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REALIZATION RELATIONS IN METAPHYSICS

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1 Introduction

In contemporary philosophy of mind, metaphysics, and philosophy of science, one encounters many usages of the technical term "realization", (sometimes used interchangeably with "implementation"[2] and "constitution"[3]) which is purported to denote some relation that holds between higher-level properties or states and lower-level properties or states.[4] For example, it is almost shared wisdom in philosophy of mind and cognitive science that mental properties, such as *believing that it is raining*, *having pain*, and so on, are realized by physical properties. Generalising from psychology to other "special sciences", it is argued that properties that are invoked in such sciences are realized by properties that are studied by physics. In fact, it is maintained that such properties are *multiply* realized: they are realized by different physical properties in different cases, so they are not reducible to any physical properties (Putnam 1967; Fodor 1974). Functional and computational properties, which are individuated by their causal/functional roles, are said to be realized by first-order properties that "play" such roles or the properties of the parts of systems that have certain functions (Block 1980; Cummins 1983). It is said that dispositional properties, such as *being fragile*, are realized by categorical (non-dispositional) properties or micro-structural properties (Prior et al 1982). Determinable properties, such as *being red*, are said to be realized by their determinate properties, such as being *scarlet* (Yablo 1992; Shoemaker 2001; Wilson 2009).[5] It is maintained that structural properties are realized by non-structural properties (Gillett 2002).[6] Furthermore, it is suggested that Ramsey sentences are realized by concrete states of affairs (Lewis 2009).

This list of realization claims is by no means complete, but it suffices to establish the point that the term "realization" has become an umbrella term to refer to some *dependence* relation between higher-level properties or states (or in some cases *descriptions*, rather than worldly items like properties or states) and lower-level properties or states in the following sense: the instantiation of a higher-level property or a state depends on, and is necessitated by, the instantiation of its lower-level realizer (or realizers). Due to the heterogeneous use of the

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[2] e.g. Chalmers (1994).

[3] e.g. Gillett (2013).

[4] There are a few sources currently in the literature some parts of which might serve the purposes of a survey on the concept of realization. Polger (2004: Ch 4) provides a critical survey of varieties of functional realization. Endicott (2005) has an encyclopaedia entry on multiple realization, which starts with a brief section on realization. Craver & Wilson (2006) explain different usages of the concept of realization in both cognitive science and metaphysics. Morris (2010) discuss a number of realization relations and makes some methodological points about theorizing about realization. Walter (2010) discusses several accounts of realization in relation to the issue of mental causation. Bennett (2011) proposes a theory of *building* relations some of which are the realization relations that I shall discuss in section 3 below.

[5] More accurately, Yablo (1992) and Wilson (2009) argue that mental properties are determinable properties whose realizers are their determinates.

[6] Strictly speaking, Gillett (2002) is sceptical of the notion of a "structural property", but argues that if there were any, they would be realized by non-structural properties and relations in the same way a higher-level property is realized by physical properties and relations.

term "realization", it would be highly ambitious to assume that there can be at most one relation, namely *the realization relation*, that this term is supposed to denote in each and every case, unless one simply means "dependence" by "realization". Rather, it should be acknowledged that there could be several relations that the term "realization" denotes in different cases. [7] I suggest that any relation that this term denotes can be called a realization relation.

In Section 2, I will outline some general constraints on the notion of realization. For this, I will discuss what the *relata* of realization relations can be, what formal and non-formal features realization relations have, how the concept of realization is linked to the concepts of explanation and necessitation, and what theoretical roles realization relations are expected to play. In Section 3, I will introduce four realization relations that have received much attention in the current literature, and briefly discuss which roles these relations are suitable for.

2 Some General Constraints

2.1 Relata of Realization Relations

We encounter claims about different kinds, or categories, of entity as the *relata* of realization relations, which leads to the following question: What might be the *relata* of realization relations? Mainly, there has been mention of *properties*, *kinds*, *types*, *states, (property) instances*, *events* and *tokens* as the *relata* of realization relations. [8] Assuming that these categories fall under the categories of *property* and *instance*, I shall articulate the *relata* question in the following way: Do realization relations relate properties or their instances?

One might think, like Polger and Shapiro (2008), that realization relations cannot relate property instances, as what is realized should be multiply realizable, hence repeatable, and that a property instance is not the type of entity that is repeatable. Since properties are repeatable entities, they seem to be better candidates to be the *relata* of realization relations. But can we understand realization relations between properties in terms of realization relations between their instances? According to Shoemaker, "to speak of one property as realizing another is shorthand for saying that instances of one are among the possible realizers of the instances of the other" (2007: 3). This suggests that realization relations could be "category-inclusive", to borrow Endicott's (2010) term. That is, realization relations can relate entities from multiple ontological categories. I propose that we can formalise this idea as follows:

> (I1) A property P property-realizes a property Q if and only if each instance of P instance-realizes an instance of Q.
> (I2) An instance of P instance-realizes an instance of Q if and only if P property-realizes Q.

Let us call the conjunction of (I1) and (I2) *the inclusion thesis*. The inclusion thesis invokes two seemingly different relations, namely property-realization and instance-realization. In line with this, I suggest that when one makes a realization claim about properties, she makes a claim about property-realization, and when one makes a realization claim about instances, she makes a claim about instance-realization. The equivalence thesis

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[7] Polger (2004; 2007) makes a similar comment about the notion of *functional* realization. He argues that since there are many different concepts of function (i.e. causal, teleological, etc.), there should also be many different relations by which functions are realized.

[8] Two notable exceptions to this are John Heil's and Thomas Polger's discussions of realization. Heil (1999; 2003) analyses realization in terms of a relationship between predicates and properties: the predicate "is in pain" truly applies to different organisms which have different physical properties. If one wants to see this *reference* relation as a realization relation, predicates can be included in this list too. Polger takes the relation of functional realization to relate objects (bearers) to functions (functional properties): realizing a function is having a function (2004: 125).

implies that if an instance of a property *P* instance-realizes an instance of a property *Q*, then every instance of *P* instance-realizes an instance of *Q*. [9]

2.2 Some Features

By and large, realization relations are taken to be *asymmetric*, *irreflexive*, and *transitive* relations.

> *Asymmetry*: If *P* realizes *Q*, then *Q* does not realize *P*.
> *Irreflexivity*: No property realizes itself.
> *Transitivity*: If *P* realizes *Q,* and *Q* realizes *R,* then *P* realizes *R*.

Another feature that is commonly attributed to realization relations is synchronicity. If an instance of *C-fibre stimulation* realizes and instance of *having pain*, these properties are instantiated in an individual at synchronically. Shapiro thinks that one of the features that distinguish realization from causation is that causation is, paradigmatically, a diachronic relation, whereas realization is a synchronic relation (2004: 35). However, Robert Wilson (2001) observes that some properties might be individuated historically. For example, in order to be a genuine instance of a dollar bill*,* a piece of paper must have an appropriate historical connection with the central bank that printed it. In such cases, the realizer's instantiation would not be completely synchronous with the instantiation of the realized property. Yet, it should be noted that even if the realizer and realized property instances are not entirely synchronous, they at least partially synchronically overlap. [10]

2.3 Explanation and Necessitation

Realization relations are thought to be *explanation* and *necessitation* relations: if a property *P* realizes a property *Q*, then, (i) *P*'s instantiation explains *Q*'s instantiation, and (ii) *P*'s instantiation necessitates *Q*'s instantiation. For example, LePore and Loewer suggest that

> the usual conception is that *e*'s being *P* realizes *e*'s being *F* iff *e* is *P* and there is a strong connection of some sort between *P* and *F*. We propose to understand this connection as a necessary connection which is explanatory. The existence of an explanatory connection between two properties is stronger than the claim that *P* ' *F* is ... necessary since not every ... necessary connection is explanatory (1989: 179).

That realization relations are not merely necessitation relations is already implicit in the assumption that realization relations are dependence relations. It is commonly agreed that necessitation does not guarantee dependence. For example, the existence of the set {Socrates} necessitates the existence of its member Socrates, but the existence of Socrates does not depend on the existence of {Socrates} (Fine 1994). Similarly, although the conjunctive property *being red and being square* necessitates *being red,* it would be wrong to think that something's being red depends on its having this conjunctive property. So, *being red and being square* should not count as a realizer of *being red*. [11] But note that this can be spelled out by invoking the notion of explanation too. [12] This conjunctive property should not count as a realizer of *being red*, because there is no interesting explanatory connection between something's having this conjunctive property and its being red.

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[9] The inclusion thesis is deliberately circular: it gives us a tool to translate the property-realization talk into instance-realization talk and *vice versa*.

[10] I thank an anonymous referee for this observation.

[11] Yablo (1992: 253), Funkhouser (2006: 550), (Shoemaker 2007: 27), Wilson (2009: 152).

[12] In metaphysics, there is a growing literature on the notion of *grounding*, and arguably, the notion of dependence that is used in this paper is the same notion as grounding. In one sense, grounding is a form of *metaphysical explanation*. It is thought that explanation relations are different than necessitation relations in the following sense. Let us assume that my

Although it is a matter of dispute as to how "rich" a realizer property has to be in order for a realization relation to entail necessitation, it is generally accepted that the following sort of entailment holds:

> (Entailment) If P realizes Q, then, as a matter of *metaphysical* necessity, if something has P, then it has Q.

In particular, some physicalists who appeal to the notion of realization in order to explain the dependence of the mental on the physical want to rule out cases where two physical duplicates (from any two possible worlds) fail to be mentally alike (e.g. Levine 2001; Melnyk 2006; Shoemaker 2007). However, in some paradigm examples of realization, we see the failure of such metaphysical necessitation. In fact, in some cases, even weaker forms of necessitation, such as nomological necessitation, fail too. Think of the philosophers' favourite example of realization: *C-fibre stimulation* realizes *having pain.* But it is not even *contingently* true that any entity which is capable of having *C-fibre stimulation* also has pain. *C-fibre stimulation* in a Petri dish will not necessitate (either nomologically or metaphysically) an instantiation of *having pain* (Shoemaker 2007: 21). So an instance of *C-fibre stimulation* cannot be a realizer of an instance of *having pain.* In order to deal with such cases, a distinction between *total realization* and *core realization,* and a corresponding distinction between *core realizers* and *total realizers* are made (Shoemaker 1981). Whereas total realizers are sufficient conditions for realized properties, core realizers are weaker conditions than total realizers. Total realizers include, in addition to core realizers, some background conditions that specify what kind of an organism the realizer property is instantiated in, and what things exist (and do not exist) in the relevant environment. Whereas *C-fibre stimulation* might be seen as a core realizer of *having pain*, a total realizer of *having pain* will have to some extrinsic property.

If the metaphysical sufficiency feature of realization is desired to be perservered, one can take total realizers to be metaphysically sufficient conditions.[13] But, a total realizer of P in this metaphysically strong sense will have to specify a highly detailed sufficient condition for the instantiation of P. It might be thought that even fundamental causal laws of physics might be included in the background conditions, if laws of nature are deemed to be contingent. Let us assume, for the sake of illustrating this point, that laws of nature hold only contingently. Let us say that P is a property that is nomologically sufficient for the instantiation of *pain*. P will have to be a very "rich" property. But since laws of nature are assumed to be contingent, P might fail to be a metaphysically sufficient condition for the instantiation of *having pain*. Let us say that L is the property that one has just in case one inhabits the actual world or any world that is nomologically alike (with respect to the fundamental causal laws of physics). Then, the conjunctive property *(P & L)* will be metaphysically sufficient for *having pain*. So, it will be metaphysically necessary that if one has *(P & L)*, then one has pain. That is, it will be true in all worlds that if one has *(P & L)*, then one has pain. In worlds where L is instantiated, having P will entail having *(P & L)*, which necessitates *having pain*. In worlds where L is not instantiated, *(P & L)* is not instantiated either, in which case it will be vacuously true that, in such worlds, if one has *(P & L)*, then one has pain. So either way, *(P & L)* will metaphysically necessitate *having pain*.

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throwing the rock necessitates the breaking of the window. If this is true, then so is the following: my throwing the rock *and a dog's barking in another continent* necessitate the breaking of the window. However, although the breaking of the window can be explained by my throwing the rock, it cannot be said that my throwing the rock *and a dog's barking in another continent* explain the breaking of the window. The dog's barking is explanatorily irrelevant to the breaking of the window.

[13] Shoemaker's (1981; 2007) intended use of the term total realizer indicates a metaphysically sufficient condition.

2.4 Some Theoretical Roles

As was suggested in the introduction section, philosophers appeal to realization relations in order to explain a multitude of phenomena. In different cases, different relations are purported to be picked out by the term "realization". These different relations may have different theoretical roles.

In philosophy of mind, some versions of functionalism and physicalism have been formulated in terms of realization theses (e.g. Boyd 1980; Melnyk 1996; 2003; Wilson 1999; Shoemaker 2007). Varieties of functionalism abound, but the core claim of functionalism is that mental properties are functional properties, which are individuated by their causal/functional roles. Non-reductive physicalism, of which functionalism is a variant, is the view that mental properties supervene on physical properties where this supervenience cannot be explained in terms of a reductive relation, such as identity. Non-reductive physicalism should be able to account for the physicalist contention that mental properties are "nothing over and above" physical properties. How to interpret the phrase "nothing over and above" is itself a difficult philosophical question. Whether the obtaining of a supervenience relation between mental properties and physical properties can explain this contention is disputed (see Horgan 1993; Wilson 1999). In philosophical mereology, some argue that a whole is "nothing over and above" its parts (e.g. Lewis 1991). As a working hypothesis, I shall hold that the fact that a whole is *metaphysically non-distinct* from its parts suffices to account for the fact that the whole is "nothing over and above" its parts.[14] This can be seen to suggest that, for physicalist purposes, a realization relation should also relate metaphysically non-distinct properties. As was hinted in the previous section, one way of achieving this is by stipulating that mental properties are metaphysically necessitated by physical properties. In line with this, we can follow Morris (2010) in that a good theory of realization should provide the resources to explain how a realized property is metaphysically necessitated by its realizers.

In addition to the explanation of how mental properties are metaphysically necessitated by their realizers, a theory of realization can also be asked to provide an explanation of how realized properties can be causally efficacious. Following Kim (e.g. 1989; 1998; 2005), it is commonly thought that non-reductive physicalism faces *the exclusion problem*: mental properties are causally excluded by the physical properties that they are thought to depend on. The idea is that any causal work we would normally assign to a mental property is already carried out by the physical property it depends on. Many non-reductive physicalists think that a theory of realization should also provide the resources to deal with this problem (e.g. Shoemaker 2001; Wilson 1999).[15]

So, a non-reductive physicalist's theory of realization should be able to explain, or at least should provide the resources to explain, (i) how a property is metaphysical necessitated by its realizer, and (ii) how a property is not causally excluded by its realizer. Nevertheless, in line with the pluralist approach that is embraced here, not all realization relations should be asked to occupy both of these theoretical roles.

3 Some Formulations

In this section, I will introduce four formulations of realization that have received considerable attention in the recent literature. These are: *functional realization* (*f-realization*), *determinable realization* (*d-realization*), *subset realization* (*s-realization*), and *mereological realization* (*m-realization*).

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[14] Note that this also has the following result: *pace* Horgan (1993), the obtaining of a supervenience relation between mental properties and physical properties, insofar as the supervenient properties are metaphysically necessitated by the subvening properties, ensures that mental properties are nothing over and above their physical supervenience bases. I thank an anonymous referee for suggesting that this should be highlighted.

[15] See Walter (2010) for a sceptical proposal about this issue. Walter argues that none of the existing theories of realization can solve the exclusion problem.

3.1 Functional Realization

As was suggested above, functionalists in philosophy of mind have appealed to the notion of realization in order to explain the instantiation of mental properties by physical properties. The relation that is supposed to relate functional properties to properties that occupy the roles of such functional properties might be called functional realization (or f-realization for short). There might be different senses in which functional roles can be occupied, and this arguably depends on the fact that there are different conceptions of "function". In relation to this, Polger (2004) argues that there are (at least) as many realization relations as there are concepts of function, which suggests that even f-realization may have different varieties. For example, if we take the notion of functional role to correspond to the notion of causal role, occupying a functional role would be nothing but being caused and causing certain states of affairs. If functions in question are computational functions, occupying a functional role would be implementing a computation. Or, we have a teleological/biological understanding of function, according to which having a function may also have to do with having some evolutionary history, occupying a functional role would also entail being selected to have that function.[16]

The realization relation that functionalists of different varieties appeal to may be formulated as follows:

> (f-realization) A property P f-realizes a property Q if and only if for some role functional R (i) Q is the property of having a property that occupies R, and (ii) P is a property that occupies R.[17]

Let us, for the sake of simplicity, take the notion of functional role to be the same as the one of causal role. If mental properties are functional properties in this sense, then a given mental property, such as *having pain,* would be individuated by a causal role, say the pain-role. Let us say that the pain-role consists in wincing and being distressed in response to tissue damage. If *C-fibre stimulation* can occupy this role, that is, if the instantiation of *C-fibre stimulation* is caused by tissue damage and causes its bearer to wince and be distressed, then *C-fibre stimulation* f-realizes *pain.*

Whether f-realization plays the theoretical role that some physicalists want a realization relation to play is disputed. In particular, f-realization seems to fail to accommodate mental causation. The realizer property in f-realization is the property that *plays* the causal work, which implies that the causal work of an f-realized property is always carried out by its realizer. As Shoemaker suggests, the functionalist conception of realization "seems to make it true, *by stipulation*, that any causal role we might want to assign to the realized property is preempted by its realizers" (2007: 11, emphasis added). So, if we want a theory of realization to explain how mental properties can be causally efficacious, we may have to look somewhere else.

3.2 Determinable Realization

In order to solve the aforementioned exclusion problem about mental causation, Yablo (1992) suggests that the realization relation that is thought to obtain between mental properties and their dependence bases can be seen as the *determinable-determinate property relation*. This relation obtains between something's *being red* and its *being scarlet* or being another shade of red. Yablo argues that since determinable properties and their determinates do not causally compete, mental properties and their realizers do not causally compete either. So, on this view, a realization relation of the following sort is formulated:

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[16] See Polger (2004: Ch 5) for these and some "hybrid" concepts of function, and the associated functionalisms.

[17] See Block (1980) and Melynk (2003) for formulations of realization along these lines. Cummins (1983) also appeals to a similar account of realization when he explains how a component of a system contributes to the function of a whole system. Because of its mereological nature, I shall remark on this account in my discussion of mereological realization in 3.4 below.

(d-realization) A property *P* d-realizes a property *Q* if and only if for an individual to have *P* is for it to have *Q*, not *simpliciter*, but in a specific way.

Whether determinable properties and their determinates casually compete or not can be disputed. At any rate, even if it is accepted that determinables and their determinates do not causally compete, one might still ask for an explanation of why this is the case.[18] However, there is nothing illegitimate with the proposal that the determination relation that d-realization captures can be a realization relation. Note that it is incontestable that a property is metaphysically necessitated by a property that d-realizes it: necessarily, if something is scarlet, then it is red.

Nevertheless, the view that d-realization is *the* relation that non-reductive physicalists should appeal to in order explain the necessitation of the mental by the physical has come under attack (e.g. Ehring 1996; Funkhouser 2006). The most notable objection to this view is from Funkhouser (2006). Consider a *maximally* determinate mental property *M*. (*Having sharp pain* is a determinate of *having pain*, and *having very sharp* pain is a determinate of *having sharp pain*. Assume that *M* is a pain property that cannot be determined any further.) Assuming physicalism, *M* needs to be realized by a physical property. If realization is d-realization, then *M* should be determined by other properties. However, being maximally determinate, *M* cannot be determined any further. Therefore, physicalists' realization relation should be something other than d-realization.[19]

3.3 Subset Realization

There has been copious amount of work on what has come to be known as *the subset view of realization*, defenders of which include Wilson (1999; 2011), Clapp (2001) and Shoemaker (2001; 2007; 2013). On a simplified version of this view, the realization relation that physicalists should appeal to is the following relation:

(s-realization) A property *P* s-realizes a property *Q* if and only if the causal powers of *Q* are a proper subset of the causal powers of P.

The requirement that a realized property can have only a subset of the causal powers of its realizers comes from the following observation:

[physicalists] cannot ... allow that mental properties have any causal powers that are different from those of their physicalistically acceptable base properties, for this violates the physicalist thesis that mental properties are 'nothing over and above' their base properties (Wilson 1999: 41).

Whether the specified power-inclusion requirement satisfies the "nothing over and above" constraint might be disputed. Recall that one way of understanding the "nothing over and above" constraint is the stipulation that a realized property is metaphysically necessitated by its realizer. However, as pointed out by Melnyk (2006) and Kim (2010), the fact that a property *P* includes the causal powers of *Q* as a proper subset does not, on its own, entail the fact that having *P* metaphysically necessitates having *Q*. In order to account for such entailment, one might have to endorse a *dispositionalist* conception of properties according to which properties are to be identified by sets of causal powers (Shoemaker 1980).

One attractive feature of s-realization is the fact that it provides resources to explain how a realized property is not causally excluded by its realizers. As all defenders of the subset view emphasise, the view is designed to

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[18] See Bennett (2003) for an explanation of how causal exclusion worries about mental properties and their realizers can be remedied. Bennett's account applies to determinables and their determinates too.

[19] Jessica Wilson (2009) responds to Funkhouser's objection, and argues that a property that is maximally determinate according to one science (e.g. psychology) can be seen as a determinable property according to another science (e.g. physics). If she is right, then Funkhouser's maximally determinate mental properties can still be determined by physical properties.

solve the exclusion problem.[20] On Shoemaker's (2001; 2007; 2013) and Clapp's (2001) versions of the subset view, since the causal powers of an s-realized property are included in the causal powers of its s-realizer, there is (something like) a part-whole relationship between the instances of these properties. Since parts and wholes do not causally compete, s-realized properties and their s-realizers do not causally compete. And since they do not causally compete, an s-realizer does not causally exclude the property it s-realizes.

Nevertheless, the parthood claim that this version of the subset view appeals to received some criticism. Walter (2010) argues that the alleged causal autonomy of a mental property *M* disappears if *M* is rendered to be a part of a physical property. Audi (2011) argues that the idea that an *M* instance is a part of a physical property instance suggests something which is at odds with physicalism. Standardly, wholes are thought to depend on their parts; but physicalism should imply that mental properties depend on physical properties. I propose that these worries can be remedied if we take the parthood claim that this version of the subset view makes metaphorical: mental properties are not literally mereological parts of their realizers; the relationship between mental properties and their realizers is *analogous* to the relationship between parts and wholes. At any rate, Wilson's (2011) version of the subset view does not make the parthood claim that Shoemaker's and Clapp's do. According to Wilson, because of the said proper subset relation, the causal powers of a mental property are token-identical with some of the causal powers its realizer. Thanks to this token-identity of causal powers, there is nothing worrisome about mental causation. In fact, she suggests that mental properties are rendered causally autonomous due to being associated with distinctive *sets* of causal powers. Although each causal power of a mental property *M* will be identical with a causal power of its realizer *P*, the set of causal powers that is associated with *M* is not identical with the set of causal powers of that are associated with *P*. This version of the subset view, according to Wilson, explains the causal autonomy of mental properties better than other versions do.

3.4 Mereological Realization

Some authors who have invoked the notion of realization have had mereological relations in mind. Cummins (1983), for example, proposes a functional realization account that is mereological in nature. According to Cummins, systems have the functions they do in virtue of the functions of the parts that compose them. Suppose that *A* is a part of a complex system *S*. *A* has a function *F* in *S* just in case *S* has a function *G*, and *S*'s having *G* is partly explained by *A*'s having *F* (ibid: 100). This suggests that complex functions of large systems are realized by less complex functions of the parts of these systems. [21]

Another mereological account of realization is Pereboom's (2002) *constitution* account. Pereboom takes realization and material constitution to be very much alike: just as material objects are constituted by, but not identical with, their parts, Pereboom argues, higher-level property instances are constituted by, but not identical with, lower-level property instances. But Pereboom also identifies property instances with tokens of causal powers that are associated with the properties that they are instances of. Hence he ultimately analyses the realization of a higher-level property *P* by a lower-level property *Q* in terms of the constitution of the token causal powers of *P* by the token causal powers of *Q*.

Finally, I shall discuss Gillett's mereological conception of realization. In a series of papers, Gillett (e.g. 2002; 2003; 2010) has developed what has come to be known as *the dimensioned view of realization,* according to

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[20] Clapp (2001: 133), Shoemaker (2007: 11), and Wilson (1999: 47-48) advertise their views as solutions to the exclusion problem.

[21] See Craver (2001) for further discussion.

which the realization relation that is implicitly invoked in scientific theories about the relationship between higher-level properties and lower-level properties is the following relation:

> (m-realization) Property/relation instance(s) P_1-P_n, m-realize an instance of a property Q, in an individual A, if and only if A has the causal powers of Q in virtue of the causal powers of P_1-P_n that are conferred on the constituents of A, but not *vice versa*.

On this view, a piece of diamond's *hardness* is m-realized by the property instances and relations of the atoms that mereologically constitute the piece of diamond. Such realization obtains because the causal powers of *hardness* are conferred on the cut diamond in virtue of the conferment of the causal powers of the properties and relations of its parts.

Gillett argues that

> a survey of any number of examples of mechanistic explanation in the sciences, or the entities found at the distinct 'levels' related by such explanations, establishes that the relevant *relata* are usually of qualitatively different kinds (2010: 172, emphasis added).

This, according to Gillett, is a reason to rule out theories of realization that appeal to, in his terminology, "flat" realization relations, which obtain between the properties of the same individual. The three realization relations that are discussed above are flat relations, as each obtains between the properties of the very same individual. Gillett thinks that the theories that postulate flat realization relations (e.g. f-realization, d-realization, s-realization) overlook the fact that the *relata* of realization relations might be qualitatively distinct. In response to this, Shoemaker acknowledges that

> we need an account of realization that gives a role to the properties of micro-entities other parts of macroscopic objects ... [but] the cure for this is not to count the properties of parts of macroscopic objects as the realizers of properties of the macroscopic objects (2007: 32).

A theory about a realization relation that gives a role to micro-level entities and their properties might be required, but this does not mean that the relation through which this is to be established should be counted as *the* realization relation.[22] Surely, from the fact that higher-level properties are m-realized by some lower-level properties, it does not follow that higher-level properties are not s-realized, or d-realized, or realized in terms of any "flat" view's realization relation. This is in line with the pluralist assumption that I have endorsed here, according to which different realization relations can be used in order to perform different theoretical tasks.

4 Concluding Remarks

Given the wide usage of the term "realization", it would be highly ambitious to think that there could be at most one relation that this term picks out at each and every case. I proposed a pluralist conception of realization according to which there could be several realization relations. In accordance with some constraints on how to theorise about realization, what is common to these realization relations is that they should be explanation and necessitation relations. I identified some theoretical roles that realization relations are thought to play. According to one line of thought, realization can be used to formulate a non-reductive version of physicalism in the following sense: non-reductive physicalism is the view that mental properties are realized by physical

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[22] Similarly, Endicott (2011) reports on the dispute between the dimensioned view and the flat views of realization and argues that the debate can be solved by acknowledging that different scientific programs can appeal to different types of realization relation.

properties. Having looked at four theories about realization, I identified four realization relations, and discussed how each of these relations does with respect to satisfying some theoretical demands. [23]

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