Realization, Determination, and Mechanisms
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Abstract
Several philosophers (e.g. Ehring 1996, Funkhouser 2006, Walter 2007) have argued that there are metaphysical differences between the determinable-determinate relation and the realization relation between mental and physical properties. Others have challenged this claim (e.g. Wilson 2009). In this paper, I argue that there are indeed such differences and propose a “mechanistic” account of realization that elucidates why these differences hold. This account of realization incorporates two distinct roles that mechanisms play in the realization of mental (and other special science) properties which are implicit, but undeveloped, in the literature – what I call “constitutive” and “integrative” mechanisms. I then use these two notions of mechanism to clarify some debates about the relations between realization, multiple realizability, and irreducibility.

1. Introduction
When Stephen Yablo suggested that the mental-physical relation be assimilated to the determinable-determinate relation, he expected many to balk at it (1992, 256-7). He admits that there is a conceptual difference between the scarlet/red and physical/mental cases but challenges those who balk to find a metaphysical difference (ibid., 260). Yablo claims that “P determines Q iff: for a thing to be P is for it to be Q, not simpliciter, but in a specific way” (1992, 252). For instance, for a fire engine to be vermilion is for it to be red in a specific way, so being vermilion is a determinate of the determinable being red. Likewise, it seems right to claim that, say, having C-fibers firing in a nervous system of the appropriate kind is having pain in a specific way. So, according to Yablo’s analysis having C-fibers firing in a nervous system of the appropriate kind is a determinate of the
determinable having pain. However, I think that the “specific way” is metaphysically different in these two cases. Consequently, these relations should not be assimilated to one another.

That there may be some metaphysical difference between the determinable-determinate relation and the relation between special science properties and their physical realizers is suggested by the fact that there seems to be nothing to fill the blank in this analogy: to be in the physical condition K of this steaming tea is to be at 95°C in a certain micromechanical way just as to be the scarlet of Hester Prynne’s letter A is to be red in a certain ___ way (see Yablo 1992, 253 for the tea example). While being scarlet is a way of being red, it makes no sense to try to characterize further the kind of mechanism by which scarlet, as opposed to crimson, determines red. By contrast, not only is a physical realizer a way of being the mental property it realizes, it is perfectly coherent to ask how, or by what kind of mechanism, the realizer determines the mental property. Robbie the robot thinks that \(2 + 2 = 4\) in a mechanical way, I do so in a neurochemical way. Similarly, this paint stripper removes paint in a chemical way, that one does so in an electronic way; this braking system slows the car mechanically, that one does so hydraulically.

If realization is the relation that establishes that mental properties (and realized properties in general) are physically acceptable, then it is crucial that it provides a framework in which to spell out the physical mechanism by which mental properties are realized. It appears that the determinable-determinate relation is unable to satisfy this demand. Thus, it does not establish that, or how, mental properties fit into a physical universe. Further, since the influential “subset” account of realization includes the determinable-determinate relation as a special case (see Shoemaker 2007), it cannot provide a complete, positive account of the mental-physical relation. In the next section, I elaborate

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1 Jessica Wilson (2009) has recently defended the claim that mental-physical realization has the “core” feature of the determinable-determinable relation (the “specificity principle” expressed by the quotation from Yablo above) and all of the features that “flow” from this feature and are required to solve the problem of mental causation. She proposes a “proper subset” account of determination, which is very similar to the subset account of realization (e.g. Shoemaker 2007). As will become clear below, I am happy to allow that there is a general relation of realization or “determination” that
on the metaphysical differences suggested by the above example, noting that realized properties are not abstract relative to their realizers in the same way that determinables are abstract relative to their determinates. In Section 3, I connect this difference concerning abstractness to two conditions on determinables and determinates that need not be satisfied by mental properties and their physical realizers: maximally determinate realizers of a given determinable are *incompatible* with one another – they cannot be instantiated in the same place at the same time; and determinates of different ultimate determinables are *incomparable* to one another – they fall into non-overlapping hierarchies. In Section 4, I discuss two roles that mechanisms play in the realization of special science properties – *constitutive* and *integrative* roles – and show how they can further elucidate the aforementioned metaphysical differences and be used to formulate an account of how physical properties realize special science properties. In the final section, I sketch a couple applications of incorporating notions of mechanism into an account of realization.

2. Abstraction and Property Aspects

To get clearer about the metaphysical differences adumbrated above, note that when we say that red is multiply realized we may mean two different things. We may mean (1a) that entities can have different “rednesses” – that *redness* is realized by *scarlet*, *vermillion*, and *titian*. Or we may mean (1b) that *redness* (even the same determinate shade of, say, vermillion) is realized by a variety of physical properties (and sustained by a variety of physical mechanisms): for example, by the way in which light is affected or produced by the properties and interactions of the particles in a bird’s wing (diffraction), a dragonfly’s wing (thin film interference), or neon and gas flames (incandescence). Or consider the claim that temperature is multiply realized. We may mean (2a) that

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applies to both the mental/physical case and “traditional” determinable-determinate cases and even perhaps that this relation provides a basis for solving the problem of mental causation. Thus, my motivation for distinguishing the mental-physical realization from a more restrictive determination relation differs from the motivations of Ehring, Funkhouser, and Walter. I am more concerned with the relations between properties at different levels of abstraction (i.e. those that play a role in different sciences) and what is required of a relation that establishes that mental properties are physicalistically acceptable.
things can have different temperatures (different determinate values of the same determinable). Or we may mean (2b) that a determinate temperature value can be realized in a variety of physical media by different properties and mechanisms: in gases by mean translational kinetic energy of the gas molecules, in plasmas (not in local thermodynamical equilibrium) by mean translational kinetic energy of the free electrons or by the mean translational kinetic energy of the ions, or in a vacuum by the blackbody distribution of transient radiation.

We can capture this difference as follows: determinates of a single determinable differ with respect to aspects of the determinable itself. For example, the way in which (an instance of) scarlet differs from (an instance of) crimson is in its redness. One plausible account of perceived colors sees them as individuated by three aspects: hue, saturation, and brightness. A determinate shade of red, like scarlet, is concrete in that it has a particular value of hue, saturation, and brightness. The determinable red is abstract in that it is less specific regarding these aspects; it is characterized by a range of hue, saturation, and brightness values. The very same aspects exhaustively characterize both the determinable and determinate. In general, the hue, saturation and brightness values associated with a determinate color are a subset of those associated with its determinables. For example, the hue, saturation, and brightness values associated with the sequence – vermilion, bright red, red, colored – form a nested sequence of volumes of a single three-dimensional space, moving from vermilion’s very small, almost point-sized region to the entire space, which characterizes the ultimate determinable colored (cf. Funkhouser’s (2006, 2007) discussion of “determination dimensions”).

By contrast, two realizers of a mental property differ in ways that are not captured by aspects of the mental property itself. In order to specify how physical realizers of pain differ, we need not say that they differ in their “painness,” in the aspects that characterize pains – for example, in the

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2 As I discuss below, this is related to the fact that a determinate falls under only a single hierarchy of determinables. This point is also related to what Ehring calls the “difference principle: distinct same-level determinates of a determinable Q differ with respect to Q (are different Q’s)” (1996, 471).
intensity, duration, qualitative, or affective aspects of the pain. Rather, we can list “non-pain” ways in which the realizers differ. For example, the realizers will be characterized by various aspects and distinguished along different dimensions, e.g., physiological, chemical, and physical. That is, the mental property is characterized by different aspects than those that characterize its realizer. It varies with respect to dimensions along which its physical realizers do not vary, and it need not vary along dimensions that characterize its physical realizers: qualitatively identical pains could be realized in different kinds of physical systems (at least if pain is multiply realizable). In general, special science realized properties and their physical realizers differ from determinables and determinates in that they belong to different aspect spaces.\(^3\)

This difference regarding aspects is reflected in the fact that mental properties are not abstract with respect to their realizers in the same way that determinables are abstract relative to their determinates. As noted above, a determinable is abstract relative to one of its determinates in that it takes up a larger volume of an aspect space common to both of them. A mental property is not abstract relative to one of its physical realizers in this way, but the way in which it is more abstract is harder to state precisely. If the intuitions behind the multiple realization argument are correct, mental properties are more “modally flexible” than physical ones. They are paradigms of the properties Robert Stalnaker describes as “more abstract, and so might apply to things even if the properties on which they seem to supervene did not” (1996, 233). They could be instantiated over a wider range of physical conditions or situations than their realizers could. Realized properties are abstract relative to their realizers in that they are relatively indifferent to which aspect space characterizes their realizers.

\(^3\) I am officially neutral on whether the aspects that characterize realizers include those that characterize the properties they realize in addition to others, or whether the aspect spaces for realized properties and their realizers are disjoint (although I incline toward the former view). The answer to this question will be relevant at one point in Section 5. Wilson (2009) argues, in effect, that psychological determinables may have explicitly physical aspects. This may be true, but I suspect that such physical aspects cannot be essential to psychological properties. If they were, then such psychological properties would be essentially physical, and physicalism, if true at all, would be necessarily true.
For example, realizers of a mental property can be mechanical, neurochemical, hydraulic, etc. as long as these aspects “combine” or “aggregate” so as to result in the instantiation of the mental property.

This difference regarding abstraction has sometimes been overlooked in the literature. For example, in his 1998 book, Jaegwon Kim does not appreciate that it is one thing to claim that *having a primary color* is realized by *being blue*, *being red* and *being green* and another to claim that *dormitivy* is realized by chemical structural properties of *diazepam* and *secobarbital* (1998, 20-1). Kim is wrong to suggest that these two examples are exactly alike as instances of realization. For, a determinable bears two subset relations to one of its determinates: (i) the range of values of the aspects that characterize the *determinate* are a subset of those that characterize the *determinable*, and (ii) the causal powers contributed by the *determinable* are a subset of those contributed by the *determinate*. I claim that the former subset relation does not hold for high-level properties and their microphysical realizers.\(^4\) The values of the aspects that characterize the chemical structure of *diazepam* are not a subset of those that characterize *dormitivy*. Likewise, the values of the aspects of a mental property are not a subset of those of its physical realizers. Thus, these physical realizers are not determinates of the mental properties they realize.

3. Incomparability, Incompatibility, and Multiple Determinativity

Although a given determinate will determine several different determinable properties, all of these determinables will fall under the same ultimate determinable. For example, every first-order property of individuals that a shade of *red-orange* determines will be some more or less determinate *color*. In his seminal writings on determinables, W.E. Johnson claims that color is “distinctly other” than determinables like shape or tone (1921, 174). “Further, what have been assumed to be determinables—e.g. colour, pitch, etc—are ultimately different in the important sense that they cannot be subsumed under some one higher determinable, with the result that they are incomparable with one another” (ibid., 175).

\(^4\) I use the terms ‘high-level’ and ‘special science’ interchangeably.
For any two determinates, \( X \) and \( Y \), of a given ultimate determinable \( D \), every property determined by \( X \) falls under the same ultimate determinable as every property determined by \( Y \). No property determined by \( X \) falls under an ultimate determinable other than \( D \). Two shades of red are comparable to each other and every other color, but are incomparable to shapes. No shade of red can determine a shape. Two determinate properties either fall under the same ultimate determinable or fall under different ultimate determinables, but they cannot do both.\(^5\) Since scarlet and crimson are two determinates of redness, they cannot determine any determinable that does not fall under color. This is because properties that fall under different ultimate determinables are incomparable, as Johnson points out.

Now consider properties that fall under the same ultimate determinable. Johnson claims that “… the several colours are put into the same group and given the same name colour, not on the ground of any partial agreement, but on the ground of the special kind of difference which distinguishes one colour from another; whereas no such difference exists between a color and a shape” (1921, 176). As A.N. Prior notes, Johnson was struck by the incompatibility of the determinates that are all at the same level under a given determinable – by the fact that, for example, nothing can be both red and blue at the same time (in the same part).\(^6\) This “special kind of difference” or incompatibility can be nicely captured within an aspect space. What unites determinates of a determinable is simply the fact that they all have different locations in the same aspect space. Two shades of red are similar in that they are close together in hue-saturation-

\(^5\) As Richard Boyd pointed out (personal communication), these claims will hold only for non-conjunctive properties, since the property of being a red square will of course determine both being red and being square. Further, he raised the example of “cross-modal” adjectives like warm and grating, which might be used to compare colors and tones, and thus might be thought of as determinables covering both colors and tones. One way to handle such cases is to note that such adjectives are properties of properties and restrict the requirements on determinables and determinates to properties of individuals.

\(^6\) One might think that determinate sounds or tones are not incompatible in this way. However, while two sounds may be present in the same room at the same time, their waveforms will occupy different regions of that room at any given instant (or will interfere to produce a third tone). Thanks to Mark Crimmins for raising this point.
brightness space; they fall within a certain volume of that space, but they are different colors simply because they occupy different regions in that same volume – the very thing by which they are grouped together. The *incompatibility* of determinates under a common determinable is captured by the fact that any part of an object can only have one maximally determinate property from a given aspect space at a time. It is metaphysically impossible for a maximally determinate property to be located in two particular locations in that aspect space.⁷

If physical properties are determinates of the mental properties they realize, then two claims should follow about them. First, all properties realized by a realizer, \( P \), of a determinable mental property, \( M \), should be *incomparable* to determinables that fall under an ultimate determinable other than that under which \( M \) falls. That is, \( P \) should not realize any properties that fall under a different ultimate determinable than that under which \( M \) falls. Second, \( P \) should be *incompatible* with any other (maximally determine) realizer of \( M \): no two maximally determinate realizers of \( M \) are instantiable in the same place at the same time.⁸ However, as I argue below, neither of these claims holds, which again shows that mental properties are not determinables of their physical realizers.

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⁷ Wilson (2009) claims that different sciences may treat the same determinable as being characterized by different aspects (i.e. that the aspects that characterize a particular property may be science-relative). Even if this is true, the claim made in the text still holds as long as we hold fixed the relevant science. (See the end of note 1.) Further, I am skeptical about Wilson’s claim that her “proper subset” causal power account of determination can accommodate the science-relativity of aspects. This point should be reflected in different sciences assigning different numbers of dimensions to the aspect space for mental properties. As Wilson correctly notes: “what looks like a point relative to a particular property space, defined by a specific set of determination dimensions, is (under the effective “magnification” associated with a finer level of metaphysical grain) in fact an extended space, with further (possibly physical) determination dimensions.” However, when she discusses how the “proper subset” account of determination allegedly handles this phenomenon she makes a different point: “The laws of one science may be sensitive to relatively small supersets of the set of causal powers had by the determinable, while the laws of another science may be sensitive to relatively large supersets of the determinable set.” This may be true, but it is a point about different sciences’ sensitivity to different determinates within a *common aspect space*, not about the structure of the *aspect space itself* being science-relative.

⁸ This claim is a special case of Ehring’s “principle of exclusion: If \( P_1, \ldots, P_n \) is a complete set of same-level determinates of \( Q \), then if \( x \) has \( Q \), then \( x \) has only one of the properties in this set” (1996, 470). Walter (2007, 226) argues that the principle of exclusion is not a necessary condition on the determinable/determinate relation. He cites cases of vague, same-level determinates such as *being*
Suppose the physiological property *having Aδ-fibers firing in a nervous system of the appropriate kind* realizes *having an acute pain*. As just noted, if *having Aδ-fibers firing in a nervous system of the appropriate kind* is a determinate of *having an acute pain*, then it should realize no properties that fall under a determinable other than *having pain*. Further, the same should be true of all the realizers of this physiological property, including one of its microphysical realizers, say, *S*, an immensely complicated structural property of the organism involving properties of and relations between molecules and ions.

However, *having Aδ-fibers firing in a nervous system of the appropriate kind* realizes *having myelinated fibers firing in a nervous system of the appropriate kind* which does not, in turn, realize *having pain* or even *having a sensation* (supposing that is the ultimate determinable under which *having pain* falls). The microphysical realizer *S* realizes an even greater variety of properties of the nervous system in question: *having a certain mass, having a certain charge, elasticity, and electrical conductivity*. These two realizers of *having an acute pain* simultaneously realize properties that fall under different ultimate determinables and thus are not incomparable to those other determinables.

Likewise, two realizers of *having an acute pain* need not be incompatible; it is metaphysically possible for two maximally determinate realizers of *having an acute pain* to be instantiated at the same time in the same part of an object. For example, suppose that *having Aδ-fibers vibrating in a nervous system of the appropriate kind* also realizes *having an acute pain*. Then, in an organism with a redundant nervous system that works both electrochemically and mechanically, *having Aδ-fibers firing... and having Aδ-fibers vibrating...* will both realize *having an red and being orange* and suggests that objects which have a property that is a borderline case between such same-level determinates violate the principle of exclusion. Even if Walter is correct that such cases are counterexamples to the general principle of exclusion, they pose no problem for *incompatibility* as formulated above, assuming that maximally determinate properties have no borderline cases.

Note that this is a total realizer – a realizer whose instantiation is metaphysically sufficient for (i.e. necessitates) the instantiation of *having an acute pain* – not a core realizer (such as *having Aδ-fibers firing*), whose instantiation does not necessitate the instantiation of the realized property. If the laws of nature are metaphysically contingent, then they should be also included in the total realizer.
acute pain in that organism. Since a single Aδ-fiber could both be firing and be vibrating at the same time, these realizers are not incompatible.

The fact that physical realizers of mental properties are comparable to other realized properties opens up the possibility that physical realizers are multiply determinative: they may realize different kinds of high-level properties, properties that fall under different ultimate determinables.¹⁰ This terminology is meant to contrast with cases where a realized property is multiply determinable, i.e. multiply realizable. Consider Putnam’s (1975) classic discussion of a cubical peg. The structural property instantiated by the rigid lattice of atoms that make up the peg realizes the specific mass, color, and rigidity of the peg, in addition to its shape. Similarly, the atomic structure of a metal (the core realizer of which is its free electrons) realizes the metal’s ductility, conductivity, opacity, and luster (see Menzies 1988).

4. Mechanisms: Constitutive and Integrative

Although the notion of mechanism has received increasing attention in the philosophy of science literature (especially as the notion figures in neuroscience and biology) (see, e.g., Bechtel and Richardson (1993); Machamer, Darden and Craver (2000)), it has largely remained in the background in discussions of realization. In this section, I discuss two roles that mechanisms play in

¹⁰ Several authors have discussed relations that are similar to multiple determinativity, e.g., Menzies (1988), Gasper’s “multiple supervenience” (1992), and Endicott’s “constructival plasticity” (1994). Menzies discusses many interesting examples where two properties supervene on the same base property; multiple determinativity is most like the examples he discusses under “typical causal role supervenience” (except it is explicitly about total realizers). Philip Gasper (1992) discusses a similar phenomenon, which he calls “multiple supervenience,” and argues that it blocks reductive explanation. But Gasper cites an example of what Menzies calls “logical supervenience” where a hierarchy of determinables (being less than 1 cm in length, being less than 0.9 cm in length, etc.) supervenes on a single molecular base (1992, 668) as an example of multiple supervenience. Determinates of a given determinable obviously exhibit this phenomenon, but I claim that these determinates are not multiply determinative (in the right way)—they do not realize different kinds of properties, properties which fall under different ultimate determinables. Menzies’ and Gasper’s discussions are too broad—conflating relations that should be kept distinct. Endicott’s “constructival plasticity” is simply the phenomenon of a single core realizer realizing incompatible properties when embedded in different total realizers. By contrast, multiple determinativity is not the converse of multiple realizability. It is not the claim that a (core) physical realizer could have realized different mental properties from those it actually does.
the realization of psychological (and other special science) properties. The first, *constitutive* role of mechanisms, typically involves properties of and relations between constituents of the object that has a given realized property. The second, *integrative* role of mechanisms involves a broader network of realizers of other properties and includes the constitutive mechanism for the given realized property as a proper component.\(^ {11}\) The integrative mechanism provides an explanation of how the realized property is integrated into causal or nomological relations with other realized properties. After using the distinction between integrative and constitutive mechanisms to elucidate the metaphysical differences discussed above, I use these two notions of mechanism to provide a positive account of the realization relation between mental and physical properties.

The following passage suggests that mechanisms play two roles in the realization of high-level properties:

When \( P \) is said to ‘realize’ \( M \) in system \( s \), \( P \) must specify a microstructural property of \( s \) that provides a causal mechanism for the implementation of \( M \) in \( s \); moreover, in interesting cases — in fact, if we are to speak meaningfully of ‘implementation’ of \( M \) — \( P \) will be a member of a family of physical properties forming a network of nomologically connected microstructural states that provides a causal mechanism, in systems appropriately like \( s \), for the nomological connections among a broad system of mental properties of which \( M \) is an element. These underlying microstates will form an explanatory basis for the higher properties and the nomic relations among them. (Kim 1993, 197)

First, the realizer \( P \) must itself provide a causal mechanism for the instantiation of \( M \) — a *constitutive mechanism*, in which the instantiation of \( M \) in \( s \) is explained by the components of \( s \) being propertied and related in certain ways. (See Figure 1, below.) Second, this constitutive mechanism is part of a larger causal or nomological network that provides what I call an *integrative mechanism* for a network of high-level properties of which \( M \) is but one member.\(^ {12}\) Note that the integrative

\(^{11}\) The integrative role of mechanisms is similar to what Craver (2007), following Wesley Salmon, calls the “etiological” aspect of causal-mechanical explanation. However, the integrative role of mechanisms is both backward- and forward-looking.

\(^{12}\) Note that I am not I imposing the restriction that the integrative network be causal; it may be a set of lawlike relations between properties that are mathematically, intentionally, or otherwise individuated (see Polger 2007, 239-247 for discussion of such cases). For the purposes of this paper,
mechanism is not constitutive (or decompositional). That is, the properties that are components of the integrative mechanism and the properties in the high-level network that is mechanistically explained both belong to the same entity (or, to entities at the same mereological level) (e.g. in Figure 1 below, K, L, M, and N and P, Q, R, and S all belong to the same entity, s). By contrast, in a constitutive mechanism, the properties (in Figure 1: w, x, y, z) involved in the mechanism belong to proper parts or sub-systems of s. However, unlike an integrative mechanism, a constitutive mechanism alone does provide an explanation of the laws or generalizations that are the typical subject matter of the special sciences. Rather, a constitutive mechanism explains how it is that a given special science property is instantiated, which is often presupposed by the special sciences.  

For example, the microstructure of acids (including the crucial activity of proton donation) provides a constitutive mechanism for being an acid and is part of an integrative mechanism that can be used to explain why acids behave the way they do (e.g., dissolve metal, form a salt when combined with a base, turn litmus paper red).

[Figure 1: Constitutive and Integrative Mechanisms]  

Recall that realized properties are abstract relative to their physical realizers in that they belong to different aspect spaces and that realized properties are indifferent regarding which aspects characterize their realizers. By contrast, determinables and determinates share the same aspect space. These claims are connected to the fact that determinates do not provide constitutive mechanisms for the properties they determine.

Properties for which physical constitutive mechanisms are especially needed are special science properties that belong to a macroscopic object but (physically) could not belong to that  

I remain neutral on the question of whether such non-causal cases are relevant to the realization of mental properties. In general, I will restrict my discussion to causal cases for simplicity.

Block (1997) seems to have something like an integrative mechanism in mind when he writes: “The relations among temperature, pressure, entropy, etc are mirrored by relations among mean molecular kinetic energy, momentum exchange, etc, and the latter family provide[s] a mechanism for explaining the relations among the former. That is what makes the latter properties realize the former, or anyway it is closely connected to what makes for this realization” (118, italics added).
object’s microphysical parts (like *being alive* and *being in pain*). Constitutive mechanisms give details about the properties of, and relations between, parts of an object that are responsible for the instantiation of that object’s realized properties. This suggests the following requirement on constitutive mechanisms. In order for a realizer to provide a constitutive mechanism for the property it realizes, the realizer must be characterized by different aspects than those that characterize the realized property. An explanation utilizing a constitutive mechanism would be uninformative and circular, in a sense, if it included the same type of property (a property characterized by the same aspects) whose instantiation the mechanism is intended to explain. This is why determinates of a given determinable do not provide constitutive mechanisms for the properties they realize; they belong to the same aspect space as their realized properties. This requirement (that the aspects that characterize the properties in the constitutive mechanism be different than those that characterize the realized property) also helps to clarify the popular spatial metaphor of mechanisms and realizers “underlying” the properties whose instantiations they explain. The realizer properties involved in the mechanism often belong to an aspect space that is more basic – in the sense of characterizing properties of objects at a lower mereological level – than the aspect space to which the realized property belongs.

While aspect spaces are connected to the notion of a constitutive mechanism, multiple determinativity is connected to the notion of an integrative mechanism. The different kinds of properties that are simultaneously realized by a multiply determinative physical realizer correspond to different integrative mechanisms in which that realizer plays a role. For example, the molecular structure of a metal will be a component in an integrative mechanism that explains the relations between the metal’s electrical conductance\(^{14}\) and other macroscopic properties, but it will also be a component in a different integrative mechanism that explains the relations between the metal’s\(^{14}\) Conductance (like resistance and current) is a macroscopic property of a sample of a substance as a whole, as opposed to conductivity (like resistivity and current density), which is a microscopic property, having values at every point in a body.
rigidity and other macroscopic properties. Hence, a single constitutive mechanism type (specified by the type(s) of components of the constitutive realizer) can play a role in multiple types of integrative mechanisms.\textsuperscript{15}

With these points regarding mechanisms and their relation to the foregoing discussion in mind, I propose the following positive account of the way in which physical properties realize mental (and other high-level) properties. A physical property $X$ realizes property $Y$ if and only if (a) the set of causal powers contributed by $Y$ is a subset of the causal powers contributed by $X$ (if $X$ contributes any causal powers at all)\textsuperscript{16}, and (b) the components of $X$ provide a constitutive mechanism for the instantiation of $Y$, which (c) fits into a family of realizers that, in turn, provides an integrative mechanism for $Y$’s causal or nomological relations to other (usually high-level) properties.\textsuperscript{17}

5. Applications

Incorporating a mechanistic element into an account of how special science properties are realized by physical properties clarifies why mental properties are not determinables of their physical realizers and why the “subset” account of realization does not exhaustively characterize the mental-physical relation. Rethinking the mental-physical relation in a mechanistic framework promises to be fruitful in thinking about questions of multiple realizability and irreducibility, as well. I shall outline a couple of these applications in the remainder of the paper.

\textsuperscript{15} Arguably, different types of integrative mechanism will correspond to different special science domains. E.g., there will be biological, psychological, and geological integrative mechanisms. For some explanatory purposes, one might want to distinguish sub-types of integrative mechanism as well (e.g. affective and cognitive mechanisms in psychology). Wilson (2009) suggests that a special science property can even have low-level physical aspects; this will be true if, e.g., relations to low-level physical properties are included in some integrative mechanism for the special science property.

\textsuperscript{16} I include the parenthetical clause to allow for the possibility of realized properties that are not causally individuated (see Polger 2007, 239-247). In such cases, condition (a) will be vacuously satisfied.

\textsuperscript{17} An anonymous referee raised the concern that the notion of a mechanism presupposes, rather than explains, the realization relation. While this worry merits further discussion, I should note that I am not committed to a reductive analysis of realization in terms of a conceptually prior notion of mechanism.
First, the distinction between constitutive and integrative mechanisms can be used to spell out
the intuitive contrast Lawrence Shapiro (2000, 2004) draws between “trivial” and “substantive”
multiple realization and to show what is involved in disputes about such cases. Shapiro uses this
distinction to argue that the prevalence and significance of multiple realization have been overstated
by some of its proponents. Some differences between realizers of a given realized property or kind
seem to be trivial, and these should have no implications for the irreducibility of that realized
property or kind. Consider a controversial example: if the only difference between two corkscrews is
that one is made of aluminum and the other is made of steel, does this show that being a corkscrew
is multiply realized? Shapiro says no; only differences that are relevant to the functional role of being a
corkscrew, like that between a waiter’s corkscrew and a winged corkscrew, make for substantive
multiple realization. By contrast, Carl Gillett (2003) claims that the difference in composition is
sufficient for substantive multiple realization.

How should this dispute be adjudicated? Apparently, Gillett believes that answering this
question requires adopting the correct account of realization. He writes, “it appears plausible that
providing … an account of realization would be a necessary step in any precise understanding of
multiple realization” (2002, 592). Further, Gillett (2003) holds that Shapiro arrives at the wrong
answer in the corkscrew case because he is implicitly relying on a “flat” account of realization,
according to which the realized and realizer properties are both had by the same individual and share
at least some of the causal powers contributed to that individual. By contrast, Thomas Polger claims
that this gets things methodologically backward: “We must fix our [multiple realization] judgements
and then formulate an appropriate account of realization” (2007, 255).

I think that neither view is entirely right. Polger is correct that multiple realizability is “a
claim about the diversity of things that can have common states or properties, i.e., about the
generality of certain explanatory kinds” (ibid.) and that this is largely independent of the
metaphysical nature of the realization relation. However, I believe that Polger’s notion of multiple
realization is too weak and general to be of much interest. It is so weak that it allows for the possibility of a property being multiply realized without being realized at all: “The class of things that experience pains cross-cuts some biological classes, such as species. In this sense, pain is multiply realizable—it is realized in biologically distinct kinds of things. But whether it is realized differently in various kinds of things is another matter. … If pain can be identified with a brain process that is common across pain-experiencing species, then it is not realized in the [realization physicalism] sense” (ibid., 256).

Although multiple realizability is a claim about the diversity of things that have common properties, not just any kind of diversity makes for substantive cases of multiple realizability. Substantive multiple realization occurs only if there is significant variation in the components or activities of the constitutive mechanisms for a given realized property.\(^{18}\) That is, multiple realization occurs only if a type of single integrative mechanism is underwritten by different types of constitutive mechanisms. The species of a pain-experiencing organism is certainly not a component of the constitutive mechanism (e.g. brain process) that realizes being in pain. So, the fact that organisms of different species can experience pain does not show that being in pain is (substantively) multiply realized. This may seem like merely a semantic point about how broadly to apply the term “(substantive) multiple realization,” but I believe there are important theoretical reasons to restrict the use of the term so that it does not apply to cases like Polger’s. When we ask whether pain is multiply realized we are asking whether the same property is “brought about” in different ways (is

\(^{18}\) I suspect that Carl Craver’s discussion of “constitutive relevance” – how to determine whether a part of a system S is a component in the mechanism for S’s having or exercising a certain capacity (2007, 139-160) – could be adapted to help determine whether the differences between components of constitutive mechanisms count as cases of substantive multiple realizability. For example, if one took an aluminum lever-style corkscrew and gradually replaced its aluminum atoms with iron, carbon, and chromium atoms (that bear the appropriate relations to one another) and the resulting corkscrews performed in ways that were expected given the equations or functional relationships corresponding to the relevant integrative mechanism, then this would support the claim that this is a case of substantive multiple realizability, since the changes in composition would be relevant to the differences in the corkscrews’ functionality as corkscrews. See the discussion below.
constituted by different mechanisms), not merely whether some things that have pain differ in any way at all (e.g. are members of different species). It is only the former question that is relevant to questions of irreducibility, to whether being in pain is an irreducible natural mental property or identical to a natural biochemical property.

Returning to the question about the corkscrews, does the correct answer to this question depend on adopting a particular account of realization, as Gillett seems to claim? I think not. (Here I agree with Polger (2007, 255-257).) However, while judgments about multiple realizability do not presuppose a specific view about the nature of the realization relation, this does not imply that judgments about multiple realization are completely independent of the nature of realization. An account of realization is to be preferred if it facilitates such judgments by codifying and illuminating the relevant kinds of variation in systems that have the realized property. On the one hand, it may seem that the difference between an aluminum and a steel corkscrew is not relevant to multiple realization since both utilize the same mechanism for removing corks, as Shapiro points out. On the other, it seems clear that the atoms in the corkscrews are components of different constitutive mechanisms for being a corkscrew, so doesn’t this difference generate a case of multiple realization, after all, as Gillett claims?

It may seem that the differences between the determinable-determinate relation and the realization relation show that Shapiro is mistaken about this case. One might think that Shapiro mistakenly equates variation with respect to determinates of a single determinable property (being a waiter’s corkscrew and being a winged corkscrew) with substantive multiple realization. This is Eric Funkhouser’s interpretation:

Corkscrew [multiple realization] consists in sameness of corkscrew type through difference in some other Y-type, though the corkscrew type is realized in the Y-type properties. Shapiro offers the different mechanisms – “waiter’s” and “winged” – as different Y-types that serve as multiple realizations. But note that a difference in corkscrew mechanism is a “corkscrew difference.” Indeed, this seems to be Shapiro’s whole point. But, importantly, multiple realizations of an X-type do not make a X-type difference! Multiple realizations of a mental kind like pain, if they exist, do not
differ in their “pain-ness”. In contrast, different mechanisms of corkscrews do differ in their “corkscrew-ness”. (2007, 479, italics in original)

While I agree with the general tenor of this passage, I believe that it does not definitively show that Shapiro is mistaken. Whether or not the difference between a waiter’s and a winged corkscrew counts as a “corkscrew difference” depends on how we individuate the property of being a corkscrew. If we take it to be characterized by only one aspect, say, variation in performance with respect to removing corks made of different material, then the difference in corkscrew mechanism does not count as a “corkscrew difference.” Rather, the waiter’s and winged corkscrews are different constitutive mechanisms for the property being a corkscrew, which is individuated by a very simple integrative mechanism that relates being a corkscrew only to properties concerning cork composition. However, if we take the aspect space of being a corkscrew to include variation in the mechanism by which corks are removed, then being a waiter’s corkscrew and being a winged corkscrew are not distinct realizers of being a corkscrew; rather, they are rather determinates of this determinable property. This difference is now incorporated into the integrative mechanism (and associated aspect space) that defines what it is to be a corkscrew; it is no longer a difference in constitutive mechanism.¹⁹

Note that this does not determine whether or not a mere difference in composition makes for substantive multiple realization of being a corkscrew. The relevant question is whether the difference between a corkscrew made out of aluminum and one made out of steel is a difference in kind between (chemical) constitutive mechanisms (as, in effect, Gillett holds), or whether it is instead either not such a difference (and thus amounts merely to different instantiations of the same realized property, as Shapiro holds) or a difference in integrative mechanisms (and thus amounts to a “corkscrew difference” between different determinates of a single determinable). This is partially an

¹⁹ Part of the difficulty of evaluating this case is the artificiality involved in talking about “corkscrew science” or a “corkscrew level of abstraction.” It is very plausible that a “science of corkscrews” is merely part of the study of simple machines (or of the mechanics of rigid bodies, more generally). This would suggest that the latter characterization of the relevant aspect space is to be preferred.
empirical question that will be answered by doing some chemistry and rigid body mechanics (see notes 18 and 19). However, the end of the quotation from Funkhouser suggests a misleading constraint on answering this question, and, in general, on determining whether or not high-level determinable properties are multiple realized. Funkhouser claims that multiple realizers of a property X do not differ in their X-ness. But, this may not be true when X is a high-level determinable property. What is true is that any difference in X-ness among distinct realizers is not what makes those realizers distinct.

Clearly, a sufficient condition for a determinable to be multiply realized is that one of its maximally determinate properties is multiply realized. However, this is not a necessary condition on the multiple realization of high-level determinable properties. Suppose that there is only one possible realizer, $R_1$, of a maximally determinate shade of red, $S_1$; there is only one physical constitutive mechanism that can “produce” this shade. Suppose also that this is sufficient to warrant the identity, “$R_1 = S_1$.” Suppose that the same is true of a distinct maximally determinate shade of red $S_2$; some distinct kind of mechanism uniquely realizes it, so $R_2 = S_2$. In this case, being red is multiply realized, but the distinct realizers do differ in their “redness”, contra the passage from Funkhouser. However, this difference in redness is not that in virtue of which being red is multiply realized. If $R_1$ and $R_2$ were merely instances of the same kind of constitutive mechanism, this would not be sufficient for the multiple realization of being red.

Distinct realizers of being a corkscrew all have to be sufficient for the instantiation of some determinate kind of corkscrew or other, but these need not be the same determinate kind of corkscrew. If each distinct determinate is realized by a structural property that involves a

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20 This assumes, I think, that the aspects that characterize the realized property are a proper subset of those that characterize its realizer. If one denied this, and claimed that the respective aspect spaces were disjoint (see note 3), then there would be no property identity, but the general point I am making about the multiple realization of determinable properties would still hold: sometimes distinct realizers of determinable property X may be put in a one-one correspondence with determinates that differ in their X-ness.
constitutive mechanism that is distinct in kind from those constitutive mechanisms involved in the realizers of the other determinates, then we will have a case of substantive multiple realization of the determinable being a corkscrew by distinct realizers corresponding (perhaps uniquely, as in the hypothetical color case above) to distinct determinates. In this case, all that the “sameness through difference” of multiple realization requires is that the distinct realizers are sufficient for properties that all fall within some broad region of the same aspect space. Put another way, if we think of the functional relationships or equations specified by the structure of the integrative mechanism for being a corkscrew as corresponding to different aspects of that property, then different values of these functional relationships will correspond to different determinate kinds of corkscrew and if these differences are grounded in different kinds of constitutive mechanism, then we will have substantive multiple realization.

So, the fact that the determinable-determinate relation is not the realization relation (or that “specification” is not “realization,” in the terms of (Funkhouser 2007)) does not completely settle this dispute about multiple realizability. Disputes about the multiple realization of determinable properties sometimes concern whether or not some difference in composition corresponds to a type difference in constitutive mechanisms that underwrites differences in the objects’ functionality with respect to that determinable (e.g. the performance of corkscrews as corkscrews). Whether or not one endorses a “flat” or “dimensioned” account of realization also does not settle this matter (contra Gillett). If a proponent of a “flat” account thought that the compositional difference was relevant, she would distinguish between aluminum-winged and steel-winged corkscrews within a hypothetical “corkscrew science,” instead of grouping them together as Shapiro does.

Settling the dispute about multiple realizability depends in part on how much detail the relevant special science includes in the integrative mechanism for the realized property. If the integrative mechanism in the corkscrew case is very detailed, including equations or functional relationships describing how the corkscrews perform under a variety of conditions (e.g. how they
fare with corks made of different materials, how much force can be applied to their levers before they
deform), then it is more likely that the compositional difference amounts to substantive multiple
realization via distinct realization of distinct determinates. For example, the aluminum corkscrew
may not be as successful at removing stubborn corks as its steel counterpart because of its smaller
mass and density. In this case, the difference in composition is relevant to how the two corkscrews
perform as corkscrews. If our best chemical theories claim that the mechanisms involved in the
bonding structure in aluminum are different in kind from those involved in steel, then the same
integrative mechanism, given by the form of the functional relationships and equations used to
specify it, is implemented by different constitutive mechanisms.

On the other hand, if the integrative mechanism is “bare bones,” including only the functional
property that the corkscrews can remove at least some corks, then the compositional difference does
not count as a case of substantive multiple realization via distinct realization of distinct determinates.
For, changing the composition from aluminum to steel does not change the corkscrews’ performance
with respect to this functional property.\(^{21}\) (Note that this difference in the level of detail used to
characterize the integrative mechanism does not amount to being less or more restrictive in what we
classify as a corkscrew. Of course, putting fewer constraints on what it takes to instantiate being a
corkscrew will make the property more likely to be multiply realizable (i.e. it is more likely that a
wider variety of constitutive mechanisms will be able to fulfill the weak constraints on being a
corkscrew). The point I am making here is that, given that we have fixed the extension of the
realized property, the richer the causal/functional profile specified by the integrative mechanism, the
more likely it is that fine-grain details of the constitutive mechanism will be relevant to (changes in)
this functional profile and that fine-grain differences between constitutive mechanisms will make for
substantive multiple realization.)

\(^{21}\) Of course, this still could count as substantive multiple realization of a single “maximally
determinate” kind of corkscrew. But, it is unlikely that any interesting “corkscrew science” would
individuate kinds of corkscrews this coarsely. See note 19.
The upshot is that judgments about substantive multiple realizability depend upon considerations of both constitutive and integrative mechanisms. A necessary condition for a property $M$ to be substantively multiple realized is that there are different kinds of constitutive mechanisms for $M$. And whether or not $M$ is substantively multiply realizable also depends on how fine-grained the integrative mechanism for $M$ is. If a wider variety of functional relationships, specified at a finer level of detail, are used to individuate the realized property, then it will be easier to find cases of substantive multiple realizability via distinct realization of distinct determinates. If we make the functional profile of the realized property richer, there will, in general, be more changes in the constitutive mechanism that affect aspects of this functional profile.

Finally, and more briefly, if the discussion in this paper is correct, it suggests that the prima facie irreducibility of certain special science properties (and the autonomy of explanations that utilize them) is not ultimately grounded in their multiple realizability. Rather, it is based in the fact that the relation between constitutive and integrative mechanisms is, in general, many-many. Substantive multiple realizability is simply one facet of this phenomenon, corresponding to the one-many relation between a single type of integrative mechanism (e.g. the causal-nomological network in which being in pain enters) and several kinds of constitutive mechanisms (e.g., c-fibers firing in us, valves opening in a Martian’s feet, etc.). However, the other facet, multiple determinativity, the many-one relation between several types of integrative mechanisms (e.g., psychological and physiological networks) and a single type of constitutive mechanism (e.g., components of a complicated microphysical structural property of a nervous system), may also establish the irreducibility of realized properties (see Haug (unpublished) for a defense of this claim). For instance, suppose that the properties being an airfoil and being a thermoregulator were uniquely realizable by specific microstructural property, $P$, of a dragonfly’s wing. It is plausible that neither of these properties is identical to $P$, assuming that each is a component of distinct integrative mechanisms – one involving
properties related to fluid dynamics and airflow, the other involving properties of thermodynamics and heat exchange.\textsuperscript{22}

6. Concluding Remark

Philosophers of biology and of neuroscience have used the notion of mechanism to provide illuminating accounts of explanation (among other things). In this paper, I have argued that philosophers of mind should follow their lead and incorporate the notion of mechanism into their thinking about realization. Not only does this show why mental and physical properties are not related as determinables are to determinates, it also helps to clarify debates about the extent and significance of multiple realization within the special sciences.

\textsuperscript{22} On the subset model of realization, we have one causal profile corresponding to $P$, which has two distinct but overlapping subsets corresponding to \textit{being an airfoil} and \textit{being a thermoregulator}, respectively.
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