A PROCESS-BASED UNDERSTANDING OF CAUSATION AND EMERGENCE

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One of the crucial issues underlying the whole interactivist program has not, to my knowledge, been much discussed. It assumes an understanding of causation which is at odds with the prevailing neo-Humean understanding which prevails in contemporary analytic philosophy. The very concept of interaction presupposes that something acts upon something else to bring about some change. But, as Nicholas Capaldi pointed out in 1991, the denial of agency is one of the three identifying features of analytic philosophy.[1] That is not surprising. For the current orthodoxy amongst philosophers, at least in my part of the world, is a reductive form of metaphysics which goes by the name of "physicalism".

However, a small but growing number of philosophers dispute the adequacy of that understanding of causation. They argue instead for a revival of the concept of powers, which was discredited and rejected in the 17th Century. If the concept of *powers* is once again to be taken seriously, it must be shown *why* and *how* objects have powers. That is the challenge I will address in this presentation.

In the first part of my talk I shall discuss a recent book in which it is argued that powers are required to make sense of the success of reductive explanation in much of current science. In the second part I shall then argue that although that analysis of reductive explanation is plausible, its extension to causation in general is deficient precisely because it remains focussed on objects. I will argue that causation has to be understood to be grounded in *processes*, and that it is because objects are constituted by processes that causation can be attributed to them and that there is genuine ontological emergence.

One of my many disagreements with so much of contemporary analytic philosophy is its lack of any sense of history. For we cannot understand the questions we are trying to answer unless we understand how they have arisen. That is true of the issue of causation. So, in order to show why it is now time to reconsider the nature of causation a few historical remarks are in order.

By the dawn of the 17th Century the very possibility of attaining the kind of knowledge the medievals called *scientia* – knowledge of necessary truths describing the essences of substances – had become seriously problematic. The synthesis of Christian theology and Aristotelian metaphysics, forged in the 13th Century, was disintegrating. It was to establish the possibility of *scientia* on a new basis that Descartes wrote his *Meditations*. Since he had argued that the essence of matter is extension, all physics needs is geometry. Therefore, he declared that "final causes are useless in physics".[2] Expunging from physics the notion that

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1 Nicholas Capaldi, 'Analytic Philosophy and Language' in R. Harré and R. Harris (eds), *Linguistics and Philosophy* (Oxford: Pergamon Press), p. 47.

2 René Descartes, *Meditations*, IV.

things act to achieve ends also rendered the notion of powers otiose, since they too were supposed to have intrinsic objectives. Talk of powers had literally been laughed off the stage.

That is why it is so startling that a burgeoning number of philosophers are now advocating that such talk not only can, but must, be revived. Those advocates will have to present a very strong case if they are to convince those philosophers who regard themselves as hard-headed empiricists, lest they invoke the same scoffing rhetoric to dismiss this renewed advocacy as a retreat to occult and unobservable entities which have no place in modern science.

Given Descartes's dismissal of final causes, and Locke's insistence that we have no knowledge of the 'real essences' of things, David Hume relabelled efficient causes as "secret powers", remarking,

> We always presume, when we see like sensible qualities, that they have like secret powers, and expect that effects, similar to those we have experienced, will follow from them.[3]

He proposed that that expectation is all there is to our *idea* of a cause, and there is nothing in reality to justify that idea other than the fact that objects similar to what we call the cause are always followed by objects similar to what we call the effect. Contemporary debates about causation uncritically follow John Stuart Mill's lead and convert Hume's account of causation as constant conjunction into statements of necessary and sufficient conditions. That historical summary shows that the first step in the case for reviving powers must be to refute this neo-Humean understanding of causation.

I observe first of all that the consequent discussion of causation has become bogged down in inconclusive debates about a variety of questions. Is causation a binary relation between a cause and an effect, or does it also involve other *relata*? Are causes objects, or events, or facts, or states of affairs, or situations, or something else? How are causes individuated? Do they have to be defined relative to some comparison or contrast? Can absences count as causes? Is causation transitive? The list of problematic issues seems endless.

I surmise that these philosophical debates are so inconclusive because they uncritically presuppose the neo-Humean understanding of causation. It is becoming increasingly clear that that presupposition is false. Strict regularities of phenomena are rarely observed.[4] There are almost always exceptions because few observable phenomena are so isolated that their occurrence can be attributed to just one cause. What actually occurs is always the resultant of more than one influence being exerted in some region, because gravity is universal. Likewise, the operation of natural laws is regularly subject to interference by other influences. Even Newton's law of universal gravitation does not describe what we always observe, because we have all seen stones being thrown upwards, and birds and aeroplanes flying. Manifestly, the universality of natural laws has to be explained differently.

A more sophisticated way of explaining natural laws is to say that they describe the *dispositions* of things to manifest certain properties and behaviour when the conditions are appropriate, such as solubility. But because dispositions, like powers, are not always

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[3] David Hume, *An Enquiring Concerning Human Understanding*, §IV, Part II, 29.

[4] As Nancy Cartwright, for example, kept pointing out in her 'Do the Laws of Physics State the Facts?' *Pacific Philosophical Quarterly* 61:1–2 (1980), pp. 75–84; *How the Laws of Physics Lie*; *Nature's Capacities and their Measurement*; *The Dappled World: A Study of the Boundaries of Science*.

manifest, Humeans insist that they must be reducible to non-dispositional properties. But that insistence generates the same problems as the Humean interpretation of natural laws.

Identifying those deficiencies has led a small number of philosophers to challenge the neo-Humean understanding of causation. In the 1970s Rom Harré published a couple of articles and a book on *Causal Powers*, but they were largely ignored. However, over the past twenty years some philosophers have begun to argue that, in order to account both for causality in general, and for the explanatory function which laws serve in natural science, the concept of *powers* needs again to be taken seriously.

The book I propose to discuss is Richard Corry's *Power and Influence*, published in 2019, for he presents the most carefully worked-out alternative to the neo-Humean understanding of causation. Noting that reductive method of explanation has achieved remarkable success in many scientific contexts, he devotes the first half of his book to a meticulous analysis of it. That account provides the next, positive step in the case I am arguing.

It would take too long to report his analysis in detail, but it is relevant to mention its most salient points. Typically, reductive explanations are causal explanations, explaining the behaviour of the whole in terms of causal interactions between its parts.[5] Because this method works by identifying all those objects which, in the conditions prevailing, have influenced the production of that phenomenon, the first step in his analysis is to introduce the notion of basic objects:

> (**Basic Objects**): An object is *basic* with respect to an attempt at reductive explanation if, and only if, the explanation treats these objects as having no parts.[6]

That is, objects are 'basic' *relative* to some attempt at explanation. He says that they are "not necessarily fundamental atoms, but may themselves be complex entities like planets, people, or breeding pairs".

He then observes that all attempts at reductive explanation assume the existence of something which plays the same explanatory role, but this role cannot be fulfilled by anything in the standard ontologies.[7] They all involve a new kind of entity which he calls a "causal influence".[8] Because the reductive method is most spectacularly successful in the context of fundamental physics, there is good reason to think that causal influences are a fundamental part of reality.

To complement that addition to the sparse world allowed by the Humeans, Corry argues that it is necessary to distinguish carefully three different, but related factors: powers; influences; and changes. *Powers* are dispositions to exert *influences*.[9] The *manifestation* of a power is not typically a change in some property, but, rather, the existence of a causal *influence* which makes a contribution to such a change.[10] Influences combine to produce a *change* in the state of a system.[11] Defining powers in this way enables this analysis to

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5 Richard Corry, *Power and Influence*, p. 14.

6 Corry, *Power and Influence*, p. 14.

7 Corry, *Power and Influence*, p. 40.

8 Corry, *Power and Influence*, p. 20.

9 Corry, *Power and Influence*, p. 43.

10 Corry, *Power and Influence*, p. 48.

11 Corry, *Power and Influence*, p. 49.

accommodate the fact that what happens is almost always the result of the interaction of multiple influences.

Corry defines **basic powers** as a set of causal powers such that each power is distinct and that all influences that are relevant for the phenomenon are manifestations of powers in the set. Arguing that while some dispositions can be properly described by singular subjunctive conditionals, powers are best represented by mathematical functions, rather than by singular subjunctive conditionals,[12] he then defines the **explanatory basis** for some phenomenon *P* as a set of basic objects together with a set of basic powers for *P* such that each power in the set can be represented by a function whose domain is the state-space of some subsystem of those basic objects.[13]

He then argues that the following five assumptions underlie any attempt to provide a reductive explanation of some phenomenon *P* in a complex system *S*. They are :

(1) (**Supervenience**): There is a set of basic objects such that the relevant properties of that phenomenon supervene on the properties of, and the relations between, these basic objects.

(2) (**Limited Rank**): There is an explanatory basis for *P* in *S* which does not include any basic powers that have a rank greater than the highest ranked causal power in the explanatory basis being used, where the rank *n* is assigned to a power just in case that *n* basic entities are required to determine whether, and in what manner, that power is manifest.

(3) (**Changes Determined by Influence**): The changes in any property of a basic object at any time are determined by the set of all and only the basic influences which are individually directed towards changes in that phenomenon in that object at that time.

(4) (**Algebra of Composition**): In cases where there are more than two influences operating at the same time, we construct a rule which relates each pair of influences to a third, resultant, influence, and that composition rule can be used to calculate the resultant of any number of influences.[14]

(5) (**Influence Characterized by Effect**): Causal influences are uniquely characterized by the effect which they would bring about if they were acting in isolation.

Corry illustrates his definitions and principles by a wide variety of examples, from electrons to the ecology of populations. He shows how this account can accommodate a probability distribution over possibly manifested influences, so it is not necessarily deterministic. It is also able to accommodate the fact that, outside fundamental physics, it is likely that many, if not all, the powers and influences are composite rather than fundamental. And he argues successfully both that macroscopic powers can be composed of more fundamental powers, and that it is possible that there are some truly fundamental high-rank powers.

Since reductive explanations typically explain phenomena in terms of the behaviour of lower-level objects, I find this analysis convincing and commend it for your consideration. Both the widespread success of applying this method in the various sciences, and the

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12 Corry, *Power and Influence*, pp.58-63.

13 Corry, *Power and Influence*, p. 73.

14 Corry, *Power and Influence*, pp. 80-82.

universality of natural laws, requires this threefold model of powers, their manifestation as causal influences, and the observable changes those influences produce, typically in combination.

Another reason for commending his analysis is that it enables a clear definition of physicalism. Although many philosophers subscribe to this doctrine, no-one to date has been able to give a clear account of what exactly it is claiming, as Daniel Stoljar has demonstrated. Since physicalism is a reductive view, I offer the following as a definition of physicalism:

> All the things which exist in the universe either are, or are composed of parts which are, the particular objects found by physics to be found by physics to be fundamental in the sense that, in principle, the behaviour of them all is entirely explicable in terms of the properties and relations of those ultimate parts.

It is understandable why so many analytic philosophers have adopted this position. Most of them write in a Western language which prioritizes nouns over verbs. They accept the system of predicate logic introduced over a century ago by Frege and Russell in which quantifiers range over domains of particular objects. They are also heirs to a metaphysical tradition which for nearly two and a half millennia has assumed that the prime category of being is what Aristotle called "*ousia*" [entity], the medieval philosophers called "*substantia*", and which analytic philosophers today often call "objects" or 'basic particulars".

Moving on to the third step of the case I am presenting, Corry himself argues that there is a flip side of this analysis. He claims that "there is a close connection between the concept of emergence and the failure of reductive explanation", that is, emergence occurs "in situations in which the assumption of supervenience holds, but reductive explanation fails".[15] He claims that the existence of higher-rank powers limits the capacity of the second assumption, and that the fourth assumption – the Algebra of Composition – fails in complex cases. Those failures show that there exist phenomena which may legitimately be regarded as genuine cases of ontological emergence. Moreover, he rebuts three arguments mounted by Jaegwon Kim's objecting to the very possibility of emergence. Unfortunately, I do not have enough time to discuss Corry's arguments about emergence here; I simply commend his book for you to assess their cogency yourselves.

The fourth step is to broaden this analysis so that it applies to causation in general, which Corry attempts to do in Chapters Eight and Nine. He denies that causation can be simply identified with influence, on the grounds that causation is an abstract relation, while causal influences are entities as real as tables, electrons, and electromagnetic fields.[16] However, in a discussion of intuitions around causation as production, he considers a basic influence I – that is, an influence which is the manifestation of a single basic power – which is directed towards changes in some particular property of some basic object x. He asserts that:

> There will be a power P which belongs to part of some system (which includes x) will be part of some system which includes that object, such that the system's being in state S triggers the causal power P to manifest the influence I. It makes perfect sense to regard S as the productive cause of the change in x.

So, it seems that he is identifying the cause of a change as *the state of a system*, although he also comments that the influence I can be regarded as the physical embodiment of the causal

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15 Corry, *Power and Influence*, p.186.

16 Corry, *Power and Influence*, p.145.

relation. He recognizes what he calls "a connection of directedness" between cause and effect, but to explain it he draws on the account of causation just given.[17]

I find this account disappointing. Although the notions of a power and an influence are notions of something dynamic, the notion of the state of a system certainly is not. Corry had introduced a system as "a collection of basic objects together with all their properties and relations".[18] So, according to his account of causation, a cause is a set of objects. Of course, objects and persons are often identified as the cause of some occurrence, but so are items in many other categories. What I miss is any account which explicates what is common to all of these different kinds of cause.

Now, Corry is aware that there is a serious problem in attributing powers to fundamental objects or sets of objects. For in the final section of Chapter Three, he comments that if reality were as described by classical – that is, Newtonian – physics, then it would be very tempting to suppose that the most basic influences are the fundamental forces, and that these are indeed *sui generis* constituents of reality.[19] However, since quantum field theory – hereafter QFT – has displaced Newtonian physics as our best description of the fundamental nature of the world, Corry notes that one might be worried that it actually *contradicts* the arguments he has given. His response, however, is simply to note that the fundamental forces are commonly described as constituted by the exchange of elementary subatomic particles, and commenting that:

> Even if it is true that forces are constituted by the exchange of particles, these 'particles' are not like the objects that are found in standard ontologies. For QFT tells us that subatomic particles can also be viewed as 'field excitations', and, unlike ordinary particles, these field excitations can be added together (or *superposed*) in a similar way to forces.[20]

QFT challenges one of the bedrock assumptions of Western metaphysics, but instead of engaging with that issue, Corry comments "For the moment, then, the fundamental ontology of forces, and hence influences in general, remains unresolved". He suggests that it is possible that most basic influences might be constituted from more fundamental ingredients which are not themselves influences. In that case, the reductive method would not be applicable at this fundamental level. Or, influences might be a fundamental part of reality, in which case he says that it is likely that the fundamental influences include the fundamental forces.[21]

I also find it disappointing that, by formulating those two possibilities in terms of influences, he has sidestepped the challenge which he himself has recognized: that QFT appears to contradict the assumption at the heart of his arguments: that influences are the manifestations of powers, and powers are dispositional properties of objects. By not addressing that challenge he has left the plausibility of his whole account as a hostage to fortune. I was surprised to find this deficiency in Corry's analysis, since I find it to be a be plausible and illuminating analysis of reductive explanation. While I do not pretend to have sufficient expertise to unravel all of the notorious difficulties generated by quantum physics, I

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17 Corry, *Power and Influence*, p.147.

18 Corry, *Power and Influence*, p.15.

19 Corry, *Power and Influence*, p.40-41.

20 Corry, *Power and Influence*, p.41.

21 Corry, *Power and Influence*, p.41.

do have some thoughts to share concerning the challenge posed by QFT, which will provide the fifth step in the case I am presenting.

Corry offers one remark on the two possibilities he has articulated. He tells his readers to "Note that fundamental influences need not be forces". He justifies that claim by citing the four-dimensionalist view of the universe and pointing out that a natural way to make sense of that interpretation of spacetime is to propose that a three-dimensional object at a given time produces an influence directed toward the existence of a similar three-dimensional object at a later time. Many analytic philosophers are predisposed to adopt such an interpretation of the universe as a four-dimensional 'block' because they inconsistently combine their professed empiricism with an understanding of logic which assumes that truth is timeless – a conception of truth inherited from Plato.

But that interpretation of the universe in which we live is simply incredible. The universe is full of movement and is populated by living creatures who exist by performing future-related actions. Not only that, but also the spatializing of time involved in that interpretation of the universe is inconsistent with the General Theory of Relativity, which has been confirmed over the past 100 years by increasingly fine-tuned astronomical observations. As the theoretical physicist Carlo Rovelli has pointed out, at the core of general relativity is a *radical relationism*. There is no independent 'background' framework of spacetime within which three-dimensional objects could be located. Spatiotemporal locations can be distinguished only relative to other spatiotemporal locations. So the argument which Corry invokes to support his claim that fundamental influences need not be forces is not sustainable.

When quantum mechanics first emerged early in the 20th Century, it had two features which generated deep puzzlement and debate. The phenomena seemed to manifest both wave-like and particle-like features. The famous two-slit experiment seemed to show that photons are waves, whereas single spots on a photographic plate, tracks in a bubble chamber and clicks on a Geiger counter seemed to show that photons are particles. That apparent contradiction was essentially resolved by Paul Dirac, who proposed an interpretation of relativity theory in which these subatomic phenomena are explained by quantizing Maxwell's electromagnetic field. Dirac then extended that analysis to apply also to electrons, and further refinements have been made to QFT since.

Those phenomena were puzzling enough, but even more puzzling was a principle which Werner Heisenberg proposed in 1927. It seems that a quantum 'particle', such as a photon or an electron, can be described by a wave-function which specifies the evolving probabilities of its possible trajectories but so long as it is not measured, it has neither a determinate location nor a determinate momentum. Yet when such a 'particle' is detected, either its location or its momentum becomes determinate – but not both. This strange phenomenon came to be called "the collapse of the wave-function". Initially this 'collapse' was understood to be a fact about observation, but that was a mistake. The so-called 'collapse of the wave-function' happens whenever a quantum system interacts with *any* other.

Also in the early decades of quantum physics many physicists advocated a theory in which fields and particles were both acknowledged as associated, but over the past forty years leading quantum field theorists have developed 'a pure fields view'. The physicist Art Hobson published a representative exposition of this view in 2013 under the title "There are no particles; there are only fields". Explaining how a quantum field fluctuates back and forth like a harmonic oscillator, he asserts that even a quantum field which is in the so-called 'ground state' of a space devoid of all so-called 'elementary particles' cannot sit still, because of the so-called uncertainty principle. So, he comments that:

> an important feature of QFT is the existence of a vacuum state, which manifests itself experimentally in many ways, which would be curious if particles were really fundamental because there are no particles (quanta) in this state.[22]

He observes that:

> Some authors conclude, incorrectly, that the countability of quanta implies a particle interpretation of the quantized system. Discreteness is a necessary but not sufficient condition for particles. Quanta are countable, but they are spatially extended and certainly not particles. [23]

Hobson's thesis attracted objections from a number of physicists, who argued that "quantum fields are no more fields than quantum particles are particles"[24] and "in addition to there being no particles, there are not even fields".[25] They insist that the state of a quantum system is an abstraction. Hobson rebutted the technical objections posed by his critics, and on the issue of the reality of fields replied that: "There is no reason to regard quantum fields as less real than rocks. Indeed, rocks are made of them".[26]

It appears from my reading that the debate between the realist and the instrumentalist interpretations of quantum field theory continues to be a standoff. But I suggest that there is a way of moving beyond it. I invoked above Rovelli's radically relational interpretation of general relativity. Since on his interpretation there is no absolute viewpoint from which a can be observed, he infers that:

> In quantum mechanics different observers may give different accounts of the same sequence of events.[27]

That leads Federico Laudisa and Rovelli himself to assert:

> The physical world must be described as a net of interacting components, where there is no meaning to 'the state of an isolated system', or the value of the variables of an isolated system. The state of a physical system is the net of the relations it entertains with the surrounding systems.[28]

Consequently, Rovelli argues that the wave function is merely a predictive, instrumental device with no ontological role; it does not stand for something real, but simply records the probabilistic outcomes of previous interactions between systems of a certain kind.

However, I share Hobson's realist intuitions. To say that *all* we can know at the quantum level are discrete events which occur when an observer interacts with such a system is one thing; to deny that anything real is happening in between such interactive events is

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22 Art Hobson, 'There are no Particles; There are Only Fields, *American Journal of Physics*, 81.(3), 2013. p. 214.

23 Art Hobson, 'There are not particles, there are only fields' pp. 211-223.

24 Massimilano Sassoli de Bianchi, 'Comment on "There are no Particles, There are Only Fields" by Art Hobson', *American Journal of Physics*, 81(9), 2013, p. 707.

25 Robert J. Sciamanda, Letters to the Editor, American Journal of Physics, 81(9), 2013, p.645.

26 Art Hobson, 'Hobson Responds', *American Journal of Physics*, 81(9), 2013, p. 645.

27 Carlo Rovelli, 'Relational Quantum Mechanics', *International Journal of Theoretical Physics*, 1996, pp. 1637-78, Revised 2008.

28 Laudisa, Federico and Carlo Rovelli, 'Relational Quantum Mechanics', *The Stanford Encyclopedia of Philosophy* (Spring 2021 Edition), Edward N. Zalta (ed.), URL = <https://plato.stanford.edu/archives/spr2021/entries/qm-relational/>.

something else. What is the "it" with which an observer interacts? And if quantum fields are real only intermittently, how can rocks, which certainly are real, be made of them?

In an extensive evaluation of Rovelli's relational quantum mechanics, Mauro Dorato notes that his relationist interpretation of quantum physics can be formulated in two different ways.

> either it *does not make sense* to talk about a quantum non-interacting system, or, to put it more metaphysically, non-interacting quantum systems have no intrinsic properties, except *dispositional* ones.[29]

Rovelli does not describe quantum systems as having "dispositional properties", but Dorato's introduction of them in this context is both insightful and brilliant. For that notion enables Rovelli's position to be interpreted in a way which is both coherent and satisfies the realist intuitions I endorsed above. For if the properties of such systems are dispositional, it becomes possible to acknowledge the reality of the wave-function even though whenever that disposition is isolated, its state is probabilistic and indeterminate. Furthermore, there is no need for such a disposition always to be manifest, for that is true of any disposition. Yet one of those probabilities can become determinate when the system interacts with another such system. Thus, it is possible to accommodate Heisenberg's so-called uncertainty principle, without adopting a purely instrumentalist interpretation of it. Laudisa and Rovelli commend Dorato's analysis as fitting "particularly well in the context of Relational Quantum Mechanics". Since dispositional properties are real, that endorsement should have led them to modify their earlier instrumentalist claims.

Another question Dorato asks is: "How can we identify the 'same' sequence of events within a relationist view of quantum mechanics?" He answers that stressing the relationality of the identity of process systems:

> helps us to realize how the identity of a sequence of events, i.e., the *processes* that characterize the primitive ontology of the theory, is relative to the different observers.

The argument he presents to support that contention is too technical to repeat here. But to secure the next step in the case I am building it is enough to highlight that Rovelli must be referring to *processes* when he speaks of "the same sequence of events". That makes it clear that the primitive ontology of QFT must consist not just of fields, but of fields which are always *in process*. Like harmonic oscillators, quantum fields are constantly in a state of excitation. Consequently, the so-called 'elementary particles' are not particles at all; they are *processual* in nature.

I propose that Dorato's interpretation dissolves the problem which ungrounded influences generated for Corry's account of influences. Once the processual nature of these vibrations in quantum fields is recognized, it becomes obvious that processes were already implicit in describing the so-called 'particles' of QFT as "excitations.

This finding provides what I discerned to be missing in Corry's account of causation. Whilst he nominated basic objects as the bearers of powers in the case of reductive explanations, if influences are the manifestations of powers, and powers are dispositional properties only of objects, then his case is undermined by the fact that so-called subatomic particles are not particular objects. We have now found good reasons to say not only that

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[29] Mauro Dorato, ' Rovelli's relational quantum mechanics, monism and quantum becoming', in in *The Metaphysics of Relations*, Anna Marmodoro and David Yates (eds.), (Oxford: Oxford University Press), 2016, pp. 235–262.

quantum fields are always in process, but because they are dispositional in nature, it is processes which are the ultimate bearers of powers to manifest influences upon each other and upon higher-level entities.

It follows from QFT that *all* the standard ontologies are obsolete, and must be either abandoned or radically revised. We have seen that the ambition of physicalists is to reduce everything to the particular objects found by physics to be fundamental such that the behaviour of everything is entirely explicable in terms of the properties and relations of those ultimate parts. But if there are no basic particulars, the metaphysical assumption upon which physicalism is based is simply false. The irony of modern analytic philosophy is that its adoption of physicalism makes it appear to be state-of-the-art and scientifically literate, whereas it is in fact the lingering hangover of an ancient metaphysical model which is inconsistent with the findings of physics itself.

Since quantum fields in process are the best candidates we currently have for what is fundamental in the universe, this finding has significance for the whole of metaphysics. As I argued in my 2015 book, *The Metaphysics of Emergence*, it is no longer tenable to promote metaphysical models which accord ontological priority to particular objects. What is needed to understand the world better is nothing less than a metaphysical revolution which reverses ontological priorities, so that the primary category of being is understood to be generic processes. In a metaphysical model based on processes, particular objects are emergent, not basic.

Processes are a *sui generis* category, largely neglected by philosophers. While Whitehead is standardly classified as a process philosopher, he was unable to recognize the *continuity* of processes – perhaps in deference to the discoveries in the early days of quantum mechanics. For he wrote "continuity concerns what is potential, whereas actuality is incurably atomic".[30]

When we think about processes in general, it becomes obvious that they are different from both objects and properties. They are *somewhat* like objects in being concrete, having properties and spatiotemporal locations, and causally influencing each other. On the other hand, processes are *somewhat* like properties in being able to occur, with varying degrees of intensity, in different periods and in different regions of varying sizes.

Most significantly, however, is the fact that a process consists in something happening continuously as it moves forward in time. Because it is inherent in every process that it is flowing forward, it is that 'towardness' which endows them with power. For processes necessarily have both *momentum* and *direction*; they are necessarily future-orientated. Flows of air and water, for example, can wreak great destruction. Because processes have momentum, they have both mass and velocity. Provided a process keeps flowing, the greater the momentum of a process, the greater is the force, or influence, it exerts on other processes which are entering the same locality at the same time. That is why processes are what justifies the revival of the concept of powers, and why the forces exerted by processes are what distinguishes causation from mere correlation. Accordingly, I claim that it is processes , not states, which are what exert the powers which are *manifested as* causal *influences*, and therefore are the ultimate bearers of powers.

For centuries people have utilized the force of the wind to sail ships and to turn the sails of windmills to harness its energy. While that is true of causation in general, the processes working in quantum fields are what ground the influences which so-called subatomic

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30 A.N. Whitehead, *Process and Reality*, 1929, p. 95.

'particles' have upon each other as they interact. Some antirealists about QFT object to talk of forces in that context, insisting that forces make sense only in the context of Newton's laws. But that is simply false. Three of the four fundamental forces are integral to QFT.

I submit that the process-based metaphysical model I have just sketched presents an even stronger case for the reality of powers than the case Corry has presented. The refutation of physicalism does not rule out the possibility that the properties and behaviour of every observable thing supervene upon physical processes. But it does imply that ontological emergence is possible.

Since so-called elementary particles are not particles at all, but are processual in nature, they exert the forces which bind electrons, protons, and neutrons into forming atoms of all the different kinds which feature in the Periodic Table of Elements. The way those atoms are organized is what enables them to bind together to form molecules which not only have properties and relations, but *also* are incessantly vibrating process-systems. Macroscopic objects are likewise integrated process-systems which have emerged as relatively stable wholes with different degrees of vulnerability to destruction depending on the type and strength of the bonds which constitute them. Consequently, powers may also be ascribed to particular objects, but the powers of objects are derivative from the way the processes which constitute them are interacting.

Anyone who is having trouble understanding how macro-objects emerge from the way in which their constituent processes have organized themselves needs only to reflect upon the fact that everything in the universe has some temperature. As we now know, heat is kinetic, that is, processual. We observe, for example, water evaporates, and lowering its temperature causes water to freeze into a solid block of ice: a phase change. We also observe that raising the temperature of water turns it from a liquid into steam: a different phase change. Furthermore, when water is heated, a primitive form of self-organization emerges, with the formation of Bénard cells. Again, it is the kinetic nature of heat which produces the processes which constitute Mark's paradigm of a process-system which is self-maintenant: a candle flame. While these are inorganic examples, living creatures appeared on this planet when certain process-system emerged which are *recursively* self-maintenant.

I submit that once powers are understood as inherent in processes, the accusation that to speak of them is to admit occult and unobservable entities into one's ontology is quite baseless. The fact that processes exert observable influences on what happens is no more mysterious, or secret, than the fact that while we cannot observe the wind, we regularly see and feel its effects. Processes and their influences are everywhere around us and in us, all the time, constituting the objects we see and enabling the emergence of life.