© Johannes Persson, Department of Philosophy, Lund University, Sweden
Email: johannes.persson@fil.lu.se
Homepage: http://www.fil.lu.se/staff/person.asp?id=26&lang=eng

Mechanisms are entities and activities organized such that they are productive of regular changes from start or set-up to finish or termination conditions. (Machamer et al.2000, 3)

Mechanism-as-activity and the threat of polygenic effects[1]

Polygenic effects have more than one cause.[2] They testify to the fact that several causal contributors are sometimes simultaneously involved in causation.[3] The importance of polygenic causation was noticed early on by Mill (1893). It has since been shown to be a problem for causal-law approaches to causation[4] and accounts of causation cast in terms of capacities.[5] However, polygenic causation needs to be examined more thoroughly in the emerging literature on causal mechanisms. In this paper I examine whether an influential theory of mechanisms proposed by Peter Machamer, Lindley Darden and Carl Craver can accommodate polygenic effects and other forms of causal interaction. This theory is problematic, I will argue, because it ascribes a central role to activities. In it, activities are needed not only to constitute mechanisms but also to perform the causal role of mechanisms. Any such mechanism-as-activity will be incompatible with causal situations where either *no* or merely *another* kind of activity occurs.[6] But, as I will try to illustrate in this paper, both kinds of situation may be frequent. If I am right, the view that Machamer and colleagues suggest leads to an impoverished conception of mechanism.

[1] This article was written …
[2] Dupré (1993), p. 123-124; Molnar (2003), p. 194.
[3] Most causal contributors are causes, but sometimes contributors balance each other so perfectly that no net-effect occurs.
[4] Cartwright (1983), p. 59.
[5] Dupré (1993) and Glennan (1997).
[6] Psillos (2004, p. 314) also discusses the way in which activities struggle to explain causal interaction, but he focuses on another problem: "Note that it wouldn't help to try to explain the interaction between two parts of a mechanism (say parts A and B) by positing an intermediate part C. For then we would have to explain the interaction between parts A and C by positing another intermediate part D and so on (ad infinitum?)."

1. Mechanisms and their activities

Together with his colleagues Lindley Darden and Carl Craver, Peter Machamer[7] has designed an influential framework for understanding mechanisms. In the following discussion, I shall examine some of the key ideas in this framework without claiming to replicate its exact position. The building blocks of the mechanisms I am interested in here are entities and activities. These are, furthermore, organized in such a way that they are productive of regular changes between the mechanism's condition at onset and termination. For instance, the arrangement of entities and activities that are involved in my clock is absolutely crucial for the work it does. It is particularly interesting that, in the relationship between activities and entities, activities are supposed to play the more important causal role:

> Activities are the producers of change. Entities are the things that engage in activities. (Machamer et al.2000, 3)

To mark the pronounced causal role of activities here I shall refer to the framework as a *mechanism-as-activity approach*. This approach draws its examples from scientific research in molecular biology and neurobiology, but it is clear both from the original work and from Machamer's further elaboration of the metaphysics of activities, that the intended application is wider. The vast majority of activities referred to in Machamer (2004) are not limited to scientific settings at all. Examples of activities used there include: running, bonding, flowing, the glass shattering and flying into a thousand pieces, breaking, boozing, covering up, and hiding.

2. What is an activity?

To examine the mechanism-as-activity framework we need to identify some of its testable consequences. Below, I will describe one such consequence. It should be noted, however, that Machamer and his colleagues have not found it easy to provide a useful characterization of activities. They offer plenty of examples; and Machamer (2004, 29) gives quite a number of synonyms, or near-synonyms, of 'activity' as well: *producings*, *happenings*, *ways of acting*,

[7] Machamer et al.(2000).

processes and *behaviours*. But nothing resembling a general account of activities has been provided.

It should be clear that a central element in the concept of activity is *actualization*. In his work on Aristotle, Ross (1930, 82) says: "In each moment of activity, potentiality is completely cancelled and transformed into actuality." There are no references back to Aristotle in Machamer *et al.*(2000) or Machamer (2004) on this matter, but this characteristic of activities cannot have changed much. On the other hand, it is far from obvious that everyone interested in activities would be keen to postulate potentiality in the world; and in view of this, I would prefer to sidestep any possibly controversial issues surrounding potentialities and actualities by claiming only that the following implication holds:

If entity E engages in activity A, then E is A-ing

If the wheel (entity) engages in spinning (activity) then the wheel is spinning. If the heart (entity) engages in pumping blood (activity) then the heart is pumping blood. This relationship relates activities to all of the near-synonyms listed above—to producings, happenings, ways of acting, processes, and behaviours; and it should be perfectly obvious. Thus this implication holds true for anyone who wants to use activities in the causal role attributed to them by Machamer and colleagues as well.

We might add the following observation to the trivial one above. There might be two ways in which we would like to cash out A-ing. First, nobody engages in the activity of running unless someone is running. It is not enough that there is merely an attempted running, or that there is potential or a capacity to run. Second, the glass does not engage in the activity of shattering into a thousand pieces unless the thousand pieces actually result. It is not enough that the process begins but is never completed, say, because I catch the glass before it hits the ground. Now compare these two:

The first kind of A-ing, running, is most naturally understood in terms of its intrinsic qualities. If there is an A-ing of this sort, there is a *process* of a certain kind. Here is an illustration that starts with the activity: If Peter, the entity, engages in the activity of running, then Peter is running. This A-ing fits well with the idea that activities are usually designated by a verb or verb form—something which is noted in Machamer et al. (2000, 4), and which is reminiscent of Anscombe's (1981/1993) comparable take on causation a few decades ago.

The second case of A-ing, shattering into a thousand pieces, is more naturally understood in terms of the result or endstate of what happens. If there is an A-ing of this sort there is an *effect* of a certain kind. Here again is an illustration that starts with the activity: If the glass on my table, the entity, engages in the activity of shattering into a thousand pieces then the glass on my table causes the effect that there are a thousand pieces on my floor. This A-ing fits well with the idea that activities are constitutive of transformations that yield new states of affairs.[8] I should perhaps emphasize here that I am not claiming that there are two distinct kinds of activity. Presumably every A-ing has both an intrinsic quality and a causal role. At least, this should be true of activities in mechanisms.

Indeed, both characteristics seem to be highly relevant to a mechanistic project of the sort described above. Activities are supposed to provide a *productive continuity* between cause and effect, and accounting for this productive continuity is a major concern within the mechanism-as-activity framework:

> Productive continuities are what make the connection between stages intelligible. If a mechanism is represented schematically by A→B→C, then the continuity lies in the arrows and their explication is in terms of the activities that the arrows represent. A missing arrow, namely, the inability to specify an activity, leaves an explanatory gap in the productive continuity of the mechanism. (Machamer et al.2000. 3)

Looking at our two ways of conceiving activities, the intrinsic quality of A-ing is central to the account because it ensures continuity. One of the things driving the mechanism-as-activity program is a strong dislike of conceptions of change couched in terms of merely having different properties at different times. This is made explicit in the particular program I am taking as my starting point:

> Mechanisms do things. They are active and so ought to be described in terms of the activities of their entities, not merely in terms of changes in their properties. (Machamer et al.2000, 5)
>
> … we might say that activities are ways of acting, processes, or behaviours; they are active rather than passive; dynamic rather than static. (Machamer 2004, 29)

But while an activity provides continuity in virtue of the intrinsic qualities of A-ing, it may not produce the characteristic result or endstate. Therefore, the effect-element of activities is

[8] Compare Machamer et al.(2000, 4).

important too. Whether or not A-ing is cashed out in terms of their effects,[9] the fact that activities in mechanisms are productive is important:

> Particularly, discovering activities, the 'doing' or productive parts of mechanisms, is the finding of causes. (Machamer 2004, 28)

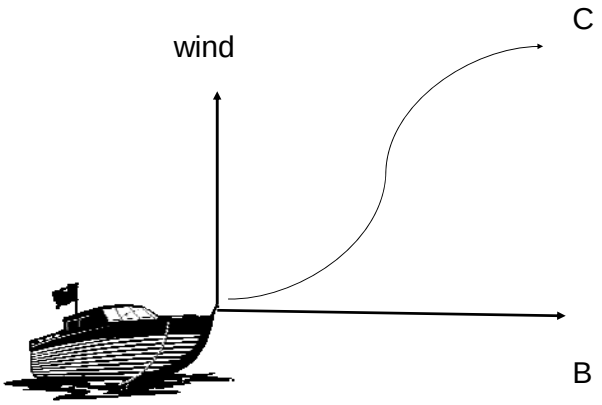
If I were to defend a mechanism-as-activity view, I would like to combine these two characteristics of activities so that the relevant activities of a mechanism were those involving both an intrinsic quality of A-ing (a certain kind of process) and a certain effect of it. Only in that way could it be guaranteed that a certain A-ing provides not only continuity (process) or production (effect) but a combination of these—that is to say, a *productive continuity* between the input and the output of the mechanism. This view, however, cannot easily be extracted from the writings of Machamer and colleagues; so here I no longer claim to be following their example. Be that as it may. I now have the testable consequence I need.

3. Polygenic effects

In their definition of mechanisms, Machamer and his colleagues speak about the organization of activities. Since activities are supposed to be closely related to causes, it is a small step from such talk to the idea of polygenic effects, i.e. effects that have more than one cause (or effects resulting from the organization of several activities). *Prima facie* it seems plausible that many activities are difficult to arrange in a way that preserves the A-ings and B-ings, and whatnot, that we have just concluded are necessary if some entity is to engage in a certain activity. In other words, activities seem to face a threat from polygenicity. It is this threat that I examine in the remainder of the paper.

As a simple case of a polygenic effect, consider a setting with a motorboat heading east (B). It is suddenly affected by strong winds from the south. The effect is that it ends up northeast of its present position (C). This effect is polygenic.

[9] Activity as a functional kind is the strongest expression of this idea. It combines well with the teleological understanding of mechanisms one sometimes finds in the literature on mechanisms-as-activity. Machamer et al.(2000), Machamer (2004, 36).



It is natural to picture this example, as Mill (1893, Bk III, ch. VI) did, in terms of forces: "a body is propelled in two directions by two forces, one tending to drive it to the north and the other to the east […]." It is, moreover, tempting to follow Mill (ibid.) in claiming that, in this case, both forces have their *full effect*. The boat is "left precisely where it would have arrived if it had been acted upon first by one of the two forces, and afterwards by the other." However, in cases such as a real-life boat trip it is probably not true that both forces have their full effect in this sense. The wind causes changes such as waves in the environment around the boat which make a difference to its capacity, or capacities, to move forward. There is some interaction between the causal contributors which I will assume is typical in real-life situations.

The motorboat example is interesting, also, for the reason that a similar setup has recently been used by the psychologist Phillip Wolff (2007) to study causal perception. In a series of experiments he shows that we judge processes of this kind to be typically causal. That is, we use the word 'cause' (and its cousins 'force', 'get', 'stimulate', and so on) to report them without further ado. Moreover, we use this expression rather than other types of causal verb such as 'enable' ('help', 'leave', 'allow', 'let') or 'prevent' ('keep', 'block', 'hinder') to describe our causal experiences in precisely these kinds of situation. Something is reported as a cause, rather than as an enabler or preventer, Wolff claims, when there is a patient (the boat) an affector (the wind) acts upon, and where the tendency of the patient (B) is different from both the affector (the wind) and the actual endstate (C). As far as these

psychological findings go, perceived effects are polygenic. Effects are typically thought to be the result of many contributing forces working together in a certain way.

4. Two kinds of polygenicity

There is a common and in many ways unproblematic kind of polygenicity: polygenicity with respect to different properties of the effect or affected object. In many cases polygenic effects emerge precisely because the effect or affected object has many properties which the various causal contributors act upon. An apple, for instance, becomes ripe and red at the same time, but ripening, we may assume, is a response to temperature, and reddening is a response to UV-exposure. Or, to recycle Hempel's (1970, 421-423) example: the lava stream from the eruption of Vesuvius took a certain path; it had certain physical and chemical properties; and it occurred at a certain time that day in the year AD 79. Each of these properties may have been affected by different combinations of causal contributor. If the effect is the event, i.e. the eruption of Vesuvius, then this event is polygenic in virtue of the contributions to various properties of it. Therefore, polygenicity is an especially common feature of theories positing events or particulars such as causal relata.

The motorboat example, however, is of a different kind. There the causal contributors act simultaneously, not on different, but the same property of the affected object. The forces exerted by the wind and the boat's engine both contribute to the same kind of effect—the position of the boat. They also affect the same kind of process leading there—the direction of the boat's movement.[10]

So, if we take the causal relata to be events or particulars with several properties or aspects, polygenicity is a phenomenon that emerges in two ways. The first emerges when different properties of the particular are affected by different causal contributors. The second emerges when there is a joint contribution to one of its properties. Polygenicity might also occur where the causal relata are facts or aspects of particulars, but then only in the second way. I will assume that it is primarily the handling of polygenicity of the second kind that might be problematic within the mechanism-as-activity framework.

[10] Both forces certainly contribute to other aspects, such as the speed of the boat, as well. This is because powers are often pleiotropic, i.e. contribute to several effects. Compare Molnar (2003, 194).

5. Activities and polygenicity

The mechanisms-as-activity framework makes a lot of sense. Accounts of mechanisms cast in terms of what their many parts do, and what results from this, are useful in a number of ways. However, these accounts also have limitations. One limitation becomes visible when we look into two kinds of situation where more than one causal contributor is acting simultaneously. In the first kind of situation, as a result of balancing causal contributors, nothing relevant happens, i.e. there is neither a relevant process nor a relevant effect. Hence there is no relevant activity. In the second kind of situation, as a result of polygenicity, there is a *different* kind of process and a different (kind of) effect than there would have been if the activities were causal contributors. The problems this poses for activities I take to be the following: the first kind of case is undoubtedly causal, but activities can neither account for the presence of more than one causal contributor nor indeed for the fact that the situation is causal. So the mechanisms-as-activity view has limitations as a causal account. For those who are only interested in deploying mechanisms to describe or explain typical cases this might be of little consequence; but for those who are looking for something more it might be reason to rethink the causal role attributed to activities. The second kind of case is not incompatible with the mechanism-as-activity approach as far as causality goes, but the approach cannot account for it as a case of polygenicity. Hence, the mechanism-as-activity approach gives at best a restricted, or partial, picture of the causal complexity at issue. On the plausible assumption that the second kind of case is frequent this is, I think, at least as serious a problem as the first. It shows that the mechanism-as-activity view turns mechanisms into something less complex than we expected, and something highly dependent on environmental factors as well. This problem suggests that the mechanism-as-activity framework conflates what a mechanism is with the way it works in a certain context.

6. The argument from perfectly balancing causal contributors

Let us start with the first problem and have a look at our motorboat again. Now the wind has turned. It comes directly from the east. Moreover, it perfectly balances the causal contribution

made by the engine. The boat has no speed or movement any longer. Neither the boat nor the engine takes part in the forward-moving activity at all. At the relevant level of mechanism nothing happens. There is no relevant activity:

What we have here is an extreme form of polygenicity, one without change at the level of mechanism in which we are interested. If change is a condition of effect here, this is a case of polygenicity without effect. It can also be described in terms of the complete masking of the two capacities involved, or in terms of the perfect balancing of the two forces or causal contributors. Nevertheless, this situation is clearly causal. In Wolff's terms, for instance, we still have a patient (the boat) which the affector (the wind) acts on, where the tendency of the patient (B) is different from both the affector (the wind) and the actual endstate (status quo). The masking or balancing, like the outcome in typical cases of causation, is the result of many contributing forces—only in a different kind of configuration. The situation would also be categorized as causal on many dependency approaches to causation.

Unlike many other polygenic effects, however, this extreme form of polygenicity can occur only where two causal contributors act on the same property of the affected object. It is because the wind and the engine both contribute to the same properties—the direction and speed of the boat—that the one capacity masks the other and the one force, or causal contributor, balances the other. The upshot is that neither of these causal contributors can be activities.

To say this is not to deny that there are activities in this situation. There are activities inside the engine, and as a result its propeller takes part in one. But, as we should

immediately concede, this is not something located at the mechanistic level of interest. It is not something occurring at the level at which we assumed polygenicity to start with. It is thus irrelevant to our study.

We have identified at least one kind of situation where the mechanism-as-activity approach breaks down despite the fact that this situation is clearly causal. It should be easy to mimic this kind of extreme situation in connection with any other activities that lie at the heart of mechanistic interest: pushing/pulling, opening/closing, heating/cooling, attracting/repelling and binding/releasing. I can certainly *try* to push when someone else is pulling, but the *pushing* and its effect has to occur for it to be an A-ing, i.e. for the entity to engage in the activity. Similarly with the extreme polygenic effects that can result from *trying* to open and close at the same time—to simultaneously heat and cool, attract and repel, bind and release, and so on.

7. The argument from different effects and processes

It is time to turn to the other, possibly much more widespread, kind of situation where advocates of activities are threatened by polygenicity. In these cases, the Φ-ing which actually occurs is substantially different from the A-ing that would have occurred if the entity had engaged in a certain activity A. Since Φ-ing and A-ing were previously understood in terms of both their intrinsic qualities (i.e. as kinds of process) and their effect, we need to discuss dissimilarities in respect of both characteristics.

Let us start with differences in the effect. Even our first motorboat example, in all its simplicity, might be a perfect example of how a polygenic effect cannot be accounted for in terms of more than one activity. What is the alternative to understanding what actually goes on as one activity? Obviously it is to say that the end-effect is a combination of two activities both of which occur. The boat is left more or less precisely where it would have arrived if it had been engaged first in one of the two activities and then in the other.[11] But in cases of causal interaction this is not really true. There is no real sense in which the effect is the combination of the effects of an A-ing and a B-ing. In cases of causal interaction activities cannot account for the polygenicity of the effect. And in many cases the allegedly polygenic

[11] Compare Mill (1893), Bk III, ch. VI.

effect differs more dramatically from the aggregate effect of A-ing and B-ing. The effects of combined medication are well-known cases in point.

This becomes even clearer when we characterize activities in terms of their intrinsic qualities of A-ing and B-ing instead. Suppose there is an intrinsic difference between being guided by the wind and being guided by the engine. Then the actual process taking place will be of neither kind. Or compare two more clearly different activities. The activity of running, for instance, cannot survive a situation where resistance is powerful enough to slow down the process to ultra slow. Running has a number of intrinsic qualities. It is possible that none of these is alone necessary, but it is clear that if several of them are lacking the activity will not count as running. Similarly, we cannot subtract very many of the intrinsic qualities of a closing process without changing the relevant A-ing, and therefore the relevant activity, into something else. Again, many processes of heating and cooling appear to have to exceed an environmental threshold in order to be the activities they are. And *trying* to think and listen at the same time often have the result, at least for me, that there is neither an activity of thinking nor of listening, since another process *takes place*. It would be fanciful to claim that both activities nevertheless occur. This cannot be because the corresponding A-ings are absent. But then, if they do not occur, then again, of course, they cannot be the two interacting causal contributors to the polygenic effect under study. Activities and polygenicity do not match.

In truth it does not matter whether we focus on effects or intrinsic qualities when we characterize the A-ing in 'if entity E engages in activity A then E is A-ing.' Potentially there are plenty of polygenic cases where only *one* A-ing occurs—an A-ing, moreover, that does not correspond to any of the causal contributors involved. Thus the mechanism-as-activity approach breaks down in these circumstances, too. This time the breakdown consists in the inability to capture the phenomenon of polygenicity: there is an activity, but there is, so to speak, only one and not more, and hence the effect does not appear polygenic.

This might be thought less alarming than the complete inability to handle the causal situation alleged above. For the reasons I have given, however, I regard this suggestion as naive. In order to be embeddable, mechanisms must be rather robust. But in these situations of polygenicity they seem highly volatile. The only activities occurring are resultants, so there are simply different mechanisms-as-activities in different situations of 'polygenicity'. (I use scare quotes here because strictly speaking the framework cannot acknowledge that these mechanisms-as-activities are polygenic.) But then, talk about embeddability becomes empty

in such environments. There is nothing about the mechanism that makes it identical across different 'polygenic' contexts. Depending on which activity takes place, different meachanisms will be involved. Accordingly, much of the explanatory power of the mechanistic framework will be lost. Full explanatory power will be limited to environments where the mechanism is set up in the right way, i.e. so as to be free of the threat of polygenicity.

8. Why bother?

Why should mechanistic philosophers care about polygenicity? It might be claimed that there is no compelling reason for a mechanistic theory to accommodate polygenic effects. That would be an unfortunate claim for at least two reasons. First, theories that do not recognize polygenicity cannot account for some typical cases of causation. This is a high price to pay, since it seriously diminishes their value as theories of causation. Secondly, and what is even more alarming, failure to recognize polygenicity will limit a theory's usefulness *qua* theory of mechanism as well. This is because many important mechanisms are thought to be decomposable into intricate patterns of parts, which are themselves mechanisms, and to be embedded in larger mechanisms. For instance, the mechanism of which the motorboat is a part might be decomposed into finer mechanisms of the engine, propeller, and construction of the body, and embedded in a larger mechanism including the wind. If these are going to do anything other than act serially, one after another, polygenicity is required. Thus the inability to accommodate polygenicity is a serious shortcoming in a theory of mechanisms.

How common are the kinds of case we have just described? Just how serious is the threat from polygenicity? If causal interaction in the real world is frequent, almost any case of polygenicity is a potential threat to activities-as-mechanisms. The only exceptions that can be ruled out as threats *a priori* might be cases where polygenicity results from different aspects of the effect, as when the apple becomes ripe and red at the same time. There is a clear sense in which all forms of polygenicity with respect to one aspect involve a moderate masking or balancing. Activities that are fragile with respect either to their intrinsic qualities or to their effects will lead to the loss of polygenicity. Their mechanism-based explanatory power will be impoverished as a result.

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