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Hansson Wahlberg, Tobias

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PO Box 117
221 00 Lund
+46 46-222 00 00

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Meso-level Objects, Powers, and Simultaneous Causation

Tobias Hansson Wahlberg

Lund University

Abstract:

I argue that Mumford and Anjum's recent theory of simultaneous causation among powerful meso-level objects is problematic in several respects: it is based on a false dichotomy, it is incompatible with standard meso-level physics, it is explanatory deficient, and it threatens to render the powers metaphysics incoherent. Powers theorists are advised, therefore, to adopt a purely sequential conception of causation.

1. Introduction

In their book *Getting Causes from Powers* (Mumford and Anjum, 2011), Stephen Mumford and Rani Lill Anjum develop an anti-Humean powers-conception of causation. Drawing on earlier work by philosophers such as Aristotle (e.g. *Metaphysics*, Theta 5), Mellor (1974), Harré and Madden (1975), Shoemaker (1980), Ellis (2001), Molnar (2003) and Mumford himself (e.g. 1998, 2004), Mumford and Anjum argue that the properties of meso-level objects are irreducible powers (or dispositions, such as being water-soluble) that together with appropriate stimulus conditions (e.g. water) cause characteristic manifestation effects (e.g. a sugar cube dissolving in a glass of water). They part company with many powers theorists, however, in that they hold that powers never necessitate their effects (Ch. 3) and that causes and their effects are simultaneous (Ch. 5). In this paper, I argue that Mumford and Anjum ought to give up the latter claim for a number of reasons:¹ their theory of simultaneous causation is based on a false dichotomy (Section 2), is incompatible with standard meso-level

¹ Elsewhere I have criticized the powers conception insofar it involves a redundant postulation of both active and passive powers for the same effect (Hansson, 2006; see also Hennig, 2016). For an objection to the claim that powers never necessitate their effects, see Lowe (2012). Note, though, that if one holds that powers are indeterministic propensities (e.g. Dupré, 1993, Ch. 9), giving up necessitation, or sufficient conditions, is not radical. What is unorthodox about Mumford and Anjum's view is that they reject necessitation and sufficient conditions without (necessarily) endorsing propensities.

physics (Section 3), is explanatory deficient (Section 4), and threatens to render the powers metaphysics incoherent (Section 4).

In what follows, I shall assume the reader is acquainted with the basics of the powers metaphysics, as do Mumford and Anjum in their book (2011: 4). I will turn my attention directly to simultaneous causation among powerful meso-level objects.

2. A false dichotomy

Why believe in simultaneous causation? Well, apart from giving putative examples of simultaneous power-causation among meso-level objects (addressed below, Sect. 3), Mumford and Anjum offer the following principled reason for believing in simultaneous causation: “Either causation is simultaneous and effects occur immediately once the causes are assembled, or there is a time gap between causes and effects” (Mumford and Anjum, 2011: 111). They reject the second disjunct because it allegedly issues in a regress:

Suppose we have some assemblage of causes: then either their effect begins as soon [i.e., at the same time] as the causes are assembled, which [is] the position we will defend, or it doesn’t. Suppose it doesn’t and there is some gap between cause and effect. Then what, after such a gap, produces the effect? One might say that nothing makes the effect occur, after the gap, conceding that one cannot answer the question. Alternately, one might say that something more does occur that explains why the effect did eventually happen after a time interval. But then shouldn’t this further factor be considered one of the causes of the effect, among the others, and shouldn’t we then say that once it is in place, along with everything else, then the effect occurs immediately? If we deny this, and allow a gap between this assemblage of causes and its effect, we are left with exactly the same question again. What else was needed for the effect to occur? (Mumford and Anjum, 2011:111)

The first thing to be noted about this argument is that it alludes to the idea that there must be something *extra* after the assemblage of the putative causes—in effect, *simultaneously* with the onset of the effect—that ultimately produces (and explains) the effect. (Mumford and Anjum ask, for example: “Then what, after such a gap, produces the effect?”)² This notion is

² An anonymous reviewer for *Metaphysica* maintains that Mumford and Anjum are probably (although they do not state this explicitly) motivated by the (putatively) Aristotelian position that for a cause to affect an effect, it must exist at the same time as it. Such a view of causation is possibly expressed in

as such question-begging since the denial of simultaneous causation involves precisely the claim that causes and effects do *not* ensue at the same time. What makes the simultaneity option compelling here, I think, is rather Mumford and Anjum's premise that rejecting simultaneity commits one to postulating a *time gap* or a *time interval* between the causes and the effect. If such a gap is postulated it can reasonably be asked: Why does the effect occur after that precise interval, and not earlier or later (Mumford and Anjum, 2011: 106, 111)? Also, such a view seems to be in conflict with the "No action [or production] at a temporal distance" principle, commonly endorsed by philosophers (see e.g. Humer and Kovitz, 2003: 561), even by philosophers *not* defending simultaneous causation (e.g. David Hume, 1740/1978: 75)).

However, in this section I shall argue that the dichotomy upon which Mumford and Anjum's argument is based—i.e., that either causation is simultaneous or there is a time gap between causes and effects—is simply mistaken: causation can be non-simultaneous *without* there being a time interval between cause and effect.

Mumford and Anjum apparently rely on the reasoning of Bertrand Russell in his famous paper "On the Notion of Cause" (Russell, 1912-1913; see Mumford and Anjum, 2011:111). Russell claims that if time is dense (or "compact"), cause and effect must be separated by a positive time interval, unless they overlap in time (Russell, 1912-13: 5). The implicit reason is this: if time is dense, then between any two instants of time there is a third instant; consequently, there are *infinitely* many distinct instants between any two instants of time. Thus, if the cause ceases to be or operate at instant t , and the effect does not yet exist, the effect can only begin to exist at some later instant t^* separated from t by some positive interval Δt constituted by the infinitely many instants existing between t and t^* .³ However, Russell does not consider *open* (here symbolized (t, t^*)) and *half-open* ($(t, t^*]$ or $[t, t^*)$) time intervals, i.e. intervals that contain all of the instants between t and t^* but lack either t or t^* (i.e. $(t, t^*]$ or $[t, t^*)$) or both $((t, t^*))$. Given open and half-open time intervals, it may very well be that while the cause exists through the closed interval $[t, t^*]$, the effect exists, for

Aristotle's *Physics* (see Book II, Chapter 3, and Book III, Chapters 1-3—but see the *Metaphysics*, Lambda 3, for a seemingly contrary view). However, it is question-begging to rely on such a view of causation in an argument for simultaneous causation. It should moreover be noted that there are modern Aristotelians who explicitly deny that effects are simultaneous with their causes: see e.g. Ingthorsson (2002: 113) who maintains that "interactions [causal productions] always precede their effects in time" (although he holds that the objects involved in the interaction co-exist); see also Ingthorsson (2007).

³ However, to constitute a positive interval, arguably the instants (each of zero duration) must not only be densely ordered (as assumed by Russell), they must form a *continuum*, i.e. the instants have to be *uncountably* many; otherwise Zeno's paradox of metrical extension kicks in (see Grünbaum, 1967: 129-135).

example, through the half-open interval $(t^*, t^{**}]$. In such a case, cause and effect are *not* separated by a positive time interval Δt , although they do not overlap temporally. In the example in question, there is no *first* time of the effect's existence, although there is a *last* time of its non-existence (and of the cause's existence), namely instant t^* . In a case of overlap, cause and effect can still be non-simultaneous in the sense that they do not *begin to exist* at strictly the same time—which, in fact, is the sense of non-simultaneity which Mumford and Anjum are primarily discussing and rejecting⁴—even if there is no positive time interval separating their “onsets”. For example, the cause may exist over the closed interval $[t, t^*]$ and the effect over the half-closed, overlapping interval $(t, t^*]$. (Note that other combinations of half-open/open/closed intervals can be utilized to make the essential point; cf. e.g. Mellor, 1995: 230.)⁵

Now, this rejection of the dichotomy presupposes that the cause or the effect are non-instantaneous (in the sense of existing at more than one instant). But this presupposition is in line with Mumford and Anjum's own theorizing: they explicitly defend the view that causes and effects persist. More specifically, they hold that causes and effects are, or fundamentally involve, enduring powers of enduring meso-level objects (pp. 1-3, 116, 122-123; see also Mumford, 2009).⁶

Admittedly, nothing of what I have said in this section forces Mumford and Anjum to abandon simultaneous causation. The point of this section has rather been to highlight that their principled argument for endorsing simultaneous causation is based on an oversight.

⁴ They write, for example: “For causes and effects to be simultaneous, on the other hand, they must entirely coincide temporally. [...] For causes and effects to be simultaneous, however, requires that they be instantaneous in the [non-standard] sense that the effect would commence as soon as the cause commences, or is in place.” (Mumford and Anjum, 2011: 112; see also pp. 111-112, 122-124)

⁵ Just to mention a further illustrative example: the cause may exist over the closed, degenerate interval $[t, t]$ and the effect over the open interval (t, t^*) .

⁶ They write, for example: “It is properties that do the causal work, and they do so because they are powerful. [...] A world of powers suggests a world of active, dynamic particulars (see Harré and Madden 1973) and there are some problems in squaring that with time-slice views of persistence and change. [...] Instead, an ontology in which particulars and events *endure* through processes is more suitable to dispositionalism.” (Mumford and Anjum, 2011: 1, 26, 116, my emphasis). Their reference to events and processes complicates the picture though. Processes and non-instantaneous events are usually understood as *perdurant* entities that persist by having distinct temporal parts at distinct times (see e.g. Mellor, 1998: 85-87). (Perdurance is to be contrasted with endurance which involves persisting by being “wholly present” at distinct times as numerically the same entity; see Lewis, 1986: 202.) Moreover, a process of *continuous* change will have to involve a continuous succession of *instantaneous* events, states, or states of affairs (see also below, footnotes 18 and 21). This is so even if the *object* undergoing the continuous change itself endures through the process. Thus, if Mumford and Anjum want to reject instantaneous entities altogether (see e.g. Mumford and Anjum, 2011: 116), they need to reject continuous change—a phenomenon they in fact tend to endorse (e.g. pp. 116, 124).

Before I move on I should point out that another obvious way of rejecting the dichotomy—acknowledged by Mumford and Anjum (p. 112)—is to hold, with Hume (1740/1978: 31), that time is *discrete* (each atom of time being followed by a *next* atom of time, except for the last one, if there is one) and that there consequently are no time gaps between consecutive “chronons” (i.e. temporally extended atoms) of time. Alternatively, one could simply accept the separation thesis but maintain that such time gaps are always filled by mediating causes and effects (allowing for transitive causal chains). On the latter view, there will be no *unmediated* action (or production) at a temporal distance (cf. Mellor 1998: 110). Of course, this solution is unavailable to Mumford and Anjum unless they give up their hostility to instantaneous events (pp. 116, 121).

3. Against simultaneous power-causation among meso-level objects

As we have seen, Mumford and Anjum’s principled argument for believing in simultaneous causation is based on a false dichotomy. I will now argue that causation understood as a “passing around of powers” (Mumford and Anjum, 2011: 5) among meso-level objects is in conflict with standard meso-level physics—in particular with the special theory of relativity (STR)—if the passing and the acquisition of the power occur simultaneously.⁷

According to STR, nothing—forces included—can move or propagate faster than 299 792 458 m/s, the speed of light in a vacuum (commonly denoted c), which is the same in all reference frames. Thus, if powers are “passed around” over a spatial distance, the passing and the acquisition cannot occur at the same time. Mumford and Anjum acknowledge this general speed-limit to causal propagation (p. 119), but go on to argue that the limit is compatible with simultaneous causation assuming that causes and their effects are *co-located* in space (p. 121). Moreover, they maintain that in their paradigm meso-level examples, cause and effect *are* co-located in space:

⁷ According to Mumford and Anjum, the manifestation of a power, or of interacting powers that are “mutual manifestation partners”(pp. 2-3, 34-35), is itself a power. A fragile glass hit by a hammer breaks, and thereby “it” (the broken glass) acquires the power to cut (pp. 6-7). A free-standing billiard ball hit by another billiard ball acquires the second ball’s momentum, which is a power according Mumford and Anjum (p. 6). Both sorts of causation—i.e. irrespective of whether the manifestation power is strictly speaking of the same type as the stimuli powers—are referred to as a “passing around of powers” by Mumford and Anjum (p. 5).

Our cause and effect are co-located. The melting of the ice cube is a process occurring in the glass [of water], the stove is in the same room it heats, and the colliding billiard balls touch. (Mumford and Anjum, 2011: 121)⁸

Initial objection: the relevant meso-level objects in the examples are clearly not co-located as *wholes*. At best, the objects are co-located at their borders. More appropriately put, at best only some of their *proper parts* at the micro-level are co-located. But even that can be seriously questioned.⁹ Let us, however, for the sake of the argument assume with Mumford and Anjum that the relevant meso-level objects *are* co-located, at least at their borders. Disregard moreover the objection that the relevant causation (the passing around of powers) has to propagate *within* the relevant meso-level objects or substances, *from* the co-located proper parts *to* the other proper parts of the object/substances, at no speed faster than c . That is, let us assume that the *local* causation occurring at the objects' borders, occurring at the micro-level, simultaneously results in the acquisition of genuine meso-level powers by the relevant objects/substances understood as *wholes* (whereby we also violate STR's relativity of simultaneity of spatially separated events). This assumption, in conflict with relativity theory, is needed if we are going to postulate, and investigate, simultaneous causation at the *meso*-level.¹⁰

Additional difficulties ensue: conservation laws holding in both classical and relativistic mechanics are violated (cf. already Poidevin, 1991: 89). Let me illustrate this by discussing Mumford and Anjum's analysis of Hume's "perfect instance" of causation: two billiard balls colliding.

Mumford and Anjum conceptualize the scenario as follows:

A ball rolls across the surface. It has momentum—a disposition to movement—which it manifests in rolling. It strikes a second ball which then moves along the table while the first ball stops. The power of momentum has been passed from the

⁸ They also mention examples such as Kant's ball on a cushion, two books leaning against each other, a magnet sitting on the front of a fridge, a locomotive pulling a truck, someone lifting a book, and so on (Mumford and Anjum, 2011: 114, 206).

⁹ Smith and Varzi (2003), for example, argue that physical objects with non-arbitrary "bona fide" spatial boundaries (as Mumford and Anjum's examples seem to involve) are never co-located, nor even in strict spatial contact; see also Glynn (2012: 1103). I admit, however, that things become hazy when we start speaking of elementary particles, since they do not have a determinate position in space, at least not if their momentum is determinate (see Heisenberg's uncertainty principle, e.g. in Benson, 1995: 868).

¹⁰ See footnote 15, below, for discussion of what the bearer of this meso-level power could be taken to be if the power is total momentum and the proper parts of the relevant object are moving relative to each other.

first ball to the second, and could be transferred to a third or fourth (though again with a caveat that some of the power is lost because of the friction between the ball or the cloth). [...] In the cases of heat and momentum, the same power in the cause is passed on to the effect, which acquires the power. (Mumford and Anjum, 2011: 6; for their more detailed account, see pp. 108-109)

To get rid of the friction issue, the billiard balls can be taken to collide in outer space (an astronaut, say, hurls a billiard ball at another billiard ball, considered to be at rest). More generally, let us assume that the billiard balls, as a system, are not subjected to *any* external forces (after the throw).

Now, Mumford and Anjum hold that momentum is a power which manifests itself (simultaneously, p. 109) in movement. This is no doubt already in tension with both classical and relativistic mechanics according to which momentum simply *is* mass times velocity (and in STR, times the stretch factor): in these theories, movement or velocity is a *component* of momentum; it is not held to be *caused* by momentum. But disregard this and also the fact that momentum is not an *intrinsic* property¹¹ but a frame relative phenomenon in both classical and relativistic mechanics;¹² i.e. follow Mumford and Anjum in construing momentum as a power.

Now, assume first, for simplicity, that the billiard balls are perfectly rigid and that the collision is instantaneous, occurring at an instant of time t . Then, if a 's momentum is passed to ball b at t — b acquiring the momentum (the effect) *simultaneously* with a being, for the last time, in possession of its momentum—the *sum total* of the objects' momenta is doubled at t . The consequence is that the law of conservation of system momentum is violated at t , a law holding of isolated systems in both classical (at low relative velocities) and

¹¹ Powers—understood as genuine properties, as opposed to applicable dispositional predicates—are standardly taken to be intrinsic properties; see e.g. Harré and Madden (1975: 86-87), Ellis (2001: 106, 112), Molnar (2003: 108-110), and Bird (2007: 29-30).

¹² Relative to one inertial reference frame, a 's momentum may be positive, relative to another it might be zero, and relative to yet another it might be “negative” (depending on the orientation of the coordinate axes). Newton of course postulated absolute space, but “absolute velocity” is still a kind of *relative* motion, namely velocity relative to absolute space. Moreover, note that in Galilean space-times, which have structure sufficient for classical mechanics, absolute velocities do not exist at all (although absolute accelerations do); see Maudlin (2012, Ch. 3). Mumford and Anjum are not alone, however, in treating momentum as an intrinsic property. For example, Aronson's influential transference theory of causation (1971) seems to involve this mistake as well; for discussion, see Fair (1979: 240). Fair argues that the “transference” of momentum and kinetic energy (and hence causation, on the transference theory) instead is a frame-relative phenomenon.

relativistic mechanics (see e.g. Benson 1995: 174, and Taylor and Wheeler 1992: 209, respectively).¹³

Assume next that the collision occurs during a brief interval of time (the billiard balls, now construed as non-rigid, undergoing slight compression and decompression during the collision), as Mumford and Anjum maintain it does (p. 109). Under this assumption, suppose initially that the transfer of *a*'s momentum to *b* is divided into *discrete steps*.¹⁴ That is to say, assume that quantized packages of momenta Δp are transferred from *a* to *b*¹⁵ at distinct chronons (if time is discrete) or at distinct instants of time separated by finite

¹³ An anonymous reviewer for *Metaphysica* suggests that a defender of simultaneous causation could try to circumvent this objection by adopting Franz Brentano's theory of coincident moments, as characterized in his (1988). It is not completely obvious, however, how the argument would go, and I therefore leave its exact development to the defenders of simultaneous causation. Presumably, though, the idea is to exploit Brentano's concept of *plerosis* – roughly, the notion that spatial and temporal boundaries are boundaries in *various directions* in *n*-dimensional space or in one-dimensional time, and that boundaries thus can be said in a certain sense to have “parts” although they are not extended (Brentano, 1988: 11; see also Körner and Chisholm, 1988: xvi-xvii). A defender of simultaneous causation could then hold that an object that begins to move at a certain (present) instant both has and does not have a certain momentum at that instant (which is a mere boundary between the relevant, coinciding, past and future time intervals): the object has momentum in relation to the future-directed plerosis of the boundary but no momentum in relation to the past-directed plerosis of the boundary (or the other way round if the object ceases to move). As Brentano himself puts it, when discussing the motion of an object that suddenly goes in reverse: “What we must say in this latter case is rather that the two movements in opposite directions touch each other in time and that in one and the same present moment, whose plerosis is two-sided, the body experiences two opposite motions in half plerosis, each having a plerosis in relation to a different side.” (Brentano, 1988: 30). In our case of the two colliding billiard balls, the idea would presumably be that the conservation law is not violated at instant *t*, because *t* is strictly speaking a boundary with a two-sided plerosis, and the conservation law must not be evaluated relative to *t simpliciter* but relative to the plerosis-aspects of *t*: *a* has but *b* does not have momentum relative to *t*'s past-directed plerosis, and *b* has but *a* does not have momentum relative to *t*'s future-directed plerosis. However, an account which holds that an object both has and does not have a certain momentum at a certain non-extended instant *t* is dubiously coherent (cf. Varzi, 2013). Moreover, such an account looks even less coherent when it is specified that momentum is an *intrinsic* power which an object has (or does not have), at a time, *in relation to* the time's plerosis-features. Also, the notion of plerosis simply does not figure in accounts of momentum in physics. I doubt that modern defenders of simultaneous power-causation would want to take this path.

¹⁴ Mumford and Anjum seem in general to favour *continuous* changes (e.g., pp. 116, 124), but in order to cover logical space I begin by considering the case where momentum is transferred in discrete steps. (In fact, in some places Mumford and Anjum express a wish to be neutral about the structure of time: see e.g. pp. 112, 120-121. If time is discrete, then fundamentally time consists of discretely ordered chronons; and in discrete time, change *has* to be ultimately discrete.) Continuous transference of momentum is addressed in the text below.

¹⁵ I assume that Mumford and Anjum—although they are silent on the issue—would want to say that *a*'s momentum (a real meso-level property, on their scheme of things) is transferred to *b*'s *center of mass* (from *a*'s center of mass). Centers of mass are standardly taken to be the “bearers” (although for pragmatic reasons) of meso-level objects' total momentum in physics (see e.g. Benson, 1995: 198). I do not see where else this putative meso-level property, realistically construed, could be instantiated or inhering *when the proper parts of the relevant non-rigid meso-level object are moving relative to each other*. Note also that *a*'s center of mass and *b*'s center of mass will not be in contact during the billiard balls' collision (unless both *a* and *b* get *completely* compressed in the process). In physics, the location of an object's center of mass is kind of statistical location, a weighted average of the locations of the object's constituents (Benson 1995: 195).

subintervals (if time is continuous). The same problem reoccurs. Consider, for example, the first transfer: at that moment, the magnitude of the system momentum goes up with amount Δp , violating the conservation law. If ball a then loses the corresponding amount of momentum, the original system value is restored—but only to be increased again when the second package of momentum is transferred; and so on.

Notice that Mumford and Anjum cannot avoid this difficulty by holding that b acquires momentum Δp simultaneously with a losing Δp , at some time t . In such a case, assuming simultaneous causation, Mumford and Anjum would in effect be saying that it is the *diminishing* of momentum—i.e. the sudden *lack* or *absence* of Δp in ball a at t —that causes b to gain Δp at t . Such a move would involve defending a version of causation by absence (a kind of *negative causation*), which is in conflict with an out-and-out powers account of causation, according to which powers are doing *all* the causing in world. Mumford and Anjum themselves argue strongly against causation by absence elsewhere in their book (Mumford Anjum, 2011: 143-148). Thus, I take it that on a thoroughgoing powers metaphysics, a 's causing (i.e. its “passing” of momentum) must be construed as occurring while a is in possession of the relevant power, not when it has lost it. Moreover, given simultaneous causation, b 's acquisition of the relevant amount of momentum (the effect) must occur simultaneously with the passing of it – resulting in a violation of the conservation law.

But could not Mumford and Anjum account for b 's acquisition of Δp at t (i.e. when a has lost Δp , in line with the scenario of the preceding paragraph) in terms of a 's *remaining* momentum at t (thanks to an anonymous reviewer here)? In such an account, no causation by absence would be involved and the relevant conservation law would not be violated.

One problem with this kind of response is that it cannot be applied to the whole collision process. To see this, consider the final step when b receives its last boost of momentum and a has (according to this type of account) lost *all* of its momentum: there is then *no* momentum, no relevant power, left in a to do the work of accelerating b to its final velocity. (I suppose that Mumford and Anjum would not want to say that it is b 's *own* momentum that accelerates b at this stage, since that would involve some strange kind of self-acceleration.) Thus, this response fails.

I take it, then, that the conclusion, four paragraphs back, stands: assuming simultaneous power-causation, the conservation law is violated even in a collision process consisting of discrete steps.

Assume finally that the transfer does not consist of discrete steps but is a *continuous* process; this is the scenario that Mumford and Anjum apparently tend to favour (pp. 109, 116,

124, *passim*). In such a case, *a* does not pass, and *b* does not receive, finite amounts of momentum at individual instants. Rather, *b* gains a finite amount of momentum over a finite period of time, Δt ; and *a* loses the corresponding amount of momentum during a finite period of time, $\Delta t'$. But what, on the powers metaphysics, causes *b*'s momentum to go up with amount Δp (which we will take to be of exactly the same magnitude, expressed by some real number, as *a*'s original and determinate momentum) during interval Δt , *simultaneously* with Δt ? Mumford and Anjum cannot invoke *a*'s losing of Δp , because that would again involve endorsing a kind of negative causation—more specifically, a version of causation by absence.¹⁶ On their view, it must be *a*'s passing of its positive power/momentum that causes *b*'s momentum to go up. Importantly, *a*'s losing of *all* of its momentum must occur *after* the whole passing transaction to *b* has ended. That is, on this view, *b* must have gained the relevant finite and determinate amount of momentum at some point in time that is *before* the

¹⁶ Huemer and Kovitz—who defend continuous and simultaneous causation, and to whom Mumford and Anjum repeatedly refer—claim that,

the collision occupies a finite, albeit brief, interval of time, during which *a*'s momentum is continuously decreasing and *b*'s is continuously increasing. At any given time, the instantaneous rate of change of *a*'s momentum is causally related to the instantaneous rate of change of *b*'s momentum – we can say loosely that *a* is transferring its momentum to *b*. (Huemer and Kovitz, 2003: 563)

Were Mumford and Anjum to endorse this story, they would be defending a version of causation by absence, which is incompatible with the powers metaphysics: the instantaneous *negative* rate of change of *a*'s momentum (involving *a* *losing* momentum) is held to be causally related to the simultaneous and instantaneous *positive* rate of change of *b*'s momentum. Note that Huemer and Kovitz's account can be questioned even if it is decoupled from the powers metaphysics (they do not themselves argue for a powers metaphysics): given that velocities and momenta are frame relative, what justifies the notion that *a* is "transferring" its momentum to *b* rather than vice versa? What justifies the imputed causal asymmetry here? (The same objection can of course be made against Hume's original account (Hume, 1740/1978: 649).) Elsewhere in their article, Huemer and Kovitz (2003: 558–559) invoke *forces* as the causally operative factors in collisions between billiard balls, and they moreover argue that net forces cause accelerations (in both billiard balls) *simultaneously* with them being exerted, in accordance with Newton's second law of motion. But notice that in STR, it only makes sense to say that force and acceleration are absolutely simultaneous in relation to point-particles. (Absolute simultaneity is required here, because events that have a space-like separation—i.e. are simultaneous in some reference frame, but not in all—cannot be causally related in STR; see e.g. Taylor and Wheeler, 1992, Ch. 6.) Moreover, in contrast to classical mechanics, forces cannot propagate faster than c in STR. Thus, given STR, it is incorrect to say "that a body's rate of acceleration at a given time is causally determined simply by the configuration *at that time* of the physical system of which it is part" (Huemer and Kovitz, 2003: 559, my emphasis). In any case, it is unclear how the notion of force relates to concept of power. Mumford and Anjum do not invoke forces in their own causal accounts, and they state that, "powers are not necessarily physically reducible, to forces, for instance" (2011: 102). Elsewhere they explicitly deny that powers are reducible (*ibid.*: 7–11, 175–196). And as we have seen, in the case of colliding billiard balls, Mumford and Anjum hold that it is *momentum* that is causally operative, not forces. For a historical survey of various conceptions of force, see Jammer (1999).

point in time at which a has for the first time lost all of its momentum.¹⁷ Thus, the conservation law will be violated in this case as well.¹⁸

It should be observed here that the difficulty is not confined to the passing around of momentum. A similar story could be told about the passing around of positive amounts of *energy* (such as kinetic energy, in an elastic collision), which would be in conflict with the law(s) of energy conservation in classical and relativistic mechanics (see e.g. Benson, 1995: 182, and Taylor and Wheeler, 1992: 206).¹⁹

In conclusion, if Mumford and Anjum want to defend simultaneous causation, and if momentum (or energy) is taken to be a power that can be “passed around” among meso-level objects, they will violate conservation laws holding in both classical and relativistic mechanics—apart from the fact that the resulting theory is in conflict with the relative character of motion in these theories, STR’s speed-limit to causal propagation, and STR’s relativity of simultaneity.

4. Against rejection of sequential power-causation

The lesson of the foregoing section was that a powers metaphysics coupled with simultaneous causation is hard to combine with standard meso-level physics. I will now argue that an explanatory rich powers ontology should make room for at least some sequential (i.e. non-simultaneous) causation. This is in opposition to Mumford and Anjum who want to stay clear of sequential causation altogether (2011: 125-128).

David Hume famously argued that causes must precede their effects: if they do not, Hume argued, all causation will occur at a single moment in time (cause a being simultaneous with its effect b , effect c being simultaneous with its cause b , effect d being simultaneous with its cause c , and so on – see Hume, 1740/1978: 76). Hume jumped to conclusion though. In

¹⁷ The ploy with open/half-open intervals cannot be invoked here since we are concerned with distinct end-points of the intervals Δt and $\Delta t'$.

¹⁸ Note that if the transfer is taken to be continuous, uncountably many instantaneous momentum-powers of distinct magnitude, inhering in a and b in succession, are postulated. Thus, the following claim by Huemer and Kovitz, approvingly cited by Mumford and Anjum (2011: 120), is mistaken: “[on a continuous] understanding of time and change, temporally extended events are not ‘built up’ from some smallest units.” If time and change can be mapped onto the real number line, then temporally extended events *are* built up from smallest units of zero duration. For more on this, see e.g. Grünbaum (1967). Maudlin (2012: 24-30) is also relevant here. Thus, I observe that if Mumford and Anjum want to endorse causation involving continuous change, they should give up their overarching scepticism towards instantaneous events or states of affairs (cf. footnote 6, above).

¹⁹ Admittedly, in quantum mechanics, the energy of a system of elementary particles can fluctuate (extremely briefly) due to Heisenberg’s uncertainty principle (see e.g. Benson, 1995: 928). Also, in the quantum realm, there are phenomena that seem to violate STR’s strictures of locality (for discussion, see Maudlin, 2002). In this paper, however, I am concerned with *ordinary meso-level objects*, as are Mumford and Anjum (2011: 16-18, 102, 215-218).

order to deny universal co-temporary causation one may simply hold that: a) *some* causes occur before their effects (i.e. one need not claim that *all* causes precede their effects, as Hume does); or b) that there exist distinct simultaneous (but possibly temporally extended) cause and effect pairs at distinct, causally unrelated, times.²⁰

Mumford and Anjum (2011) firmly reject a), but they endorse a version of b) (see pp. 124-125 and 125-128, respectively). According to them, causation typically comes in discrete, “temporally extended wholes” (p. 121)—in the form of “processes” (p. 123)—in which cause and effect are temporally extended but fully contemporary, exemplifying simultaneous causation (pp. 121-124). Zooming in a bit, the cause in a temporally extended causal process is the coming together of objects’ powers (and their remaining together for some time), and the effect is the acquisition of new powers by some or all of the objects involved (pp. 122-123).²¹ The effect commences simultaneously with the relevant powers beginning to interact—for example, a sugar cube begins to dissolve as soon as it is placed in a glass of water (p. 122). These distinct causal processes existing at various time intervals do not cause each other, however. They merely “enable” (pp. 125, 126) subsequent causal processes by producing, or passing around, powers that might interact in causal processes in the future. Thus, on Mumford and Anjum’s view, although simultaneous causation occurs at distinct times, no causes ever precede their effects, i.e. there is no sequential causation.²²

I have the following three concerns with Mumford and Anjum’s rejection of sequential causation (Ch. 5). I present them in order of increasing severity.

First, by eschewing sequential causation, Mumford and Anjum arguably have to take the temporal *directedness* of the dynamics — i.e., the arrow of time—for granted. They

²⁰ But of course, as we saw in section 3, if one advocates simultaneous causation, one will have to struggle with STR, etcetera.

²¹ Note that, in Mumford and Anjum’s account, strictly speaking cause and effect are not powers *simpliciter*, but rather *states of affairs* or *events* involving enduring objects with powers arranged in certain configurations (such as the coming together of objects powers, or the acquisition of new powers by objects). Such states of affairs or events (including the powers in these states of affairs or events) are usually very short-lived, certainly so if the causal processes in question involve *continuous* change of properties/powers. See also notes 6 and 18, above. Mumford and Anjum are generally somewhat imprecise in their characterizations of the nature of the causal relata (although see Mumford and Anjum 2011: 1-3, for some explicit discussion), which tends to make the exact interpretation of their theory non-straightforward.

²² They assert, for example: “It might then be concluded that at least some cases of causation must be non-simultaneous. We are nevertheless going to resist this conclusion.” (Mumford and Anjum, 2011: 125) However, elsewhere in their book, Mumford and Anjum seem occasionally to endorse some sequential causation, for example in the form of transitive causal chains extending over time (see e.g. pp. 167-169) — although they do reject the notion that causation is in general transitive (pp. 169-174). It is hard to square such claims about temporally extended causal chains with what they say in their chapter on simultaneous causation (for a similar complaint, see McKittrick, 2013: 403-404).

clearly assume that there is such an arrow: for example, they speak of processes “developing” and “unfolding” in time (p. 117), and of causal processes being enabled by powers “instantiated in earlier causal processes” (p. 125). However, as has been discussed in detail by various philosophers (e.g. Price, 1996; Mellor 1998, Ch. 11), there is little hope of reducing the arrow of time to non-causal de facto asymmetric phenomena, such as entropy “increase” or the “expansion” of the universe: such phenomena seem to rely on the direction of time, or the direction of causation, for their putative directedness (cf. Price, 1996: 17). The best hope for having the temporal arrow reduced involves the invocation of an irreducible, sequential causal arrow (see e.g. Tooley, 1997, Ch. 9; Mellor 1998, Chs. 10-12). Now, powers are generally taken to be irreducible and inherently directed (see e.g. Ellis, 2001, Ch. 3; Molnar, 2003, Ch. 3; Bird, 2007, Ch. 5), and thus they seem to fit the bill perfectly. Hence, by denying sequential causation, Mumford and Anjum turn their back on what I take to be one of the promising features of the traditional powers metaphysics, namely its potential to ground the arrow of time: viz., in irreducible and inherently directed causal processes leading *from* interacting causal powers *to* manifestation effects existing at *other* times. (Surprisingly enough, this potential of the powers metaphysics is, to my knowledge, little discussed in the modern literature.²³) Humean causation, by contrast, has often been criticized for not being able to account for the arrow of time (since cause and effect are distinguished by reference to the temporal arrow in Hume’s scheme). By rejecting sequential power-causation, Mumford and Anjum thus put the powers metaphysics in essentially the same boat.

Secondly, it seems that Mumford and Anjum cannot explain *why* the physical world unfolds as it does (even if a brute *direction* of the unfolding is granted). What produces the specific, successive states of the world, or of one of its subsystems? How do the distinct times come to have the specific contents they have? For example, what accounts for what happens between the ending of a causal process and the beginning of a new, later one? Indeed, what accounts for the physical development *within* a temporally extended process of simultaneous causation?

²³ Some commentators on Aristotle touch upon this issue when discussing Aristotle’s theory of change, interpreted as involving potentialities or powers pointing towards later end states that the potentialities bring about or make actual (thanks to an anonymous reviewer here). For example, Edward Hussey writes in his introduction to Aristotle’s *Physics, Book III*: “So the incompleteness of change is due to the fact, reflected in the definition of change, that the key potentiality involved is that of which the actuality is the end-state. So there is an essential asymmetry: a change ‘points forward’ to its completion in a way in which it does not ‘point backward’ to its inception” (Hussey, 1983/1993: xiv). Notice that this notion of powers (and the changes they bring about) “pointing forwards” only makes sense if powers are taken to involve *sequential causation* (apart from any putative simultaneous causation), as I try to make clear in the text (see also footnote 24).

Consider, for example, the case of a sugar cube dissolving in a glass of water, which Mumford and Anjum take to be an example of a discrete but temporally extended process exemplifying simultaneous causation between interacting powerful objects and substances. They write:

The cause in this case is the sugar being in the liquid, or rather the coming together of their powers, and the effect is its dissolving. How the sugar got there, who placed it in, or whether it fell in accidentally without human agency, is not a matter that need detain us. For the effect of it dissolving, all that matters from a causal point of view—as an accurate and informative explanation of its dissolving—is that it is in the liquid and appropriately empowered. The effect is depicted [in standard, sequential causal stories] as being the dissolving of the sugar at t_2 but this also is inaccurate and misleading. At t_2 , the sugar is entirely dissolved but it starts dissolving before that point. Our hypothesis is that at t_1 , the moment the sugar is in the liquid, it begins to dissolve but, as Kant said, it takes time for the full effect of this process to be realized. Causation is going on right from the first moment at t_1 . [...] We have a coming together of mutual manifestation partners and they begin their work the moment they are together. But what we then have between [t_1 and t_2] is the development and unfolding of the process that takes the sugar from solid to solute. (Mumford and Anjum, 2011: 122-123)

But merely postulating simultaneous causation—occurring already at t_1 and perhaps at all the times (which may be chronons, instants, or whatnot) up to t_2 —does not explain the specific physical *development* from t_1 to t_2 . For example, why does simultaneous causation occur at $t_{1.5}$, with the configuration being as it is then? That is, why are the *causes* assembled as they are at $t_{1.5}$? More radically, why does anything exist at $t_{1.5}$, or after t_1 ? These questions cannot be answered by merely relying on simultaneous causation. By rejecting sequential causation, Mumford and Anjum have to regard the causal configuration at any time as a brute fact. They cannot explain the configurations after t_1 by invoking, for example, “immanent causation” (Johnson, 1924, Ch. VII; Armstrong, 1997: 105), “inertia” (Dowe, 2000: 52-55), “causal lines” (Russell 1948: 475-477), or “powers to persist” (Mumford, 2009: 225), since all such notions involve sequential causation. Now, Humean regularity theories of causation have often been criticized for not being able to explain why cross-time regularities exist (see e.g. Armstrong, 1983: 40-41, and Mumford, 2004: 156). The modern powers metaphysics was to

a great measure developed with the specific purpose of being an alternative that *would* explain cross-time regularities (see e.g. Mumford, 2004, and Bird, 2007). If sequential causation is rejected, the powers metaphysics can no longer be claimed to be explanatory virtuous in this respect. At best, it can only account (waiving problems having to do with STR and so on, see Section 3) for what happens *at a certain moment*, in isolation.²⁴

Worse (and this takes us to the third concern): if sequential causation is rejected, the powers metaphysics threatens to become inconsistent. What is the nature of the putative power *being water-soluble*? Traditionally, powers theorists take this power or disposition to essentially involve an ability to cause (together with the properties of water) the bearer to dissolve in water (the characteristic manifestation effect). Mumford and Anjum themselves claim that:

talk of the power to F makes it clear that a disposition must have a type of manifestation: to F, to G, to H, and so on. The disposition whose manifestation is dissolving is solubility, the disposition whose manifestation is stretching is elasticity, and so on. *The manifestation type determines the identity of the disposition.*

(Mumford and Anjum, 2011: 5, my emphasis)

²⁴ An anonymous reviewer for *Metaphysica* suggests that Mumford and Anjum *can* explain why the physical world unfolds as it does: "particulars have powers for natural causal processes: and the power is for the whole process, not just for the end state of that process". I retort that if the power existing at t_1 is for the *whole* process, all the way up to t_2 , then the power at t_1 involves *sequential* causation (apart from putative simultaneous causation), i.e. causation extending *beyond* t_1 . Now, Mumford and Anjum explicitly deny in their book that there is any sequential causation (2011: 125-126). However, they do speak of earlier processes "enabling" later processes (pp. 125-126), an idea that could perhaps be applied (although they do not claim this themselves) to the internal dynamics of the causal processes themselves (e.g. one state of affairs enabling a later state of affairs (cf. note 21), which in its turn causes a simultaneous effect). The problem with this proposal, is that "enabling", in all likelihood, has to involve some form of sequential causation if it is to be explanatory. Enabling apparently involves the production and subsequent persistence of powers. If this persistence is not to be taken as a brute unexplained phenomenon, arguably something like inertia (Dowe, 2000: 52-55), causal lines (Russell, 1948: 475-477), immanent causation (Armstrong, 1997: 105), or powers to persists (Mumford, 2009: 225), must be invoked, and then we are back with sequential causation. But again, Mumford and Anjum reject sequential causation and thus also the kind of causal accounts of persistence (and enabling) just mentioned. A second reviewer worries that Mumford and Anjum's rejection of sequential causation is merely "verbal" since they do endorse the notion of an earlier process enabling a later process. But notice that what enabling amounts to *diachronically* (once the relevant powers have been synchronically produced or caused) is, as I have just indicated, mere brute persistence. Someone who endorses sequential causation can go a step further and (seek to) explain this diachronic aspect of enabling; but Mumford and Anjum cannot. Hence, there is more than a mere verbal disagreement here. On *this* I think Mumford and Anjum would unhesitatingly agree; they write, for example: "A key point to note in this model is that one causal process is not seen as the cause of another but only as an enabler; thus, we do not need to invoke causation between temporally distinct events. Is this a mere ad hoc dodge to avoid temporal priority in causation? No." (Mumford and Anjum, 2011: 126)

But if the manifestation type in question involves some kind of marked, non-negligible change, as dissolving arguably does, the relevant power must, if it is to be a power of the kind in question, be an ability to cause this kind of marked, non-negligible change in the subject. I am not claiming that the power of being water-soluble must involve (or “point at”) the subject being *completely* dissolved (although I think that is plausibly the case, see my 2009: 36). For the present purpose, I only want to propound the weaker claim that water-solubility must at least involve the possibility of the subject undergoing a marked, non-negligible, relevant change – i.e., that the power can cause (together with water) the subject to become, roughly put, at least *partly* dissolved. How much change is needed (e.g. the number of broken bonds, the distance the freed molecules must have travelled) for the subject to become at least partly dissolved may be a vague matter; but my worry is that, whatever happens during a chronon – and certainly at an instant – that is *not* enough to realize or constitute the subject even partly dissolving (see also my 2009, Section 4, for a related discussion). Consider Mumford and Anjum’s sugar cube: if the sugar cube is to be water-soluble at t_1 , and to be manifesting this power at t_1 , it has to have a power to change non-negligibly at t_1 , a power (to become partly dissolved) which is moreover actually manifested at t_1 . But if t_1 is a chronon or an instant (and not a long interval of time), nothing could realize this manifestation at t_1 .²⁵ So it must be *false* to say of the sugar cube – *pace* Mumford and Anjum – that it is water-soluble at t_1 ! In order for such an ascription to be true (assuming a realist powers semantics), the sugar cube must have, at t_1 , a power to cause itself (with the aid of water) to become partly dissolved over an interval of time that extends *beyond* t_1 . Hence, to be water-soluble at t_1 in the power sense, the sugar cube must have an inherent ability that essentially involves *sequential* causation. Merely having a power that “tends” towards an – at best minuscule – simultaneous effect is not enough.

Thus, if sequential causation is denied, arguably there can be no genuine powers of being water-soluble, fragile, corrosive, explosive, flammable, lethal, poisonous, a unit of inheritance, and so on, had by objects at times. Yet, these are precisely the kind of powers postulated in Mumford and Anjum’s book.

²⁵ Thus, I here largely agree with Chakravartty (2013: 898-899).

5. Conclusion

In light of the arguments in sections 2-4, I recommend that powers theorists adopt a purely sequential conception of causation, at least in relation to the (putative) powers of actual meso-level objects.

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