Can Multiple Realisation be Explained?

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July 12, 2019

Abstract

Multiple realisation prompts the question: how is it that multiple systems all exhibit the same phenomena despite their different underlying properties? In this paper I develop a framework for addressing that question and argue that multiple realisation can be reductively explained. I defend this position by applying the framework to a simple example – the multiple realisation of electrical conductors. I go on to compare my position to those advocated in Polger & Shapiro (2016), Batterman (2018), and Sober (1999). Contra these respective authors I claim that multiple realisation is commonplace, that it can be explained, but that it requires a *sui generis* reductive explanatory strategy. As such, multiple realisation poses a non-trivial challenge to reduction which can, nonetheless, be met.

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1 Introduction

That some phenomena are multiply realised by different kinds of lower-level system poses a challenge to reduction. In part, this challenge can be expressed as a demand for explanation: how is it that multiple different kinds of systems can exhibit the same phenomena? The challenge to reduction then depends on the claim that this demand for explanation cannot be met – that multiple realisation (MR) cannot be reductively explained.[1] My goal in this paper is to rebut that view: I'll offer a framework for explaining MR.

A further goal of the paper relates to the somewhat confusing array of views regarding multiple realisation and explanation in the philosophy literature – one upshot of this paper will be to disentangle the various philosophical positions.

Polger and Shapiro (2016) articulate a position whereby multiple realisation cannot be explained. However, their view of multiple realisation also implies that it is hardly ever (if ever) instantiated. In other words, they argue that, insofar as putative instances of multiple realisation can be explained, these do not count as genuine instances of multiple realisation.

For reasons developed below, I think that this approach is strategically mistaken: first, it's typical among both philosophers and scientists to accept that multiple realisation is commonplace (examples range from pegs and boards to pain), thus the re-labelling strategy implicitly advocated by Polger and Shapiro seems unlikely to catch on. Second, the demand for explanation is a genuine one – multiple realisation poses an *explanandum* which ought to be taken seriously. Were Polger and Shapiro's view to be accepted, it's not even clear how to express this *explanandum*, let alone how it could be addressed.

So let's say that there is MR in the world. What, then, of the question with which we started: can MR be explained? A forceful advocate of the claim that there is MR in the world is Batterman (2018), who provides various examples from physics where it seems incontrovertible that different kinds of system do in fact exhibit the same phenomena. However, Batterman's view is that MR blocks reduction; he claims that the kinds of explanation of MR which are available essentially involve anti-reductionist ex-

[1] I use 'MR' to refer to 'multiple realisation', 'multiple realisability', 'multiply realised', …

planatory strategies; for similar arguments see Morrison (2012, 2014). While I agree with Batterman and Morrison that MR is found in the world, I disagree that it can't be reductively explained.[2]

I accept that MR is found in the world, that MR posits a non-trivial *explanandum*, and that a reductive answer to that *explanandum* can be found in at least some cases. A likely ally might thus be Sober (1999) who advocates explanatory pluralism in answering questions about MR. However, I claim that none of the explanatory strategies canvassed by Sober is sufficient to explain how MR is instantiated in the world. As such, I argue that an additional explanatory strategy ought to be added to the toolbox in order to rebut claims that MR is reductively inexplicable.

In §2 I'll set out what I take MR to involve, and how it might be explained. I'll develop this account with a simple case study from physics in §3. The remainder of the paper will be taken up with a discussion of the relation between my position and those of the authors just discussed. In summary: with Polger & Shapiro I accept that putative instances of MR can be offered reductive explanations, but *pace* Polger & Shapiro, I hold that these still ought to count as MR; with Batterman I accept that there is MR, but *pace* Batterman I hold that this is reductively explicable; with Sober I accept that there is MR and that it can be explained, but *pace* Sober I argue that an additional explanatory strategy is required in order satisfactorily to address the MR *explanandum*.

2 What is Multiple Realisation?

2.1 Definition

> A higher-level phenomenon is multiply realised iff the same phenomenon is realised in at least two different lower-level systems.

In §2.2 I articulate what would be required for a reductive explanation of instances of MR which conform to this definition. First, the definition

[2]More technical aspects of the discussion which specifically concern the renormalisation group explanation of universality are found in Franklin (2018, 2019) with a response in Batterman (2019).

requires clarification on two counts: what is meant by 'same phenomenon'? And what is meant by 'different systems'?

Phenomena are posited on the basis of experimental data and provide evidence for more general theories.[3] Examples of phenomena include "weak neutral currents, the decay of the proton, and chunking and recency effects in human memory" (Bogen and Woodward (1988, p. 306)). Phenomena are individuated by the scientific theory which describes them, thus we may say it's the same phenomenon if it is well described by the same theory in the same conditions.

Importantly for compatibility with multiple realisability, phenomena are not individuated in terms of their realisers. Thus, as discussed below, an entity may be identified as an electrical conductor because it satisfies aspects of circuit theory, but it's not consequently possible to infer its specific constitution. A principal feature of systems instantiating MR is that they may be identified at multiple levels where higher-level identification does not commit us to any specific realisation.

Multiply realised phenomena are invariant with respect to certain perturbations of the underlying system. I distinguish between two ways a system might be perturbed.[4] On the one hand, consider varying the particular microstate of a particular system – i.e. changes which the system might actually undergo. On the other, consider varying the very nature and make-up of the system itself – these are counterlegal or imagined changes.

Phenomena which are invariant with respect to the first kind of perturbation are called 'robust' – some phenomenon is robust if it's invariant with respect to changes allowed by the laws at the lower level. For example, most thermodynamic phenomena are robust across a wide range of different molecular arrangements, where the molecular laws allow the system to transition from one to another arrangement.[5] The notion of changes allowed by the laws is level-relative: when discussing the robustness or multiple realisation of a given phenomenon we (implicitly) specify a higher and lower level of description. Relative to such level-based descriptions

[3]MR is here defined in terms of (kinds of) phenomena. Although MR may alternatively be defined in terms of kinds of entities, nothing crucial to the argument relies on this choice: one may view *electrical conductivity* as a multiply realised phenomenon, or, alternatively *electrical conductor* may be considered to be a kind of entity.

[4]See Bickle (2016); Hüttemann, Kühn, and Terzidis (2015) for similar distinctions.

[5]Robustness is particularly relevant to characterising emergence, see Butterfield (2011); Franklin and Knox (2018).

a particular precision of description will be appropriate, and the allowed changes will be consequently defined.

By contrast, a phenomenon is multiply realisable if its description is invariant with respect to changes at the lower level forbidden by the laws. This distinction will be further exemplified in the next section where I claim that electrical conductivity is multiply realised by, say, lithium and potassium, where no realistic process can convert a strip of lithium into a strip of potassium. On the other hand, strips of either metal will be robust for a range of different perturbations: the same macroscopic physical properties will be exhibited even where constituent atoms have moved about.

The aim in making this distinction is to ensure that MR is not too cheap: every higher-level phenomenon is robust with respect to some perturbations, but MR phenomena are thought to posit special *explananda*.

Two further comments are relevant. First, higher levels are generically restricted both temporally and spatially; consequently, changes are nomologically impossible at some level if they happen so rarely that they fall outside the time-scale of that level. As such, a phenomenon may count as multiply realised by two different systems even where, on sufficiently long time-scales, some set of otherwise allowed changes would lead to one system's becoming the other. Thus, pressure in a CO_2 gas is robust because there are various different microstates which realise the same pressure, and transitions between those microstates are allowed by the lower-level laws. On the other hand, pressure in gases is multiply realised because both CO_2 and Ne gases may realise the same pressure, but on timescales less than the age of the universe a CO_2 gas cannot change into an Ne gas.

Second, this distinction will not define a division between robustness and MR which always squares with our intuitions. For example, certain colour changes in metals will be dynamically possible while others will not; thus differently coloured metals are, in some instances, trivial but genuine examples of MR. Any way of excluding such boring cases would be arbitrary, but this is not a problem. As soon as we can explain a given instance of MR, it may count as less surprising, or even boring; but the requirement that MR be surprising would, thus, effectively undermine the interesting philosophical and scientific projects of explaining MR – such a stipulation would beg the title question of the paper.

The distinction between MR and robustness is useful: it allows that, while there are genuine instances of MR in the world, not every higher-level phenomenon is multiply realised; however, I do not claim that the distinction is profound. The distinction is nonetheless essential to those who wish to claim both that MR is instantiated in various contexts, and that it is by definition incompatible with reduction. If those philosophers fail to make this distinction they will have a very difficult case to argue; if all robust phenomena count as multiply realised, and multiply realised phenomena are irreducible, then every higher-level phenomenon will be classed as irreducible.

2.2 Explanation and Reduction

A further distinction is worth making at this stage between explanations which refer to MR phenomena, and reductive explanations which tell us how MR is possible. One reason to take MR seriously within the philosophy of science is that the former kind of explanation is commonplace: many different scientific explanations refer to MR phenomena; that fact leaves it open whether or not reductive explanations of MR are available. My goal is non-eliminativist – as such I think it inadvisable to attempt to purge science of reference to MR phenomena. In other words, I do not purport to replace explanations which refer to MR phenomena with reductive explanations, rather I aim to explain why such reference is successful.

With that distinction in hand, MR may be offered two kinds of reductive explanation. First, one may explain the MR phenomenon in terms of the properties of each individual realiser – call this 'specificity explanation'; second, one may explain the MR phenomenon in terms of the common features shared by each realiser, and the details which make such common features sufficient for the occurrence of the phenomenon – call this 'commonality explanation'. Specificity explanations do not explain multiple realisation, they rather focus on the individual behaviour in each system; commonality explanations, by contrast, do explain multiple realisation. One may get an intuitive grasp on the need for commonality explanations if one considers the following story, used by Franklin (2018, p. 228) to illustrate the distinction between these two explanatory strategies:

> a traveler visits a foreign country and goes from house to house observing the local customs. She observes an oddity in the locals' behavior: in each family she visits, the youngest child sleeps in a bed angled such that his or her head is vertically

> lower than his or her feet. At each visit, she asks for an explanation of this phenomenon, and every family offers a different answer: "because he's short and this way he'll grow taller," "because greater blood flow to her head will increase her intelligence," "because it's cooler and his head otherwise becomes hot," "because that's the only way to avoid the awakening smell of dinner," and so on.

The dissatisfaction the traveller will experience is due, I claim, to the inadequacy of specificity explanations. By contrast, if the traveller were told of a shared communal belief that the peculiar sleep orientation reduces cholesterol, and that cholesterol reduction is prized in that country above all countervailing considerations, this would amount to a commonality explanation and resolve her confusion.

One way to justify this distinction is by thinking of such explanations as contrastive. A relevant contrast for specificity explanations is a case where each instance exhibits a different phenomenon – specificity explanations should tell us why children sleep head down *rather than* head up. The relevant contrast for commonality explanations is where the behaviour is no longer shared – commonality explanations tell us why all children sleep with the same orientation *rather than* sleeping with different orientations in each household.

The way to offer a commonality explanation is as follows: one explains the common behaviour by identifying an aspect or feature which is shared by the different systems. While merely pointing to the commonality is inadequate to a full explanation of MR, a commonality explanation explains if one additionally demonstrates that the common features lead to the observed common behaviour in each case. While in some cases this second step may be left out, it is implicitly required. For example, in the analogy the commonality explanation would be undermined if it turned out that many of the families did not think that avoiding the build-up of cholesterol trumps the relative discomfort of their children.

In summary, when MR is instantiated and explicable, its realisers have both commonalities and heterogeneities; so, an explanation of MR must both identify the commonalities and demonstrate that the heterogeneities are irrelevant. That is, I claim that the only adequate explanations of MR are commonality explanations. As such, henceforth, all references to explanations of MR carry the implicit assumption that the explanation is a commonality explanation.

Now we have a general model for how one might explain MR, we ought to ask: are such explanations reductive explanations? If reduction is possible, for any given phenomenon, one may understand why it's multiply realised from the bottom up. The reductive constraint on explanation of MR amounts to the stipulation that the identified commonalities are lower-level commonalities, and the processes which secure the irrelevance of the heterogeneities are lower-level processes.

Such reductive explanations need not be eliminativist: in fact, many reductive explanations will establish that the MR phenomenon is to be included in our ontology – identifying the commonalities and the processes which secure the irrelevance of heterogeneities establish that the multiple realisation is not a pure artefact of our descriptive practices. Reductive explanations of MR thus underwrite the value of the unified multiply realised description and explanation even while it allows us to understand, from the bottom up, why the multiple realisation obtains.

Note that, at various stages through the process of seeking to explain commonalities, we may acknowledge that the commonality is not in fact out there in the world; that, instead, it's illusory, or that it's a consequence of our epistemic limitations, or an artefact of our organisation of the world. Where that happens the demands for explanation, and the prospects for anti-reductionism if explanation fails are correspondingly lessened – this overlaps with the debate over scientific realism, and, as such, will not be further discussed here.[6]

A reductive explanation of MR involves the identification of underlying common features and the demonstration, in lower-level terms, that such features are sufficient for the common behaviour. In the next section this framework for explaining MR is exemplified with a case study. Note that different processes may be responsible in each realiser for the irrelevance of the heterogeneities. It's thus worth emphasising that, while the commonalities are in common, an account of each individual system is generically required in order to establish that the commonalities are sufficient for the MR phenomena to occur.

[6]It's worth emphasising that the question here is not whether we should be metaphysical realists about the universal which putatively underlies a given common feature; rather we are interested in whether or not there is any stable way of identifying the putative commonality such that it doesn't depend on the way we happen to do science.

The upshot of this section is that MR is defined such that it is instantiated in the world and that reductive explanation is possible. I do not claim that all cases of MR can be offered reductive explanations; in my view, that's an empirically sensitive question. The advantage of my framework is that that question can be addressed.

3 A Case Study

The reductive strategy outlined above is, in this section, cashed out in terms of a prototype reductive explanation of multiple realisation.

Consider the fact that various different metals conduct electricity.[7] For our purposes, we may restrict attention to the Alkali (group I) metals; although electrical conductivity is, of course, multiply realised by a far wider class of materials, the reductive story is much simpler if we stick to this restricted class, though the philosophical moral generalises. Group I metals all have many properties in common, but do have clear differences: for example they have different melting and boiling points, different densities, and burn with different colours.[8] While each metal has different resistivity, their electrical conductivity is the multiply realised phenomenon which serves as my case study. If one prefers to think of MR in terms of kinds, then this could be substituted for the claim that *electrical conductor* is multiply realised by these different metals.

It's worth emphasising that this example is fairly naturalistic: we needn't think of electrical conductivity in terms of human interactions – it manifests, for example, when lightning strikes. If one still has reservations that the example is unacceptably *ad hoc* or anthropocentric, a similar reductive approach is applied to the universality of critical phenomena in Franklin (2019), which, as briefly discussed in §4.2, has been touted by some as a paradigm instance of irreducible MR.

Moreover, the phenomenon fits my definition: first, the phenomenon is the same phenomenon insofar as it is described by the same higher-level scientific theory. Solid state physics, see e.g. Kantorovich (2004), uses the same formalism to describe the conductivity of all such metals. At a

[7] This example is in part inspired by that in Aizawa (2013).

[8] Lithium, sodium, potassium, rubidium and caesium burn with red, yellow, violet, yellow violet and blue flames respectively; see Dye and Tepper (2018).

greater level of abstraction, circuit theory also uses the same functional relationships to describe this phenomenon independently of which particular metal realises the conductivity.

Second, the realisers of electrical conductivity are different. Although fission and fusion may occur in specialised circumstances at an atomic level, it is nomologically impossible for a piece of lithium to transform into a piece of sodium within a time-scale of the order of the age of the universe. Despite their sharing a variety of physical properties, there is no non-question-begging way of saying that lithium is identical to, say, sodium.

Can the fact that electrical conductivity is multiply realised be reductively explained? Following the framework outlined above, such explanation requires the identification of commonalities between realisers and features which make the heterogeneities irrelevant to the shared behaviour, all in lower-level terms.

Two properties of group I metals make them such good conductors: the fact that they have a single electron in their outer shell, and the arrangement of the repeated unit cells of the metal's lattice structure.

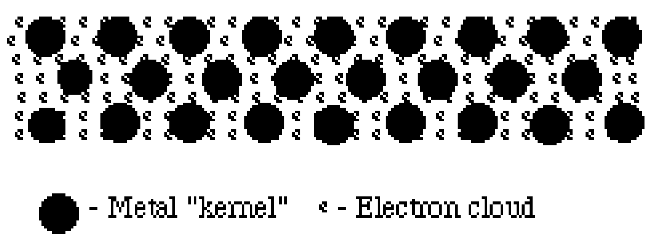

Figure 1: Figure from Lewis (1995). A representation of the distribution of electrons in a metal. This is not to scale.

Group I metals all have a free electron in their outer shell. This electron may, with little energetic cost, dissociate from its atom. As displayed in figure 1, such electrons form a cloud which is distributed among the atoms in the lattice. The crucial feature which allows for conductivity is that the quantum wavefunction which represents the state of each electron will then be delocalised and spread across the whole material. The exclusion principle precludes such electrons from inhabiting the same state, as such they are effectively non-interacting in the delocalised cloud, which is consequently well described as a freely moving gas.

The regular lattice structure in figure 1 means that there is no net force acting on the cloud. This has the consequence that, when an electric field is applied, the electron gas may freely travel in the direction of the field lines and form an electric current. In brief: dissociated electrons form quantum mechanical waves in periodic potentials – that's what allows electrical conductivity to be exhibited in multiple different metals.

The commonality among all the metals is that they have the same number of electrons in their outer shell and that they have similar lattice structures. These are, of course, lower-level commonalities. Although conductivity is identifiable at the higher level, the features which lead to common electrical conductivity in various systems can be specified in lower-level terms.

The remaining feature to be explained is that the differences between the metals – the heterogeneities – are irrelevant to the behaviour of interest. Only if that can be established may we explain how the common features are sufficient for the common behaviour. The irrelevance of heterogeneities may, however, also be explained in lower-level terms. There are two salient features which distinguish group I metals at the atomic scale; first, each metal has a different number of electrons – that difference is irrelevant due to the stability of the filled shells. At low temperatures, electrons in inner shells are not readily excited and their different numbers are irrelevant. Although these differences will become relevant as the temperature is increased, this does not undermine the explanation – it is a generic feature of multiple realisation that the common behaviour is only exhibited in restricted contexts.

The second way in which group I metals differ from each other lies in their different proton and neutron numbers. However, the different constitutions of the nuclei are irrelevant since they all compose lattice structures. As noted above, this structure ensures a periodic potential which allows the electron gas to flow freely throughout the metal. The periodic potential of the lattice can be explained in terms of the underlying atomic bonding structure which leads to the lattice formation.

It's important to bear in mind that, while this simplified case study involves a similar account of the irrelevance of heterogeneities for each realiser, in many contexts such stories will diverge – so long as the different systems have different underlying properties and these are irrelevant, the process by which they are irrelevant may differ for each system. Even in the current case study, the processes which secure irrelevance of heterogeneities may differ between materials: I noted that the different nuclear constitutions are screened off by the fact that the electrons interact with a periodic potential, but the fact that there's a periodic potential depends on the lattice structure, which may differ among different metals. This is a mild difference, but it illustrates the broader point that part of explaining MR involves taking account of the peculiarities of each realiser.

In sum, we may adduce, in lower-level terms: first, the commonalities – alkali metals conduct electricity in the same way because of their single outer-shell electron; and second, the irrelevance of the heterogeneities which follows from the stability of the inner shells and the periodic lattice structure.

In the following, I compare my account, where MR is fairly commonplace but can be reductively explained, to some recent literature on explaining MR.

4 Views in the Literature

4.1 Polger and Shapiro

Polger and Shapiro in numerous publications (see their (2016) and references therein) have done a great deal of work to demonstrate that, for various putative instances of MR, the realisers in fact share common causal structure. Insofar as their project can, thus, be construed as providing reductive explanations of MR, our methodologies overlap.

According to Shapiro (2000, p. 646):

> two realizations of a kind *T* are in fact different kinds of realizations of *T* only when they differ in their causally relevant properties, that is, the properties by which they contribute to the capacity, purpose, goal, and the like that serves to individuate *T* as the kind that it is.

Shapiro goes on to argue that MR is in fact rather rare, because in many putative instances of MR the two realisations don't differ with respect to causally relevant properties, they rather differ with respect to their causally irrelevant properties. For example, given the analysis in the previous section, his account implies that one ought not to say that the kind *electrical conductor* is multiply realised simply in virtue of the fact that both lithium and potassium conduct electricity. This is because the features which distinguish lithium from potassium are causally irrelevant to individuation *qua* electrical conductor.

This view is defended by Polger and Shapiro (2016) who consider a range of neurological case studies that have been described as instances of MR. They suggest that in almost all such cases the causal process which gives rise to the putatively multiply realised kind is identical.[9] For these philosophers, in order to qualify as MR, the salient causal structure must be different.

However, in my view, Polger and Shapiro err in claiming that once common causal structure has been identified, the phenomena in question should no longer count as multiply realised.

Firstly, I think the project of relabelling putatively multiply realised phenomena is unlikely to succeed. It's commonplace in philosophy to consider phenomena such as *pain* and *a square peg failing to fit into a round hole* to be multiply realised, and one is unlikely to make much headway in changing the way such phenomena are talked about. Moreover, as discussed in more detail in the next subsection, the term 'universality' in physics seems well described as a subspecies of MR, yet physicists find universality throughout the physical world. I think it far better to agree that the cases so described are in fact instances of MR, and then to seek to explain them.

This discussion results in a stand-off: on my view multiple realisation is fairly commonplace, but can be explained, on Polger and Shapiro's view, it's much rarer, but can't be explained. In Polger and Shapiro (2016, p. 39), they defend their view by claiming that a more liberal view "entails an undesirable profligacy of distinct realizations for every kind, and undermines the significance of realization within debates over the autonomy of the special sciences". While I agree that just any lower-level variation is insufficient for MR, I think that the MR-robustness distinction drawn above in §2 rules out 'undesirable profligacy'. On the other hand, regarding autonomy,

[9]While they (ibid., p. 73) accept that genuine multiple realisation is commonly found among artefactual kinds, they note that the interesting philosophy of science questions presuppose naturalistic multiple realisation.

I'd argue that the autonomy of the special sciences is, in fact, closely related to multiple realisation as I define it: as Polger and Shapiro acknowledge (ibid., chapter 10.4), a system has some claim to autonomy if it provides for prediction and explanation at the higher level. Insofar as such autonomy can be explained, the threat to reduction is mitigated, but the debate over such cases is only confused by claiming that autonomy, or indeed MR, is rare but mysterious.

Secondly, Polger and Shapiro's position makes the MR *explanandum* extremely difficult to express. We can no longer ask 'how come this phenomenon is multiply realised?' – multiple realisation cannot be explained in principle, this is because the explanatory strategy outlined above would render a phenomenon singly realised on Polger and Shapiro's account. While we might instead ask 'how come these systems share a common causal structure?' that *explanandum* does not seem to call out for explanation, as, on their view, it is the same kind of system which shares a common causal structure with itself.

The inability to express this *explanandum* is a non-trivial loss to the philosophical enterprise. It's a discovered fact about the world that there are many phenomena which are identified independently of their realisation and seem to be instantiated in multiple different kinds of system. Failing to acknowledge this as an *explanandum* would be sidestep the substantial challenge to reduction which MR (or putative MR) poses. Where we find MR there seems to be something about the world which the reductionist can't account for; it's only by accepting MR as something to be explained, and showing how it can indeed be reductively explained that that challenge may be met.

Lastly, even if Polger and Shapiro's approach is taken to provide an explanation of MR, their explanatory strategy is somewhat lacking. That's because, while they rightly emphasise the importance of demonstrating what's in common between the realisers, they do not require that we also demonstrate that the heterogeneous features are irrelevant. As discussed above, this is a significant aspect of the *explanandum*. MR prompts us to wonder how these *different* systems end up behaving the same way. It's the very fact that different systems act similarly which is so remarkable – that's what motivates Fodor (1974) in his discussion of the multiple realisation of currency and Putnam (1975) in his discussion of the multiple realisation of square and round pegs. That there is MR is a consequence of the fact that genuinely different systems do, in some circumstances, exhibit identical phenomena. MR is thus explained by showing both that such systems have features in common, and that, in those circumstances, their differences are irrelevant. By missing this latter part of the explanation, Polger and Shapiro fail adequately to respond to the anti-reductionist's challenge.

4.2 Batterman and Sober

Multiple realisation in physics has not received the same degree of attention in the literature as cases from psychology. This is unfortunate because the physics context significantly undermines the plausibility of claims that multiple realisation is purely an artefact of our linguistic practices.

Batterman (2000, 2018) is primarily responsible for bringing attention to such cases, though a significant literature has developed in response to some of his claims.[10] Multiple realisation in physics is generally known as 'universality', and there are many striking examples whereby systems as diverse as liquids and ferromagnets exhibit quantitatively identical phenomena in particular circumstances. Many hundreds of scientific papers have been written on this topic and many can be construed as seeking to explain how it is that the multiple realisation comes about.

Batterman's view is that there is MR, and that it can be explained, but he claims that MR can only be explained anti-reductionistically. As such, he denies the potential for the kind of reductive explanatory strategy outlined above. This is not the place to rebut Batterman's technical arguments, for that, see Franklin (2019). However, an important insight due to Batterman, on which I build in this paper, is that the MR *explanandum* requires a *sui generis* explanatory strategy. While I have argued that carrying out such a strategy can provide evidence for reduction, and Batterman disagrees, I follow him in claiming that once one acknowledges that there is MR in the world, a novel *explanandum* follows. It's particularly worth highlighting this set of claims due to Batterman because they serve to undermine the explanatory pluralism advocated by Sober (1999).

My claim in this paper has been that specificity explanations of MR phenomena are inadequate to address the MR *explanandum*. Once we have a reductive explanation for why lithium is a good electrical conductor, and why sodium is a good electrical conductor we still have an explanatory de-

[10] See e.g. Saatsi and Reutlinger (2018) and references therein; Wilson (1985) is an earlier example of discussion of MR in physics.

mand: what common feature of group I metals leads to the phenomenon that they all conduct electricity? Where the same phenomenon is observed in all these different systems we have multiple realisation and thus we have an *explanandum* for which the reductionist ought to be able to provide a reductive explanation. Insofar as they can't, the MR challenge to reduction remains unanswered.

Elliott Sober purports to deflate an argument of this flavour with explanatory pluralism:

> Generality is one virtue that an explanation can have, but a distinct – and competing – virtue is depth, and it is on this dimension that lower-level explanations often score better than higher-level explanations. The reductionist claim that lower-level explanations are *always* better and the anti-reductionist claim that they are *always* worse are both mistaken.
> [Sober (1999, p. 560), original emphasis]

Sober argues that multiple realisation need not trouble the reductionist. He does so by observing that different kinds of explanation are useful or applicable to different ends. He observes that adding content to an explanation does not stop its being an explanation and that reductions – which offer bottom-up explanations – will generally be of interest even if the higher-level explanations are adequate in some contexts. Sober's arguments are well-taken: it's certainly the case that proportionate higher-level explanations are often superior *qua* explanations of higher-level *explananda*. However, not just any kind of explanation is adequate to explain MR *per se*. Given that Sober is talking about multiple realisation and explanatory approaches thereto, it seems fair to say that he has missed the anti-reductionist MR advocates' point. This observation is emphasised by Batterman (2018), who identifies an *explanandum* which is missed by many reductionists:[11]

> **MR**: How can systems that are heterogeneous at some (typically) micro-scale exhibit the same pattern of behavior at the macro-scale?

[11] Note that Morrison (2012, pp. 164-165) makes a similar point – she argues that what I call specificity explanations are inadequate to explaining instances of MR and that some top-down (anti-reductionist) constraints are necessary.

> ...
>
> if one thinks (**MR**) is a legitimate scientific question, one needs to consider different explanatory strategies. The renormalization group and the theory of homogenization are just such strategies. They are inherently multi-scale. They are not bottom-up derivational explanations.
>
> [Batterman (2018, pp. 4, 14-15)]

I agree with Batterman that standard reductionist approaches miss the MR *explananda*. The question labelled **MR** prompts us to look at the distinct realisers of multiply realised phenomena and ask why all of these different underlying systems realise the same higher-level phenomenon. Batterman counters Sober's explanatory pluralism by arguing that, in certain cases, answers to **MR** are incompatible with reduction. He claims that universality is an instance of multiple realisation and that the full explanation of universality necessarily proceeds at the higher level. Batterman's contention is that lower-level and higher-level explanations are not equally adequate for understanding cases of MR. In fact, specifically for certain such cases the higher-level explanations are the only ones which are able to address the principal *explanandum*.[12]

While I disagree with Batterman's anti-reductionist conclusion, I accept his more general assertion: that it's not good enough simply to say, as Sober does, that different explanations are good for different ends. The different descriptions and explanations of electrical conductivity – some in terms of abstracted circuit theory, and others in terms of the microscopic details of each metal – do not lead to an answer to **MR**. And it is that question which really provides the motivation for the anti-reductionist. Sober's pluralism is inadequate to refute the assertion that multiple realisation is, *ipso facto*, inexplicable from the bottom up.

I have argued in this paper that **MR** may nonetheless be answered reductively. That is, I claim that, if we adduce the commonalities among lower-level realisers and identify the lower-level processes which make the heterogeneities irrelevant to the common behaviour, then we have provided a reductive explanation of MR. As such, the anti-reductionist's motivations may be addressed, and the compatibility of MR with reduction

[12] Although Batterman thinks that universality can be offered an explanation, he contends that this explanation is unavailable from the bottom up due to its appeal to renormalisation group (RG) methods; his technical argument is criticised in Franklin (2018, 2019).

may be established. MR poses an *explanandum* which requires a *sui generis* explanation; it's just that reductive explanations of MR are available.

5 Conclusion

Multiple realisation arguments have been taken by many to settle the case against reduction. And yet there's a fair bit of ambiguity over the structure of the argument. One strand of the debate observes that, given multiple realisation, the higher-level facts do not determinately pick out unique lower-level states. However, rather than an argument, this is more a restatement of multiple realisation, and it is hardly surprising: everyone accepts that higher levels are more coarse grained and less determinate than lower levels.

A better argument notes that multiple realisation implies that the higher-level descriptions are autonomous in a well-defined sense: they are invariant with respect to a swapping out of the lower-level constituents. It is then claimed that this autonomy poses an explanatory challenge to reduction – how come a common higher-level description is available despite lower-level heterogeneity? I take this challenge to be one which the reductionist ought to meet, and it's the purpose of this paper to show that this challenge may be answered. Consequently, I've set out and defended a framework for providing reductive explanations of MR.

It's worth considering once again the response of those philosophers who'd define MR such that it's, in principle, incompatible with reduction. First, they might argue that the kind of reductive explanation discussed here is insufficient for reduction. As such, they might accept that MR can be reductively explained in the sense articulated above, but that some other kind of reduction is ruled out. Importantly, I think that MR is, in general, a sign that we should think the higher level ineliminable: that, in most cases, MR phenomena should be included in our ontological inventory. As such, I have no quarrel with those who take MR to be incompatible with eliminativist reduction. I have merely argued that this does not imply that MR is mysterious or is inexplicable from the bottom up.

Second, they might claim that, while the framework developed here does lead to greater understanding of various worldly phenomena in many contexts, such phenomena do not count as MR. MR would thus be rather rare, but wherever it was in fact instantiated, it would be inexplicable. My disagreement here is pragmatic: I think it more useful to define the term such that it poses an explanatory challenge which can, in some though not necessarily all cases, be answered.

In this paper, I claimed that multiple realisation is found whenever the same phenomenon is realised by multiple different systems. I went on to argue that it is best to view the MR argument against reduction as posing a novel *explanandum*. MR requires new explanations in addition to those provided by traditional reductive approaches; the availability of such explanations must be assessed on a case by case basis. Thus, MR does raise a problem for reduction, and it's an empirically sensitive matter whether or not reduction can withstand the MR argument.

Acknowledgements

Thanks to the audience at the King's College London research seminar and to Eleanor Knox for helpful comments. This work was in part supported by the European Research Council Project 'The Metaphysical Unity of Science' (ERC CoG), grant no. 771509.

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