

UC Office of the President

Recent Work

Title

"Editing" Genes: A Case Study About How Language Matters in Bioethics

Permalink

<https://escholarship.org/uc/item/8p24c8wq>

Journal

American Journal of Bioethics, 15(12)

ISSN

1526-5161

Authors

Yarborough, Mark
O'Keefe, Meaghan
Perrault, Sarah
[et al.](#)

Publication Date

2015

Peer reviewed



“Editing” Genes: A Case Study About How Language Matters in Bioethics

Meaghan O'Keefe, Sarah Perrault, Jodi Halpern, Lisa Ikemoto, Mark Yarborough & UC North Bioethics Collaboratory for Life & Health Sciences

To cite this article: Meaghan O'Keefe, Sarah Perrault, Jodi Halpern, Lisa Ikemoto, Mark Yarborough & UC North Bioethics Collaboratory for Life & Health Sciences (2015) “Editing” Genes: A Case Study About How Language Matters in Bioethics, *The American Journal of Bioethics*, 15:12, 3-10, DOI: [10.1080/15265161.2015.1103804](https://doi.org/10.1080/15265161.2015.1103804)

To link to this article: <http://dx.doi.org/10.1080/15265161.2015.1103804>



Published online: 02 Dec 2015.



Submit your article to this journal [↗](#)



Article views: 206



View related articles [↗](#)



View Crossmark data [↗](#)



Citing articles: 4 View citing articles [↗](#)

Target Article

“Editing” Genes: A Case Study About How Language Matters in Bioethics

Meaghan O’Keefe, University of California Davis

Sarah Perrault, University of California Davis

Jodi Halpern, University of California Berkeley

Lisa Ikemoto, University of California Davis School of Law

Mark Yarborough, University of California Davis Medical School

UC North Bioethics Collaboratory for Life & Health Sciences*

Metaphors used to describe new technologies mediate public understanding of the innovations. Analyzing the linguistic, rhetorical, and affective aspects of these metaphors opens the range of issues available for bioethical scrutiny and increases public accountability. This article shows how such a multidisciplinary approach can be useful by looking at a set of texts about one issue, the use of a newly developed technique for genetic modification, CRISPRcas9.

Keywords: CRISPR, genomic, germline modification, metaphor, public engagement, rhetoric

New techniques for modifying genes have raised ethical concerns and stimulated multiple calls for public engagement and bioethical scrutiny. While some leaders (including those in science¹) are calling for consensus guidelines regarding use of the techniques, especially human germline applications, most of the public will form opinions about these new technologies from mass media sources such as Web and print versions of newspapers and popular magazines. Metaphors used by scientists to describe the new technologies are quickly migrating to these popular media, thus influencing public opinion.

Metaphors operate both consciously and unconsciously, influencing how people understand and respond to discourse. Metaphors in science, such as electrical “current,” not only shape public conversations but also frame and guide how researchers pose questions and conduct research. Since metaphors condense and represent formative information in complex linguistic, rhetorical, and psychological ways, a multidisciplinary approach is critically needed to understand the impact that metaphors can have for bioethics.

CRISPRcas9 (hereafter CRISPR) is an excellent case for examining metaphor’s role in bioethics and public discussion because the technology and the metaphors used to describe it are still emerging. Journalists relay and introduce a wide variety of metaphors to explain the CRISPR technology. For example, when Jennifer Doudna, whose team helped develop CRISPR, likened it to microsurgery and emphasized its precision, that metaphor proliferated across media platforms such as the *Washington Post*, *Discover*, and CNN, to name just a few. Because the metaphors around CRISPR are still in the formation stage, we advocate for a multidisciplinary conversation among scientists, bioethicists, and academics studying cognition, linguistics, and rhetoric to begin exploring possibilities for metaphors that accurately capture the complexity of the ethical issues involved in CRISPR. In this article, we examine the current public discourse on CRISPR in order to establish what our starting point should be.

Such an exploration is critical for bioethics, public engagement, and policymaking. Informed public debate,

1. See, for example, Baltimore and Berg’s *Wall Street Journal* Editorial “Let’s Hit Pause” as well as their piece in *Science*, “A prudent path forward for genomic engineering and germline gene modification.”

*The UC North Bioethics Collaboratory for Life & Health Sciences is a collaboration among the University of California (UC) Berkeley (Jodi Halpern—PI), UC Davis (Mark Yarborough—PI), UC Santa Cruz (Jenny Reardon—PI), and UC San Francisco (Barbara Koenig—PI) campuses of the University of California.

Address correspondence to Meaghan O’Keefe, University of California Davis, Religious Studies Department, 1 Shields Avenue, Davis, CA 95616, USA. E-mail: mmokeefe@ucdavis.edu

as well as sound policymaking, requires words and phrases that convey at least three aspects of the technology and how it is used: (1) the ethical complexity of the technology; (2) an accurate description of the technology, how it works, and how it can be used; and (3) what is known and unknown about its potential consequences. As we show below, current predominant metaphors miss all of these important marks. They do not convey potential long-term consequences in humans, other organisms, and ecosystems. If left unchecked, the limitations of these metaphors will have a ripple effect across the public, political, and scientific commons and the decisions made within them.

As a first step in such work, we tracked the use of metaphors associated with CRISPR in key American newspapers and popular science publications from the first mention of CRISPR in January 2013 until July 11, 2015. Working as a multidisciplinary team, we explored how these metaphors work linguistically, rhetorically, and psychologically and how this affects bioethical considerations. Based on our analysis, we have begun what will be a series of conversations with researchers using the CRISPR technology about how to communicate with the public in a way that is both scientifically accurate and ethically responsible. With this article, we seek to open this conversation further, through our exploration of the extent to which the dominant metaphors are problematic and how they thus pose challenges to conversations about CRISPR both within bioethics scholarship and in the public sphere.

BRIEF OVERVIEW OF METAPHOR

The study of metaphor has a long and distinguished history in rhetoric, philosophy, linguistics, and psychology, as well as other disciplines. While there are multiple, rich ongoing disciplinary debates about many facets of metaphor, we do not plan to engage those debates for the purposes of this essay. Rather, we want to talk about why bioethics scholarship should include attention to metaphor in public understanding/assessment of new biotechnologies like CRISPR. In doing so, we use Lakoff and Johnson's (2003) definition of metaphor as "understanding and experiencing one kind of thing in terms of the other" (5).² Thus, we review in general terms what metaphors are, what they do, and how critical features of them shape both the development and uptake of new technologies.

While we turn a critical gaze on metaphors that have clustered around CRISPR, we are not advocating a metaphor-free zone. Metaphors, in addition to being unavoidable, do essential work. They allow people to

acquire new knowledge by linking new terms and concepts to the familiar. For example, elementary school students learn that wetlands act as a sponge and a filter so that they can understand the role wetlands play in controlling flooding and improving water quality (Davenport et al. 2003). Metaphors, particularly vivid metaphors, improve retention (Petrie and Oshlag 1993, 581). Augustine of Hippo's (1958) famous imagery of saints as the "teeth of the church" (37) tearing off and chewing up sinners, is difficult to forget. While these metaphors are fairly straightforward, metaphors can also function as part of complex modeling systems. To illustrate, Niels Bohr's pioneering model of the atom as a solar system allowed early 20th-century physicists to theorize subatomic interactions (Dancygier and Sweetser 2014, 204).

Metaphors are able to do this work because, like other aspects of cognition, they operate on many levels. Cognitively, abstract thinking includes processing things at a concrete, associative level. Recent work in cognitive science has shown that metaphors, such as "spilling the beans," activate both associations with actual items (here, beans) as well as the metaphorical sense (here, of revealing secrets) (Gibbs 2005, 182). Metaphors thus represent "inferential shortcuts" and help to form and sustain basic "reasoning patterns," (Dancygier and Sweetser 2014, 41, 203–4). Metaphors also form less obvious cognitive structures, such as ideas about when and where action is understood to have taken place, what caused what, and relative size, weight, or importance (Dancygier and Sweetser 2014, 74). For instance, "we are at a crossroads" expresses immediacy and situates the speaker and audience on a road that forks (Lakoff 1993), and "computer virus" indicates outside infection as the cause of software malfunction (Fauconnier and Turner 2008, 274). Similarly, comparing the development of CRISPR-based technologies to the development of HTML (the standard markup language for creating webpages) conveys the sense that a seemingly small technological advance might completely change the world, as HTML did by making it possible for large numbers of people to build their own websites using HTML.

On the affective level, metaphorical phrases seem to "more acutely engage motivation, emotion, and memory systems of the brain" (Sidtis 2014, 584). Further, when metaphor engages emotion, it can influence cognitive uptake of information and distort that information in the process (Covello 2001). For example, during the SARS (severe acute respiratory syndrome) outbreak of the early 2000s, initial media coverage in the United Kingdom centered on the disease as a "killer" that needed to be "hunted down" (Wallis and Nerlich 2005). This set of metaphors suggested a greater level of risk than the disease's actual morbidity (Nerlich and Halliday 2007). Similarly, metaphors can downplay risk or invoke a domain that implies benefits that are not relevant. For example, comparing biobanking to organ donation can create "a down-scaling of the risk to donors as well as emphasis on product safety issues" (Hofmann, Solbakk, and Holm 2006, 51).

2. We are not here concerned about distinctions between *metaphor* and *analogy*, or between those and simile; each is, as López notes in this journal, a form of "semantic exchange between a source and target domain" (López 2006, 61).

This combination of cognitive and affective influence means that while metaphors function as a "fundamental ... cognitive process" (Bono 2001, 219) that can foster understanding by making the new familiar in terms of the old; they can also confuse, confound, oversimplify, and hinder good ethical deliberation and policymaking. This is true of scientific research as well as public debate. As Baake (2003) points out, metaphor in science is "theory constitutive" (72), serving epistemological as well as interpretive and explanatory functions; Dancygier and Sweetser (2014, 203) agree that metaphor shapes how problems are viewed, inferences are drawn, and implications are conjectured.

Metaphors are particularly important as new technologies are introduced to the public because they not only represent scientific concepts and techniques, they also shape regulatory and ethical frames used to assess appropriate use. For example, in the context of biobanking, analogy with commercial banking steers debate toward transactional issues such as international exchange and assigning trade value at the expense of privacy concerns (Hofmann, Solbakk, and Holm 2006). Along similar lines, in public discussion of the CRISPR technology, we worry that the dominant metaphors—"editing" and "targeting"—currently in circulation (see below) are misleading. Overall, we see a pattern of reduced complexity and exaggerated control of outcomes that has troubling implications that we explore below.

APPROACH

The sources for this project are large-circulation newspapers and popular science publications from January 2013 through July 11, 2015. We chose to examine mass media texts because "mass media constitute the most important forum for the public sphere in modern societies, providing an organising framework for societal self-observation" (Schäfer 2012, 650).

Following approaches developed in communication scholarship (Lively and Conroy 2013; Weaver and Bimber 2008), we selected newspapers based on circulation and regional representation. Our selection comprised *USA Today*, the *Wall Street Journal*, the *New York Times*, the *Los Angeles Times*, the *Washington Post*, the *Houston Chronicle*, and the *Denver Post*. Searches were conducted through *LexisNexis* and *ProQuest*. Not only does this selection include newspapers of record, these sources are also part of "common distribution networks" (Lively and Conroy 2013, 230), such as Tribune Publishing (2015) and Gannett (2015), that control nearly 200 print and digital news sources, including local newspapers in nearly every state. These sources provide a preliminary representation of the emergent metaphors associated with CRISPR in popular media. As news coverage increases, more quantitative assessment will be possible, but given the number of available sources

at this point in time as well as the variation inherent in coverage of new topics (Weaver and Bimber 2008), a quantitative study would be precipitous.

Popular science texts were drawn from print and online versions of the top-circulation science publications aimed at nonspecialist audiences (*National Geographic*, *Smithsonian*, and *Popular Science*), as well as two smaller circulation but still well-regarded publications (*Scientific American* and *Discover*). Such high-profile media provide models for other writers, an especially powerful influence in science writing where there is "more of a common interest [in each others' work] than those in many other genres" (Turney 87), so much so that writers in this area draw on one another's work for ideas, analogies, and "even turns of phrase from one another" (Turney 2007, 87).

The search criterion used for selection was any appearance of the term *CRISPR*. The search yielded 45 articles, 22 from newspapers and 24 from popular science publications. As a qualitative methodology, we adopted Schmitt's (2005) and Andriessen and Gubbins's (2009) approaches to identifying metaphor. We chose in advance the topic of CRISPR technologies (Andriessen and Gubbins 2009, 5). We then marked each reference to CRISPR technology. Once phrases that described, referred to, or identified aspects of CRISPR technologies were highlighted, we then assessed whether the passage or phrase under examination was metaphorical using Schmitt's (2005) three-part identification formula: (1) The word or phrase has meaning that is not strictly literal; (2) "the literal meaning stems from an area of physical or cultural experience"; and (3) this literal meaning is being used in a different context than its literal source (Schmidt 2005, 383). These metaphors were then grouped according to the "underlying metaphorical concept" (Andriessen and Gubbins 2009, 5). Those metaphors that were used by more than one author and appeared most frequently across texts were categorized as the dominant metaphors and therefore the subject of more extensive analysis.

ANALYSIS

Articulations of how CRISPR works rely on metaphors for CRISPR itself, but also for genetics, since any explanation of what CRISPR does is affected by what larger metaphorical frame is used to describe genomes and genes. Historically, genomes have been described as code to be deciphered, territory to be mapped, blueprints for creating organisms, and many other metaphors (Condit 1999). Newspaper and popular science articles about CRISPR use these metaphors and deploy new ones. While this article focuses on dominant metaphors used for CRISPR, the full range of metaphors used for CRISPR technologies and for the genomes being modified shows that the metaphorical profile of this technology is far from settled (see Table 1).

Within the broad range of metaphors found in Table 1, a few appear with greater frequency; those that configure

Table 1. Range of metaphors describing genomes and CRISPR in popular media

Metaphor	Example	Found in
Blueprint/construction	Every human genome contains the blueprints for building a person, a library of roughly 20,000 genes that encode everything from eye color to cancer risk (Kim 2015).	Newspapers and popular science
Code	And that system, whose very existence was unknown until about seven years ago, may provide scientists with unprecedented power to rewrite the code of life (Pollack 2014).	Newspapers and popular science
Gambling	But gene drives stack the deck, says Esvelt, making it much more likely that progeny will acquire an altered genetic element. (Langin 2014)	Popular science
Map	Though their accuracy needs improvement, most of these wouldn't have been possible before 2000, when researchers first mapped the human genome. (Miller 2014)	Newspapers and popular science
Mechanism	A few other tools offer a similar shortcut, but CRISPR is much quicker. "It's the fastest thing I've seen yet," Church says. "It's like you throw a piston into a car and it finds its way to the right place and swaps out with one of the other pistons—while the motor's running." (Interlandi 2015)	Popular science
Medicine	Just two years ago, Jennifer Doudna of the University of California, Berkeley, commandeered a process that bacteria use to fend off viruses, creating a molecular scalpel to snip out defective genes. (Lydersen 2014; Kim 2015)	Newspapers and popular science
Origami	Think of the DNA as being folded like origami, says RNA researcher John Rinn of Harvard University. . . . lncRNA somehow pushes the DNA to make sure the steps occur in the right order. (Gorman and Maron 2014, 59)	Popular science
War/battle/fight	Viruses can evolve relatively quickly and can eventually figure out how to evade the bacterial defenses to once again take out its victim. The result forces the bacteria to once again use the CRISPR system to block the attack. As time goes on, an arms race develops in which the slowest to evolve ends up losing. (Tetro 2015)	Newspapers and popular science

Downloaded by [98.238.184.190] at 10:41 09 December 2015

the genome as texts to be edited and as targets to be aimed at predominate.³

The most common metaphor is of the genome as text. The idea of "editing" appears in nearly every article: 21 of 22 in the newspapers and 20 of 24 in popular science texts. "Edit" appears 168 times in the corpus in various functions: as predicate, subject, object, and modifier. Other metaphors that suggest editing are common: We see references to "cutting and pasting" and "copy and paste" (e.g., Fecht 2015; Fessenden 2015; Holt 2014; Miller 2014), as well as genomes as something to "read" and "write" (e.g., Miller 2014), a form of "shorthand" (Interlandi 2015), and a reference to "the first draft" of the Neanderthal genome (Hughes 2013), to name a few.

In general, editing metaphors used in regard to CRISPR emphasize what is being done to genes, presenting genomes as texts to be edited or genes as targets to be struck, and downplay any ethically troubling implications. "Editing" does not convey a sense of risk or a need for caution. It implies a "mere text" that has an overall vision and a purpose within a bounded set of rules. Editors refine, correct, suggest, but they do so to improve. A text can be seen clearly; when a semicolon is changed to a colon, the grammatical function and the effect on meaning are known. But none of this is true of "editing" a genome. It is difficult to determine the effects "cutting and pasting" part of a genome will have. Researchers rely on algorithms to predict specific locations of possible "off-target" results and confine searches for off-target results to those predicted locations. These predictions are not always accurate and "cuts" can unintentionally occur anywhere in the genome.

Writers often downplay the imprecision and the danger of unintentional cuts intrinsic to CRISPR, while expressing enthusiasm for the possibilities allowed by CRISPR. For example, writers in both popular science and newspapers discuss the role CRISPR might play in eradicating disease, such as using "gene editing" to "snip out" the HIV virus from human cells (Griffin 2015; Brown 2015), or they talk about using CRISPR to recreate the passenger pigeon by introducing cells that have been "edited to be as passenger pigeon-like as possible" (Detwiler 2015). "Editing," in these contexts, has only positive connotations.

The positive use of "editing" in general stands in contrast to the way "editing" tends to take on a negative association in conjunction with human embryos. When a human embryo appears with "edit" the technology is

seen as risky or troubling, with potential for damage. As mentioned above, "editing" implies a vision, a set of changes designed to improve the text. However, the idea of "improving" or "editing" embryos seems to be associated with eugenics. Phrases like "genetically enhance" (Brown 2015), "a new kind of eugenics" (Griffin 2015), and "designer babies" (Pollack 2014) appear in close proximity (either in the same sentence or the sentences preceding and following). While "editing" passes unnoticed when discussed in the context of the disembodied genome, once the implication is that human embryos are texts to be changed, cut, or rewritten, writers seem aware of the metaphor in a way that does not occur in other contexts. In these cases, the idea of eugenics can stimulate affective reactions like outrage and fear. These reactions, in turn, undermine informed public discussion⁴ by pushing public concern toward the potential for misuse, a potential that needs to be addressed but not at the expense of problems that demand attention now.

Hence, "editing" applied in the context of "human embryos" inflates concerns about potential misapplications while still downplaying complexity and uncertainty and obscuring its envisioned beneficial applications. In these cases, popular media situate problematic metaphors alongside stories about CRISPR that can stimulate unconscious affective reactions. These reactions, in turn, can undermine informed public discussion if metaphors inflate worries about potential misapplications of CRISPR at the expense of its potential for therapeutic significance. Thus, this particular metaphor is misleading in multiple ways; what is especially striking from a bioethics standpoint is that the same metaphor glosses over risk in some cases, emphasizes them in others, and in neither case attends to the actual uses or potentials of the technology.

In contrast with "editing," "targeting" is, perhaps, the commonly used metaphor that least obscures the unknowns and uncertainty involved in using CRISPR to modify genes. A common term in scientific research circles, "targeting" has migrated into the popular press and appears with fairly high frequency in discussions of CRISPR (27 instances in 12 of 22 articles in newspapers and 29 instances in 12 of 24 articles in popular science). While scientists have long used "target" to describe older techniques, current uses of "target" describe the active

3. These particular metaphors are also used in scientific research discourse, an aspect we do not address here. Interpretation of metaphor is always constrained by context and prior understanding of its constituents—that is, people understand metaphors based on prior associations with the words and phrases—so as the "editing" metaphor moves from context to context, writers and readers will have different sets of ideas around what it means. Because our concern is about public engagement with ethical issues around CRISPR, we focus on associations that these metaphors evoke in a popular context while recognizing that they matter in scientific contexts as well.

4. On a related note, an emerging competition narrative surrounding CRISPR illustrates the significance that affective reactions can have. U.S. researchers are calling for a moratorium on CRISPR while ethical inquiry occurs but Chinese researchers are going full speed ahead. This story casts Chinese researchers in a negative light and suggests that CRISPR is dangerous. Negative feeling about Chinese researchers is likely to increase the perception that the products of this work will be dangerous. This example illustrates how affective factors strongly influence risk perception. When the public mistrusts or feels wronged by an entity related to a risk, the public overpredicts the prevalence and severity of the risk. The affective reaction is similar to the public's reaction to use of hunting metaphors in media reports of the SARS outbreak.

process of guide RNA and the Cas9 enzyme to cut DNA; where older techniques essentially flooded the target with the hope that some of the new DNA would be taken up, the Cas9 enzyme's sole function is to chop up DNA, making the likelihood of unintentional cuts higher in CRISPR than in other technologies.

In popular sources, "target" is used both to emphasize precision and to warn of the dangers of unintended cuts. In some cases, the use of "target" assumes successful aim: "If there was a specific spot in the genome they wanted to target, all they'd have to do is design the right CRISPR machinery to get to that location" (Brown 2015). Some uses, however, address the problems that can arise when targeting fails: "The system doesn't have the same safeguards that prevent against off-target effects, like if the protein goes rogue and potentially cuts at an unintended site" (Holt 2014).

The dual use of the "targeting" metaphor has two strengths. First, it allows for discussions of actual and potential problems. Second, the metaphor suggests the risk of missing targets, even when writers fail to specifically mention the possibility. Targeting automatically implies the potential of unintended harm in a way that editing a text does not. In addition, targeting implies the presence of a dangerous projectile—an arrow, a stone, a missile, a bullet, and so on—and so conveys not only the possibility of a missed mark but a damaged unintended mark as well. Given the Cas9 enzyme's ability to cut DNA at multiple, unintended sites, the idea of collateral damage is appropriate: Cas9 can potentially cause genomic instability on a greater scale than prior, more passive technologies. However, 21st-century high-tech weapons of war are presented as usually hitting their mark, so the reference may suggest that precision is more likely than missing the target, making even targeting a far from perfect metaphor.

Overall, although CRISPR metaphors are not settled, the metaphors that are gaining traction obscure and mislead in important ways. They do not accurately describe what CRISPR does: CRISPR alters cells and Cas9 can chop up the wrong DNA. Questions about the prevalence of "off-target" effects and whether they will extend to germ cells can fail to gain adequate traction in public debates. This is compounded by editing metaphors that inaccurately convey precision on the one hand and obscure what is not currently known about CRISPR on the other. The end result is that central tasks so critical to bioethics, such as risk/benefit analyses, get truncated. The fact that relatively neutral concepts are available casts the use of value-laden terms into further relief by showing that alternatives exist; for example, "alter," "change," and "modify" are alternatives to "editing" or "repairing," ones that do not automatically imply improvement.

CONCLUSION

There is broad consensus that some form of policy action is needed to guide the introduction and use of a range of

CRISPR applications. Policy issues include whether or not to impose a moratorium on using CRISPR to alter germ-lines, and ongoing review and oversight of many other CRISPR applications. The social force of language will drive and shape issue framing and policy content.

We need metaphors for CRISPR that indicate the technology's uncertainties and unknowns, and that convey its current value to basic research and potential clinical and public health benefits. The more the language used to discuss CRISPR meets the three criteria we set forth, the better our policies will be. Metaphors should accurately represent how the technology actually works and can be used, should avoid reductionist effects, and should allow for understanding of bioethical implications.

Finding metaphors that can do this work will be challenging, as the future of CRISPR is an unfamiliar imaginary. Appropriate possibilities do exist. For example, in terms of ethical complexity, ecological metaphors could reflect the broad-ranging effects of modifying genomes and the fact that CRISPR is being used in ways that affect not only organisms but ecosystems themselves. Ecology can also represent technical complexity. Mauricio's (2005) writing illustrates this point: "Genomicists seek to understand how each gene in the genome interacts with every other gene and how each gene interacts with multiple, environmental factors" and how "gene networks connect genes as complex as the 'webs' that connect the species in an ecosystem" (205). Finally, ecological metaphors could capture the fact that "the role played by environmental factors in development, and in gene expression in the grown organism," is complicated and is "an important part of any realistic understanding of genetics" (Turney 1995, 6), thus meeting the need to convey what is known and unknown about CRISPR's potential consequences.

In general, the question of how we talk about CRISPR reflects on the larger issue: how we talk about promissory technologies that involve uncertainty. For science, bioethics, and the public, a key question is, how can our language be honest about the uncertainties in how we will use and develop the technology, and what promise and risk it uses holds, without employing terms that trigger gut reaction rather than thoughtful deliberation? How can we avoid the hype so prevalent in science communication (Caulfield 2004) so that we do not appear to be more certain than we are that it will be beneficial? Multidisciplinary bioethics research is one possible path forward in the effort to find a vocabulary and tone that will facilitate engagements that are both scientifically sound and ethically productive.

Limitations and Directions for Further Research

We acknowledge that this study has limitations, and see lines for future research.

Due to time and space constraints we were not able to examine how these metaphors are understood, adopted, adapted, rejected, or otherwise received in specific instance of use. Given that "the interaction of metaphors cannot be predicted solely from a theory about their

complementarity or their reducibility, nor by a context-independent reflection on the associated commonplaces that potentially accompany them before and after their interaction with each other" (Ceccarelli 2004, 96), such reception studies are needed for a fuller understanding of how the language uses we have identified here play out in actual use.

Our analysis was also necessarily qualitative as there are not yet sufficient discussions of CRISPR in high-circulation media for us to report valid quantitative findings. As the number of CRISPR references grows, a corpus-based approach would be useful for generating quantitative analyses of metaphors and other linguistically and rhetorically interesting aspects of CRISPR-related public discourses.

ACKNOWLEDGMENT

We thank Paul Knoepfler, PhD, for the very useful background information about CRISPRcas9 he provided to us as we prepared the article. ■

REFERENCES

- Andriessen, D., and C. Gubbins. 2009. Metaphor analysis as an approach for exploring theoretical concepts: The case of social capital. *Organization Studies* 30(8): 845–63.
- Augustine of Hippo. 1958. *On Christian doctrine*, trans. D. W. Robertson. New York, NY: Liberal Arts Press.
- Baake, K. 2003. *Metaphor and knowledge: The challenges of writing science*. Albany, NY: SUNY Press.
- Baltimore, D., and P. Berg. 2015. Let's hit 'pause' before altering humankind. *Wall Street Journal*. April 8. Available at: <http://www.wsj.com/articles/lets-hit-pause-before-altering-humankind-1428536400> (accessed August 7, 2015)
- Baltimore, B. D., P. Berg, M. Botchan, et al. 2015. A prudent path forward for genomic engineering and germline gene modification. *Science* 348(6230): 36–38.
- Biba, E. 2015. Meet the co-founder of an apocalypse think tank. *Scientific American*. Available at: <http://www.scientificamerican.com/article/meet-the-co-founder-of-an-apocalypse-think-tank> (accessed August 5, 2015).
- Bono, J. J. 2001. Why metaphor? Toward a metaphysics of scientific practice. In *Science studies: Probing the dynamics of scientific knowledge*, ed. S. Maasen and M. Winterhager, 215–34. Bielefeld, Germany: Transcript.
- Brown, E. 2015. DNA editing takes a serious step forward. *Los Angeles Times*. May 3. Available at: <http://www.latimes.com/science/la-sci-gene-editing-embryo-20150503-story.html> (accessed July 13, 2015).
- Caulfield, T. 2004. Biotechnology and the popular press: Hype and the selling of science. *Trends Biotechnol* 22(7): 337–39. Epub 2004/07/13. doi:10.1016/j.tibtech.2004.03.014 S0167779904001404 [pii]. PubMed PMID: 15245905.
- Ceccarelli, L. 2004. Neither confusing cacophony nor culinary complements: A case study of mixed metaphors for genomic science. *Written Communication* 21(1): 92–105.
- Condit, C. M. 1999. *The meanings of the gene: Public debates about human heredity*. Madison, WI: University of Wisconsin Press.
- Covello, V. T., R. G. Peters, J. G. Wojtecki, et al. 2001. Risk communication, the West Nile virus epidemic, and bioterrorism: Responding to the communication challenges posed by the intentional or unintentional release of a pathogen in an urban setting. *Journal of Urban Health* 78(2): 382–91.
- Dancygier, B., and E. Sweetser. 2014. *Figurative language*. Cambridge, UK: Cambridge UP.
- Davenport, J. C., A. K. Frankel, C. M. Parry, and California Coastal Commission. 2003. *Waves, wetlands, and watersheds: California Coastal Commission science activity guide*. San Francisco, CA: California Coastal Commission.
- Detwiler, T. 2015. Life after death. *Popular Science*. Available at: <http://www.popsci.com/de-extinction-long-live-mammoth?image=1>.
- Fauconnier, G., and M. Turner. 2008. *The way we think: Conceptual blending and the mind's hidden complexities*. New York, NY: Basic Books.
- Fecht, S. 2015. Woolly mammoth DNA successfully spliced into elephant cells. *Popular Science*. Available at: <http://www.popsci.com/woolly-mammoth-dna-brought-life-elephant-cells> (accessed August 5, 2015).
- Fessenden, M. 2015. Gene editing in human embryos ignites controversy. *Smithsonian*. Available at: <http://www.smithsonianmag.com/smart-news/first-gene-editing-human-embryos-ignites-controversy-180955087/?no-ist> (accessed August 5, 2015).
- Gannett, Inc. 2015. Our brands. Available at: <http://www.gannett.com/brands> (accessed August 27, 2015).
- Gibbs, R. W., Jr. 2005. *Embodiment and cognitive science*. New York, NY: Cambridge University Press.
- Gorman, C., and D. F. Maron. 2014. The RNA revolution. *Scientific American* 310(4):52–59.
- Greenwood, V., and V. Ross. 2013. The brilliant ten. *Popular Science* 283(4) 42.
- Griffin, A. 2015. Fears arise as Chinese modify human embryo genes. *USA Today*. April 23. Available at: <http://www.usatoday.com/story/news/world/2015/04/23/scientists-human-embryo/26227341/> (accessed July 10, 2015).
- Hofmann, B., J. H. Solbakk, and S. Holm. 2006. Analogical reasoning in handling emerging technologies: The case of umbilical cord blood biobanking. *The American Journal of Bioethics* 6.6:49–57.
- Holt, N. 2014. How DNA scissors can perform surgery directly on your genes. *Popular Science*. Available at <http://www.popsci.com/article/science/how-dna-scissors-can-perform-surgery-directly-your-genes> (accessed August 5, 2015).
- Hughes, V. 2013. Return of the Neanderthals. *National Geographic News*. Available at: <http://news.nationalgeographic.com/news/2013/03/130306-neanderthal-genome-extinction-cloning-hominid-science> (accessed August 5, 2015).

- Interlandi, J. 2015. The church of George Church. *Popular Science*. Available at: <http://www.popsci.com/church-george-church> (accessed August 5, 2015).
- Kim, M. 2015. Now that we can edit our genome, where do we go? *Washington Post* May 18, E01.
- Lakoff, G. 1993. The contemporary theory of metaphor. In *Metaphor and thought*, ed. A. Ortony, 202–51. Cambridge, UK: Cambridge University Press.
- Lakoff, G., and M. Johnson. 2003. *Metaphors we live by*. Chicago, IL: University of Chicago Press.
- Langin, K. 2014. Genetic engineering to the rescue against invasive species? *National Geographic News*. Available at: <http://news.nationalgeographic.com/news/2014/07/140717-gene-drives-invasive-species-insects-disease-science-environment> (accessed August 5, 2015).
- Lively, E., and M. Conroy. 2013. 11 News media frame novel technologies in a familiar way. *The Social Life of Nanotechnology* 18:223.
- López, J. J. 2006. Mapping metaphors and analogies. *American Journal of Bioethics* 6(6): 61–63.
- Lydersen, K. 2014. A giant step for gene surgery. *Discover*. Available at: <http://discovermagazine.com/2015/jan-feb/38-a-giant-step-for-gene-surgery> (accessed August 5, 2015).
- Mauricio, R. 2005. Can ecology help genomics: The genome as ecosystem? *Genetica* 123:205–9.
- Miller, P. 2014. George Church: The future without limit. *National Geographic News*. Available at: <http://news.nationalgeographic.com/news/innovators/2014/06/140602-george-church-innovation-biology-science-genetics-de-extinction> (accessed August 5, 2015).
- Nerlich, B., and C. Halliday. 2007. Avian flu: The creation of expectations in the interplay between science and the media. *Sociology of Health & Illness* 29(1): 46–65.
- Petrie, H. G., and R. S. Oshlag. 1993. Metaphor and learning. In *Metaphor and thought*, ed. A. Ortony, 579–609. Cambridge, UK: Cambridge University Press.
- Pollack, A. 2014. A powerful new way to edit DNA. *New York Times*. Available at: <http://www.nytimes.com/2014/03/04/health/a-powerful-new-way-to-edit-dna.html> (accessed August 5, 2015).
- Schäfer, M. S. 2012. Taking stock: A meta-analysis of studies on the media's coverage of science. *Public Understanding of Science* 21(6): 650–63.
- Schmitt, R. 2005. Systematic metaphor analysis as a method of qualitative research. *The Qualitative Report* 10(2): 358–94.
- Scientific American Board of Editors. 2015. Altering embryo genes, safely, should not be off-limits. *Scientific American*. Available at: <http://www.scientificamerican.com/article/altering-embryo-genes-safely-should-not-be-off-limits> (accessed August 5, 2015).
- Shapiro, B. 2015. Long live the mammoth. *Popular Science*. Available at: <http://www.popsci.com/de-extinction-long-live-mammoth> (accessed August 5, 2015).
- Sidtis, D. 2014. Formulaic language in an emergentist framework. In *The handbook of language emergence*, ed. B. MacWhinney and W. O'Grady, 578–99. Hoboken, NJ: Wiley-Blackwell.
- Tetro, J. 2015. An arms race of microbial proportions. *Popular Science*. Available at: <http://www.popsci.com/arms-race-microbial-proportions> (accessed August 5, 2015).
- Tribune Publishing. 2015. Our portfolio. Available at: <http://www.tribpub.com/portfolio> (accessed August 28, 2015).
- Turney, J. 1995. The public understanding of genetics—Where next? *Human Reproduction & Genetic Ethics* 1(2): 5–20.
- Turney, J. 2007. The latest boom in popular science books. In *Journalism, science and society: Science communication between news and public relations*, ed. M. W. Bauer, and M. Bucchi, 81–91. New York, NY: Routledge.
- Wallis, P., and B. Nerlich. 2005. Disease metaphors in new epidemics: The UK media framing of the 2003 SARS epidemic. *Social Science & Medicine* 60(11): 2629–39.
- Weaver, D. A., and B. Bimber. 2008. Finding news stories: a comparison of searches using LexisNexis and Google News. *Journalism & Mass Communication Quarterly* 85(3): 515–30.