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**Revisiting abstraction and idealization: How not to criticize mechanistic explanation in molecular biology**

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**Abstract**

Abstraction and idealization are the two notions that are most often discussed in the context of assumptions employed in the process of model building. These notions are also routinely used in philosophical debates such as that on the mechanistic account of explanation. Indeed, an objection to the mechanistic account has recently been formulated precisely on these grounds: mechanists cannot account for the common practice of idealizing difference-making factors in models in molecular biology. In this paper I revisit the debate and I argue that the objection does not stand up to scrutiny. This is because it is riddled with a number of conceptual inconsistencies. By attempting to resolve the tensions, I also draw several general lessons regarding the difficulties of applying abstraction and idealization in scientific practice. Finally, I argue that more care is needed only when speaking of abstraction and idealization in a context in which these concepts play an important role in an argument, such as that on mechanistic explanation.

**Keywords:** abstraction; idealization; mechanistic explanation; molecular biology; scientific models

# **1 Introduction**

The world in which we live is immensely complex. Indeed, its complexity vastly exceeds our capacity to grasp it in its entirety with all the exact detail in place. Nevertheless, scientists do more than a decent job of keeping the complexity in check by constructing models of selected phenomena that help us to understand, explain, predict and control various aspects of the world. To achieve this, models must be simple enough to facilitate insight into the phenomena. In the literature of the past several decades, much has been said about the nature(s) and function(s) of models.[[1]](#footnote-1) Naturally, disagreement has emerged on many technical aspects of these debates, yet there seems to be a well-established consensus upon the foundational claim that models, in one way or another, can safely be understood as systems, some of which are built by means of simplifying assumptions. Many, though not all, authors prefer to speak of abstraction and idealization as examples of tools for introducing simplifications into models. Overall, models are commonly considered to be relatively poor in detail and often to provide distorted accounts of their target systems.

Importantly, abstractions and idealizations have also been discussed in the context of specific philosophical debates such as that on the mechanistic account of explanation. In a recent paper, Alan Love and Marco Nathan (2015) have argued that the new mechanists’ preferred view of explanation cannot account for the common practice of idealizing difference-making factors in models in molecular biology. Thus, the mechanistic account of explanation is flawed, as the argument goes. This particular objection is an instance of a broader line of thinking that draws on the distinction between the *completeness* and *accuracy* of a model.

This paper scrutinizes the analysis provided by Love and Nathan and argues against their conclusion that the mechanistic account of explanation is in trouble. More specifically, I will argue that their analysis is insufficiently clear for a number of reasons: it is interwoven with inconsistencies regarding (i) how they treat one and the same modeling assumption, (ii) how they apply their preferred definitions, and (iii) how they formulate the core objection. Moreover, the assumptions that they present as idealizations can – instead, and perhaps more naturally – be accounted for in terms of abstractions. None of Love and Nathan’s claims, even when they are most charitably interpreted, suffice to demonstrate that the considered modeling assumptions involve idealizations of the sort that would jeopardize the accuracy of the mechanistic explanation of the gene expression, i.e. the phenomenon in question. Thus, for the objection against the mechanistic account of explanation to succeed, it needs to show idealization in a sense that can be laid out.

In the process, I also draw several general lessons for the debate on abstraction and idealization and its use. For one thing, it will be shown that philosophers developing accounts of these notions often disagree among themselves with respect to a number of issues, meaning that the notions might not be as clear cut as generally believed. Relatedly, while the distinction between abstraction and idealization is relatively easy to spell out, it proves extremely tricky to adequately apply it in scientific practice. This may, in part, be due to the fact that the various existing accounts have been developed within different disciplinary contexts; and applying the distinction originally developed within one context to another may not be a straightforward process, for it may overlook important differences in epistemic practices characteristic of the respective disciplines. Finally, the arguments laid out in this paper should also serve as a cautionary note to those who have embraced the objection to the mechanists, not realizing the fundamental issues underlying such criticism. More generally, philosophers may need to pay special attention when using the concepts of abstraction and idealization before these concepts can do any real work in a philosophical argument.

The structure of this paper is as follow. Section 2 discusses abstraction and idealization and notes that while some papers present detailed accounts of these notions, other papers rely on a ready-made distinction. Section 3 reviews the key parts of Love and Nathan’s analysis, including their case study on models of gene expression, which is followed by a detailed critical examination in Section 4. Section 5 provides concluding remarks.

# **2 Abstraction and idealization**

The philosophical debates over the last several decades have made abundantly clear that much scientific practice relies upon the construction of models that, in some sense, are simplified versions of their target systems. Among the most frequently mentioned techniques for introducing simplifying assumptions into models are the practices of abstraction and idealization. It should be noted that these two, however, hardly present an exhaustive list of the forms of simplification. Indeed, many other notions are commonly discussed, some with partially overlapping or otherwise interconnected meanings (e.g., approximation).

An important distinction concerns the nature of these assumptions on the one hand, and on the other hand, the roles these assumptions play. For instance, Demetris Portides states clearly that the “character [of idealization] and its epistemological implications” (Portides 2013, p. 253) are separate issues. Philosophers usually tend to focus exclusively on one or the other, perhaps somewhat more rarely on both (e.g., Potochnik 2017).[[2]](#footnote-2) This is, of course, a perfectly legitimate endeavor which reflects various interests.[[3]](#footnote-3) However, as should become clear in Section 4, what is at stake here is both the former issue, i.e. the character of abstraction and idealization, and the question of what implications it has for the latter, i.e. for the way in which these concepts figure in at least some explanatory practices in molecular biology.

One set of papers that deals with the topic of abstraction and idealization often relies on a ready-made distinction. In the simplest terms, idealization is construed in terms of (deliberate) distortion, misrepresentation and/or falsehood and amounts to providing an inaccurate picture of the studied system, whereas abstraction concerns the omission of an (irrelevant) feature.[[4]](#footnote-4)

For instance, according to Roman Frigg and Stephan Hartmann,

“Aristotelian idealization [i.e. abstraction] amounts to ‘stripping away’, in our imagination, all properties from a concrete object that we believe are not relevant to the problem at hand” (Frigg and Hartmann 2020).

“Galilean idealizations [i.e. idealization] are ones that involve deliberate distortions” (Frigg and Hartmann 2020).

Arnon Levy and William Bechtel claim that,

“Broadly understood, idealization is the introduction into a theoretical model of simplifying falsehoods—assumptions that are known not to describe accurately the target phenomenon but that nevertheless expedite analysis and understanding. To say that a population of rabbits is infinitely large is an idealization, in this sense. Insofar as a model is abstract, it need not contain any falsehood or inaccuracy. Abstractions are poor in detail yet potentially true and accurate. Idealizations are by definition mismatched to reality” (Levy and Bechtel 2013, p. 243).

While referring to Godfrey-Smith (2009), Alan Love and Marco Nathan state that abstraction concerns “the intentional omission of detail” and that “abstraction must be distinguished from idealization, the deliberate misrepresentation of detail in a model” (Love and Nathan 2015, p. 763). Similarly, in the words of Marta Halina, models “are abstractin the sense of omitting detail about the target system and idealized in the sense of distorting elements of that system” (Halina 2018, p. 219).

Referring to Jones (2005), Mazviita Chirimuuta explains that “by ‘abstract’ [she means] a model which leaves out much biophysical detail, in other words ‘highly incomplete’; by ‘idealized’ [she means] a model which describes a system in an inaccurate or unrealistic way” (Chirimuuta 2014, p. 133).

Finally, Worth Boone and Gualtiero Piccinini state that

“mathematical and computational models are typically constructed not only by abstracting away from many details of the target system but also by replacing those details with simplifications and idealizations that distort or misrepresent the target system” (Boone and Piccinini 2016, p. 680).

As hinted above, some of the authors who use the distinction explicitly draw on another set of papers which aims to provide a more nuanced characterization of the terms by clarifying in what precise sense idealizations may be thought of in terms of distortion, misrepresentation and falsehood, and abstraction in terms of omission of details (e.g., Godfrey-Smith 2009; M. R. Jones 2005; Levy 2018; Mäki 1992; Portides 2018; Potochnik 2017). Although there exists a consensus among the authors developing more nuanced accounts on some of the general features such as the need to distinguish between at least two meanings of the process of omitting certain features in a model – one of which may better be understood as an idealization rather than an abstraction – many other issues remain a matter of debate.[[5]](#footnote-5)

For example, while some authors, including Levy (2018), argue that idealization must be intentional, such requirement is explicitly denied in Jones (2005). Philosophers also disagree on the question whether idealizations are best construed as concerning individual claims (Levy 2018), or whether they should be thought of holistically, that is, as applicable to models as wholes (Rice 2018, 2019). Another interesting issue concerns the extent to which it is legitimate to construe abstraction in terms of omission-as-subtraction, a term coined by Portides (2018). On this view, according to Portides, abstraction amounts to stripping away – subtracting – features which presupposes that the modeler knows beforehand whether or not the modeled system in fact possesses the features in question. Portides claims that the omission-as-subtraction view is implicit in how abstraction is commonly understood, referring to Cartwright’s work to illustrate the point. Cartwright states that abstraction “is not a matter of *changing* any particular features or properties, but rather of *subtracting*” (Cartwright 1989, p. 187) and that “abstraction in science works by subtracting all those factors which are only locally relevant to the effect” (Cartwright 1989, p. 224). This interpretation is suggestive and is often motivated by a handful of examples. For instance, when modeling the movement of a ball by writing down the equations of motion, color is subtracted from the description since it is considered irrelevant to the task at hand (Cartwright 1989, p. 187). Similarly, Julie Jebeile states that “there is no point in specifying the Moon phase for describing the motion of a body, or, of including the presence of oxygen or the average temperature for describing the trajectory of planets” and that “the description, once cleared of the less relevant details, contains all the relevant representational aspects” (Jebeile 2017, p. 216). Although abstraction by subtracting features is indeed descriptive of cases in which enough knowledge has been accumulated, i.e. where scientists are fairly familiar with many of the features of the studied system, it may be more adequate to characterize abstraction generally in terms of omission-as-extraction, whereby certain features are ‘extracted’ from the system irrespective of what the other features may be (Portides 2018). This is because, although omission-as-subtraction may adequately capture what is going on in domains in which the concept was developed, the fact remains that such characterization fails as a general characterization of abstraction – a thing to note when applying it in fields other than those in which the notion was originally discussed (Portides presents an example from quantum mechanics to that effect). Indeed, in many areas including much of molecular biology the details are being filled in in a piecemeal fashion rather than crossed out from the outset. For instance, prior to figuring out the detailed workings of a signaling pathway, the exact molecular complexes involved in the pathway are usually not known (see Craver and Darden 2013).[[6]](#footnote-6)

Importantly, authors developing accounts of abstraction and idealization often characterize the notions against a backdrop of a specific disciplinary context, ranging from economics to various domains of physics and biology. Extrapolating the distinction from one disciplinary context and applying it within another may prove challenging (see Section 4.1), for the range of practices in these disciplines may differ considerably.

Naturally, some of the authors who develop accounts of abstraction and idealization then end up using them, or *vice versa*. For instance, Levy in Levy and Bechtel (2013) quoted above simply uses the distinction, referring to Jones (2005) and Godfrey-Smith (2009), while in his (2018) he develops a more nuanced account.[[7]](#footnote-7)

Finally, one may wonder whether a more thorough conceptual analysis of abstraction and idealization is required. In fact, two reasons may be offered for thinking it has both practical and otherwise important consequences (see also Levy 2018). Providing conceptual clarity with respect to the notions discussed here may prove useful for scientists who engage in various methodological debates in their community, including the arguments over the issues of the *realisticness* of assumptions in providing understanding of phenomena (Mäki 1992). The other reason, the one that concerns us here, is to avoid using arguments in philosophical discussions which are grounded in concepts that are ill-defined for the purposes at hand. Failing to clarify the key concepts may generate great misunderstandings and lead to cycles of fruitless debates, generating even more confusion.

# **3 Love and Nathan on the mechanistic account of explanation in molecular biology**

In a recent paper, Alan Love and Marco Nathan (2015) present a case against the mechanistic account of explanation, arguing that the account fails as it is unable to account for what they see as the widespread practice of idealizing difference-making factors in scientific models, which, thus, brings us back to the debate on abstraction and idealization. In particular, they argue that "the intentional misrepresentation of causal relations, which are the source of explanatory power in a description of a mechanism’s components and activities, generates a significant—albeit neglected—problem for the mechanistic framework” (Love and Nathan 2015, p. 762).

There are several key concepts to unpack first. The concept of a mechanism, so ubiquitous in the life sciences, has received considerable attention over the past two decades. Naturally, a number of views have been discussed in the literature that differ from each other in various ways,[[8]](#footnote-8) including in the criteria delimiting purported mechanisms. For instance, according to a highly influential account, “mechanisms are entities and activities organized such that they are productive of regular changes from start or set-up to finish or termination conditions” (Machamer et al. 2000, p. 3). However, for our purposes and in line with Love and Nathan’s stated intention, we may refer to the core conception[[9]](#footnote-9) of a mechanism, according to which “a mechanism for a phenomenon consists of entities and activities organized in such a way that they are responsible for the phenomenon” (Illari and Williamson 2012, p. 120).

Similar treatment may be applied to the related notion of mechanistic explanation. While there are now many diverse accounts of mechanistic explanation,[[10]](#footnote-10) Love and Nathan remain uncommitted to any particular account in order for their analysis to be as broad as possible. Instead of insisting on the technical details of this or that account, they focus on the core assumption and “treat mechanistic explanation as the claim that many areas of science explain by decomposing systems into their constituent parts, localizing their characteristic activities, and articulating how they are organized to produce a particular effect” (Love and Nathan 2015, p. 762).

Central to their argument is the claim that

“If the actual difference-making causes are idealized, they do not show how the mechanism actually works. The dilemma should now be apparent. A practice widely used in describing mechanisms—the deliberate misrepresentation of the productive continuity between difference makers—conflicts with the explicit goal of accurately representing causal relations, which is often taken as the hallmark of mechanistic explanation. The idealization of causal relations demonstrates that these models do not depict how the mechanism actually works. If actual difference makers are represented in such a way that they are not difference makers, according to what is already known about the mechanism, mechanistic explanations appear to fail according to their own criteria” (Love and Nathan 2015, p. 768).

Elsewhere they claim that

“The widespread use of irreducible abstractions challenges the ideal of descriptive completeness, but it is compatible with the goal of describing how mechanisms actually work; abstractions make the model more perspicuous. Idealizations, in contrast, provide a further layer of complexity as they overtly violate the actuality requirement. The introduction of deliberate misrepresentations in a model clashes directly with the claim that mechanistic representations should represent how systems (or their subcomponents) actually work” (Love and Nathan 2015, p. 770).

And finally,

“accounts of mechanistic explanation face a problem in accommodating the deliberate misrepresentation of causal relations among components and activities that play a difference-making role in producing the explanandum” (Love and Nathan 2015, p. 770).

In their view – adopted in a brief form from Godfrey-Smith’s (2009) view – abstraction concerns “the intentional omission of detail”; furthermore, “abstraction must be distinguished from idealization, the deliberate misrepresentation of detail in a model” (Love and Nathan 2015, p. 763). Thus, Love and Nathan’s paper belongs to the set of papers that makes use of the distinction.

Many mechanisms in molecular and cellular biology are ordinarily depicted by means of diagrammatic representation accompanied by a description. These often involve depicting entities by means of various geometrical shapes that are connected to each other by arrows standing for causal relations, accompanied by symbols such as ‘+’ or ‘-’ which suggest that a given causal relation is an activating or inhibiting process, respectively. All these shapes and symbols are intended to stand for certain entities and causal processes which purportedly occur inside (or outside) the cell. With respect to these geometrical shapes, any arrows and pluses or minuses that disregard the particular details and the ways in which the entities and causal relations are instantiated are to be considered an intentional omission of details, as abstractions. Other aspects of models in molecular biology are to be taken as instances of idealization, according to Love and Nathan.

The authors present and discuss three assumptions employed in diagrammatic models of gene expression, all of which purportedly introduce important and intentional misrepresentations into the models. Remember that that these misrepresentations should be understood as instances of idealization and since they represent the difference-making factors in a distorted fashion, they cannot provide mechanistic explanations.

Let us look in turn at the modeling assumptions discussed by Love and Nathan.

1. Figure 1 depicts the process of gene expression which is initiated by a transcription factor binding to its binding site. However, as illustrated by Figure 2, the overall picture is actually much more complex. Instead of a single molecule, a transcription factor, attaching to its binding site, it is actually a functional molecular complex, which consists of various molecules, which does the binding.
2. Both Figure 1 and Figure 2 “depict gene expression as triggered by a single transcription factor, or, more accurately, a single complex of molecules—call this functional unit p1. While p1 unquestionably plays a role in the process, it is not a difference maker by itself; its presence (or absence) makes virtually no difference to the outcome. This is because even if p1 was not there, another molecular complex of the same type (p2, p3, . . . , p546, . . .) would take its place” (Love and Nathan 2015, pp. 766–767). Furthermore, the functional units continuously bind and detach. Hence, they do not represent an individual binding event but rather a sequence of events that takes place in time and constantly changes.
3. It is the concentration of a transcription factor in the system that fundamentally contributes to its difference-making role.[[11]](#footnote-11) Thus, the diagrams fail to represent aspects of the system that make the actual difference to the occurrence of the modeled phenomenon. More specifically, the key information is the concentration of a transcription factor relative to a repressor.[[12]](#footnote-12)

Figure 1. A simple schema of gene expression. Figure drawn by Filip Měšťáněk, after Saurabh Sinha.

Figure 2. A schema of gene expression which depicts the role of many different molecular components in the initiation of transcription. Figure drawn by Filip Měšťánek, after Levine and Tjian (2003).



Love and Nathan are very explicit in stressing that each of the assumptions at hand is an idealization, a misrepresentation of an aspect of the system, and not an abstraction.

# **4 How not to criticize the mechanistic account of explanation in molecular biology**

In what follows it will be argued that Love and Nathan’s argument suffers from several issues. It is insufficiently clear because the authors are inconsistent with respect to what they argue against as well as to how they use the key concepts; and even if these problems are somehow presumed to be resolved, it still does not provide much support to their intended conclusion. Consequently, their objection to the new mechanistic account of explanation does not stand up to scrutiny, hence, the new mechanists need not worry about this particular objection.

There are two reasons – addressed in turn in Sections 4.1 and 4.2, respectively – for making the claim that Love and Nathan’s account lacks clarity, and each, even if resolved, fails to provide support to the effect that one would be justified in thinking that the mechanistic account of explanation is in trouble.

## **4.1 First problem: an unclear distinction**

The first problem concerns the fact that despite their insistence on treating all the assumptions discussed in Section 3 as misrepresentations (i.e. idealizations), it turns out that they are inconsistent, for they do treat one and the same assumption both as an abstraction and an idealization. With respect to the assumption (1) – the binding site binding a single molecule (Figure 1) rather than a complex of molecules (Figure 2) – Love and Nathan claim that “under normal circumstances, individual molecules do not act as difference makers, but complex functional units do. Thus, the diagram does not “merely leave things out” (abstraction) but “fictionalizes in the service of simplification” (idealization)” (Love and Nathan 2015, p. 766). Clearly, then, we are to think of the concept of a transcription factor as an idealization. However, one page earlier, with respect to the same assumption and the same concept of transcription factor, the authors claim that the “more specific description [i.e. Figure 2] of the apparatus for the regulation of eukaryotic gene expression exposes a variety of abstractions that were present in [Figure 1]” (Love and Nathan 2015, p. 765). Hence, we are left wondering whether the concept of a transcription factor is an idealization, or an abstraction after all. This is even more pressing when we take at face value the authors’ insistence on the claim that “abstraction must be distinguished from idealization” (Love and Nathan 2015, p. 763).

Furthermore, the authors are also inconsistent with respect to their own proposed standards. With respect to the assumption (3) regarding the difference-making role of the concentration of a transcription factor, the authors claim that when “known difference makers are intentionally omitted from the representation” (Love and Nathan 2015, p. 767) we are to understand it as an act of idealization. This, however, is in direct contradiction with their previous definition of abstraction as “the intentional omission of detail” (Love and Nathan 2015, p. 763). Consequently, these contradictory suggestions make the conceptual analysis unclear.

Let us assume, for the sake of argument, that the preceding problems are somehow resolved so that no inconsistencies arise. We may now consider the question of the extent to which the authors are justified in claiming that the assumptions are indeed idealizations. Love and Nathan define idealization as “the deliberate misrepresentation of detail in a model” (Love and Nathan 2015, p. 763) which they adopt from Godfrey-Smith (2009). However, there is no immediate way in which to assess whether or not all the assumptions would in fact count as idealizations in Godfrey-Smith’s view. One reason for that is that Godfrey-Smith developed his account in the context of certain kinds of models in evolutionary biology, which, arguably, are very different from the kinds of models used in molecular biology. Indeed, one should be careful when applying a distinction developed originally in the context of a particular field to another field. Distinguishing abstraction from idealization, as it turns out, is also extremely problematic when the notions are applied to scientific practice. Both these points become clear as soon as one considers the large literature devoted to making the conceptual distinction between abstraction and idealization, rather than relying merely on the first approximation.

To illustrate, consider again the assumption (3) concerning the omission of concentrations from the model of gene transcription. How should such omission be interpreted? It depends. Discussing an example taken from physics, Martin Jones has the following to say:

 “If a model of a particular fluid flow represents the flow as irrotational when it is not, we can in one sense correctly say that the model omits the rotation involved in the flow. However, such a model omits a certain feature of the real system in a way which involves misrepresenting how things stand in that respect; on the proposal I am putting forward, however, abstractions involve omission *without* misrepresentation. Omission in this restricted sense is, so to speak, a matter of complete silence” (M. R. Jones 2005, p. 175).

According to Jones’ view, we may be inclined to construe the assumption as one about which the model remains completely silent (i.e. an abstraction) rather than misrepresenting it. Similarly, Portides (2018) argues that in the process of model building, scientists abstract away from the complexities of the studied system by extracting certain features from it (omission-as-extraction in Portides’ terminology) that will serve as the focus of subsequent investigation. Those features which have been retained in a model may then be further modified in an important way, i.e. idealized. The omission of concentrations seems to fit naturally with the notion of abstraction, for this feature is completely missing from the model rather than being modified. Indeed, it is not the case, in contrast with many other cases of idealization, that the parameter of concentrations would be set to zero in this particular model: the model simply does not mention it at all. These remarks are further supported by Love and Nathan who admit that the “explicit descriptions associated with the diagrams (…) do not invoke concentrations” (Love and Nathan 2015, pp. 767–768). Thus, they unwittingly build a case for the assumption to count as an abstraction.

In contrast, other philosophers such as Potochnik (2017) suggest that an omission, sometimes being a failure to explicitly reference a feature, may nonetheless count as an implicit idealization. According to her view, idealization concerns the representation of a target system as if it has a feature it does not, whereas abstraction consists of a straightforward omission which has no consequence for the representation.[[13]](#footnote-13) She then claims that

“It is important to distinguish this sense of omission—ignoring without representational consequences—from omission in the sense of failing to explicitly reference. It is the former sense that is definitive of abstractions; many idealizations are also omissions in the latter sense” (Potochnik 2017, p. 55).

In support of the proposed distinction, Potochnik provides the example of evolutionary game theory models that hardly ever explicitly state the assumption of the population size being infinite. This assumption allows the modeler to disregard the role of genetic drift. Thus, Potochnik argues, an apparent abstraction is sometimes discovered to be a covert idealization. Understood this way, we may side with Love and Nathan, since their claim that the “explicit descriptions associated with the diagrams (…) do not invoke concentrations” (Love and Nathan 2015, pp. 767–768) is in line with treating the omission of concentrations as an instance of covert idealization. Thus, much can be said about both attitudes towards the assumption of omitting concentrations. However, until this question is adequately settled, it may be unfair to proclaim that the mechanistic account should be rejected.

What this shows is that there may be no general agreement among the philosophers writing on the topic of abstraction and idealization on whether a particular assumption should best be viewed as an instance of abstraction or idealization. This can, in part, be due to different epistemic commitments exhibited by different modeling practices in different disciplines such as physics, evolutionary biology and molecular biology.

Consider further the assumption (2): gene expression depicted as being triggered by a continuous event of a single transcription factor binding to the appropriate site as opposed to many transcription factors of the same type and the event being discontinuous. According to Love and Nathan, we should interpret it as an idealization. However, some authors writing on the distinction between idealization and abstraction call for more caution when reaching such conclusions. Describing what is effectively the same type of example – the workings of ribosomes as they are usually depicted – Arnon Levy writes:

“The ribosome in fact moves back and forth along the mRNA, attaches and detaches, constantly changing conformation. However, it is hard to tell whether standard depictions of this process are idealized or abstract (or both). Do they portray the ribosome as having a sequential, deterministic character, *contra* the realities of ribosomal action? Or are these abstractions that highlight certain functional states and activities of the ribosome while staying silent about others?” (Levy 2018)

Thus, the assumption (2), too, presents a dilemma even for authors who specifically focus on developing a nuanced view of abstraction and idealization.

Moreover, speaking of arrows as means of depicting causal relations in diagrammatic models in molecular biology, Love and Nathan claim that the “arrows simply stand in for causal relations, regardless of how they are instantiated” and that the “typical representation of biochemical components as distinguishable geometrical shapes and the exclusion of known components involves *abstraction*: the intentional omission of detail” (Love and Nathan 2015, p. 763).[[14]](#footnote-14) Causal arrows leave out the particular details regarding how the causal relations are instantiated. In some cases, however, this omission has important consequences for understanding the extent to which a reaction occurs, if at all. Consider a simple model of enzymatic regulation via negative feedback, in which a substrate is turned into a product which feeds back into the pathway and inhibits, thus regulates, the given pathway. Generally, two types of inhibition are recognized: competitive and non-competitive. Holding the concentrations and other conditions fixed, the rates of reaction differ between the two types of inhibitions. Therefore, depending on the particular research question, omitting such details results in withholding potentially crucial information regarding a difference-making factor. Yet, I concur with Love and Nathan that it feels natural to think of causal arrows which stand for any number of causal relations as abstractions. Perhaps the notion of vertical abstraction coined by Mäki (1992), which, arguably, also happens to capture much of Levy and Bechtel’s (2013) discussion would help to clarify the matters.[[15]](#footnote-15) When the level of abstraction changes, Mäki (1992, pp. 322–323) thinks of vertical abstraction, in contrast to horizontal abstraction which concerns cases in which the level of abstraction remains unchanged. For instance, concepts such as inhibition that are abstracted away from the particular details can be viewed as cases of vertical abstraction, whereas models that do not include all the molecules that causally interact can be thought of as involving horizontal abstraction.

Let us summarize the implications of the preceding paragraphs to Love and Nathan’s approach. The authors’ account lacks clarity in part due to their inconsistent use of abstraction and idealization. Arguably, philosophers who develop more nuanced accounts of these notions would give conflicting recommendations as to whether the particular assumptions should be interpreted one way or the other. Additional clues suggest that the assumptions could be understood as certain kinds of abstractions after all. Therefore, the arguments presented by Love and Nathan – hence the conclusion, too – should be taken with a grain of salt. However, another argument in favor of Love and Nathan’s approach must be considered before rejecting their analysis completely.

## **4.2 Second problem: an unclear core objection**

The second problem causing confusion concerns the core objection raised against the mechanistic account of explanation. Recall that *the* problem identified for the mechanistic account pertains to the purported practice of idealizing difference-making factors. In the words of Love and Nathan (2015, p. 768), “if the actual difference-making causes are idealized, they do not show how the mechanism actually works.” Although passages like this can be found throughout the text (as evidenced in Section 3), in one place they make the following statement: “we would not expect features that play a central explanatory role to be abstracted away or distorted in a mechanistic description. Yet, in molecular biology, the causal relations responsible for the explanandum are deliberately misrepresented on a regular basis” (Love and Nathan 2015, p. 764). What to make of such remarks? On the one hand, we are told that the causal relations in molecular biology are deliberately misrepresented, i.e., idealized, which is why the mechanistic account purportedly fails. That is also why Love and Nathan focus on arguing that the assumptions employed in models in molecular biology are idealizations rather than abstractions (but see the discussion in previous Section). On the other hand, though they neither show it, nor argue for it, they seem to casually suggest that abstractions, too, may present a problem for the mechanists. Thus, although they explicitly favor the problem of idealization as a reason for rejecting the mechanistic account, it is not clear whether the problem of abstraction would also be sufficient for them to reject it.

Let us assume, for the sake of argument, that this confusion, too, is somehow resolved and let us consider what happens if, contrary to Love and Nathan’s preferred analysis, we treat the assumptions as abstractions, and if we take at face value their proposal that abstractions present a good enough reason for rejecting the mechanistic account. How would this fair with respect to their own views, and in comparison with other existing views?

Recall that Love and Nathan take issue with what they identify to be the hallmark of mechanistic explanation, namely the goal of accurately representing causal relations (Love and Nathan 2015, p. 768). If causal relations are represented in an idealized – non-accurate – way, then that goal may not be achieved. But the authors argue that abstraction concerns “the intentional omission of detail” and it “must be distinguished from idealization, the deliberate misrepresentation of detail in a model” (Love and Nathan 2015, p. 763). They say nothing to the effect that abstraction would interfere with the goal of accurate representation, i.e., how mechanisms actually work. Instead, they say precisely the opposite, namely that “the widespread use of irreducible abstractions challenges the ideal of descriptive completeness, but it is compatible with the goal of describing how mechanisms actually work; abstractions make the model more perspicuous” (Love and Nathan 2015, p. 770). However, since they explicitly refer to Godfrey-Smith’s (2009) analysis of the notions, one may legitimately ask whether Godfrey-Smith has anything to say on the matter. And he has the following to say: “an abstract description of a system leaves a lot out. But it is not intended to say things that are literally false” (Godfrey-Smith 2009, p. 48). Indeed, as shown in Section 2, this view is shared by many who use the conceptual distinction between abstraction and idealization as well as those who develop accounts of the distinction.[[16]](#footnote-16) Furthermore, although mechanists have identified research projects in which abstraction proceeds differently in different explanatory contexts – making a representation less abstract by progressively filling in more concrete details (Machamer et al. 2000), or overlooking more detailed descriptions in order to develop more abstract representations such as network models (Levy and Bechtel 2013) –, abstraction is generally construed as harmless with respect to the goal of accurate representation on these accounts.

Thus, even if all the three assumptions are interpreted as abstractions, and even if Love and Nathan do in fact propose that abstractions should somehow, too, pose a problem for the mechanistic account, nothing they say provides support for their conclusion. Instead, most of the clues point in the other direction.

## **4.3 Why should we care?**

One key point is that making the precise distinction would not be required if not much depended on it. That is not the case for Love and Nathan, however, who attempt to use the distinction to challenge the mechanistic framework. You will recall that central to their argument is the claim that “the intentional misrepresentation of causal relations, which are the source of explanatory power in a description of a mechanism’s components and activities, generates a significant—albeit neglected—problem for the mechanistic framework” (Love and Nathan 2015, p. 762). More specifically, “if the actual difference-making causes are idealized, they do not show how the mechanism actually works” (Love and Nathan 2015, p. 768). However, as has been argued herein, the failure to adequately characterize abstraction and idealization invites trouble for the whole objection to the mechanistic account of explanation precisely because those notions are at the heart of the objection and are presupposed to be clearly defined when they are not. Indeed, unless a stronger foundation is provided, the objection has little traction.

That said, we observe a number of authors expressing sympathies toward Love and Nathan’s analysis. Thus, it is worth noting that the detailed analysis of Love and Nathan’s approach provided herein may prove illuminating for those engaged in the debate on mechanisms who either explicitly embrace Love and Nathan’s views, or follow similar lines of argument.

For example, Collin Rice references Love and Nathan’s work to support his claim that “using idealizations that distort difference-making factors is pervasive in biological modelling—even within mechanistic modelling” (Rice 2019, p. 195). However, I believe I have demonstrated that we have reasons to think that this is something Love and Nathan have failed to show. Similarly, in discussing models of cancer, Anya Plutynski, referring to Love and Nathan, claims that “it is permissible in model building to deliberately represent the system falsely” (Plutynski 2017, p. 131). This is something Love and Nathan failed to prove, so if what Plutynski says is true, it is so for entirely independent reasons. Others (e.g., Halina 2018; van Eck and Mennes 2016) also seem to embrace the core message of Love and Nathan in various contexts.[[17]](#footnote-17)

# **5 Conclusion**

The vast literature on scientific modeling often invokes the concepts of abstraction and idealization. Roughly, two sets of papers may be distinguished: one that develops detailed accounts of the notions, the other that applies these concepts while often referring to the first set of papers. Alan Love and Marco Nathan have relied on these notions when arguing that the mechanistic account of explanation is deeply flawed as it fails to account for the common practice of idealizing difference-making factors.

In this paper I scrutinized the arguments and examples provided by Love and Nathan and I presented reasons for thinking that their analysis fails to provide support to their conclusion. In particular, I argued that their analysis is insufficiently clear because it is interwoven with inconsistencies regarding (i) how they treat one and the assumption, and (ii) how they apply their preferred definitions.

Setting aside these inconsistencies by assuming none arise, I showed that the assumptions discussed by Love and Nathan are far from clear examples of idealization. Instead, they may very well be interpreted as abstractions. I further showed that philosophers who develop more nuanced accounts would give conflicting recommendations when applied to the particular assumptions discussed herein. In addition to the fact that philosophers disagree on a number of things regarding how precisely to characterize abstraction and idealization, they also develop these notions in a particular disciplinary context. Extrapolating the distinction from one disciplinary context and applying it in another proves challenging, for the range of practices in various disciplines differ considerably.

Furthermore, I argued that Love and Nathan are unclear with respect to the core objection. While they have a beef with idealization not being accounted for in mechanistic explanation, they also seem to suggest that abstraction, too, may be problematic – something for which they do not present any arguments, however. I considered the implications of taking their suggestion at face value and I showed that it does not support their claim that the mechanistic account of explanation is flawed.

Taken together, the analysis provided by Love and Nathan does not provide a sufficient reason for rejecting the mechanistic account. The arguments presented herein should also serve as a cautionary note to those who have embraced the objection to the mechanists, not realizing the fundamental issues underlying such criticism.[[18]](#footnote-18)

It is worth noting that, notwithstanding the intrinsic difficulties of the accounts of abstraction and idealization, these notions may legitimately be invoked in those contexts that do not require a carefully argued analysis. The problem arises only in situations in which these concepts make an appearance in a philosophical debate that calls for careful analysis, such as that on mechanistic explanation. In other words, the concepts of abstraction and idealization concern an important philosophical dispute that should not be treated lightly if we wish to clarify many of the debates which invoke these notions.

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1. See, e.g., Frigg and Hartmann (2020) for a comprehensive review. Extended discussions can also be found in a number of monographs or book editions. (Bailer-Jones 2009; Cartwright 1983; Gelfert 2016; Giere 1988; Magnani and Bertolotti 2017; Morgan 2012; Morgan and Morrison 1999; Morrison 2015; Toon 2012; Weisberg 2013) [↑](#footnote-ref-1)
2. For example, when presenting the notions of Galilean idealization, minimalist idealization and multiple-models idealization, Michael Weisberg claims that “despite the differences between minimalist idealization and Galilean idealization, minimalist idealizers could in principle produce an identical model to Galilean idealizers” and that “the most important differences between Galilean and minimalist idealization are the ways that they are justified. Even when they produce the same representations, they can be distinguished by the rationales they give for idealization” (Weisberg 2013, p. 102). Arguably, then, Weisberg’s Galilean and minimalist idealizations are (or at least can be) one and the same (kind of) assumption that is put to work in different ways. [↑](#footnote-ref-2)
3. Much focus has been devoted to inquiring into those various functions. For instance, they may allow for making a model mathematically tractable (Jebeile 2017), although it should be noted that it is not necessarily the case that all assumptions are limited to mathematical modeling. Abstraction and idealization can also help in isolating difference-making factors by narrowing down the focus of a model (Mäki 1992; Strevens 2008; Weisberg 2013), and they play various roles in explanation (Batterman 2009; Bokulich 2011; Jebeile and Kennedy 2015; Kennedy 2012; Reiss 2012; Rice 2015; Rohwer and Rice 2013; Wayne 2011) or understanding (Elgin 2007, 2017; Potochnik 2015, 2017; Reutlinger et al. 2018; Rice 2016; Strevens 2017). [↑](#footnote-ref-3)
4. Commenting on the available relevant literature, Margaret Morrison states that “most of [the literature] draws a distinction between idealization which is construed as the distortion of a particular property (e.g. frictionless planes) and abstraction which involves the omission of properties (e.g. a body’s material in calculating its trajectory)” (Morrison 2011, p. 343). [↑](#footnote-ref-4)
5. In the main text I discuss several examples in some detail. However, it is worth to list at least some of the many other questions which also remain a subject of controversy. Among such issues we find questions related to the nature and function(s) of abstraction and idealization. For instance, consider the following questions: how exactly do abstraction and idealization relate to truth (M. R. Jones 2005; Levy 2018; Portides 2018; Teller 2012), to mathematics (Jebeile 2017), to fictions (Bokulich 2011; Suárez 2009), or to approximations (M. R. Jones 2005; Morrison 1998; Norton 2012; Portides 2007)? How should we adjust our views regarding the historical development of theories? More specifically, can we reinterpret certain theories or models from the past *as if* such theories were postulating simplifying assumptions even though these ‘assumptions’ used to be taken at face value? Or should we refrain from such practice and instead consider only an intentional usage as possible instances of these assumptions? Are they eliminable, should they always be, and how are they justified (Batterman 2002, 2009; Batterman and Rice 2014; Bokulich 2017)? Are they best construed as concerning individual claims or rather holistically as pertaining to the models as wholes (M. R. Jones 2005; Levy 2018; Rice 2019)? Do they come in degrees? And if so, how can we estimate different degrees (M. R. Jones 2005; Levy 2018)? Should we think of them in terms of the processes by which models are built or as model products? All these issues, many of which remain unresolved, suggest that the topic of abstraction and idealization is, in fact, very complex. [↑](#footnote-ref-5)
6. Additionally, andin parallel to explaining how models are built, the philosophical literature has also addressed the ontological question of what models are. Abstraction as subtraction naturally fits with some metaphysical debates: the process of subtracting features generates abstract objects and scientific models have been construed as such (Giere 1988; Glennan 2017; Mäki 2009; Psillos 2011; Teller 2001). Thus, some of the accounts could be interpreted as dealing with the question of ontology for which it is presumably well equipped (but see Frigg and Nguyen 2017; Thomson-Jones 2010; Toon 2012 for arguments against models as abstract objects). However, some (N. Jones 2018; Levy 2013) have explicitly warned against making connections between abstraction employed in the service of constructing scientific representations and abstract objects. [↑](#footnote-ref-6)
7. Similarly, in Frigg and Hartmann (2020), Frigg presents the usual distinction, but in later work he also develops a more detailed account (Frigg forthcoming, chap. 11). [↑](#footnote-ref-7)
8. See, e.g., Nicholson (2012), Levy (2013) and Andersen (2014a, 2014b) for excellent analysis and overview. [↑](#footnote-ref-8)
9. Also known as the minimal conception, see Glennan (2017, p. 17). [↑](#footnote-ref-9)
10. Kaplan introduces the model-to-mechanism mapping account (also abbreviated as the 3M account), according to which “a model of a target phenomenon explains that phenomenon to the extent that (a) the variables in the model correspond to identifiable components, activities, and organizational features of the target mechanism that produces, maintains, or underlies the phenomenon, and (b) the (perhaps mathematical) dependencies posited among these (perhaps mathematical) variables in the model correspond to causal relations among the components of the target mechanism,” to which he further adds that the “3M aligns with the highly plausible assumption that the more accurate and detailed the model is for a target system or phenomenon the better it explains that phenomenon” (Kaplan 2011, p. 347). This particular account has been challenged by, for example, Chirimuuta (2014), who argues against the presumption that the more details the model provides the better it explains the target phenomenon (see also Batterman 2002 for an earlier argument in the same direction, albeit in a somewhat different context; see also Batterman and Rice 2014; Deulofeu et al. 2019). However, it is not clear that Kaplan may be interpreted as subscribing to such a strong statement since elsewhere he states that abstractions and idealizations are a necessary part of scientific work and that they do not jeopardize the explanatory project (Kaplan 2011, p. 348; see also Kaplan and Craver 2011, pp. 609–610). [↑](#footnote-ref-10)
11. The causal role of concentrations is discussed in detail in Nathan (2014). [↑](#footnote-ref-11)
12. A repressor is any molecule that binds DNA, resulting in either blocking the binding of RNA polymerase to its promoter region, or blocking its function, which, in effect, blocks the DNA transcription. [↑](#footnote-ref-12)
13. Of course, one may ask for clarification of what it precisely means to be of no consequence to representation. Since the validity of Potochnik’s views are of little concern to us here, we may simply refer the reader to her original text. [↑](#footnote-ref-13)
14. It is rather illustrative of the conceptual difficulties that the authors speak of the geometrical shapes by which the entities are typically represented as abstractions. Whether or a not a particular reaction takes place is influenced by a variety of factors, including – importantly – the particular shapes of the reactants. Thus, although shapes are in fact key difference-making factors for a reaction to occur, they are clearly misrepresented by the diagrammatic sketches. Thus, shapes could potentially be re-interpreted as idealizations. [↑](#footnote-ref-14)
15. Love and Nathan are very well aware of the fact that the appropriateness of the chosen level of description must be evaluated with respect to the particular issue at hand (research question, educational purpose etc.). They propose to address this using Weisberg’s (2013) multiple model idealization approach. Here we may suggest that the notion of vertical abstraction might serve the purpose better. However, it should also be noted that this particular problem could potentially be re-interpreted as an instance of generalization rather than abstraction, a distinction discussed by Levy (2018). [↑](#footnote-ref-15)
16. Note that in the previous Section I briefly introduced the example of the negative feedback mechanism and I argued that the arrows representing a causal process may best be viewed as an instance of vertical abstraction. Although such an abstraction is found wanting in context in which a more detailed description is required in order to answer a specific research question, it nevertheless does not say things that are literally false; hence, it does not contradict the received view about abstraction. [↑](#footnote-ref-16)
17. More precisely, van Eck and Mennes focus on the part where Love and Nathan discuss the use of the multiple-model approach. Halina concerns herself with the representational ideal of completeness. However, the specific details are of little concern to us; the issue at hand is only that these authors touch upon Love and Nathan approvingly without realizing the fundamental problems discussed herein. [↑](#footnote-ref-17)
18. However, one should also be wary of interpreting this paper as a general defense of the mechanistic framework. Indeed, the rich philosophical literature on the mechanistic explanation has many interesting points to offer regarding the tenability of the framework in molecular biology (see, e.g., Skillings 2015). This paper only meant to show that whatever the means of challenging the mechanistic account of explanation, arguments such as those found in Love and Nathan’s analysis are not a good way of accomplishing that goal. [↑](#footnote-ref-18)