Metaphors in Arts and Science

Walter Veit[1] & Milan Ney[2]

[1]School of History and Philosophy of Science, The University of Sydney

[2]Graduate Center, City University of New York

Abstract

Metaphors abound in both the arts and in science. Due to the traditional division between these enterprises as one concerned with aesthetic values and the other with epistemic values there has unfortunately been very little work on the relation between metaphors in the arts and sciences. In this paper, we aim to remedy this omission by defending a continuity thesis regarding the function of metaphor across both domains, that is, metaphors fulfill any of the same functions in science as they do in the arts. Importantly, this involves the claim that metaphors in arts as well as science have both epistemic and aesthetic functions.

Keywords: metaphor; models; creativity; science; arts; representation: aesthetics

A dabbler in science, Mr. Holmes, a picker up of shells on the shores of the great unknown ocean.

The Hound of the Baskervilles,
Arthur Conan Doyle 2001, Introduction

1 Introduction

Metaphorical phrases are among the most widely known expressions of scientific ideas, such as Dawkins' (1976) 'selfish genes' in evolutionary biology or the 'lights being on' metaphor in discussions of animal consciousness (see Godfrey-Smith 2020). Similarly, metaphors play a central role in the arts, a field they are more traditionally associated with. This raises the so far under-appreciated question of the relation between metaphors in arts and science. In this paper, we begin addressing this question by defending the *Continuity Thesis* (**CT**). According to **CT**, metaphors in artistic and scientific texts serve the same kinds of functions. As a foil to **CT**, we consider the *Discontinuity Thesis* (**DT**). According to **DT**, metaphors in arts and science serve fundamentally different and discontinuous functions. **DT** might appear initially plausible because it seems to follow from a popular theoretical view about the relation between arts and science. Those two activities, it is commonly assumed, serve fundamentally different ends or values: aesthetic ones on the one hand and epistemic ones on the other. This suggests that the same is true of the metaphors used in these respective enterprises. In our defence of **CT**, we will thus demonstrate that metaphors have important aesthetic functions in science and important epistemic functions in art. Our paper can thus be seen as part of the larger project of problematising the traditional divide between arts as purely oriented towards aesthetic goals and science as exclusively oriented towards epistemic goals (cf. e.g. Goodman 1969; Currie forthcoming). Besides blurring the traditional divide between epistemic science and aesthetic art, we will also identify several less prominent 'minor' functions in our defence of **CT**. Those are shared by metaphors in science and the arts. Finally, we also explore how the focus on metaphors in science and their continuity with metaphors in arts opens up new avenues of thinking about *creativity* in science.

In **Section 2**, we begin our discussion by introducing examples of metaphors from arts and science. We also identify 'minor' functions that can relatively unproblematically be found in either field. In **Section 3**, we discuss the epistemic function of metaphors. We argue that comparable epistemic functions can be found in both artistic and scientific metaphors. In **Section 4**, we do the same for aesthetic functions. Finally, in **Section 5**, we conclude and offer some tentative remarks concerning the relation between metaphors and creativity in science.

Like Levy (2020), we want to remain neutral between competing accounts of metaphor. Drawing boundaries between metaphor and other kinds of non-literal language use is very difficult without relying on controversial theories of metaphor (see e.g. Cooper 1986, ch. 1, cf. Gentner et al. 2001 and Dancygier and Sweetser 2014 for the unity of the

cognitive processes involved in understanding non-literal language). Thus, we will use a relatively broad or "unmarked" (Cooper 1986) notion of metaphor. According to our working definition, metaphor covers all non-literal language uses in which two distinct enough domains are evoked where one is more presumed to be more familiar to the hearer-reader than the other. Thus, 'metaphor' will include many analogies and some synecdoches and metonymies.[1] In some respects, the unmarked view of metaphor makes **CT** more plausible. The more phenomena fall under the term 'metaphor', the more likely it is that overlap can be found between the arts and science: It might be straightforward to find (functional) equivalents in science to metaphors serving some particular function in the arts (and perhaps *vice versa*). Thus, an objector might think that we are illegitimately relying on the unmarked view to defend **CT**. To avoid this objection and convince proponents of more narrow conceptions of metaphor, we will be using primarily examples from science that fall under narrower accounts of metaphor. We will only rely on intuitively marginal cases of metaphor as examples from science to match similarly marginal cases from the arts, as in the case of visual metaphors. In considering our examples, the reader should keep in mind that it is plausible that the historic enmity to metaphors in the sciences has made us more reluctant to apply the term to scientific prose, even if this is not justified by the actual usages under consideration. To dismiss **CT** on the basis of such intuitions, or to give too much stock to them in some other way, would beg the question against our position. With this throat-clearing out of the way, let us begin by discussing the role of metaphors in the arts.

2 The 'Minor' Functions of Metaphors

In this section, we will introduce examples of metaphors from both arts and science and identify some 'minor' functions both share thar are neither directly epistemic nor directly aesthetic. We will begin by considering metaphors in the arts and then move on to those in science.

A much-admired passage in Shakespeare's *Romeo and Juliet* reads: "[b]ut soft, what light through yonder window breaks?/ It is the east and Juliet is the sun!" (Act 2, Scene 2).[2] Ralph Ellison's (1995 [1952]) celebrated novel already carries its central metaphor for the American Black experience in its title: *Invisible Man*. In the visual arts, many of the greatest works are intended by their creators to be metaphorical, and to be interpreted as such. In the *Triumph of the Medici in the Clouds of Mount Olympus* (1686, Figure 1), for example, Luca Giordano invites

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[1] While we do not have space to defend it here, we think that the correct account of metaphor would be pluralist. Metaphor isn't one thing. Such a pluralist account implies that there is no clear distinction between metaphor and many other non-literal language uses, such as analogy and parable. Veit (2020b) argues for a similar unmarked notion of models – dubbing it "model anarchism".

[2] See Shakespeare (2003).

the viewer to think metaphorically about the success of the Medici in his Florentine environment in terms of the Olympian Gods.

Figure 1: In Luca Giordano's *Triumph of the Medici in the Clouds of Mount Olympus* (1686), the Medici are metaphorically presented as Olympian Gods. (Image in the public domain, sourced from Wikimedia: https://commons.wikimedia.org/wiki/File:Luca_Giordano_023.jpg)

Evidently, such metaphors have a variety of functions. Their presence in these works isn't accidental or purposeless, but trying to reduce them to a single function would be hopeless. Firstly and, we take it, uncontroversially, most if not all of these metaphors serve some *aesthetic* function. We will come back to the aesthetic functions of metaphors, artistic and scientific, in Section 4.

As for more 'minor' functions, metaphors in arts also likely have a mnemonic function and make the texts and works more memorable (see e.g. Pearson et al. 1981, Marschark & Hunt 1985), hence supporting their other functions and the entirety of the work at large. The recall-facilitating effects of metaphor appear to be highly volatile (see e.g. Lagerwerf & Yu 2017 for negative findings). However, this doesn't mean that skilled creators cannot produce metaphors that reliably aid memory. For one thing, virtually all studies on metaphor and recall focus on the recall of information from texts containing metaphor in a relatively short timeframe of at most a few weeks. Even if metaphor provides no benefit in such settings, metaphorical expressions themselves are probably more memorable than non-metaphorical expressions. Since metaphors often introduce surprising vocabulary into a context and novelty has been linked to recall (see Reichard et al. 2020 for a recent review), this is plausible. Remembering a metaphor from a work years later can activate other related memories.

In some cases, metaphors also make communication more effective and fulfill an *economic function* (see e.g. Camp 2006a). Metaphors are typically shorter than non-metaphorical paraphrases. Saying *Black folk in America are invisible* for example, is faster than saying *Black folk in America routinely suffer failures of recognition in many domains* Thus, they can help overcoming bottlenecks in the processing of information that exist in the physical acts of articulation and inscription and in the visual perception of written text) (see e.g. Levinson 2000 for a discussion of such bottlenecks).

Finally, we can recognise a *behaviour-shaping, emotive,* or *ethical function*.[3] Some metaphors in the arts are intended to change the behaviour of the hearer-readers. For example, in her poem "The animals in that country", Margaret Atwood (1987), who is a vegetarian, uses metaphors with human source domains for a non-human animal target domain partly to motivate her readers to treat non-human animals in a kinder and more dignified way.

In contrast to the evident richness in the usage of metaphors in the arts, scientists and philosophers alike have historically been reluctant to recognise the diversity of roles metaphors can play in science. As Elisabeth Camp (2020) observes, many, including "the likes of Hobbes, Locke, and Zenon Pylyshyn", see metaphors "at best [as] a decorative trope or a mechanism for inspiration; at worst, it spins bubbles of self-confirming pseudo-science"

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[3] We choose these terms partly in allusion to the original meaning of *ethos*, 'habit'. Thus, it includes any attempt to shape an audience's dispositions to behave. Our core examples will however be 'ethical' in the narrower sense that the dispositions in question are (taken by the author to be) morally desirable.

(p. 304). Nonetheless, metaphors are common in scientific writing – didactic and popular as well as in presentation of cutting-edge research.

One notable example is Richard Dawkins' 1976 idea of the "Selfish Gene". Dawkins, however, retroactively regretted this title of his book leading many readers and non-readers alike to walk away with the wrong conclusion: that there is no altruism and that the only things that matter in the behaviour of animals are whether they benefit the interests of individual genes such that they themselves are reproduced. Nonetheless, the metaphor has been influential both in public understanding of contemporary evolutionary theory and research within that theory itself. Indeed, agential language is widespread in biology, *cheating cells*, *red queens*, *slave-making ants*, and *competition* more generally are frequently invoked and have led to theoretical advances (see for instance Veit 2019a). Often, we are warned that such metaphors lend themselves to the anthropomorphising of non-human animals. Canguilhem (1991), for instance, argued that the attribution of health and illness to other animals merely rests in "sympathetic regression". One of us has spent much time on trying to debunk such claims and take the attribution of health and agency beyond humans more seriously (Veit 2021a,b, forthcoming a, Veit & Browning forthcoming). An excellent list of metaphors in the biological sciences has been collected by Olson et al. (2019), discussing a non-exhaustive list of 19 examples, including "adaptive *radiation*", "genetic *information*" and "ecological *tipping points*". Other examples include *Big Bang* and its younger cousins *Big Bounce* and *Big Crunch*.

Just like in the arts, not all metaphors used in science are verbal. An example of a visual metaphor from science can be seen in Figure 2 which is taken from a physics textbook. In Figure 2b, the differences in voltage in the circuit of Figure 2a are represented as differences in height that a tiny stick figure has to climb. The visual imagery induced by the metaphor enables students to better understand and learn about electrical circuits.
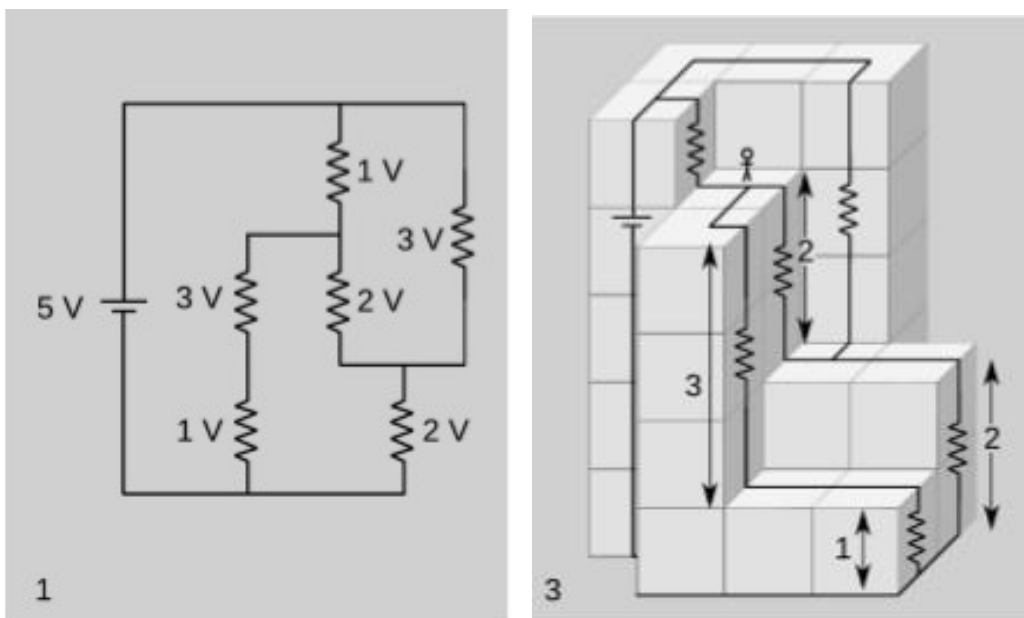
(a) An electrical circuit   (b) The circuit with voltage as height

Figure 2: An example of a visual metaphor in science education (Crowell 2019, p. 606) [cc-by-sa 3.0 license. See https://creativecommons.org/licenses/by-sa/3.0/us/.]

The minor functions identified with metaphors in art can be identified here as well. Clearly, scientists sometimes use metaphors to make statements more concise and memorable. They might, for example speak of the *Big Bang*, rather than 'the expansion of the universe from an extremely high-density, high-temperature state' because the former expression is shorter and statements containing are easier to remember. *Big Bang* might not count as a metaphor anymore, or only as a 'dead' one, since its use has been so conventionalised. However, it surely was metaphorical when it was first used by cosmologists. Taken literally according to its constituents' meaning, this expression would indicate a loud noise.

The ethical function might raise the concern that it is only found in the arts and humanities but not the sciences. However, metaphors in science can have similar effects on behaviour as metaphors in the arts. Brendon Larson (2011) argues this point for metaphors like *invasive species*, which he argues diverts conservation efforts away from addressing human effects.[4]

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[4] An editor has pointed out that this expression might not be considered metaphorical. According to dictionary definitions the verb *invade* can denote any event in which individuals enter a place in large numbers. However, we think that Larson is correct in considering the expression a metaphor. We believe that the sense the editor points out is itself a conventionalised metaphorical extension of the militaristic core meaning. A good, up-to-date dictionary should list 'defeat decisively' as a sense of *destroy*. This does not make it any less metaphorical. Furthermore, even if the description was literally

Philosophers of economics have similarly emphasized that the way we describe economic models and policies can lend itself to distinctive kinds of political messaging in policy making – emphasizing libertarian and utilitarian values over egalitarian ones.[5] Many practitioners of science presumably implicitly or explicitly take such effects into consideration when choosing metaphors. Thus, a metaphor having certain behavioural effects can be counted among the functions of metaphors in science. Even if scientists do not take such effects into consideration, plausibly they ought to.

Like most lists, our list of aesthetic, mnemonic, economic, ethical and (as we will see below) epistemic functions is to some degree arbitrary and idiosyncratic. In no way do we claim that our list is an exhaustive one. For the sake of space, however, we refrain from additional categories of functions. We believe that our list gives a good sense of the range of functions of metaphors in the arts and humanities. If, as we are set out to show, these functions can be re-identified for metaphors in science, and they similarly span the range of functions there, then that offers strong support for **CT**.

3 The Epistemic Functions of Metaphors

In this section, we address the epistemic functions of metaphors. These functions might appear more challenging to **CT** than the minor functions. After all, the epistemic is seen as much more closely related to science than to art. Thus, it might seem that only the metaphors in the former have epistemic functions. In the following, we first address the epistemic functions of metaphors in science. Then, we argue that metaphors in *art* have epistemic functions that are comparable to those and respond to objections to that claim. Finally, we address objections according to which, while metaphors in art have *some* epistemic functions, there are certain special epistemic functions that are unique to science.

It is overwhelmingly plausible that metaphors in the arts serve epistemic functions. The overarching aims of science are epistemic. They consist of (some of) truth, knowledge, understanding, etc. Some of the examples discussed above, such as agential metaphors in biology, clearly have more substantials functions than the mnemonic and economic ones. Those are most plausibly functions directly connected to the aims of science, viz. epistemic functions. Those epistemic functions can be at least as diverse as the epistemic aims of science itself. Metaphors might function to convey simple propositional knowledge, to

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apt, it could still also be a metaphor. Consider the examples "Moscow is a cold city" and "Jesus was a carpenter", which have a literal and a metaphorical meaning (Cohen 1975). In the right context, both can be simultaneously active and intended by the author. It is thus no accident that the biological sciences are full of agential language.

[5] We owe this example to a presentation by Donal Khosrowi (conflicts of values in evidence-based policy are discussed in Khosrowi & Reiss 2019).

convey information that is merely "true enough" to count as scientific achievement (cf. Elgin 2017), to produce more holistic understanding of a subject matter, to enable predictions or to inspire further research.

Scientists and science communicators particularly remark on the importance of metaphors for producing understanding and related epistemic goods. According to astronomer and science communicator Caleb A. Scharf (2013), good metaphors "elucidat[e]" and provide "something to grasp at". Scharf's colleague Philip Ball (2011) is more critical but observes that "metaphor is widely considered an essential tool for understanding". Dawkins (2012) thinks that metaphors are legitimate if they "do real explanatory work."

Metaphors can serve such epistemic functions. Firstly, as the economic function suggested, metaphorical expressions can convey the same information as non-metaphorical ones. Hence, metaphors can serve much of the same epistemic functions as the non-metaphorical expressions that can be used to paraphrase them. More importantly, however, metaphors can provide epistemic benefits that are impossible or difficult to produce with other expressions. Their effect on a hearer-reader has often been compared to the phenomenon of seeing-as (e.g. Moran 1989, Camp 2006b, 2017). This can be seen with examples from both science and art. In reading Ellison's novel, a reader can learn to see the situation of Blacks in 1950s America (and beyond) as invisibility. In reading Dawkins' book, the reader learns to see genes as if they were selfish agents. The phenomenon of seeing-as may be illustrated using the well-known duck-rabbit figure (Figure 2). That figure can be either *seen as* a rabbit
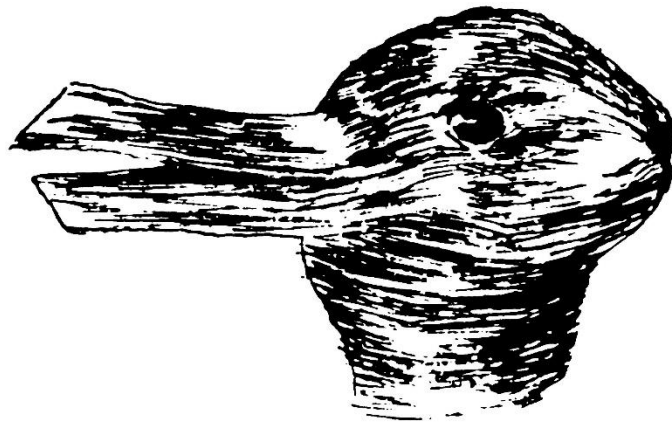

Figure 3: The duck-rabbit figure illustrates the phenomenon of seeing-as (picture in public domain, sourced from Wikimedia: https://commons.wikimedia.org/wiki/File:Duck-Rabbit_illusion.jpg)

or as a duck. The phenomenology of the epistemic effect of metaphors, at least sometimes, is comparable to the experience of shifting from seeing the figure as a duck to seeing it as a rabbit (or *vice versa*) in how it reconfigures one's understanding of a domain. A

metaphor like Dawkins' can holistically transform one's entire way of thinking about genes and evolution rather than just adding another belief about them. Indeed, metaphors can still have such an effect if they lead to no new beliefs. One can already know everything there is to know about the Medici's power, but still be affected by the picture in that way.

One possible explanation of this effect is through metaphor's creating automatic associations within the domain it is about (see Thibodeau & Borodistky 2011, 2013). Through those automatic associations, elements of the domain might appear differently to me, just like Figure 3 appears differently to me if I associate it with duck-features like quacking or rabbit-features like hopping. Since we are finite reasoners, such automatic associations might also be necessary for us to reason about the domain. As understanding is often associated with an ability to reason about a domain (e.g. Wilkenfeld 2013, Grimm 2014), we might see this as the metaphors advancing understanding.

Fortunately for **CT**, metaphors in artworks also serve a epistemic functions. They inform the receiver about something in the world they represent and transform the way they think about it. The viewer of Giordano's painting learns about the power of the Medici. They do so in a way that couldn't easily be emulated by a non-metaphorical representation of their power. Many works of art represent not the actual world but fictional worlds. Thus, Romeo's metaphor in Shakespeare's play, for example, conveys information about aspects of a fictional worlds, Romeo's love for Juliet, in a way that non-metaphorical means could not easily achieve. This is not peculiar to metaphor. Rather, the relation of metaphor in fictional texts to those in non-fictional ones parallels that of non-metaphorical declarative expressions in fictional and non-fictional texts.

Some might hold that the fictionality of the content of many artworks supplies an argument against **CT**. Some metaphors in the arts have the special epistemic function of describing fictional realities, while none in the sciences has. Since 'describing' a fictional world amounts to constructing it, in a way that describing the real world does not, this would constitute a significant difference. However, as Gibson (2009: 467) remarks, "[i]t is common to claim that in works of literature we find some of the most powerful representations of reality our culture has to offer." Whether or not this applies to literature, we believe that is applies to most metaphors used in literature and also in other artistic disciplines. Specifically, firstly, even in most works of fiction, many metaphors are used to describe the real world, since the fictional world is assumed to be like the real word unless it obviously deviates (cf. Woodward 2011). If Dickens uses a metaphor to describe the smell of an East End alley, a reader will take him to describe the conditions on real London streets of the time. Furthermore, a lot of fictional writing aspires to be psychologically realistic. Thus, when a metaphor describes a relation between characters or a character's mental state, the metaphor aims at describing a scenario that is possible or likely for humans as they are in fact given the fictional circumstances. Goethe (2002: 25-26) has his Werther write in a letter: "[h]ow I was *feasting* [*mich weidete,* lit. 'grazing'] on her dark eyes --- how her lively lips and fresh, gay cheeks had *pulled in* [*angezogen*] my soul in its wholeness --- how I, *submerged* [*versunken*] entirely in the magnificent sense of her discourse, often did not hear the words she used to express herself --- of that you will have an idea, for you know me" (our translation and emphasis). Writing

thus, Goethe aims not only at describing the emotional state of the man Werther who only exists in fiction. Rather, he describes that fictional state as a state that is at least the ideal type of a potential or tendency contained in actual humans. Describing what is possible for actual entities rather than what is actual is also the aim of some scientific writing, as when prognoses of climate change are generated using models. Ralph Ellison (1995) uses the metaphor of an *invisible man* not only to describe the state of his fictional protagonist. Rather he picks out a social position that is inhabited by (many) Blacks in America.

Similarly, some scientific writing aims at describing properties that are instantiated by actual particulars without describing any such particular. For example, the theoretical notion of predator might be discussed with reference to hypothetical eco-systems. The same is the case with many metaphors in fictional worlds.

This leaves some potential counterexamples to **CT**, in which metaphors describe merely fictional states or properties of fictional particulars. They might include, for example, the descriptions of an impossible building or a magical sword in a fantasy novel. However, even these metaphors often describe scenarios which provide the context for exploring the dispositions of real human beings. Fantasy writer G.R.R. Martin (*A Game of Thrones*, 1996) for example often affirmingly quotes William Faulkner to the effect that "the human heart in conflict with itself is the only thing worth writing about" (see e.g. Brown 2011). Scientific writing contains close analogues of such fictions (cf. Frigg 2008). Scientific models often contain hypothetical scenarios that are known not to obtain, e.g. scenarios in which every living being has one direct ancestor and there is no horizontal gene transfer or scenarios in which there are three sexes rather than two. And, indeed, we can use our understanding of these fictional worlds such as Tolkien's Middle Earth or Martin's Westeros to help us understand how idealized models can lend themselves to understanding (see also Godfrey-Smith 2006). Indeed, there is now an extensive and well-developed literature in the philosophy of models that explicitly defends them as fictional entities. Once seen as a thorn in the eyes of those defending a realist picture of science, they are now seen by many as an ineliminable and important feature to be embraced and cherished, rather than rejected and banned (Frigg and Hartmann 2020). So, it is not at all implausible to think that our examples can lend themselves as a demonstration of epistemic functions similar to those found in science served by metaphors in speculative fantasy or sci-fi fictions.

A critic might complain that we reduce fiction to (psychologically) realist prose. However, these points can also apply to works that jettison psychological realism. The works of Goethe and Ellison are not psychologically *realistic*. Goethe exhibits an artificially heightened mental state that corresponds to a mere 'adulterated' potential in actual humans. Ellison's novel, which has been described as having "Kafka-like absurdity" (Badbury 1992: 380), does not display psychologically realistic characters either. One character, a supervisor of the narrator, sets him up to cause an explosion after seeing him attend a union meeting and he himself lives in a flat with hundreds of lightbulbs. Rather, these unrealistic situations and characters let the author characterise real social structures through symbolism, metaphor and hyperbole.

Of course, some (purportedly) artistic writing that contains metaphors might fail to have any such links to actual reality. Some such writing may be considered deficient relative to epistemic functions suggested by its form. Escapist pulp fiction with psychologically unrealistic superman-like heroes or *uber*-Stoic detectives gives readers an incorrect image of human psychology. Thus, it is plausible that those metaphors have an epistemic function (or that an observer ascribes such a function to them in considering them as more than mere entertainment), which they however fail to discharge. That they have, in some sense, epistemic functions can be seen from the fact they provide their escapist pleasure precisely because they are taken to have links to what's possible in the real world. They allow the reader to let themselves believe, at least for a time and with a part of their mind, that such heroes are possible. You could be such a hero! A hero might save you! Such metaphors are comparable to the use of metaphors in *pseudo*-scientific writing - aimed to provide an illusion of scientific understanding. Of course, both escapist fiction and pseudoscience-like activities can be quite fun. For an example of the latter, consider fairground astrologers. We do not wish to denigrate such pleasures. But in either case, responsible consumers must keep it in the back of their mind that their entertainment does not serve some epistemic functions that are suggested by its form.

A critic might also complain that we seem to be endorsing cognitivism about art, i.e. the claim that art is a source of knowledge. In 1983, Catherine Wilson noted "[t]here is probably no subject in the philosophy of art which has prompted more impassioned theorizing than the question of the 'cognitive value' of works of art" (p. 489). Thus, it would be undesirable for us to make **CT** depend on cognitivism about art. However, a strong denial of cognitivism strikes us as absurd according to which no artwork can provide knowledge or understanding to a reader. Clearly, there is something to be learnt about the situation of Blacks in America in the 1950s from Ellison's novel. One might think that a novel like Ellison's has this cognitive value simply as a cultural artefact. Every artefact, including utility buildings and hammers, allows some inferences about the society that created it. However, this doesn't seem right. In articulating the insights gained from the novel, one could naturally use conceptual resources taken from it. One might say, for example, metaphorically, that American Blacks at the time were like invisibles, not seen by White society. Similarly, in describing the insight gained from Whether, we might say that we learnt that it is possible for people to be in a state of mind where they feel like being 'pulled in' by another human being. However much a tenement building might tell me about the society that built it, it won't also give me the conceptual resources to express that knowledge.

We do not need to endorse any stronger forms of cognitivism. Thus, for example, we do not need to argue that there is a special kind of knowledge which cannot be gained or conveyed any way except through art. This is the strong form of cognitivism influentially attacked by Stolnitz (1992). In fact, **CT** suggests this strong form of cognitivism is *false*, at least concerning metaphors. If metaphors in arts and science serve the same kind of epistemic functions, they are likely to convey the same kind of knowledge. Similarly, we can accept the claim that artistic value, the (purported) intrinsic value artworks have *qua* artworks, is completely distinct from their cognitive value. Cognitive value might merely be an additional

intended instrumental value in artworks (cf. Lamarque 2009). Our focus is on the *metaphors* used in an artwork, not on the artwork itself. Contributing to the artistic value of the artwork and to its epistemic or cognitive value are equivalent *for the metaphor* even if the artistic value is more essentially linked *to the artwork*. In fact, we can concede that *most* art might not have any cognitive value. It might be that most art is not representational in the relevant sense, representing neither the real word nor fictional worlds that tell us about the real world. This might be true of most painting and sculpture, music, dance, video art, conceptual art, concrete poetry etc. As long as those art forms do not ordinarily feature metaphors, they might ordinarily lack any cognitive value without that posing a challenge to **CT**.

Given the epistemic nature of science, one might worry that metaphors used within it serve some specific epistemic functions that are not found in the arts. These would provide counterexamples to **CT.** Thus, we will now argue for several such functions that, if metaphors in science have them, they are shared by some in the arts.

The first such purported function we consider is the *referential function*. According to Boyd (1993), metaphors like those of "information retrieval" and "information storage", which are projected from informatics into cognitive science, enable scientists to refer to homeostatic property clusters which they cannot (yet) pick out through non-metaphorical definite descriptions. A more contemporary example from cognitive science might be "global workspace" and "broadcasting" in the discussion of consciousness (e.g. Prinz 2012). Homeostatic property clusters are collections of properties that are variously causally interconnected so that they regularly co-occur. Under the heading of the referential function, we can also include cases in which a metaphor is supposed to but fails to determine a referent. At the core of caloric theory was the metaphoric notion of heat as a fluid. It turned out that that theory was seriously mistaken, and hence the name of the 'heatfluid' *caloric* failed to refer. If the theory had been more successful, however, the name would have referred. Hence, (one of) its function(s) is still to refer. Only, it fails to realise that function.

The example of *caloric* also shows how the referential function might combine with the epistemic, inference-enabling function of metaphor to give metaphors, at least occasionally, an important role in scientific concept formation and thereby structure an entire research programme. Through the referential function, the metaphor (purportedly) enables scientists to refer to some kind. Through the inferences it enables, it allows them to reason about it. Hence, it gives them a concept of that kind. We may grant that metaphors can achieve this. However, homeostatic property clusters can be more or less unified. Different clusters, for example, might contain more or fewer peripheral properties whose presence is only partially caused by the cluster's other members and whose absence would merely make the cluster *less* stable. On the one hand, the property clusters featured in the exact sciences, such as *lightwaves* or *black holes* are highly unified. On the other hand, kinds appealed to in the social sciences and functional kinds like in Boyd's own examples are less unified. Even if metaphors in practice often fail to pick out clusters of unified phenomena, investigative kinds, or natural phenomena (however one may wish to characterize the targets of science), this general observation would remain accurate.

With this in mind, consider again the core metaphor of Giordano's painting (Figure 1). Here, the Medici are metaphorically equated with the Olympian Gods to ascribe to them a certain kind of power and success. That specific combination of power and success of dominant families in Renaissance Italian city states can be seen as a mapping onto a homeostatic property cluster or investigative pattern in the social sciences that might just as well be represented by a social scientist. In Ralph Ellison's *Invisible Man*, the eponymous metaphor of invisibility can be interpreted as referring to a certain social kind or property cluster consisting *inter alia* of the property of failing to be recognised as agents, suffering testimonial injustice, and having internalised oppression (see also Mills 2007 for a philosophical discussion of the metaphor). As Ellison sees things, this kind is instantiated by (many) Blacks in America. Admittedly, such kinds or cluster are likely less unified than those appealed to in the exact sciences, but this poses no challenge to the continuity between metaphors in arts and science in general. In this respect, metaphors in arts are simply closer to those in the less exact sciences, such as Boyd's own examples from cognitive science. Thus, if metaphors in science can refer to homeostatic property clusters, so can metaphors in the arts and this is no counterexample to **CT**.

One might also worry that there is a unique epistemic function for metaphors in science that consists in shaping research programmes. An example of this might be the metaphors of time as an arrow and time as a cycle in the beginning of modern geological science discussed by Gould (1987). However, this can be seen as one of the epistemic functions described above, which we have already seen can be found in the arts and the sciences. The metaphors in question enable inferences about geological phenomena and about which avenues of research are likely to prove fruitful that are constitutive of different research programmes. Moreover, comparable uses of metaphors can be found in the arts: Metaphors such as that of the nature as an ensouled being in the German *Sturm und Drang* are partly constitutive of artistic movements or 'programmes', and they affect that way those under their sway understand many phenomena. One may even take this line of reasoning further and recognize as Dennett (1991) does, a "war of metaphors" that is waging in the sciences and philosophy alike.[6]

Finally, another epistemic function an objector might suggest is unique to metaphors in science is a *modelling function*. They might argue that some metaphors in science constitute scientific models of their target domains, such as agential metaphors in the biological sciences and perhaps *Homo oeconomicus* in economics as rational agent models. As such, the objector continues, they serve an epistemic function that is not served by any metaphor in the arts. However, even if one were to designate scientific models as only those that are present and used in science, hence making it a tautology that only metaphors in science may constitute scientific models, this doesn't mean that this term designates any distinctive epistemic functions. A popular cluster of views understands models as manipulable representations of their target (Frigg and Nguyen 2018; Frigg and Hartmann 2018). A related view is to see models simply as ways of generating predictions about a domain. In either case, any metaphor

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[6] See also Veit (forthcoming b) for a discussion of metaphor wars in philosophy of science.

can be understood as a model according to the structure-mapping view. Some of the information that can be projected from the source to the target domain concerns what would happen in certain scenarios, i.e. predictions. In order to generate that information, a thinker manipulates their representations of the target domain. Through metaphorical mappings, these representations also act as representations of their target domains. Other authors in the modeling literature have embraced a model pluralism, according to which different models fulfill different functions and hence should be embraced, rather than discarded (Weisberg 2013; Aydinonat 2018; Veit 2019b, 2020a,b). Similarly, we should recognize that metaphors serve a multiplicity of functions that undermine the idea that there is a hard dividing line between metaphors in the sciences and the arts. As we shall argue in the next section, this also applies to their aesthetic functions in both domains.

4 The Aesthetic Functions of Metaphors

Besides epistemic functions, aesthetic functions may pose a challenge to **CT**. Since the arts but not science have traditionally been associated with aesthetic values, one might think that metaphors in arts have aesthetic functions that aren't shared by metaphors in science. In this section we address this worry. We first briefly focus on aesthetic functions in the arts. Then we move on to showing that metaphors in scientific texts have comparable aesthetic functions. In doing so, we will discuss several ways in which those aesthetic functions contribute to the generally epistemic aims of science. Finally, we discuss ways in which metaphors, especially with regard to their aesthetic properties, provide dangers to the scientific enterprise.

We take it to be uncontroversial that metaphors in the arts have aesthetic functions. They contribute to the aesthetic value of the works they are part of. If we are asked to explain what makes *Romeo and Juliet* an aesthetic success, for example, its metaphors would be among the points we could list in a response. Perhaps, there is a single aesthetic function of contributing to 'beauty' or aesthetic value as such. More plausibly, there are a variety of aesthetic goals. Artists aim at making us admire their ingenuity, feel pleasant surprise or an urge to laugh at a novel combination of words, and more generally experience positive mental states such as enjoyment and pleasure. Plausibly metaphors also have the function of realising negatively valenced aesthetic properties like ugliness. Another aesthetic effect metaphors function to produce could be estrangement or *Verfremdung* (cf. Brecht 1990). Through the use of metaphors, an otherwise familiar domain is made to appear strange. Thus, it is opened up to new critical reflection or emotional valuation. A plausible example of this is George Orwell's (1945) *Animal Farm.* There, the metaphor of the October Revolution and its consequences as the events on a farm that comes to be run by the animals produces an effect of estrangement that allows readers to re-evaluate the real-world events with less preconceptions. A differentiated monism that allows for diverse contributions to an ultimately unified aesthetic value and pluralism about aesthetic goals, are both compatible with our discussion

The claim that metaphors in science have aesthetic functions might seem more surprising. However, metaphors used in science evidently exhibit a variety of aesthetic values. They can be elegant, as in the metaphor of Figure 2 linking electrical current with height. They can be beautiful and awe-inspiring as in the *tree of life*. They can be witty and humorous, as in the *Big Bounce* as a rival to the Big Bang theory and the *Big Crunch* as a related view. They can be sublime and awe-inspiring as in a metaphorical expression of Bohr's atomic model: *The atom is a star system*.

One might worry that these aesthetic values are merely accidental to the metaphors. If so, they would not correspond to any aesthetic *function* of metaphors any more than metaphors involving five-letter words would correspond to a five-word function of metaphors. However, firstly, some of these metaphor's aesthetic qualities are too conspicuous to be merely unintended accidents. Furthermore, many philosophers of science have noted and defended the scientific practice of treating a *theory's* or *model's* aesthetic values or beauty as counting in its favour (see e.g. McAllister 1996, McAllister 1998, De Regt 1998, McAllister 2002, De Regt 2002, Kuipers 2002, Thagard 2005, Montano 2013). Scientists generally agree with this assessment. Ivanova (2017) and Breitenbach (2013) collect citations from illustrious roster of scientiest attesting to the importance of "beauty" in their and their colleagues' research: Henri Poincare, Paul Dirac, Werner Heisenberg, Pierre Duhem, Ernest Rutherford and James Watson talking about Rosalind Franklin. None of the authors cited here explicitly refer to metaphors. However, given the general recognition of aesthetic values as at least a relative end in science, and the evident aesthetic value of some metaphors, it is very plausible that metaphors' aesthetic properties are relevant as an end in science.

It might be objected that the aesthetic values appealed to by the scientists referenced above consist in kinds of 'elegance', 'simplicity' or 'unity in diversity' that are typically instantiated by models and theories, but not by metaphors (cf. Baker 2016). Thus, the analogy drawn in the last paragraph between the latter's and the former's aesthetic values would fail. However, firstly, metaphors can exhibit aesthetic values of the kind discussed most commonly by scientists. A metaphor that based on simple correspondences and analogies systematically connects two or more fundamental domains of science can appropriately described as 'elegant'. A simple example of such a metaphor is that of Figure 2. Furthermore, there are sciences in which other aesthetic values, connected to detail, complexity and nuance, are at least as highly priced as elegance and simplicity. An example of this is palaeontology (cf. Currie forthcoming).

An objector might also worry about the legitimacy of aesthetic goals for metaphors in science. If such goals are incompatible with the (largely) epistemic overarching ends of science, they could not correspond to aesthetic functions. Either scientists would not be motivated by them, or they would be producing bad science. In either case, it wouldn't be appropriate to ascribe aesthetic functions to the metaphors in questions. In order to respond to this objection, we will now describe several plausible, mutually compatible ways in which aiming for aesthetic values might contribute to conventional goals of science, such as epistemic value and utility.

Firstly we can appeal to *functional beauty*. This is the kind of beauty artefacts or other functional objects have if they realise a function effectively and conspicuously, i.e. in a way that is evident and intelligible to the observer (see e.g. Carroll 1992, Davies 2006, Parsons and Carlson 2008). In this sense, the work activity of a craft master or a wolf pack hunting a deer can be beautiful. Metaphors can also realise their (non-aesthetic) functions in such a way and thus exhibit functional beauty. One way in which metaphors in science can be beautiful is thus by fulfilling its other functions in an efficient and conspicuous way. Such functionally beautiful metaphors would likely often be *elegant* in the sense discussed above. Clearly, by aiming at such functional beauty in their metaphors, scientists would advance the goals of science. They would aim at producing epistemically valuable metaphors and metaphors who through their memorability and efficiency indirectly contribute to science's epistemic goals. Even aiming for metaphors that do so *conspicuously* in particular would indirectly contribute to those goals. It makes it easier for other scientists to evaluate the metaphors.

Secondly, we can appeal to aesthetic appreciation rooted in prior exposure and familiarity. Stimuli of a given type are experienced as more pleasant if stimuli of the type have been encountered before. This includes objects of aesthetic appreciation. This is known as the Mere Exposure Effect (see e.g. Cutting 2003). Admittedly, if a specific metaphorical phrase, such as *life is a journey* is encountered repeatedly, it will be perceived as hackneyed and boring. However, if metaphors of a more complex, gestalt-like type a re-encountered, this is likely aesthetically pleasing. Regarding science, Currie (forthcoming) argues that in scientific education and continuing in scientific practice, scientists train their aesthetic sensibility through exposure to appreciate certain qualities that are reliable indicators of truth or other values, such as understanding or usefulness, within their respective (sub-)field. While Currie doesn't discuss metaphors, the same mechanism could clearly apply to metaphors. Engaging the aesthetic sensibility in this way plausibly has the advantages of making certain gestalt-recognition capabilities useful to scientific practice that it would otherwise be difficult to integrate, and of creating (additional) emotionally charged motivations for scientists to aim for such indicators, and hence indirectly for the values they indicate. This approach can explain why aesthetic standards, including for metaphor, are somewhat different in science and the arts. The exemplars and paradigms on which the aesthetic appreciation is based are different. Similarly, different paradigms might ground the appreciation of different aesthetic values like beauty, elegance, sublimity, nuance and wit.

'Creative' understood as a property of *original*, *spontaneous*, and *valuable* metaphors might also be understood as a specific aesthetic property in this sense (see Kronfelder 2018 for this three-part conception of creativity). Such metaphors would be especially valuable in science because scientists' standards of such these properties would have been shaped by paradigms such that it is a reliable indicator of a metaphor's epistemic valuableness. Gentner and Jeziorski (1993) describe how medieval sciences like alchemy were shaped by metaphors that quite haphazardly connected different domains like colours, the heavens, the human

body and metals[7]. In contrast, modern science is based on stricter and more systematic analogies. Using our broader conception of metaphor, we can understand this as a shift within the paradigms for the aesthetic appreciation of metaphors in science.

Occasionally, scientists might learn to recognise specific negatively valenced aesthetic properties and treat them as indicators of aptness. Evolutionary biologists, for example, might metaphorically see evolved mechanisms as solutions to engineering problems. As engineering solutions, however, such mechanisms often aren't perceived as 'elegant' but as 'dirty', 'kludgy' and 'hackish'. Evolutionary biologist Suzanne Sadedin (2016) describes the menstrual cycle in a popular article as "just the kind of effect natural selection is renowned for: odd, hackish solutions that work to solve proximate problems." Neuroscientist David Linden (2007: 245) observes that "at every turn, brain design has been a kludge, a workaround, a jumble, a pastiche." Academic psychologist Gary Marcus (2008) titled a pop-sci book *Kluge: The Haphazard Construction of the Human Mind*. Nobel Prize laureate François Jacob (1977) described evolution through natural selection as "tinkering". While the general metaphor of evolution as a hackish tinkerer might have no negatively valanced aesthetic properties, specific metaphors of, say, the menstrual cycle as an engineering solution have such a property. That property is expressed with thick aesthetic terms like *kludgy*. Probably no evolutionary biologist would use such kludginess as an argument in justifying an evolutionary explanatory story. But they could reasonably use it (and likely do so) to evaluate for themselves whether a proposed explanation is worth exploring. Thus, a metaphor's negative aesthetic property has become a likely indicator of good understanding, and thus an appropriate aesthetic goal. This is comparable to the special cases in which artists aims for negatively valenced aesthetic properties in their metaphors.

Finally, aesthetic values in scientific metaphors are plausibly closely linked to the epistemic value of *understanding*. Kosso (2002) and Breitenbach (2013) have both argued that beauty is a legitimate goal in science because beautiful theories (or models) are more likely to contribute to our understanding of the world or phenomena in it (see also Ivanova 2016). Kosso argues that understanding consists in recognising the *connections* between facts rather than knowing facts. Analogously, (the relevant kind of) "beauty" consists in a tightly fitting, organic unity of a whole's components. A perfectly beautiful theory, like a perfectly beautiful novel or symphony, is such that no component could be removed or changed without leaving a gap. Breitenbach appeals to similar considerations, but she adds an explicitly Kantian component. In appreciating the beauty of a scientific product, I (implicitly) appreciate the fit between it and my capability to understand. Now, as we have seen above, the epistemic function of metaphors is often closely linked with understanding and a holistic view of the subject matter. A metaphor may summarise various facts and the connections between them in a way that can be handled by a finite human mind. It may also create automatic associations between aspects of its source domain that enable to reason about it. Thus, at least under

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[7] Since Gentner and Jeziorski use a narrower conception of metaphor, they call this a shift from metaphor to analogy. Using our broader, unmarked conception, we can see the same development instead as a shift within metaphor use.

some conceptions of understanding, it enables me to understand. Thus, if we accept Kosso's or Breitenbach's notion of aesthetic value, at least as accounts of *one* among many aesthetic values, then one aesthetic function of metaphors in science would be the following. They would provide the scientific text they are part of with this holistic intellectual beauty by allowing the reader to understand the subject matter, and (per Breitenbach) be aware of themselves as understanding it. Aiming for this kind of aesthetic value would mean aiming for understanding, a legitimate aim for science. In fact, this kind of aesthetic value might be understood as a special case of functional beauty. The metaphors in question might be beautiful because they discharge their epistemic function of producing understanding efficiently and conspicuously.

Even though Kosso and Breitenbach speak of "beauty" in general terms, at least regarding metaphor this aesthetic value can be closely linked to awesomeness --- viz. the quality of inspiring awe --- and sublimity. Both these aesthetic properties are linked to a human appreciator's awareness of their relation to a whole that is larger and (at least apparently) more powerful than themselves (cf. Brady 2013, Valdesolo et al. 2016, 2017, Fingerhut & Prinz 2020). The subject matter of a metaphor sometimes is precisely such a whole, as with the *tree of life*. By enabling the hearer-reader to understand and be aware of that whole, the metaphor might exactly occasion awe and the appreciation of sublimity.

The foregoing notwithstanding, we can readily accept that there are dangers and pitfalls with using metaphors in science, especially in connection to their aesthetic values. Thus like, Levy (2020: 301-302), we can agree with a quote commonly attributed to Norbert Wiener: "[t]he price of metaphor is eternal vigilance." However, those dangers are not exclusive to science, but shared by metaphors in the arts. Hence, this is no challenge to **CT**. Metaphors that are memorable, aesthetically pleasing or seemingly conducive to desirable behaviour can indeed seduce scientists into accepting theories or models that are not appropriate given the evidence, or that are too obscure to be accepted as good science. One might think of alchemy or Goethe's colour theory for some cautionary tales. However, the risk that an author might pursue the particular goals of metaphor at the expense of the overall goals of their work is not particular to science. A novelist can be enamoured with the aesthetic features of their metaphors and overuse them so that the plot becomes difficult to follow and extraordinary metaphors cease to highlight important plot points. A poet attempting to write a poem in the idiom of some specific character might be too concerned about how his metaphors will affect his readers' behaviour and fail to get the tone right. Of course, the aims of the text at the expense of which a metaphor's aims are developed are likely specific to the arts and sciences respectively. Nonetheless, the danger of the subordinate goals of metaphor being realised at the expense of the goals of the overarching enterprise and the mechanism through which this happens are likely continuous.

Thus, **CT** doesn't mean *all* metaphors in science are legitimate. Just like some metaphors in artistic works are bad in various ways – bland, tasteless, confusing, etc. – some in science might be bad. Neither does it imply that the same criteria need to be used in evaluating metaphors in science as in the arts. In fact, there is no such thing as *the* criteria

used in the arts. Different artistic genres have their own criteria. Similarly, scientific 'genres' like research articles, grant proposals, lectures and textbooks might have their own criteria.

To use a metaphor to emphasize this point: Metaphors are an elegant set of 'tools' shared by both the sciences and the arts. They have advantages and disadvantages just like any other tools in both domains. Experiments can be designed in such a view as to lack any ecological validity and models may lack any empirical relevance for the real world due to trade-offs with simplicity and elegance (Weisberg 2013). Depending on their ultimate goals, there are dangers and pitfalls inherent to any 'tools' scientists and artists use. And as our defence of **CT** in this paper hopefully illustrated, metaphors are no exception sharing a continuous set of functions across both domains.

5 Conclusion and Further Discussion

In the preceding sections, we have discussed metaphors in arts and in science. We have argued that the functions of metaphors in both contexts are continuous. Both share a set of functions that are 'minor', at least relative to the aim of this paper. They have *mnemonic*, *economic* and *ethical/emotive* functions that are difficult to place in more traditional views about the divide between the aesthetic and the epistemic. More importantly, however, metaphors have both aesthetic and epistemic functions irrespective of their domain. In order to defend this *Continuity Thesis* over the *Discontinuity Thesis* we have provided an array of examples for our arguments that metaphors in the arts have epistemic functions and that metaphors in the sciences have aesthetic ones. One of our motivations was thus to shoot an additional arrow in the heart of the traditional division between the sciences as purely epistemic disciplines and the arts as aesthetic ones. Metaphors as fluid as they are, point to a striking continuity between the sciences and the arts.

Finally, focussing on metaphors in science and relating them to metaphors in art also opens up new avenues of thinking about *creativity* in science. As Levy and Godfrey-Smith (2020) argue, science is "both a creative endeavour and a highly regimented one". Yet, the former aspect has only received minimal attention in the "positivist and post-positivist philosophy of science" of its time (p. 1). This is a similar criticism to the one earlier noted by Camp. Due to the popular distinction between the *context of justification* and the *context of discovery*, introduced by Reichenbach (1938), philosophers have tended to relegate the role of imagination to a backseat in the scientific practice – at best like a child that could come up with new roads to travel – but with rigorous empirical investigation at the steering wheel. The lack of philosophical attention paid to creativity, however, is not exclusive to the philosophy of science. As Currie (2019) argues, "philosophy in the analytic tradition has been pretty quiet regarding creativity, certainly in comparison to notions like beauty, truth, knowledge, [...] and so on" (p. 1). Despite the attention philosophical giants such as Plato and Kant have given to the role of imagination and creativity (see Gaut 2010), much of this work has been "consigned to the Davy Jones' locker of collected volumes" (p. 1). By tearing down, in parts, the dividing line between metaphors in the arts and sciences we hope to return these topics to the core of philosophy of science.

Focussing on metaphors and their functions as they have been illuminated by the connection to artistic metaphors, we can make several points about creativity in science. Firstly, as we have seen above, 'creativeness' can be understood as a specific aesthetic property of metaphors that in science is linked to their epistemic valuableness. Furthermore, the creation of new metaphors plausibly itself is an important locus of creativity in science. Products of creativity need to be both novel and constrained. In art as in science, mere nonsense might be novel, but it is not creative or innovative (Kant 1781/2000, Elster 2000, Carrol 2003, Olsen 2003). Metaphors can fit this bill. New metaphors for some subject matter are constrained by what is already known about that subject matter. At the same time, they can be novel and unexpected. Such a novel metaphor can then give rise to innovative models and hypotheses through its implications, as described in Section 3. For an example of a metaphor in an individual mind leading, we might think of Einstein's imaging himself as an observer chasing a lightwave, which according to his autobiographical notes partly inspired the special theory of relativity (see Norton 2011). Here, Einstein metaphorically imagined a lightwave as visible wave in a material medium. Similar, Kekulé discovered the structure of benzene after dreaming of an *ouroboros*, or a snake biting its own tail (see Rothenberg 1995). Kekulé metaphorically pictured the benzene molecule as such a snake.

The focus on metaphors also sheds light on the status of creativity in science as a phenomenon within social cognition that nonetheless depends on the individual cognising scientist's social environment (cf. Nersessian 2008). The novel metaphor is created in the mind of an individual scientists, but they depend on socially construct conceptualisations of the two domains involved in the metaphor and learnt standard of preliminary evaluating metaphors (aesthetic and otherwise). Moreover, the development of innovative models, theories and hypotheses from the metaphors will often by a social process. It will typically at least involve conversations with lab partners, if not conference presentations and publications.

Finally, on the level of science as a collection of socio-political institutions, metaphors can also be an important aspect of innovative science. Metaphors can be aesthetically pleasing in various ways and they can make the unfamiliar seem more familiar. Both these features plausibly decrease the psychological resistance novel views might ordinarily encounter in people newly encountering them, including actors with power within scientific institutions such as peer reviewers and board members of funding bodies (cf. O'Connor 2019). Thus, together with formal justifications, metaphors might help innovative views in science succeed. Plausible examples of this, which should be investigated in this respect by sociologists of science, include the *Big Bounce* and the *Big Crunch*, which are both pleasingly witty and make their subject matters seem more familiar by connecting them to everyday mechanical phenomena and the established theory of the 'Big Bang'.

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