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Optimizing friction between alternative genomic metaphors: How much plurality is enough?

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Introduction

In *On Metaphor*, Wayne Booth argues that, "Criticism of metaphoric worlds, or visions, [represents] one clear and important – perhaps the clearest and most important – instance of a general human project of improving life by criticizing it."[2] Given the radical extent to which genomics may affect the "general human project", our aim to consider its metaphors would thus be one of the higher aims to which we can aspire. While some still underestimate the performativity of language – and metaphor, specifically – too many scholars from too many fields have drawn attention to its importance for us to ignore.[3] The metaphors we use to conceptualize genomics today will partly come to define humanity in the future.

Booth's argument focuses on how we might evaluate individual metaphors: good metaphors are supposed to be active, concise, accommodated to the audience, and constructive of the speaker's ethos, although he clearly demonstrates the challenges of applying these standard rhetorical judgments. Rather than focusing on such issues, however, I wish to consider a related tension. If critics wish to apply Booth's evaluative criteria to scientific metaphors, what should their objective be? In short, should we seek a single, best metaphor or a plurality of alternative metaphors? And if the latter, how many?

My argument will be that we need to find an intermediate level of metaphoric plurality. When there are too few metaphors, exemplified by the search for a single metaphor, inquiry tends to become too parochial, blind to what lies outside its metaphoric vision.[4] I will refer to this as unfruitful fiction. As we add metaphors to our repertoire, we obtain a friction between alternatives that is fruitful. But, when there are too many metaphors, inquiry tends to become stymied by diversity, a diversity that includes too many uncritical elements and which leads to an unfruitful friction. It seems that criticism is essential, although not too much criticism. We seek a middle ground where there is enough diversity that we avoid unfruitful fiction yet at the same time provide a fruitful friction between alternative perspectives.

I will sketch this argument from both scientific (epistemic) and social sides because metaphors may be appropriate for different reasons in these contrasting domains of use. Following Wittgenstein, we may view metaphors in these domains as tools serving various needs and purposes. Though I will discuss epistemic and social uses separately at first, I will increasingly present a view that questions our capacity to isolate them from one another.[5] The general question then concerns the conditions under which we should weed metaphors as opposed to cultivate plurality.

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Plurality in genomic science

I'd like first to examine the ongoing metaphoric shift within genomic science. In the late twentieth century, scientists tended to rely upon the 'blueprint' metaphor to understand and describe genes and gene action, and an academic cottage industry built up to critique this metaphor because of its potential social implication.[6] I would argue that this initial moment where we critically evaluate a particular metaphor needs to be followed by another and equally important one, the provision of alternatives that in themselves may provide a form of critique of the prevailing metaphor.[7] Recently, the genomic revolution has spawned just such an investigation of alternative metaphors that provide a more fitting epistemic basis for the genomic revolution and its subtleties. While there are numerous examples, I focus on a discussion by the esteemed geneticist John Avise in the pages of *Science*, because of its rich examples and what it reveals about how scientists themselves think about metaphors.[8] While I cannot claim that he is representative, he is certainly outspoken.

In his paper, Avise contrasts the relative rarity of traditional "good-citizen" genes found by the Human Genome Project with the "astonishing collection of noncoding regions, regulatory modules, deadbeat pseudogenes, legions of repetitive elements, and hosts of oft-shifty, self-interested nomads, renegades, and immigrants." He further called for "new and evocative metaphors" that are "both entertaining and research-stimulating," and presented a range of options not limited to those above, but also including wilderness, motley crews, vagabonds, hordes, freeloaders, tacticians, renegades, deadbeats, ramblers, foreigners, parasites, and "great armies of repetitive elements – some with hundreds of thousands of like-uniformed members."

To explain this metaphorical flurry, we might turn to the philosopher Thomas Kuhn, who proposed that when scientists are taken in by a particular paradigm they merely commit themselves to the puzzle-solving that comprises what he called "normal" science.[9] Such normal science depends in part on entrenched linguistic resources. Kuhn further proposed that paradigms may be overthrown during a revolution caused by the increasing weight of anomalies mainly internal to science. When this happens, as in the case at hand, alternative metaphors contribute to a rejigging of scientific inquiry. Reflecting on his panoply of alternative metaphors, Avise acknowledges, "Metaphors can and should evolve to accommodate new findings." We are living in a fertile time because we are dismantling the old way of understanding genes – noting that some philosophers predict the demise of the very concept of "gene"[10] – and searching through our everyday language for metaphoric resources that can aid inquiry.

However, normal science beckons, and Avise capitulates – and, I would argue, too quickly. While he recognizes that "no one metaphor is likely to be informative in all respects", he concludes his paper with the recommendation that "some new perspective that views the genome as an interactive community of evolving loci may be especially useful and stimulating at this time". Within a single paper we have gone from critique, to proliferation, to implicit advocacy for *a* new perspective, rather than maintaining a plurality of perspectives. Avise implicitly calls for the resumption of

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normal science within the context of a metaphorical monoculture, one consistent with an implicit realist view of the world. In this context, it makes sense to narrow down to a single metaphor in order to focus inquiry, but Avise does not provide any strong reasoning for choosing this metaphor. There are options, each leading in a slightly different direction.

There are multiple benefits to maintaining more of the metaphoric plurality presented in his paper. Primarily, a single metaphor cannot capture a phenomenon in its entirely, for every metaphor hides some elements of a comparison while accenting others (which Avise recognizes). Diverse metaphors are vital because they provide varied perspectives. Psychologist William James, for example, maintained an "ensemble" of metaphors to characterize human psychology.[11] Metaphors can serve different purposes within a research paradigm: for empirical or more theoretical investigations, or for maintaining inquiry at the boundary of the paradigm. Thinking ecologically, what role might there be for primary producer metaphors versus carnivore and detritivore metaphors? Perhaps "producer" metaphors elicit other metaphors or new ideas, whereas "carnivorous" metaphors swallow up alternatives, and "detritivorous" metaphors absorb meanings from elsewhere (even outside of the science in question).

This argument, then, rejects a realist view of the world. It denies that a single metaphor could ever model or capture reality in its entirety, although multiple metaphors can provide a more complete picture. While scientists might accept this claim for the early stages of inquiry in a field or during a transformative phase, as described above for recent genomics, they might still tend to believe that it is ultimately better to select a single, best-supported metaphor. And yet, as Kuhn once asked, "Does it obviously make better sense to speak of accommodating language to the world than of accommodating the world to language?"[12] If metaphors help to create a world, then a single metaphor provides only partial understanding at the intersection between the impressions highlighted by divergent metaphors. Multiple metaphors may thus reduce the inclination to attach truth to our metaphors. Donald Schön, for example, emphasizes the importance of being able to "attend to and describe the dissimilarities as well as the similarities between A and B". Such a process allows us to benefit from the Rashomon effect produced by several metaphors because "such a multiplicity of conflicting stories about the situation makes it dramatically apparent that we are dealing not with 'reality' but with various ways of making sense of a reality."[13] This is not a nefarious form of anything goes. Katherine Hayles, for example, argues that such scientific metaphors must still be constrained by empirical findings.[14]

Diverse metaphors thereby act as a prophylactic against reification. Single metaphors are all too easily entrenched, at which point they become less open to reflective critique. Not only does a single metaphor highlight only some aspects of a phenomenon, but it can actually divert our attention from its shortcomings and thus from alternative perspectives. While it might appear that the blueprint metaphor was a fruitful fiction, rather than an unfruitful one, that is only narrowly true because its successes in a certain epistemic realm may have delayed questions about its wider

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applicability. As Avise observes, "The metaphor of the genome as a well-crafted blueprint or a finely tuned machine may have blinded many biologists to genomic imperfections attributable to phylogenetic constraints and evolutionary-genetic trade-offs." It has taken a long time to escape the pull of this metaphor, an escape that might have happened more easily if other metaphors had been explored continuously.

More generally, alternative metaphors help to highlight the limits of a research paradigm. According to Kuhn, "A paradigm, can … even insulate the community from those socially important problems that are not reducible to the puzzle form, because they cannot be stated in terms of the conceptual and instrumental tools the paradigm supplies."[15] A rich set of metaphors may lessen this tendency to look through one metaphoric window on the world. Scott Allison and colleagues, for example, review the alternative metaphors used in social dilemma research and note that the triple metaphor of a "prisoner's dilemma game" has become "so deeply entrenched in the scientific lexicon that most scientists are largely unconscious of its metaphorical origins."[16] But they also review the benefits that might accrue from thinking in terms of one or more of the 45 alternative metaphors that have been used within this area of research. Diverse metaphors may expand rather than contract the bounds of scientific inquiry.

Plurality in the social realm

In contrast to Avise, who focuses mainly on epistemic issues, sociologist Dorothy Nelkin presents a critical review of the social dimensions and implications of genomic metaphors. For example, she demonstrates metaphoric plurality in the media in the form of commercial, essentialist, fatalistic, and religious metaphoric clusters, and then focuses on their social and moral implications. Her view is more constructivist than Avise's, recognizing as it does that, "The apparent precision of such reference works tends to obscure the interests and priorities that, in fact, have shaped them."[17] She would probably remark that Avise's contrast between "good-citizen" genes with deadbeats or "shifty" nomads, renegades and immigrants certainly lends itself to moral sentiments. Furthermore, the apparent diversity of Avise's metaphors may in fact obscure an underlying ideological undercurrent whereby genes are understood as human social collectives.[18] In raising such questions, Nelkin's work serves as an important reminder that we cannot just appeal to scientists' intuitions about metaphoric fertility, but must simultaneously address broader questions related to the ideologies entailed by particular metaphors.

Numerous critics have demonstrated how scientific metaphors may be a cover for ideology. Based on his review of this issue, for example, developmental biologist Scott Gilbert concludes, "Humanity must be made safe from metaphor," since "our uncritical use of [metaphors] may constrict our freedom and the freedom of others … if we are unaware of these metaphors, we risk being imprisoned by them."[19] A particular challenge is that metaphors carry not only facts, but implicit values.[20] Thereby, metaphors convert "is" into "ought," made all the more weighty by the authority vested in scientific pronouncements. As observed by Nancy Stepan, in her investigation of how women's "deficient" brains were in nineteenth century scientific

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studies considered analogous to those of "lower" races, "The tendency for metaphors to become dogmatic and to be seen as literally true and nonmetaphoric is particularly strong in science because of the identification of the language of science with the language of objectivity and reality."[21] In this context, the apparent "truth" of scientific metaphors may squelch open deliberation about alternatives in the marketplace of ideas.

Furthermore, if alternative metaphors represent alternative value systems and social ideals, scientists promoting one or the other are promoting an associated ideology, especially given their authoritative voice within society (for example, in the realm of genomics). Nelkin, for example, has elsewhere drawn attention to cases where scientists actively promote particular metaphors.[22] Given scientific authority in modern society, it is questionable whether this is appropriate, especially as there is a tendency to promote a metaphor earlier than the evidence justifies. While the media is partly responsible, and typically blamed, scientists themselves often play a role. For example, scientists have branded their attempt to develop species-specific genetic markers as "DNA barcoding," despite questions about both its empirical accuracy and suggestive social overtones.[23]

It is in such cases that a metaphor may transmogrify into an unfruitful fiction in the social realm. But by attending carefully to metaphors, "The glide from facts to recommendations no longer seems graceful or obvious."[24] In particular, we need to assess metaphoric values in the same way we assess any potentially inflammatory or harmful remarks, such as racist and sexist ones. We can certainly imagine metaphors that would be broadly unpalatable because of implied support for the ideology of vile regimes, dictators or murderous plunderers. These may represent extremes, but we need to maintain our critical faculties about the potential misuse of various metaphors in terms of the conclusions that may be drawn from them, even if mistakenly. While Celeste Condit has convincingly shown that we cannot simply assume unfruitful extrapolations from particular metaphors (such as deterministic and/or discriminatory interpretations of the "blueprint" metaphor), and reminded us that metaphors can be attributed too much causal power,[25] that is not a *carte blanche* for all and any metaphors.

Metaphoric plurality also prevents univocal authority. As more metaphors circulate, more diverse perspectives on a phenomenon will be represented, not only in terms of our approaches to a phenomenon, but also in terms of representing diverse values and interests within society. Since each metaphor highlights certain elements while veiling others, the contact and interplay between different metaphors provides a more encompassing vision, a fruitful friction. For this to occur, however, we require a revised view of science communication. The outmoded 'deficit model' contributes to the myth that science is too difficult for most people to understand and that the best they can hope for is a simplifying metaphor. In some contexts, this is an appropriate model and scientists do need to select metaphors that allow the genomic revolution to be more accessible to outsiders, but too often this approach borders on paternalism and ignores how scientists require metaphors from everyday language just as much as

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non-scientists. Both scientists and non-scientists will benefit from discussion of diverse metaphors, discussion that will necessitate inquiry about both facts and values.

In particular, some metaphors may implicitly promote a particular worldview, especially if they are unconscious, close to our *Weltanschauung*, and therefore unnoticed. When scientific authorities use a metaphor, this may imply that the discussion is closed, when in fact this may not be the case. Let me provide an example. The National Geographic Society currently funds the Genographic Project, 'A landmark study of the human journey',[26] which samples DNA from diverse peoples around the world in order to compile a complete picture of human history. Representative tribes are encouraged to contribute their DNA, and afterwards they are given the "story of their DNA" and of their lives, concerning their origin and where their peoples have come from. Given the success of the program, some people are clearly interested in obtaining such a story. The challenge, however, is whether this story is compelling given the technological problems it faces. Although the project has received extensive ethics approval, there are nonetheless questions about the risks posed by incorrect stories. More important in the current context, this story is driven by particular metaphors, especially the notion of human history as a journey. While this metaphor is being used to promote the vision that we are all one beneath surface appearances, it neglects the diversity of alternative life stories held by people around the world and raises questions about the relation between this, new knowledge, and the old. Would we be better served by a story that reveres and celebrates the diverse life stories that are actually told? In fact, Wikipedia reports that:

> Shortly after the announcement of the Genographic project in April 2005, the Indigenous Peoples Council on Biocolonialism (IPCB), released a statement protesting about the project, its connections with the Human Genome Project, and called for a boycott of IBM, Gateway Computers, and National Geographic. Around May 2006, the United Nations Permanent Forum on Indigenous Issues (UNPFII) recommended suspending the project. Concerns were that the knowledge gleaned from the research could clash with long held beliefs leading to the destruction of their culture. They also feared that it could endanger land rights and other benefits.[27]

While some tribes have refused to participate on such grounds, many others have contributed. The question remains whether a univocal journey metaphor is truly appropriate for all people.

Concluding thoughts

I have sketched an argument for the benefits of metaphoric plurality, but a critical counterpoint is that metaphoric choices must be made within a more inclusive social context rather than by scientists alone, an argument developed elsewhere.[28] Our ability to control metaphors is limited because of the multiplicity of their sites of origin and the complexity of their circulation at the science-society interface. To conceptualize this, it may be helpful to think of them through an analogy with evolutionary ecology. As Nerlich explains:

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> Evolutionary ecology studies how organisms evolve and adapt in interaction with their environments, or more radically, how organisms co-evolve with the environments. The evolutionary ecology of metaphor would similarly study how metaphors adapt, change and co-evolve in contextual use.[29]

This perspective draws attention to both the diachronic and synchronic dimensions of metaphors; that is, that they occur in a context at each point in time, but that context as well as their "fit" to it changes over time.

Scientists have the greatest flexibility for choosing metaphors at those instances where new ones are being considered. Yet this is also where there is a tendency to be constrained by an overworked set of candidate source domains. For example, Avise draws heavily on a few standard domains, including personification (of genes) as well as militaristic imagery. This is an area where open deliberation among those with differing backgrounds, both expert and non-expert, would contribute to the search for more effective and novel imagery. While scientists typically frame novel metaphors, perhaps creating "one-shot" promotional metaphors that narrow the ensuing discussion, and then society deals with its implications, we might instead imagine earlier engagement between scientists and society.

We face a contrasting situation for ensconced metaphors. While there is a similar need for dialogue about what particular metaphors might highlight and hide, there is less capacity for adjustment here. Nonetheless, there may be instances where the shortcomings of particular past choices become apparent and where there are initiatives to shift our metaphors. It may be that critiques of this sort will always remain on the fringe of the dominant discourse, but they must nonetheless be encouraged. In so doing, participants may discover wholly new perspectives on what had formerly been a narrowly constrained vision. We have to ensure that scientists are not just closed to alternatives, as everyday citizens may well have sensitivities and ask questions they do not, questions that may have important implications either in the realm of scientific fertility or social consequence.

If we wish to intervene with regard to certain metaphors we face challenges whether we are doing so prospectively or retrospectively. In particular, metaphors are entirely dependent on context, and we cannot predict future contexts. We are limited, therefore, to making the best approximations that we can. It is perhaps the democratic process that can assist us in deciding if and when to intervene, even though there are very real issues about the extent to which we can intervene in the dynamics of complex metaphoric systems. This is all the more reason to take care with those that we have and with new ones that we propose. Criticism of metaphoric worlds, as Booth describes it, remains a critical task, but will be abetted by maintaining an adequate diversity of metaphoric worldviews.

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[2] W.C. Booth. 1979. Metaphor as rhetoric: The problem of evaluation. In *On Metaphor*. S. Sacks, ed. Chicago: University of Chicago Press: 64.
[3] e.g., J.J. Bono. 1990. Science, discourse, and literature: The role/rule of metaphor in science. In *Literature and Science: Theory and Practice.* S. Peterfreund, ed. Boston: Northeastern University Press; G. Lakoff and M. Johnson. 1999. *Philosophy in the Flesh: The Embodied Mind and its Challenge to Western Thought*. New York: Basic Books; K. Baake. 2003. *Metaphor and Knowledge: The Challenges of Writing Science*. Albany: State University of New York Press; T.L. Brown. 2003. *Making Truth: Metaphor in Science*. Chicago: University of Illinois Press.
[4] This discussion has parallels with what is known as the "intermediate disturbance hypothesis" in ecology. In short, it posits that species diversity is greatest in communities having an intermediate level of disturbance (e.g., fire, windthrow or other disruptions within a forest ecosystem). If disturbance levels are too low, a few species suited to such stable conditions tend to dominate; conversely, if disturbance levels are too high, only a few species suited to such unstable conditions can survive. At intermediate levels, an admixture of both types can exist within the system, so diversity is greatest.
[5] A number of scholars have emphasized how metaphors traverse discursive boundaries, e.g., Bono, op. cit. note 3; S. Maasen and P. Weingart. Metaphors - messengers of meaning: A contribution to an evolutionary sociology of science. *Science Communication* 1995; 17: 9-31; C. Hauskeller. Science in touch: Functions of biomedical terminology. *Biology and Philosophy* 2005; 20: 815-835.
[6] This point draws attention to the fact that there were a plurality of metaphors even during the heyday of the blueprint metaphor, but I would argue that they largely fell within its shadow and that significantly different models and metaphors were marginalized such that they were not part of the standard discourse.
[7] For example, I have elsewhere presented both movements for the metaphors in the field of invasion biology, e.g., B.M.H. Larson. The war of the roses: Demilitarizing invasion biology. *Frontiers in Ecology and the Environment* 2005; 3: 495-500 and B.M.H. Larson. Reweaving humans and invasive species. *Études Rurales* 2010; in press.
[8] J.C. Avise. Evolving genomic metaphors: A new look at the language of DNA. *Science* 2001; 294: 86-87. Other explorations of alternative metaphors include A. Nordgren. Metaphors in behavioral genetics. *Theoretical Medicine and Bioethics* 2003; 24: 59-77; J. Turney. The sociable gene - Finding a working metaphor to describe the function of genes in an organism might help to ease public fears and expectations of genomic research. *EMBO Reports 2005*;
9: 808-810. And see D. Noble. 2008. *The Music of Life: Biology Beyond Genes*. New York: Oxford University Press.
[9] T.S. Kuhn. 1970. *The Structure of Scientific Revolutions*. Chicago: University of Chicago Press.
[10] e.g., Turney, op. cit. note 8; P.E. Griffiths and K. Stotz. Genes in the Postgenomic Era? *Theoretical Medicine and Bioethics* 2006; 27: 499-521.
[11] For a review of James' views, see S.T. Allison et al. The quest for "similar instances" and "simultaneous possibilities": Metaphors in social dilemma research. *Journal of Personality and Social Psychology* 1996; 71: 479-497.
[12] T.S. Kuhn. 1979. Metaphor in science. In *Metaphor and Thought*. A. Ortony, ed. Cambridge: Cambridge University Press: 418.
[13] D.A. Schön. 1979. Generative metaphor: A perspective on problem-setting in social policy. In *Metaphor and Thought*. A. Ortony, ed. Cambridge: Cambridge University Press.

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[14] N.K. Hayles. Constrained constructivism: Locating scientific inquiry in the theater of representation. *New Orleans Review* 1991; 18: 76-85.
[15] Kuhn, op. cit. note 9: 37.
[16] Allison et al., op. cit. note 12: 484.
[17] D. Nelkin. Molecular metaphors: The gene in popular discourse. *Nature Reviews: Genetics* 2001; 2: 555-559.
[18] Thanks to an anonymous reviewer for emphasizing this point.
[19] S.F. Gilbert. The metaphorical structuring of social perceptions. *Soundings* 1979; 62: 166-186. Also see E.F. Keller. 1991. Language and ideology in evolutionary theory: Reading cultural norms into natural law. In *The Boundaries of Humanity: Humans, Animals, Machines*. J.J. Sheehan and M. Sosna, eds. Berkeley: University of California Press.
[20] For example, see R. Harré et al. 1999. *Greenspeak: A Study of Environmental Discourse*. Thousand Oaks, CA.: Sage; M.S. Carolan. The values and vulnerabilities of metaphors within the environmental sciences. *Society & Natural Resources* 2006; 19: 921-930; P.A. Fleming. 2006. Can nature (legitimately) be our guide? In *Religion and the New Ecology: Environmental Responsibility in a World in Flux*. D.M. Lodge and C. Hamlin, eds. Notre Dame, Indiana: University of Notre Dame Press; B.M.H. Larson. The social resonance of competitive and progressive evolutionary metaphors. *BioScience* 2006; 56: 997-1004.
[21] N.L. Stepan. Race and gender: The role of analogy in science. *Isis* 1986; 77: 261-277.
[22] D. Nelkin. Promotional metaphors and their popular appeal. *Public Understanding of Science* 1994; 3: 25-31.
[23] B.M.H. Larson. 2009. Should scientists advocate? The case of promotional metaphors in environmental science. In *Communicating Biological Sciences: Ethical and Metaphorical Dimensions*. B. Nerlich et al., eds. Burlington, VT: Ashgate.
[24] Schön, op. cit. note 13: 268.
[25] C.M. Condit. How the public understands genetics: Non-deterministic and non-discriminatory interpretations of the "blueprint" metaphor. *Public Understanding of Science* 1999; 8: 169-180. See also C.M. Condit. The meaning and effects of discourse about genetics: methodological variations in studies of discourse and social change. *Discourse & Society* 2004; 15: 391-408.
[26] https://genographic.nationalgeographic.com/genographic/index.html (accessed 14 August 2010).
[27] http://en.wikipedia.org/wiki/Genographic_project (accessed 14 August, 2010).
[28] For further development of this argument, see B.M.H. Larson. 2011. *Metaphors for Environmental Sustainability: Redefining our Relationship with Nature*. New Haven, CT: Yale University Press.
[29] B. Nerlich. Tracking the fate of the metaphor *silent spring* in British environmental discourse: Towards an evolutionary ecology of metaphor. *metaphorik.de* 04/2003.

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