Preparing for Genome Editing Technologies: Results from Expert Foresight Interviews

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Genome editing techniques have become progressively more powerful over the last two decades (Cong et al. 2013; Doudna & Charpentier 2014; Kim 2016). With these advances has come an explosion of interest in such techniques' potential research and intervention utility in humans, around topics including reproductive failures (Bai et al. 2016), early human development (Fogarty et al. 2017), and genetic diseases (Gai et al. 2014; Kang et al. 2016; Ma et al. 2017); as well as concern and debate over their potential and desirable applications, impacts, and place in society (Baltimore 2015; Brokowski 2018; National Academies 2017). Chinese researcher He Jiankui was recently sentenced to three years in prison for modifying the genomes of two babies born in late 2018 (Cyranoski 2020; Greely 2019), and He's actions have been widely reported and commented upon as microcosm of broader issues of risk, benefit, authority, and responsibility in the development of HGE.

HGE implicates questions of patient and population risk; normativity and marginalization; access to medicine and economic inequality; ways of understanding and relating to human bodies and health; the political economy of research; democratic or other authority in and over innovation; biosecurity; and global governance, among others (German Ethics Council 2019; Jasanoff et al. 2019; National Academies 2017). Four decades ago, David Collingridge (1980) observed that it is difficult to predict the outcomes of technological innovation early in development, but difficult to alter later-stage technological systems once outcomes have been observed. Prior attempts to address this "dilemma of social control" have suffered from a lack of institutional leverage, a reactionary stance, and a failure to effectively engage citizens with scientists early in the development process (Jasanoff 2015; Juengst 2017; King et al. 2017). Recent National Academies reports on genetic technologies nonetheless assert that genome editing governance should be informed by substantive public engagement, dealing with "both facts and values[,] and in particular how anticipated changes will affect the things people value" (National Research Council 1996, p. 3; quoted in National Academies 2017, p. 127).

Anticipatory governance (AG) encompasses a suite of methods intended to build capacity among researchers, policymakers, and publics for substantive reflection and interchange around the development of emerging technologies (Barben et al. 2008; Guston 2014). These include scenario planning, a foresight method designed to highlight critical drivers of change, future uncertainties, and value tensions in technology development and deployment; and participatory technology assessment (pTA), a public engagement method eliciting informed, thoughtful public views, values, and rationalities regarding not only technologies themselves but their institutional situations and uses.

This presentation will review progress in an ongoing anticipatory governance project for HGE policy, including preliminary results both from literature review and from interviews with 22 experts on technical and social dimensions of HGE. These interviews have probed diverse expert conceptions of the drivers, important potentialities, and proper trajectories of HGE development. Qualitative coding and analysis of interviews, situated within preexisting

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scholarly discussions in the literature, will elucidate the system context and public stakes for HGE development; identify gaps in present governance and public engagement practice; and provide prescriptions for future engagement and governance foresight activities.

References

Bai, M., D. Liang, Y. Wang, Q. Li, & Y. Wu. Spermatogenic cell-specific gene mutation in mice via CRISPR/Cas9. *Journal of Genetics and Genomics 43*(5), pp. 289-296.

Baltimore, D., P. Berg, M. Botchan, D. Carroll, R.A. Charo, G. Church, J.E. Corn, G.Q. Daley, J.A. Doudna, M. Fenner, H.T. Greely, M. Jinek, G. S. Martin, E. Penhoet, J. Puck, S.H. Sternberg, J.S. Weissman, & K.R. Yamamoto (2015). A prudent path forward for genomic engineering and germline gene modification. *Science 348*(6230), pp. 36-38

Barben, D., E. Fisher, C. Selin, & D.H. Guston (2008). "Anticipatory Governance of Nanotechnology: Foresight, Engagement, and Integration." In E.J. Hackett, O. Amsterdamska, M. Lynch, & J. Wajcman (eds.), *The Handbook of Science and Technology Studies (Third Edition)* (pp. 979-1000). Cambridge, MA: The MIT Press.

Brokowski, C. (2018). Do CRISPR germline ethics statements cut it? *The CRISPR Journal 1*(2), pp. 115-125.

Collingridge, D. (1980). *The Social Control of Technology.* Milton Keynes, UK: Open University Press.

Cong, L., F.A. Ran, D. Cox, S. Lin, R. Barretto, N. Habib, P.D. Hsu, X. Wu, W. Jiang, L.A. Marrafini, & F. Zhang (2013). Multiplex genome engineering using CRISPR/Cas systems. *Science 339*(6121), pp. 819-823.

Cyranoski, D. (3 January 2020). What CRISPR-baby prison sentences mean for research. *Nature 577*, pp. 154-155. Retrieved from https://www.nature.com/articles/d41586-020-00001-y.

Doudna, J.A., & E. Charpentier (2014). The new frontier of genome engineering with CRISPR-Cas9. *Science 346*(6213), pp. 1077-1086.

Fogarty, N.M.E., A. McCarthy, K.E. Snijders, B.E. Powell, N. Kubikova, P. Blakeley, R. Lea, K. Elder, S.E. Wamaitha, D. Kim, V. Macioulyte, J. Kleinjung, J. Kin, D. Wells, L. Vallier, A. Bertero, J.M.A. Turner, & K.K. Niakan (2017). Genome editing reveals a role for OCT4 in human embryogenesis. *Nature 550*, pp. 67-73.

Gai, T., J. Guo, Y. Kato, S.J. Sirk, & C.F. Barbas (2014). Targeted gene knockout by direct delivery of zinc-finger nuclease proteins. *Nature Methods 9*(11), pp. 805-807.

German Ethics Council (2019). *Intervening in the Human Germline: Opinion-Executive Summary & Recommendations* (A. Sharpe, trans.). Berlin, DE: German Ethics Council.

Greely, H.T. (2019). CRISPR'd babies: human germline genome editing in the 'He Jiankui affair." *Journal of Law and the Biosciences 6*(1), pp. 111-183.

Guston, D.H. (2014). Understanding 'anticipatory governance.' *Social Studies of Science 44*(2), p. 218-242.

Jasanoff, S. (2015). "Future Imperfect: Science, Technology, and the Imaginations of Modernity." In S. Jasanoff & S. Kim (eds.), *Dreamscapes of Modernity* (pp. 1-33). Chicago, IL: University of Chicago Press.

Jasanoff, S., J.B. Hurlbut, & K. Saha (2019). Democratic governance of human germline genome editing. *The CRISPR Journal 2*(5), pp. 266-271.

Kang, X., W. he, Y. Huang, Q. Yu, Y. Chen, X. Gao, X. Sun, & Y. Fan (2016). Introducing precise genetic modifications into human 3PN embryos by CRISPR/Cas-mediated genome editing. *Journal of Assisted Reproduction and Genetics 33*(5), pp. 581-588.

Kim, J. (2016). Genome editing comes of age. *Nature Protocols 11*(9), pp. 1573-1578.

King, N.M.P., P.C. Lord, & D.E. Lemley. Editing the genome: Prospects, progress, implications, and cautions. *Current Genetic Medicine Reports 5*, pp. 35-43.

Ma, H., N. Marti--Gutierrez, S. Park, J. Wu, Y. Lee, K. Suzuki, A. Koski, D. Ji, T. Hayama, R. Ahmed, H. Darby, C. Van Dyken, Y. Li, E. Kang, A. Park, D. Kim, S. Kim, J. Gong, Y. Gu, X. Xu, D. Battaglia, S.A. Krieg, D.M. Lee, D.H. Wu, D.P. Wolf, S.B. Heitner, J.C. I. Belmnote, P. Amato, J. Kim, S. Kaul, & S. Mitalipov (2017). Correction of a pathogenic gene mutation in human embryos. *Nature 548*, pp. 413-419.

National Academy of Sciences & National Academy of Medicine (2017). *Human Genome Editing: Science, Ethics, and Governance*. Washington, DC: The National Academies Press.

National Research Council (1996). *Understanding risk: Informing decisions in a democratic society*. Washington, DC: The National Academies Press.