paper, however, I will not be using the term 'matter', as today it leads too readily to the concept of 'solid corpuscular substance' of Boyle, Locke and Newton. As I wish to explore a concept of substance which is to some extent independent of classical physics, I use the term 'matter' as little as possible, and instead adopt a common use of 'substance' as the 'generic substratum' that constitutes objects, but which itself seems to be obscure and in need of elucidation.

With the beginning of science, 'substance' came to have a particular meaning exemplified by Spinoza and Leibniz, who defined substance as 'that whose nature requires its separate existence'. On this view, substances are self-sufficient beings which contain within themselves the complete source of all their changes. Leibniz has for example that all natural changes of his monads come from within, as 'an external cause can have no influence upon its inner being.'[1] The difficulty then, as Kant realised, is that on this account 'it is not necessary for [a substance's] existence that it stand in relation to other things'[2]. It is a puzzle, on this account, why substances even have positional relations that might enable the acting of one substance on another. The possibility of *interactions of substances* can only be regained by denying that substances are self-sufficient beings.

We need to look for some closer relation between substances and 'powers' or 'propensities', in order that substances may endure through changes in some of their properties (their 'accidents') produced by interactions with other substances.

[1] Leibniz, [1714] ¶11.
[2] Kant, [1747] §. 7.

If substances were self-sufficient, there is always the difficult question of *how* their powers for interacting are supposed to be related to their 'underlying' nature, and it is not clear whether we can conceive of some 'naked substance' apart from all its powers. Locke explicitly had no clear idea of the relation between a substance and its powers, and it is debatable (see Ayers [1975]) whether he distinguished any power-less substance. One view is that of Boscovich, Faraday and Harré, whereby a substance is at a single place at any given time, around which its powers are 'fields of force'. All inertia still resides in the point substance, and around it the field of force extends away indefinitely. However, it is still not sufficiently clear how these 'point centres of mutual influence' are related to the extended fields.

A 'continuant' has been defined (Johnson, [1924], III p. xx) to be 'that which continues to exist throughout some limited or unlimited period of time, during which its inner states or its outer connections may be altering or remain unaltered'. Johnson used the term 'continuant' as against 'substance', for the term 'substance' is impaired by the fact that, in the history of philosophy, many diverse senses have been assigned to it, senses which give associations which may not be wanted. For example, though continuants can endure through change, they need only endure for at least a while, and not necessarily everlastingly, as many suppose that substances are required to do[3]. Further, since Locke at least, it has become obscure exactly how a substance is supposed to be related to its powers, qualities and properties, etc. 'Substance' has come to be regarded as an 'I know not what' which in some obscure manner 'underlies' and 'supports' its attributes.

A second general position is the denial of 'substance' altogether, and of any sense of continued identity, in favour of pure process. We then have a purely event or flux philosophy. Reasons for this repudiation have varied. Sometimes it has been the alleged unknowability of the real constitution of substances. At other times it has been a preference for 'flux' or 'creativity' as against the 'Parmenidean influence' that is seen to pervade much of Western philosophy. Hume and Whitehead are perhaps the two most prominent figures here. As well, between the World Wars last century, an ontology of 'events' became popular, especially under the influence of a common interpretation of relativity theory and a positivistic approach to metaphysics. Russell's *The Analysis of Matter* [1927] is a good presentation of this position, wherein events are fixed in space and time. Paradoxically, they become then like fixed substances, and the understanding of event as 'change' often fades.

After the Second World War, Nicholas Rescher [1962] noted that there was a general reaction to such an extreme event-and-no-continuant ontology. Many writers now repudiate 'events' in favour of substances and their relations. In the reaction, however, a very uncritical idea of 'substance' was taken over, practically identical with 'material object'. This has the result that there could be no very precise understanding of either the fact or the dynamics of real change.

With some philosophers, nevertheless, the realisation of the inadequacy of the event ontology came more moderately, and arguments were found for an ontology in which there are *both* events and 'continuants'. Events could now be properly construed as real changes, by reference to the changes of the continuants involved. Johnson was trying to counterbalance the middle Whitehead's *Concept of Nature* [1920] with his term 'continuant'. Without such a concept as

[3]Leibniz, for example, argues from everlasting substances to immortality

'continuant', he remarks[4], it would be impossible to distinguish the case of two events *A*, *B*, say, causing two later events *C* & *D*, respectively, from their causing *D* & *C*, respectively. The necessity for substantial continuants was further supported by Reck [1958], who argued against an ontology of only events, and for a position closer to that of Johnson. However, neither Johnson nor Reck attacked the problem of giving a fully-fledged account of such continuants: they did not consider the problem, for example, of how a substance is related to its powers.

2 Formal and Dynamic Properties

My argument will now begin with a reiteration of Aristotelian views concerning particular substances as composed of matter in some form. However, as expained in the introduction, I will adopt the terminology of saying this view concerns particular objects as composed of some substance in some form. In this new phrasing, the starting point of the Aristotelian view is that

P1: particular objects in the world exist, and all are composed of some substance in some form.

Pure forms without substance cannot exist, whether they be information, mathematics or functions. The world may have triangular objects, but is not made of triangles. Similarly, the world cannot be made of functions, whether wave functions or of some other kind.

I take 'form' to be a generic word referring to any of the following static properties of objects: shape, number, symmetry, function, field, wave, point, length, area, volume and amplitude. In objects which are aggregates, the meaning of form is extended to include the relations, configuration and structure of the parts in the composite whole.

The term 'disposition' is now taken to be a generic word referring by contrast to any of the following dynamical properties: cause, propensity, power, capability, potentiality, energy (kinetic and potential), mass, charge, field coupling, force, pressure, momentum, impetus, elasticity or rigidity. These are the properties are necessary for the causation of events, and for making the changes that constitute those events. Since Locke, these are often be called 'qualities', noting however that his 'qualities' are not static properties, but are in fact a certain kind of *power*. As he says, 'the power to produce any idea in our mind, I call the quality of the subject wherein the power is'[5]. I do not use the description 'categorical' for the formal or structural terms, since I will be arguing that dispositions may also categorically exist (see Molnar [2004, chs. 5 & 10]).

Science investigates the above causal properties in great detail, and if it is successful, it explains the large set of empirical dispositions in terms of an *underlying disposition or propensity* from which, according local structures, all its observed dispositions and causal properties may be derived. So let me assume that these underlying propensities have been found: for an

[4]Johnson, [1924], III, p. 127

[5]Locke [1706], Bk. 2, ch. 7, §8. By using the term 'quality', Locke is following the corpuscular philosophy of his day. There is a tension in Locke's definition, however, because Locke saw powers as essentially relational, but qualities as non-relational.

elementary particle, they would be characterised by the charge and mass (and couplings indicated by other quantum numbers) that determine its capacities and probabilities for interaction. For a composite object, they would be described in terms of the structure and relations of its ingredients, *along with* the propensities for interaction of these parts.

The second Aristotelian postulate is one that I have argued for elsewhere (Thompson [1988]), based on the observation that the notions of *dispositions* or *propensities* are essential in any useful science or philosophy of nature. I now go further, and assert that this is for the ontological reason that all existing things have irreducible causal powers. This is to adopt a form of dispositional essentialism[6], and postulate that

P2: probabilistic dispositions or propensities are an essential part of the nature of everything existing.

(Zero probabilities are excluded, but the probabilities can be unity for 'sure-fire' dispositions.) The remainder of this paper is within the context of such a dispositional essentialism, and will develop and extend the arguments of Molnar [2004].

So far, we have discussed *static* and *dynamical* properties, namely *forms* and *dispositions* in their most general categories. Our task now is to establish whether or not there is a link between either of these categories with those terms that denote *existence*, and are connected with 'substance', such as particle, material, matter, corpuscle, body, fluid, ether, actuality, reality. We also need to see the connection of all of these with events, change, interactions and outcomes.

The need is to create an ontology, and to describe the quantum world in existential and dynamical terms, not just formally. Talk of 'wave function' or 'probability amplitude' is not really sufficient, since these are static and formal rather than dynamical features, and existence must contain, or at least imply, some dynamics! We want to say 'what exists' as well as 'what form' it has. If we are only given the wave function from solving the Schrödinger equation, we should immediate ask: What exists with this wave function as its form? And what are its dynamical properties?

Dispositional essentialism is the position that every object with causal powers has some essential dispositions, and that these dispositions cannot be eliminated, grounded, or explained away in terms of non-dispositional properties such as shape, position or internal structure since *further internal* dispositional properties would yet have to be invoked. Shapes, positions and structures only have effects to the extent that they are shapes, positions and structures connected to dispositions. The irreducibility of dispositions suggests that there what Molnar [2004] calls 'ungrounded dispositions', that exist *as dispositions*, not as anything nondispositional. On first appearance, the idea of anything as 'ungrounded' appears to be rather peculiar. Dispositions always refer to what may happen, yet apparently in this case what 'may happen' exists in some sense without anything 'actually happening'. It may seem very strange to try giving any sub-

[6]Similar views are advocated in Bird [2004], Cartwright [1989], Chakravartty [2003] Elder [1994], Ellis [2000,2001], Ellis and Lierse [1994], Fetzer [1977], Harr and Madden [1975], Molnar [2004], Mumford [1995, 1998], Shoemaker [1984] and Swoyer [1982]. Opposing views are Ryle [1949] who sees dispositions as merely 'inference tickets' or 'promises', and Armstrong [1969] and Katzav [2004], who see them as derived from universal laws combined with nondispositional properties, concerning which account see Bird [2005].

stantial reality to the mere possibility of something happening, which Mumford [2004] claims to be a consequence of dispositional essentialism:

> To be a disposition is just to be directed to some possible manifestation. To be an ungrounded disposition is to be so directed and nothing else. In particular, it is for there to be no microstructural basis to this directedness (what Molnar calls, and accepts, the missing reduction base). But if such a property is unbased, *what in the world is it* that is directed to some manifestation? Such a property looks like no property at all. It is nothing more that the possibility of some future property, when there is a manifestation. [p. 15, italics in original]

Molnar [2004, p. 174] discusses the view that requires material objects to be 'space occupants', and that they must have some non-dispositional essence to occupy space. Molnar himself takes the view that fundamental particles do *not* occupy space, since they may be 'point particles' that are in space, without filling it; this point will be discussed later.

The task I address in this paper is therefore that of constructing a view that gives some reality and substantiality to objects that are constituted by dispositions. We thereby may seek an understanding of the nature of the so-called ungrounded dispositions, how they occupy space without being reduced to something non-dispositional, and of how to distinguish mere possibilities from what is substantial.

3 Pragmatic Ontology

Rather than becoming involved in deep Leibnizian questions about the possibility of self-sufficient versus relational existence, or about modal semantics of possible worlds, I wish here to take the approach of postulating just that ontology which is necessary for the processes we see. I call this 'pragmatic ontology', since it is based on a general analysis of actions, which then works back to find what is necessary and sufficient to produce these actions[7].

The third postulate is that 'Everything is where it can act'. In more detail, this is

P3: Every thing is (at least) at the places (in space+time) where it has a disposition to immediately act or interact.

This is pragmatic in the sense that there is no need for it to be anywhere else, since it can never have an effect there! I take 'place' in the generalised sense of both 'where' and 'when', because both are necessary to describe actions, and I do not want to assume that everything is acting all the time. A place is may be a point or region of spacetime, depending on its type. In general, there may be finite time interval between actions, and this will be important for quantum processes. The 'immediately' in the P3 definition implies that in some sense we are talking about primitive (inter)actions that are not constituted by more microscopic processes.

[7] If perhaps 'pragmatism' gives the impression of being opposed to any ontological commitment, then alternative titles could be a 'minimal' or 'efficacious' ontology. The name 'minimal', however, does not emphasize the connection with action that comes with the words 'pragmatic' or 'efficacious'

If we needed to describe the structure of an object, we could refer to the set of all places where it is, which is the set of all places where it can act. This procedure can be applied to elementary objects, in which case we are talking of something like a distribution or 'field' of operation. For composite objects, we would have the field shapes for the parts, along with a description of their organisation in some structure. In each case, we would be talking about the 'form' of the object as a field, or as a structure of fields. The interactions of two objects are their joint action at some place, and P3 implies that their respect field forms must overlap at that place.

We now come to the question of *how* an object acts at those places in spacetime. This is where its dynamical properties enter in. The set of all dispositional properties of an object is just that necessary to describe all its possible actions, in all the circumstances in which it may find itself.

The fourth postulate is again pragmatic: I define *the substance of a thing* as *the set of propensities for how it can act.* It is pragmatic, because there is nothing else needed to be given to specify an object apart from when and where it is, and how it can act.

This is a new step from the philosophical point of view, and since we attempt to derive concepts of 'existence' from those of 'dynamics'. From the scientific side this is not new, as physicists have long talked about 'electromagnetic force fields' and 'potential energy fields', and that 'matter is a form of energy'. In each case, a dynamical property (force or energy) is being pragmatically identified as some kind of substance. Instead of rolling our eyes, perhaps we should see whether this identification could be put on a firmer footing (not the least, to avoid invalid applications).

In more detail, the fourth postulate (applicable to both elementary particles and aggregates) states that

P4: the substance of an object is constituted by the set of underlying propensities for how it can act or interact.

The powers of any entity are what it is capable of doing and how it is capable of interacting. More specifically, the 'how' in P4 refers to what is is capable of doing under what conditions and how it can itself change, as well as how it is capable of interacting and changing others.

There are many different 'hows' here, and hence there may be many kinds of propensities. The question whether there are many kinds of propensities in a pluralist world, or just one kind in a monism, is something which is beyond the scope of this article. Science has its aim to reduce all propensities to just one underlying kind, but we cannot determine in advance whether the world is sufficiently simple for monism to be true.

If we combine the third and fourth postulates, we come to the view of all objects as 'fields of propensities'. In this view, the spatiotemporal field is its form, and the propensity (of some kind) is its substance, where form and substance are linked just as in Aristotle (except that he uses the term 'matter' for the 'generic substance' under discussion here).

We are therefore postulating a new notion of 'forms of propensity', to see whether such things can continuously endure through certain types of interactions, looking to see whether

they can be identified as the 'substances' of classical philosophy. Ducasse [1964], for example, lists five general things which substances are capable of doing:

- acting (as an 'enactor')
- being in a state (as a 'tenant')
- affecting another substant (as an 'agent')
- being affected by another (as a 'patient'),
- changing into something completely different (as a 'mutant'), as well as
- enduring changes (as a 'continuant').

All these details require a detailed analysis of the concept we are constructing. So far, the concept of 'substance' just refers to a particular object in the world which can continue to exist at least for a while. Further questions therefore concern whether they change continuously or intermittently, the individuation of such objects, whether they persist through changes, the question of 'matter', whether they have 'real essences', and whether they help us understand quantum physics. Some of these points will be discussed below, beginning with continuity through change.

4 Substances Which Endure Through Change?

4.1 Unchanging Substances

We first consider how particular objects, when conceived as propensity fields, can endure through time, even if they are not permitted to change at all in that time. Let there be two successive actions of an object, and then let us consider the interval between these actions. If in that period there *could* have been an interaction, should another object have tried to interact, the propensity field of dispositions for possible actions would have to exist at all the intervening times. All the natural objects we know are of this kind, so I deal with a world where the following postulate is true:

P5: between any pair of successive actions of an object, other interactions are possible, but not necessary.

Thus propensity fields certainly endure over the time between successive actions. They endure because the first and second events are separated in time, and, because the second (or another) event *could* have occurred earlier, the propensity for its occurring is distributed over all the intervening possible times. Considered as a particular thing, the whole propensity field therefore endures over the finite time interval between the events.

Admittedly, this endurance of propensity fields is not entirely conventional, for they extend 'with one span' over temporal as well as spatial intervals, rather than being a real succession of spatial fields at successive times. It of course *appears to us* as if they move successively and continuously through different spatial regions between the events, but this does *not* mean

that there is a continuous succession of *actions*, as we are really only looking at potentiality or propensity fields. It is a grave mistake to think that because something *can* occur at any time between two actual events, then something *actually* is occurring at those times: we must not confuse actualities and possibilities!

Since single propensity fields do endure, at least for a while, they can be regarded as the most basic continuants or substances, in that they never change so long as they continue to exist, and hence must remain the same even under the most technical and exacting sense of identity. They are unchanging, because they endure unchanging for their short while between two successive actions. They can be viewed as 'brittle' or 'precarious' continuants, in that they cannot change in any way without becoming strictly different continuant(s), yet while they do endure, they stay exactly the same, even staying at the same places in space-time.

Note that

1. although they are unchanging continuants, they do not prohibit natural change: only when they do lead to changes, they must mutate into something different,
2. they may still *appear* to change *for us*, if *we* change, for example, by moving our place of view during the time between two actual events for the substance being observed, and
3. these unchanging substances in nature will typically only last for some small fraction of a second, the time between successive molecular events such as collisions in typical solids, liquids, and gases.

The powers of any entity are what it is capable of doing and how it is capable of interacting. The powers of a propensity field are given entirely by the spatiotemporal distribution of propensity within the field, along with the measure or nature of the propensities at each place in the field. Given the form of the field and the kind of its propensities, one can then predict exactly how the field is likely to interact with other fields in any given situation. This is because the 'circumstances' are just the degrees of overlapping with other fields, and the actions that are possible in those circumstances are just those events to which the propensities are directed.

4.2 Changeable Substances, by Continuity

So far I have defined only particular unchanging substances, as particular propensity fields. What about *changeable* substances: continuants which can endure through certain changes to themselves but keeping the same powers and properties? Since under a strict sense of identity, nothing can itself change or move in any way, and still remain the same particular, it will be necessary to relax this strictest sense of identity if a sense of 'continued identity' is to be obtained. We want now a sense under which one substance can undergo interactions and shift around, and not only remain unchanging between some pair of events.

Perhaps the most obvious relaxation is to allow the same field form over *different places*, so that the same substances can at least move, as a whole, to extend over a different region of space and time. There is hence a sense of continued identity which treats two 'unchanging substances' as in fact the temporally-contiguous and successive stages of the same 'changeable substance' when

1. there is some action during which the two 'unchanging substances', as propensity fields, are extensively continuous with each other. This event would then be the product of the earlier substance and the cause of the later one.

2. these two substances have the same field form even though they do not extend over the same sets of places, and have the same propensities for actions within the range of this field.

That is, for a *changeable substance* to have continued identity, there must be a spatio-temporal continuity of the same field, and same kinds of propensities. Even if there is continuity of the field shape, this is not by itself sufficient for substantial continuity unless the same kinds of propensities are also repeated (or if the world is monistic, so there is only ever one kind).

When an electron elastically scatters off a proton for example, it changes its position and direction, but it definitely remains that same set of propensities, and it may retain the same shape in its field structure. If so, it is a 'changeable substance' in the sense of this section. A changeable, enduring substance is one which retains the same field form and the full possession of all its powers through any changes or interactions it may pass, so long as it lasts. It thus has the important disposition for remaining unchanged, as Williams [2004] recently reminds us.

4.3 Substantial Changes

The above conditions do *not* imply that even a changeable substance must last forever, for there *can* be sufficiently radical events in which *no* outcoming substance has all the powers that once constituted one of the ingoing substances. There can be changes in which not all the powers of a substance are preserved through the change. Such changes could be called 'substantial changes' because some substance did not survive, as can changes in which a wholly new substance is formed. Generation and decay events would be examples of substantial change, if new sets of propensities are created or destroyed. An example is the decay of a neutron, which in free space after about 18 minutes decays into separate proton, electron and neutrino fields. Most of the other interactions of the neutron such as collisions and refractions etc. do preserve that substance (that set of propensities), as in these cases there is a continuity of its field form and of its powers.

5 Questions about Substances

5.1 Individuals

Since an unchanging substance has constant powers so long as it lasts, it is that respect similar to the 'Parmenidean Individuals' of Harré [1970b]. According to Harré, 'Parmenidean individuals' are the ultimate individuals in nature at whatever level of microscopic analysis that may turn out to be, so the scientist does not have recourse to the internal arrangement of its parts to explain the powers of such an individual. It used to be thought, for example, that atoms were

Parmenidean individuals, then (later) protons and electrons. The most likely present-day candidates are quarks, leptons and field quanta such as gluons and photons. The arrangement of their parts is not needed, because they are the ultimate individuals, and their internal constitution is not separate from their powers. Since they have no separable constituents, their nature must be identical with the particular form of all their powers. That is, to completely specify the powers of a Parmenidean individual is to completely specify its nature, its real constitution, and vice versa. This is in contrast to what Harré calls an 'Aristotelian individual', which is a complex individual whose powers are explained by means of the dispositions (i.e. powers *and* arrangements) of its parts. Harré's Parmenidean individuals, however, endure indefinitely, and "cannot be altered, . . . being the bearers of numerical identity [they] cannot be transformed", whereas the 'continuants', as being conceived in the present inquiry, do not necessarily last indefinitely, only at least for a while.

The above pragmatic derivation of 'substances' has the feature that in it we can see more clearly how the nature of a substance (as a propensity field) can be identical with the 'particular form of all its powers'. This is because, as was seen just above, the form of the field as an extensive distribution of propensity. This is in broad agreement with Ducasse's [1964] account of how a 'substant' (his new association-free term for substance) is related to its capacities. He argues that

> contrary to what the etymology of 'substant' may suggest, the relation between a substant and its capacities it 'has' is not analogous to the relation between, for example, a table and the objects it 'stands under' and 'supports'. Rather, the relation between a substant and its capacities is analogous to that which obtains between, for instance . . . an automobile and its parts; or a living body and its organs; or more generally between any *whole* and its *parts*.

Now, on the present account, a propensity field is a single whole particular thing, and has various possibilities for actualising contained within its extent because it extends and endures (by definition) over all these possible places. One can regard the relation between a propensity field and the places possible within it, or equivalently between a substance and the interactions possible for it, as therefore just the relation between a unitary whole and the parts into which it may possibly (not actually!) be divided. One important consequence of this account of the substance as a 'whole' with respect to its powers as 'parts' means that substances cannot ever be properly conceived apart from their powers. Thus there never exists any separable, pure or 'naked' substance, because, not having a (field) form, it would not be at any place.

The only qualification I would give to Ducasse's account is to note that the actings of a substance are most often *interactions* with other substances, so that an account of a substance's powers – what it is capable of doing and how it is capable of interacting – must make some reference to the condition of the other substances with which it reciprocally interacts.

5.2 Monism and Pluralism

One motivational aim of science is to show there may be just *one* kind of underlying propensity. In this case, by P4 there would be only one kind of substance in the universe, and every object

would be this substance in some extensive shape or field form. In such a monism, to specify an object's essence we only need to give the formal field shape, and this could be called the 'substantial form' that completely characterises that object.

From either philosophy or science, however, we cannot tell if future progress will achieve the monistic aim, or even whether it is in principle possible. We therefore need a philosophy of nature that is capable of describing a pluralism of different kinds of substances. In present day science this is needed, as quarks for example are characterised by the many different sets of propensities of mass, charge, 'colour', 'flavour' and intrinsic spin that are *not* directly reduced to rearrangements of more microscopic constituents. Electrons are other sets of mass, charge and spin propensities. In the present account, each different set of propensities gives a different kind of substance. As explained above, these may last only a finite time, and are not eternal substances but are able occasionally to transmute into each other.

If none of the several underlying propensities in the set is reducible to others, then they all contribute to the essential nature of objects without being part of extensive field forms. This makes further demands for how we are to *specify* the essences of objects.

5.3 Essences of Substances

To specify the kind or essence of a object, on the present account we have to specify *two* sets of things. We have to specify exactly *which* set of underlying propensities constitute it, and we also have to specify the *field form* which gives the distribution of these propensities for possible actions. We can with these two aspects specify what Locke would call the 'real essence' of an object, which is defined by Locke as 'the internal, but generally (in substances) unknown, constitution, whereon their discoverable qualities depend'[8]. They may often have been unknown, but that does not mean that they are unknowable. As Copi [1954] has pointed out, 'it must be admitted that the doctrine of the unknowability of real essences was not an unreasonable doctrine to draw from the relatively undeveloped state of science in Locke's day', drawing attention to Locke's description[9] of the then sorry state of chemistry. It is, however, the real essences of things which science seeks to discover, and the sciences have made considerable progress since Locke's day. We can define the field forms by mathematical functions, and we can describe a relatively simple set of underlying propensities (mass, charge, etc.) by the general rules for what they do.

Traditionally, the phrase 'substantial form' has been used to describe the essences of objects, and for Aristotle, form is that which gives structure to matter such that it can be known. Matter, for Aristotle as here, is potentiality for natural being, but for him matter is "that which in itself is neither a particular thing nor of a certain quantity nor assigned to any of the other categories by which being is determined."[10] Aristotle appears to be looking for a kind of substratum when all qualities and quantities are stripped away, and his followers have interpreted this as the quest for prime matter. Even if we take Aristotle's definition of matter to be the matter of specific

[8] Locke [1706] Bk. 3, ch. 3, §15.
[9] Locke [1706] Bk. 3, ch. 6, §8.
[10] Aristotle, *Metaphysics*, $1029^a 20$.

things, he makes it difficult for us to say anything positive about it. All the intelligibility – everything that makes a substance knowable to us – seems to reside in the form rather than in the matter. It is the qualities and quantities which make up the form that appear readily to the intellectual understanding, with the underlying matter or subject appearing only in a negative characterisation. We cannot know matter 'in itself', he might argue, because it is form incorporating matter which is perceived by the senses, and it is pure form which is considered by the mind.

However, the above use of 'substantial forms' to describe the essences of objects erroneously suggests that all essences can be specified by giving *forms*, whereas in fact their *propensities* need to be specified as well. These propensities cannot be entirely devoid of characterisation, since we need to know not just what form they have, but what they *do*. And these can be discovered by the sciences. Both are necessary, as every action or interaction is a sort of conjunction of form and propensity, as dispositions always act according to circumstances, and circumstances are described by field forms and their relations. I agree that extensive field forms appear very readily to the intellect, especially if they have mathematical descriptions, but the no-less-essential dispositional qualities appear only slightly more slowly to the intellect, when it makes inferences or tests hypotheses from the results of actions and interactions. Our understanding does not see propensities clearly and distinctly in themselves, only by inference from their effects. Hence advances in science need both experiments as well as mathematics!

Another kind of conjunction of form and propensity occurs if the extensive forms are governed by *field equations*. In the quantum physics case to be considered below, typically the parameters in the field equations are just the values of mass, charge, spin, etc., that characterise exactly the propensities of an object. The field forms are therefore not arbitrary, but appear in some sense generated by the propensities themselves in way that is yet conditioned by outcomes of previous actions, but I leave this for further investigation.

5.4 Matter and Form: Subject and Predicate

The field form of a object can be regarded as a predicate qualifying some propensity, as it is the propensity which *has* that form. Propensity of some kind, therefore, can be regarded as the underlying 'substance' or 'matter' of any enduring thing, which are therefore 'forms *of* propensity'. 'Propensity' is thus the logical subject – 'that which is not predicated of something else' – and the field form is a predicate qualifying this subject.

Propensity is *capable* of being a subject or a substance, because propensities are kinds of potentialities. In order for potentialities to produced actions, or some actualities, they have to have some kind of *being* themselves. That is, potentialities have to exist as 'things' just as much as actualities were assumed to do. The alternative to this position would have to have 'potential objects' waiting in some kind of limbo before some of them change to be fully actual. We rejected any kind of 'subsistence' like this, and instead we hold that various kinds of potentialities *themselves* exist as things. That of which they are formed, namely the potentiality itself, is therefore the substance or logical subject of the existing thing.

5.5 Knowability and Pragmatism

Although we have characterised the substance or the 'subject' of things as propensity, and have characterised propensity as the probabilistic potentiality for actual events (and for nothing else), we are perhaps left uncertain what propensity is *in itself*. We certainly know the forms in which propensity appears, for these are the field structures of mathematics, but we might still ask *what propensity is?*

The best answer to this is that we must content ourselves with knowledge of everything that a propensity *does*, and then to take the pragmatic view of propensity as the minimal 'that which is necessary to do these things'. Thus propensities, and the substances they form, are defined as the unity of all their powers of operation. There is no reference to anything *hidden* that might be there *as well as* this unity: all the substance is 'up front' in the capacities for operations. We thus have a *kind* of operationalism or pragmatism, but with the modal 'possibilities for operations' taken realistically for an ontology.

In any case, if particular substances are field forms of propensities, when we observe substances it must be these propensities which we observe. Of course, we do not observe them *as* propensities in themselves: we only observe the propensities as they produce effects. It is not the case that we only perceive effects, as the effects are interaction events, and hence are our *acts* of perception, not the *objects* of our perception. The objects of our perception are the propensities at the moment when they produce effects. There must therefore be a sense whereby we can say that a propensity is 'in' its effects, as *during* its effects what we do observe is the substance constituted by that propensity.

6 Quantum Substances?

6.1 Introduction

Substances with the natures described as 'fields of propensity' are particularly relevant to modern quantum physics. For there, it is found that the concept of a corpuscle with definite 'extension, hardness, impenetrability, mobility, and inertia of parts' (from the beginning of Bk. III of Newton's *Principia*) is markedly inadequate, yet for which no philosophically adequate replacement has been hit upon.

With the help of the new ideas, we can try to understand some of the more mysterious quantum features, such as the nature of 'measurements' and a reason for 'non-localities'. The present concept of substance is similar to Nicholas Maxwell's notion [1982, 1985, 1988] of *smearon* or *propensiton*.

6.2 Heisenberg and 'Potentia'

Jammer [1966, p. 286] relates how

> Laws of nature, as Born and Heisenberg contended . . . determined not the occur-

> rence of an event, but the probability of the occurrence. For Heisenberg, as he later explained it[11] , such probability wave are "a quantitative formulation of the concept of 'dynamis', possibility, or in the later Latin version, 'potentia', in Aristotle's philosophy. The concept of events not determined in a peremptory manner, but that the possibility or 'tendency' for an event to take place has a kind of reality - a certain intermediate layer of reality, halfway between the massive reality of matter and the intellectual reality of the idea or the image - this concept plays a decisive role in Aristotle's philosophy. In modern quantum theory this concept takes on a new form; it is formulated quantitatively as probability and subjected to mathematically expressible laws of nature."

Unfortunately Heisenberg does not develop this interpretation much beyond the sort of generality of the above statements, and the concept of 'potentiality' remains awkwardly isolated from much of his other thought on this subject[12]. It is unclear even what he means by 'potentia'. Herbert [1985], in describing Heisenberg's ideas, imagines them to be more emphemeral than substantial:

> Heisenberg's half-real universe of potentia is reminiscent of certain oriental views developed in contexts far removed from quantum physics: "This floating world is but a phantasm /It is a momentary smoke" Though ghostly and transitory, Heisenberg's shimmering ocean of potentia is the sole support for everything we see around us. The entire visible universe, what Bishop Berkeley called "the mighty frame of the world," rests ultimately on a strange quantum kind of being no more substantial than a promise[13].

We will see below that, far from being as emphemeral as a promise, the propensities of the physical world are perfectly real and substantial, and may in fact be the very substance of all things.

6.3 Waves, Particles and Complementarity

One feature of the present account of substances is that they are not necessarily located in small fixed volumes of space, as, for example, the corpuscles or 'particles' of classical physics would be. The propensity fields that have been defined do not even have any special 'centre' distinguishable from all the other places in the field. They have no centre which could be regarded as the 'true substance', so that the surrounding field could be regarded as just the 'sphere of influence' of the central substance. This was Boscovich's conception, and it slowly percolated into physics, resulting in the 'dynamic matter' of the mid-nineteenth century. This view is best summarised by the aphorism "No matter without force, no force without matter".

[11] W. Heisenberg, 'Planck's discovery and the philosophical problems of atomic physics', pp. 3 - 20 in Heisenberg [1961].

[12] Heisenberg, for example, brings into his thought on quantum physics the Kantian phenomena/noumena distinction, as well as some of Bohr's ideas on 'complementarity' in experimental arrangements.

[13] Herbert [1985], p. 195. Note that he here uses Ryle's account of dispositions as 'inference tickets'.

Our propensity fields, though, have *no* special continuing centre: the only 'source' which could perhaps be identified as the previous action or interaction, which must have a definite place in space *and time*. The field is therefore only localised very briefly, if at all, at times just after this action. The substances we define are thus occasionally, but never necessarily, strongly localised. For most of the time they may have significant spatial extensions.

It is commonly believed (eg by Molnar [2004], and by many physicists) that high energy scattering experiments allow us to conclude that fundamental particles like electrons, quarks, etc are *point particles*, like real objects of zero size. However, this is inference is incorrect. What the experiments show is that there is *no lower limit* to the size that the wave packet of an electron (etc) may be compressed. They never show that there is actually a point particle, as this would contradict the Heisenberg Uncertainty Principle by requiring infinite energy to construct. Some other objects (eg atoms, or nuclei) *do* have a lower limit of compression, and this is interpreted as arising from a composite internal structure. No matter how small we then compress the wave packet for an atom's centre of mass motion, the atom as a whole cannot be made indefinitely small. At all times, therefore, both fundamental particles and composite objects have some varying finite size that depends on time and circumstances, and may be legitimately said to occupy the volume of this size in space. Whether they also *fill* that volume depends on the probabilities of interaction with instruments, which may be small or large, so is a matter of degree in a similar manner to the way that air 'fills' a room according to its pressure.

6.3.1 Wave Behaviour?

The substance-field does *not* have a fixed spatial size: sometimes it behaves more like a spread-out wave, and when at other times it interacts, it behaves like a localised particle. In fact, propensity fields can have practically any extensive shape over the places that are possible for it. We can allow that propensity fields are described by some kind of field equation, such as the Schrödinger or Dirac equation including the interaction potentials. They would be subject to boundary conditions set by the results of past actions, This gives continuous and wave-like propagation into the future, and allows them to propagate as wave packets around obstacles or potentials which would stop any classical atoms. They can even tunnel through barriers, as the probability for a definite interaction may be reduced but still non-zero. It becomes reasonable to expect the diffraction, interference and tunnelling effects we know in quantum physics from the solutions of Schrödinger's equation, even though we have no general grounds yet for choosing in particular equation.

6.3.2 Particle Behaviour?

On the basis of our account of propensity fields as substances:

- There are *no* such things as small particles like corpuscles with definite properties.
- *Nor* are there such things as small particles with uncertain or indeterminate properties.
- Measurements are *not* the process of assigning values to properties of particles, even if we allow that they are 'peculiar particles' in not having definite properties at all past times.

- *Nor* are measurements the momentary production of particles with definite properties for that moment.
- *Rather*, a electron is just *is* a propensity field.

To believe any of the above list (except the last) is to believe that somewhere, as it were hidden away behind the propensities, there really exist particles waiting to appear. This is not the case. Questions like 'Where is the electron and what is its speed?' have no answer, because there never exists such a thing as a small corpuscular electron. The only things that exist are propensity fields and the inter(actions) they produce. Propensity fields are not like vague, indeterminate or smeared-out particles, but are perfectly definite entities in their own right. It may not be determinate in advance which actions a propensity field will produce, but that does not mean that the propensity field is any the less real or definite when considered as a thing in itself. Its field structure can be described using perfectly definite mathematics. Its existence is as real and substantial as any existing object. In fact propensity fields are the very substances out of which all things are made! Nothing can be more substantial than them.

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* [a wave field]*, characterised by a set of quantum numbers, which is associated, in principle, with an identifiable event such as the momentum transfer in a "collision"*. We can therefore follow him as he redefines the meaning of the word 'particle' to refer to (something like) propensity fields.

6.3.3 Actual Selections

The concept of substance as dispositional contains the essential idea that they *do something*: that the dispositions are *for* some kind of event. Such events are characterised generically as 'actual events', because they have definite properties once they exist, and are selections between distinct possibilities that are arrayed like a field.

In quantum mechanics, these actual events are just the process of 'reduction of the wave packet' that physicists and philosophers have long discussed and sought for both theoretically and experimentally. The thesis of the present paper makes the physics prediction that such reduction or selection events *do* occur, and are therefore still worth seeking in nature.

The mathematical structure necessary to describe reduction events is by now plausibly given as a stochastic Schrödinger equation: for details see the review by Bassi and Ghirardi [2003] and references therein. The best known specific hypothesis is the GRW proposal of Ghirardi [1986], where fields are localised to narrow Gaussians. The GRW proposal has been criticised by Lewis [1997] as not a true selection because of finite tails of the Gaussians, and indeed it does not give a strict selection between spatial regions. What is needed in the present account, however, is not necessarily a strict *spatial* selection, but strict selection between alternative outcomes, or *histories* as these are usually now called. The theory of 'decoherent histories' shows that *almost*-decoherent histories are easily generated according to quantum mechanics. The present thesis states that there must be at finite time intervals some events in which these become *exactly* decoherent, but necessarily leaves open the precise conditions for such events.

Further philosophical work is also necessary to characterise what physics calls 'virtual events' as distinct from actual events. Virtual events, such as the emission and absorption of photons that constitutes the quantised electromagnetic field, occur continuously and do not cause actual selections. They are necessary to describe the potentials and processes that *compose* quantum objects. Further work is also necessary to elucidate how propensity fields for a system of say N particles is not just one object in $3N$-dimensional space, but a correlated state of a composite object of N parts, each in three-dimensional space, according for example to the work of Monton [2004].

7 Conclusion

This paper gives a simple summary of a 'pragmatic' or 'efficacious' approach to ontology, whereby what is necessary and sufficient for the dispositional causation of events is interpreted realistically, and postulated to exist. This leads to a general concept of 'substance', Aristotle's underlying 'matter', as being constituted by dispositions, and not just being the 'bare subject' for those dispositions. If we describe the forms of objects according their spatiotemporal range, then this form is best viewed as a field, and substances themselves are best conceived as 'fields of propensity', in a manner beyond a strict Aristotelian position.

With the help of such concepts, I have touched on how we can begin to understand some of the more mysterious quantum features of nature, such as the nature of 'measurements' as selections, the reasonableness of 'non-localities', and also the duality of wave and particle descriptions.

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