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EDITORIAL

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Gene drives and the expanding horizon of governance

Like other areas of emerging science and technology that trigger prolonged public debate over their transformative prospects, gene drives simultaneously generate prospects for new knowledge, hoped-for benefits, and formidable concerns (e.g. Cohen 2017; ETC Group 2017; Nature 2017). Their ability to bias inheritance of and in theory spread a genetic trait throughout an entire population of organisms—even to the point of extinction—is driving home the need for their responsible governance. Significantly, it is also driving home the need to develop capacities for such governance.

The title of a recent National Academies of Science, Engineering, and Medicine (NASEM 2016a) report—*Gene Drives on the Horizon: Advancing Science, Navigating Uncertainty, and Aligning Research with Public Values*—is in this respect revealing. Its language and imagery point beyond what's on the horizon, and to the horizon itself. By invoking the ideas of ongoing uncertainty, public values, and the social shaping of research, it frames the horizon not as something that unfolds beneath a cloud of inevitability, but as something that is open and susceptible to responsible research and innovation. In fact, those three ideas in the title correspond to the three 'capacities' of anticipatory governance: foresight, engagement, and integration (Guston 2014). Fifteen years ago, a National Academies committee report on nanotechnology (NRC 2002) broke ground by bringing to the attention of congressional staff and, eventually lawmakers, the innovative concept of integrating societal concerns directly into research (Fisher and Mahajan 2006). The Academies' gene drives report, which addresses normative[1] topics 'in an unusually straightforward way' (Thompson 2018), builds on this concept by noting the need for 'integrating precautionary measures into the research process' (NASEM, 2016a, 6) and by framing public engagement as a means to 'inform research directions' (7). Nor does it shy away from acknowledging the 'lack of guidance' (7) and the necessity for developing more appropriate tools for assessing risks related to gene drive modified organisms.

This special issue of the *Journal of Responsible Innovation* addresses these and related matters of pressing importance. Stemming from a 2015 workshop held at North Carolina State University's Center for Genetics and Society, it tackles some of the key socio-technical issues whose complex interactions must be considered alongside efforts to develop let alone release gene drives into the environment. Readers will find it to be a wonderfully diverse collection of disciplinary perspectives to help chart pathways through the rapidly changing landscape of technological (Min et al. 2017), agricultural (Medina 2017; Scott et al. 2017), ecological (Burt et al. 2018; Leitschuh et al. 2017; Medina 2017), ethical (Thompson 2018), economic (Baltzegar et al. 2017; Mitchell, Brown, and McRoberts 2017), regulatory (Evans and Palmer 2017; Meghani and Kuzma 2017), and risk assessment (Hayes et al. 2018) contexts. In the process, the articles adapt existing and develop new resources for responsible innovation.

Some articles develop capacities for anticipation and engagement. For instance, Kuzma et al. (2017) employ the well-known Institutional Analysis and Development framework

(IAD) as a resource for governing emerging technologies. Originally developed for analyzing collective action problems around common-pool resources, the authors show the IAD framework—in combination with small-group systems mapping exercises—to be a powerful instrument for identifying and classifying issues, characterizing variables, and learning where regulatory and other mechanisms may be needed, before a socio-technical-ecological system is in place.

Others expand our understanding of regulatory practices. Thus, while it is well known that existing regulatory frameworks often fail to encompass the novel characteristics of emerging technologies such as gene drives, Evans and Palmer (2017) place this persistent policy problem within a broader conceptual setting. Seeking to understand the different ways in which regulatory 'anomalies' are handled, they develop a framework for identifying the logic behind varying bureaucratic responses to novel technologies and for elucidating how such strategic choices are linked to broader visions of socio-technical order.

Still others address changes in scientific responsibility. Even while scientists and engineers are increasingly called upon to integrate broader normative considerations into their work, most lack formal training in the theoretical, methodological, and substantive study of doing so. In this context, Thompson (2018) anticipates that ethics will be a 'planned and structured' part of research into gene drives, but encourages readers not to 'presume that this activity will be conducted solely by ethics experts.' Instead, he points to the need to develop 'fiduciary responsibility' as a capacity distributed throughout the scientific community. Min et al. (2017) begin with a similar starting point, noting that 'few scientists can adequately assess the broader consequences of their work when combined with other powerful technologies of which they are unaware.' Their proposal, however, is for a complementary form of 'scientific reform' that is geared towards institutionalized openness and transparency.

For a comprehensive overview of all the articles and other contents included in this special issue, readers are encouraged to consult the detailed introduction by the guest editors (Delborne et al., 2018), who have done a remarkable job in pulling together this timely and invaluable collection.

Note

1. It is worth noting that the report uses the term "values" to a degree unparalleled in Academies reports on nanotechnology (NRC 2006, 2009; NASEM 2016c), synthetic biology (NRC 2010; IOM 2011; NAE-NRC 2013; NASEM 2017), and neuroscience (NASEM 2016b).

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