DIY Bio: Hacking Life in Biotech's Backyard

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DIY biologists set up home labs in garages, spare bedrooms, or use community lab spaces. They play with plasmids, yeast, and tools like CRISPR-cas9. Media stories feature glow-in-the-dark plants, beer, and even puppies. DIY bio describes itself as a loosely formed community of individualists, working separate and apart from institutional science. This Essay challenges that claim, arguing that institutional science has fostered DIY bio and that DIY bio has, thus far, tacitly conformed to institutional science values and norms. Lack of a robust ethos leaves DIY bio ripe for capture by biotech. Yet, this Essay suggests, DIY bio could serve as a laboratory for reformulating a relationship between science and society that is less about capital accumulation and more about knowledge creation premised on participation and justice.

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INTRODUCTION

Popular media depicts biohackers or Do-It-Yourself ("DIY") biologists as the ultimate science geeks. "DIY bio" refers to non-institutional science or science performed outside of professional laboratories.[1] DIY biologists set up home labs in garages, spare bedrooms, and closets or use community lab spaces.[2] The people doing DIY bio range from the self-taught to Ph.Ds.[3] Instead of building computers or creating apps, DIYers play with plasmids, jellyfish, yeast, and polymerase chain reaction in genetic engineering experiments. Media stories and DIY bio websites often feature glow-in-the-dark plants,[4] food,[5] petri dish art,[6] and even puppies.[7]

DIY bio is an emerging set of activities. A range of players, with varied ideologies, are shaping DIY bio's trajectories. DIY bio's signature claim is that it exists apart from, and even in opposition to, institutional science. This Essay challenges that claim. Whether all DIY biologists know this or not, DIY bio serves the interests of institutional science and is well-situated for capture by biotechnology. Biotechnology refers not only to the life sciences-based industry, but also to the neoliberal epistemology that values the use of applied science to commercialize the transformation of life itself into technology. DIY bio's origin stories do reflect resistance to the highly

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[1] Robert Bolton & Richard Thomas, *Biohackers: The Science, Politics, and Economics of Synthetic Biology*, 9 INNOVATIONS 213, 214 (2014).

[2] *See* Morgan Meyer, *Domesticating and Democratizing Science: A Geography of Do-It-Yourself Biology*, 18 J. MATERIAL CULTURE 117, 123-26 (2013) (describing a community lab and a home lab in a closet).

[3] DANIEL GRUSHKIN, TODD KUIKEN & PIERS MILLET, SEVEN MYTHS & REALITIES ABOUT DO-IT-YOURSELF BIOLOGY 6 (2013), https://www.wilsoncenter.org/sites/default/files/7_myths_final.pdf; Meyer, *supra* note 2, at 123.

[4] *See, e.g.*, Kristen V. Brown, *Meet the Guy Biohacking Puppies to Make Them Glow in the Dark*, SPLINTER (Sept. 28, 2016, 11:20 AM), http://splinternews.com/meet-the-guy-biohacking-puppies-to-make-them-glow-in-th-1793862258 (describing the glowing plant project).

[5] *See, e.g.*, Chris Ayres, *Biohackers Attempt to Unstitch the Fabric of Life*, TIMES (Dec. 27, 2008), http://www.precaution.org/lib/09/prn_biohackers_unstitch_life.081227.htm (describing Meredith Patterson "attempting to rewire the DNA of yoghurt bacteria so that they will glow green to signal the presence of melamine, the chemical that infamously turned Chinese-made baby milk formula into poison").

[6] *See, e.g.*, Hanno Charisius, Richard Friebe & Sascha Karberg, *Becoming Biohackers: Learning the Game*, BBC (Jan. 22, 2013), http://www.bbc.com/future/story/20130122-how-we-became-biohackers-part-1 ("[O]ne artist there was experimenting with bacteria that can produce 'beautiful patterns', using different nutrients which make colonies grow in specific ways and change colour.").

[7] *See, e.g.*, Brown, *supra* note 4.

structured and bureaucratic nature of institutional science. Yet these accounts also indicate interest convergence between DIY bio and institutional science. Accounts that forecast DIY bio's future show DIY bio conforming its practices to mainstream law, policy, and market concerns. Thus far, DIY bio has not crafted its own account of the relationship between science, society, and ethics, and is falling into a science-as-usual practice that situates DIY bio in biotech's backyard.

Part II sets out a descriptive account of biohacking, and DIY bio, in particular. Part III identifies three overlapping explanations for DIY bio. The first two, explicitly political accounts and nostalgic accounts, are largely consistent with the DIY bio claim that DIY bio is different and apart from institutional science. The third account borrows from Frederick Jackson Turner's frontier thesis and asserts that DIY bio sustains an ideology of bio-individualism embedded in biotechnology. Part IV reviews and critiques law and policy views of DIY bio and its prospects. These views apply the frames and standards applicable to biotech. Part V makes the case for biotech's annexation of DIY bio. Part V elaborates on DIY bio's failure, so far, to re-define the relationship between science and society, and suggests a few initial critical points of engagement for doing so.

I. A DESCRIPTIVE ACCOUNT OF DIY BIO

This Essay focuses on DIY bio, a category of biohacking. DIY bio is the term life science enthusiasts claim for biology work in laboratories set up outside of professional science spaces.[8] Biohacking, however, includes a wider range of activities and goals. There are the grinders or bodyhackers who modify or hack their own bodies with everything from diet supplements to implanted electronic devices.[9] Some seek basic health improvement.[10] Others identify with transhumanist goals.[11] They see implanting a neodymium magnet into a fingertip to

[8] Spencer Michels, *What Is Biohacking and Why Should We Care?*, PBS NEWSHOUR (Sept. 23, 2014, 2:57 PM), http://www.pbs.org/newshour/updates/biohacking-care (describing that DIY bio "takes place in small labs — mostly non-university — where all sorts of people get together to explore biology").

[9] *See id.* (statement of Dave Asprey) ("There are two perspectives on biohacking. One is that biohacking is something you do to biology, outside of yourself; you're going to change a cell; you're going [to] change an amoeba and make it glow in the dark. The other perspective on biohacking . . . is that you can hack your own biology, and you can gain control of systems in your body that you would never have access to.").

[10] *See, e.g.*, Joe Vennare, *Hack Your Health: 6 Biohacks That Might Surprise You*, DAILY BURN (Oct. 7, 2013), http://dailyburn.com/life/tech/health-technology-biohacking.

[11] Ben Popper, *Cyborg America: Inside the Strange New World of Basement Body*

add a sixth sense as a first step to human enhancement.[12] DIY bio, in contrast, brings a Do-It-Yourself spirit to bench science. By situating itself outside of professional science, DIY bio contrasts itself with big bio or institutional science — bioscience conducted in academic, corporate, or government spaces.[13] Science and technology studies scholar Ana Delgado identifies motivation as the key difference between DIY bio and institutional science. "What these projects have in common is that, in one way or another, they enact creativity, curiosity, and enthusiasm. That is, biohackers say, what differentiates *amateur* biology from institutionalized biology."[14]

Often, DIY bio features genetic engineering. Some DIY biologists are hobbyists learning basic genetic manipulation skills — making a home test to identify fish used in sushi took three German journalists 3,500 Euro, reviving rusty lab skills, internet sources for lab methods, and months of trial and error.[15] Others have Ph.Ds and day jobs in institutional science. Some seek to overcome obstacles that big bio has not. For example, one project's goal is to develop low-cost insulin.[16] Others aim at more quotidian problems. A genetic barcoding project, for example, would enable residential neighbors to identify pet owners by the feces their animals leave behind.[17] DIY bio artists use living organisms in aesthetic creations and to question the relationship between science, culture, and life.[18]

Hackers, VERGE (Aug. 8, 2012, 10:37 AM), https://www.theverge.com/2012/8/8/3177438/cyborg-america-biohackers-grinders-body-hackers.

[12] *Id.*

[13] *See* Ana Delgado, *DIYbio: Making Things and Making Futures*, 48 FUTURES 65, 66 (2013).

[14] *Id.* at 67.

[15] Hanno Charisius, Richard Friebe & Sascha Karberg, *Becoming Biohackers: The Experiments Begin*, BBC (Jan. 23, 2013), http://www.bbc.com/future/story/20130123-hacking-genes-in-humble-settings.

[16] Anthony Di Franco et al., *Open Insulin*, EXPERIMENT, https://experiment.com/projects/open-insulin (last visited Sept. 9, 2017); *see also* Miriam E. Tucker, *Biohackers Aim to Make Homebrew Insulin, but Don't Try It Yet*, NPR (July 15, 2015, 7:33 AM), http://www.npr.org/sections/health-shots/2015/07/15/422935288/biohackers-aim-to-make-homebrew-insulin-but-dont-try-it-yet.

[17] Annabel Slater, *The Mystery Meat Experiment*, WAAG SOC'Y (Aug. 22, 2014), https://waag.org/en/blog/mystery-meat-experiment (describing German DIY biologist Sascha Karberg's use of DNA fingerprinting to match dog saliva to dog poop left in the neighborhood).

[18] *See generally* DIYSECT, http://www.diysect.com (last visited Sept. 8, 2017) (describing a documentary web-series on DIY biology and bioart that discusses themes of the relationship between culture, science, and life throughout each episode).

DIY biologists and scholars often refer to the DIY bio "community." This refers not only to the community labs in which most people do DIY bio, but also to efforts to situate local DIY bio projects and spaces within a larger collective. For example, DIYbio.org is a non-profit organization with the stated mission of "establishing a vibrant, productive and safe community of DIY biologists."[19] The organization's website lists local groups by geographic region in the United States, Canada, Europe, Asia, Latin America, and Oceania.[20] The organization also uses Google groups to promote virtual community by posting discussion threads of DIY bio-related topics, as well as using Facebook and a blog.[21] Some in DIY bio center the commons in community. They affirm the values of open science and open source technology, most often by posting methods online and sharing materials.[22] The claim of community, then, is also used to establish a collective culture.

A 2013 survey of the DIY community found that most of the 305 respondents had bachelor's, master's, or doctorate level degrees.[23] Only eight percent work exclusively in home labs doing garage or kitchen bio.[24] Most work at one or both types of community spaces.[25] Some community labs were organized by individuals who originally had their own home labs.[26] Entrepreneurs have also launched community labs and hackerspaces.[27] Of those, the high profile labs now have foundation support.[28] And some even have civic partners.[29]

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[19] DIYBIO, https://diybio.org (last visited Sept. 8, 2017); *see also* Meyer, *supra* note 2, at 123-25 (describing BiologiGaragen, a community lab in Copenhagen, Denmark).

[20] *Local Groups*, DIYBIO, https://diybio.org/local (last visited Sept. 8, 2017).

[21] DIYBIO, *supra* note 19.

[22] *See* discussion *infra* Part III.A.

[23] GRUSHKIN ET AL., *supra* note 3, at 6; *see also* Meyer, *supra* note 2, at 123.

[24] GRUSHKIN ET AL., *supra* note 3, at 8.

[25] *Id.* at 7.

[26] *Id.* at 5.

[27] *See, e.g.*, *About*, BIOCURIOUS, http://biocurious.org/about (last visited Sept. 9, 2017). The website describes a hackerspace located in Silicon Valley, for "amateurs, inventors, entrepreneurs, and anyone who wants to experiment with friends." *Id.* The BioCurious website states, "Biocurious was co-founded by 6 entrepreneurs in 2010 . . . Countless other people helped BioCurious get off the ground in those early days, including 239 backers on Kickstarter, where we raised our original $35,319." *Id.*

[28] *See Support Us*, GENSPACE, https://www.genspace.org/support-us (last visited Sept. 9, 2017). Genspace, a New York community lab, receives support from The Pinkerton Foundation, Simons Foundation, Art Works/National Endowment for the Arts, Open Philanthropy Project, and Goldman Sachs Gives. *Id.*

[29] *About the Wetlab*, WET LAB, http://www.sdwetlab.org/the-wet-lab/about-the-wetlab (last visited Oct. 26, 2017); *see also* Lisa Peet, *San Diego Opens First Public*

Many DIY biologists embrace an open science approach.[30] The practices of collaboration and freely sharing research processes and data enable new DIYers to build lab equipment and conduct basic experiments. The most Do-It-Yourself version of a DIY bio lab is one using a mix of lab equipment purchased secondhand or fabricated from inexpensive, easily available materials.[31] In fact, one DIY bio goal is to make science products more affordable by finding ways to reduce equipment and production costs.[32] DIY biologists share their know-how on websites, blogs, and in person. Instructions for creating a bioluminescent bacterial light bulb and a decellularized heart, or "Ghost Heart," in a jar are available online.[33] Community labs offer classes, such as Biohacker Boot Camp.[34] Yet, DIY bio does not reject commercialization. Corporate science and entrepreneurial DIY biologists sell DIY bio kits.[35] Not long after CRISPR-cas9 became the newest genomic modification tool, CRISPR kits for DIY biologists

Library Biotech Lab, LIBR. J. (Sept. 9, 2015), http://lj.libraryjournal.com/2015/09/public-services/san-diego-opens-first-public-library-biotech-lab/#_. Wetlab, a DIY bio community lab, collaborates with the La Jolla-Riford Branch Library of the San Diego Public Library. *Id.*

30 *See Open Science Movement*, UNITED NATIONS EDUC. SCI. & CULTURAL ORG., http://www.unesco.org/new/en/communication-and-information/portals-and-platforms/goap/open-science-movement (last visited Sept. 9, 2017) (elaborating on the goals of open science). Open science refers to an approach to the practice of science for the purpose of making research and data accessible to all researchers and members of the public. *Id.*; *see* Dan Gezelter, *What, Exactly, Is Open Science?*, OPENSCIENCE PROJECT (July 28, 2009), http://openscience.org/what-exactly-is-open-science.

31 Thomas Landrain et al., *Do-It-Yourself Biology: Challenges and Promises for an Open Science and Technology Movement*, 7 SYS. & SYNTHETIC BIOLOGY 115, 120 (2013) (showing Table 2: DIY bio alternatives for major experimental steps and lab equipment needed to realize synthetic biology projects); *see* Patrik D'haeseleer, *How to Set Up Your Own DIY Bio Lab*, MAKE: (Apr. 11, 2017), http://makezine.com/2017/04/11/how-to-set-up-your-own-lab.

32 *See* Charisius, Friebe & Karberg, *supra* note 6 (describing a biohacker who did a test on a blood disease by building a cheap genetic test); Di Franco et al., *supra* note 16 (describing an open insulin project).

33 Drdan152, *Bioluminescent Bacterial Lightbulb/Water Pollution Tester*, INSTRUCTABLES, http://www.instructables.com/id/Bioluminescent-Bacterial-Lightbulb-Water-Polluti (last visited Sept. 9, 2017); Patrik, *Ghost Heart in a Jar!*, INSTRUCTABLES, http://www.instructables.com/id/Ghost-Heart-in-a-Jar (last visited Sept. 9, 2017).

34 *Upcoming Classes*, GENSPACE, https://www.genspace.org/classes-alt (last visited Sept. 9, 2017).

35 *See Products*, AMINO LABS, https://amino.bio/collections/all (last visited Sept. 9, 2017). Amino Labs sells a variety of kits, including classroom sets for school use. *Id.*; *All Products*, ODIN, http://www.the-odin.com/all-products (last visited Sept. 9, 2017). The Odin sells Beginner Kits and Gene Engineering Kits. *Id.*

became available for sale.[36] Community labs with sponsors or foundation support offer classes and equipment use, as well as workspace and collaboration opportunity.[37]

In some ways, DIY bio's public profile fits the hacker image. DIY bio proponent, Meredith Patterson, wrote the Biopunk Manifesto, in which she described a loosely formed community of individualists dedicated to challenging institutional and legal restraints on freedom of inquiry. "Biopunks experiment. We have questions, and we don't see the point in waiting around for someone else to answer them."[38] Josiah Zayner, a high-profile DIY biologist, sports multicolored hair and Tweets about his fluorescent mead project.[39]

Yet, DIY bio looks like institutional science in telling ways. While DIY biologists learn from resources posted online by DIYers, or from mentors and collaborators, many DIY scientists also work in academic, corporate, or government laboratories.[40] Zayner graduated from University of Chicago with a Ph.D in biophysics and biochemistry and worked in a synthetic biology lab as a NASA fellow.[41] He started The Odin, which sells biological materials and hardware for DIY biology.[42] Not surprisingly, most DIY biologists are mostly male[43] and professional scientists.[44] Although DIY biologists do not receive grant funding, entrepreneurial DIYers use crowdfunding and seek corporate sponsors.[45]

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[36] *All Products*, *supra* note 35 (showing the CRISPR DIY biology sets being sold online at the Odin).

[37] *See, e.g.*, *Our Mission*, GENSPACE, https://www.genspace.org/mission (last visited Sept. 9, 2017) (describing a New York community DIY bio lab).

[38] Meredith Patterson, *A Biopunk Manifesto*, LIVEJOURNAL (Jan. 30, 2010, 9:56 PM), http://maradydd.livejournal.com/496085.html (showing an excerpt from the UCLA "Outlaw Biology? Public Participation in the Age of Big Bio" Symposium).

[39] Josiah Zayner (@4LOVofScience), TWITTER (June 17, 2017, 3:00 PM), https://twitter.com/4LOVofScience/status/876197885355802625.

[40] GRUSHKIN ET AL., *supra* note 3, at 23.

[41] Stephanie M. Lee, *DNA Biohackers Are Giving the FDA a Headache with Glow-in-the-Dark Booze*, BUZZFEED (Dec. 6, 2016, 5:42 AM), https://www.buzzfeed.com/stephaniemlee/biohacking-booze?utm_term=.bkKw008gY#.pjQdNNw8Q.

[42] *About Us*, ODIN, http://www.the-odin.com/about-us (last visited Sept. 9, 2017).

[43] Morgan Meyer, *Hacking Life? The Politics and Poetics of DIY Biology*, *in* META-LIFE: BIOTECHNOLOGIES, SYNTHETIC BIOLOGY, A-LIFE AND THE ARTS 1, 4 n.1 (Annick Bureaud, Roger F. Malina & Louise Whiteley eds., 2014) (ebook), https://cns.asu.edu/sites/default/files/meyerm_synbiopaper2edit_2014.pdf.

[44] GRUSHKIN ET AL., *supra* note 3, at 6.

[45] While several have raised capital using Kickstarter, a general crowdfunding site, STEM-focused crowdfunding platforms have emerged. *See, e.g.*, *Discover*, EXPERIMENT, https://experiment.com/discover (last visited Sept. 9, 2017).

Moreover, DIY bio originated hand in hand with institutional science. More specifically, institutional scientists engaged in synthetic biology spurred DIY bio. Synthetic biology is an emerging field of research and technology development. Standard definitions state that synthetic biology brings an engineering approach to molecular biology, and emphasize the methodology for making things from biology.[46] Nature.com defines synthetic biology as "the design and construction of new biological parts, devices, and systems, and the re-design of existing natural biological systems for useful purposes."[47] Synthetic biology has been touted as having the potential to produce everything from new lifesaving therapeutic devices to new life forms. Histories of DIY bio identify Rob Carlson's 2005 Wired article on setting up a home lab;[48] MAKE Magazine's 2006 issue, Backyard Biology;[49] Scott Mohr's 2007 online publication of *Primer for Synthetic Biology*;[50] Jason Bobe and Mackenzie Cowell's 2008 launch of online message board DIYbio.org;[51] and the 2010 opening of the first community lab, GenSpace,[52] as formative events of DIY bio. Key actors in those events were working in synthetic biology labs or the International Genetically Engineered Machine Foundation ("iGEM") synthetic biology student competition.[53] Thus, DIY bio's origins are less spontaneous than they might appear.

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[46] STEPHANIE JOYCE, ANNE-MARIE MAZZA & STEPHEN KENDALL, POSITIONING SYNTHETIC BIOLOGY TO MEET THE CHALLENGES OF THE 21ST CENTURY: SUMMARY REPORT OF A SIX ACADEMIES SYMPOSIUM SERIES 2 (Nat'l Research Council & Nat'l Acad. of Eng'g eds., 2013).

[47] *Synthetic Biology*, NATURE.COM, http://www.nature.com/subjects/synthetic-biology (last visited Sept. 9, 2017). More detailed descriptions distinguish between traditional genetic engineering, which relies on recombinant DNA, polymerase chain reaction, automated sequencing, and synthetic biology, which adds automated construction of DNA, standards for construction, and abstraction to hide biological complexity. VitruvianMan07, *iGEM — Drew Endy Defining Synthetic Biology (video)*, YOUTUBE (June 13, 2007), https://www.youtube.com/watch?v=XIuh7KDRzLk.

[48] GRUSHKIN ET AL., *supra* note 3, at 5; Rob Carlson, *Splice It Yourself*, WIRED (May 1, 2005, 12:00 PM), https://www.wired.com/2005/05/splice-it-yourself.

[49] Sara Tocchetti, *DIYBiologists as 'Makers' of Personal Biologies: How Make Magazine and Maker Faires Contribute in Constituting Biology as a Personal Technology*, J. PEER PRODUCTION (June 2012), http://peerproduction.net/issues/issue-2/peer-reviewed-papers/diybiologists-as-makers.

[50] ANDREW BALMER & PAUL MARTIN, SYNTHETIC BIOLOGY: SOCIAL AND ETHICAL CHALLENGES 20 (2008), http://www.synbiosafe.eu/uploads/pdf/synthetic_biology_social_ethical_challenges.pdf.

[51] GRUSHKIN ET AL., *supra* note 3, at 5; *see also* Landrain et al., *supra* note 31, at 116 (identifying the 2008 launch of DIYbio.org as the start of the DIY bio movement).

[52] Sam Kean, *A Lab of Their Own*, 333 SCIENCE 1240, 1240 (2011).

[53] NAT'L RESEARCH COUNCIL, A VIEW OF GLOBAL S&T BASED ON ACTIVITIES OF THE

II. EXPLANATORY ACCOUNTS OF DIY BIO

Normative accounts of DIY bio vary, but fall within a narrow orbit of institutional science. My assessment focuses on U.S. DIY bio. While DIY bio is expanding globally, most DIY bio activity takes place in the United States.[54] More importantly, compared with its European counterparts, U.S. DIY bio's sensibility seems to embrace free market individualism more than communitarian values. Its ethos is less critical of institutional science, and more open to commercialization.[55]

Explanatory narratives group into the explicitly political and the nostalgic in ways that may be distinctly American. I specify a third explanation that posits DIY bio as both safety valve and frontier space for institutional science. Both function to protect the existing arrangements between law, science, and market. Admittedly, the accounts overlap, connect, and self-contradict more than my typology suggests. I use the typology to surface inconsistencies between DIY bio's self-defined position *vis à vis* institutional science and the normative content and political economy of biotechnology.

A. Explicitly Political Accounts

Outlaw and hacker science defines itself in contrast to institutional science.[56] The terms "outlaw" and "hacker" suggest science conducted illegally or extra-legally. Most accounts, however, use those terms to position DIY bio outside institutional science, and not law. Explicitly political accounts of DIY bio expressly challenge the structure and constraints of institutional science, but with different goals in mind.

Perhaps the most common explanatory narrative asserts DIY bio's goal as citizen science. But DIY bio deploys several political iterations of citizen science. One version challenges the structure and practices of institutional science and seeks to democratize science.[57] "Biopunks" want to see whether the wall around the fortress of Big Science is really as high as it seems."[58] While traditional citizen scientists are

BOARD ON GLOBAL SCIENCE AND TECHNOLOGY: LETTER REPORT 32 app. D.3 (2011); *see* Kean, *supra* note 52, at 1240.

[54] GRUSHKIN ET AL., *supra* note 3, at 6.

[55] *See* ALESSANDRO DELFANTI, BIOHACKERS: THE POLITICS OF OPEN SCIENCE 113 (2013); Jozef Keulartz & Henk van den Belt, *DIY-Bio — Economic, Epistemological and Ethical Implications and Ambivalences*, 12 LIFE SCI. SOC'Y & POL'Y 1, 5 (2016).

[56] *See* Keulartz & van den Belt, *supra* note 55, at 3-4.

[57] Non-U.S. DIY bio communities seem more likely to claim DIY bio as the democratization of science. *See, e.g.*, Bolton & Thomas, *supra* note 1, at 214; Meyer, *supra* note 2, at 118.

[58] MARCUS WOHLSEN, BIOPUNK: DIY SCIENTISTS HACK THE SOFTWARE OF LIFE 209

amateur scientists who gather data under supervision of professional scientists, DIY biology as citizen science seeks to disrupt "the specialization of power"[59] and the hierarchy that specialization maintains. DIY bio's challenge to institutional science is posited as expanding access to doing science, and also about contesting the siloed production of scientific knowledge. The goal, for many, is open science.[60] The open science movement seeks transparency in research methodology and data, public access and "reusability of scientific data," publicly accessible scientific communication, and use of digital media to enable research collaboration.[61] Some open science proponents hope to improve the efficiency of the research process or the reliability of scientific data. Many in DIY bio see open science as a means to achieve participatory science.

Another version of citizen science sees DIY bio as a different path to institutional science's goals — to expand opportunities for commercialization and foster new industries.[62] This vision does not necessary challenge the structure of institutional science. This version seeks access to capital and market opportunities, via science. To the extent that these citizen scientists hope to democratize science, the hope is for capitalist democracy.

Others, however, see DIY bio as an intervention in biotech's reinscription of social-political hierarchies between humans and others, and among humans.[63] This version of citizen science seeks to expose the stratification that lies behind the expert scientist. For example, critics of big bio have compared laboratory work to industrial labor sites.[64] The comparison highlights the hidden nature of that work, distinctions between technoscientific expertise and labor, and the potential abuses that lie therein. More expansive critique targets constructs and practices that maintain strict boundaries between expert, labor, human subject, and other (arguably "lower") life forms.[65] That critique, however, comes from artists and science

(2011).

[59] Eben Kirksey, Brandon Costelloe-Kuehn & Dorion Sagan, *Life in the Age of Biotechnology*, *in* THE MULTISPECIES SALON 185, 185 (Eben Kirksey ed., 2014) (citing GUY DEBORD, THE SOCIETY OF THE SPECTACLE (1967)).

[60] *See generally* DELFANTI, *supra* note 55, at 19.

[61] Gezelter, *supra* note 30.

[62] Joe Alper, *Biotech in the Basement*, 27 NATURE BIOTECHNOLOGY 1077, 1077 (2009); *see* Bolton & Thomas, *supra* note 1, at 214.

[63] *See, e.g.*, Kirksey, Costelloe-Kuehn & Sagan, *supra* note 59, at 188-96.

[64] *Id.* at 185-86.

[65] Kirksey, Costelloe-Kuehn & Sagan, *supra* note 59, at 185.

and technology studies scholars using DIY bio as a site for commentary on biotechnology. In contrast, most U.S. DIY bio lacks this critical edge.[66] Many embrace open science without rejecting neoliberalism's role in shaping biotechnology.[67]

B. Nostalgic Accounts

Anecdotally, some use DIY bio to escape the constraints of institutional science. Many DIY biologists work in institutional science and/or have formal science education.[68] In a DIY setting, funding and career do not depend on research outcomes. The explanatory narrative that emerges is that DIY bio is science for fun and discovery.[69] This narrative complains not of the rigors of career, but more specifically, of those imposed by bureaucracy, regulatory requirements, and the drive to market.[70] While the narrative implicitly critiques neoliberalism's role in reframing the life sciences into biotechnology and discovery into innovation into product, its primary message is about what science was. It is nostalgic for a past that may be part myth.

Locating science outside of those constraints defines DIY bio as authentic science. One can see in it a yearning for academic science as it supposedly existed pre-Bayh-Dole — before the "corporatization of the life sciences,"[71] when science was seeking knowledge for the sake

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[66] DELFANTI, *supra* note 55, at vi-vii; Christopher M. Kelty, *Outlaw, Hackers, Victorian Amateurs: Diagnosing Public Participation in the Life Sciences Today*, 9 J. SCI. COMM. 1, 3 (2010).

[67] Comparison between the U.S. and European Delegations' DIY Bio Codes of Ethics illustrates this point. Both include Open Access, Transparency, Safety, Education, and Peaceful Purposes as ethical principles. *See Draft DIYbio Code of Ethics from European Congress*, DIYBIO (2011), https://diybio.org/codes/draft-diybio-code-of-ethics-from-european-congress; *Draft DIYbio Code of Ethics from North American Congress*, DIYBIO (2011), https://diybio.org/codes/code-of-ethics-north-america-congress-2011. The U.S. delegates' version also lists Environment (Respect the Environment) and Tinkering (Tinkering with biology leads to insight; insight leads to innovation). *Id.* The European Delegation's Code identifies the additional principles of Modesty, Community, Respect, Responsibility, and Accountability. *Id.* The use of innovation in the Tinkering principle is biotechnology's watchword. *Id.* Modesty, community, respect, responsibility, and accountability all speak to mutuality and imply a rejection of competition. *Id.*

[68] GRUSHKIN ET AL., *supra* note 3, at 6.

[69] *See* Sara Tocchetti & Sara Angeli Aguiton, *Is an FBI Agent a DIY Biologist Like Any Other? A Cultural Analysis of a Biosecurity Risk*, 40 SCI. TECH. & HUM. VALUES 825, 826-27 (2015).

[70] *See* Delgado, *supra* note 13, at 68.

[71] Kaushik Sunder Rajan, *Introduction* to LIVELY CAPITAL: BIOTECHNOLOGIES, ETHICS, AND GOVERNANCE IN GLOBAL MARKETS 2 (Kaushik Sunder Rajan ed., 2012) [hereinafter

of knowledge. Universities and science and technology scholars describe the Bayh-Dole Act as a foundational event.[72] For universities, the Bayh-Dole Act reallocated the fruits of university research, in the form of patent control and royalties, from the government to the university.[73] Scholars note that Bayh-Dole contributed materially to the formation of the biotech industry and the reconstitution of life as capital.[74] It authorized privatization of federally funded research.[75] It also prioritized market products as the goal of life science research,[76] and valorized translational research over basic research.[77] In doing so, Bayh-Dole changed the approach and purpose of scientific knowledge production, and signaled the dominance of neoliberalism in biomedicine.[78]

A corollary nostalgic account focuses on the scientist, rather than on the science. Nostalgic accounts idealize the hacker or outlaw biologist as inventive, persistent, and pre-institutional. In these accounts, the DIY biologist harks back to early American inventors whose work was spurred not only by necessity, but also by a particular brand of individualism. Individualism manifested as persistence, hard work, idiosyncrasy, and a singular faith in one's ability to shape the future through technological innovation. This origin story positions the DIY biologist as a solo actor, free of bureaucratic and social constraints. Meredith Patterson's Biopunk Manifesto asserts that biohackers seek to reclaim diversity in citizen science. It declares citizen science as science for the people normally not seen in STEM fields.[79] And yet, as STS scholar Sara Giordano's work shows, the tinker figure remains embedded in socio-historical context.[80] Nostalgic yearning to escape

Sunder Rajan, LIVELY CAPITAL].

[72] *See, e.g.*, *id.* at 2-4; *Bayh-Dole Act*, ASS'N U. TECH. MANAGERS, https://www.autm.net/advocacy-topics/government-issues/bayh-dole-act (last visited Sept. 14, 2017) ("The Bayh-Dole Act fundamentally changed the nation's system of technology transfer by enabling universities to retain title to inventions and take the lead in patenting and licensing groundbreaking discoveries.").

[73] Sunder Rajan, LIVELY CAPITAL, *supra* note 71, at 2-4.

[74] MELINDA COOPER, LIFE AS SURPLUS: BIOTECHNOLOGY & CAPITALISM IN THE NEOLIBERAL ERA 27 (2008); KAUSHIK SUNDER RAJAN, BIOCAPITAL: THE CONSTITUTION OF POSTGENOMIC LIFE 6 (2006) [hereinafter BIOCAPITAL]; Sunder Rajan, LIVELY CAPITAL, *supra* note 71, at 2-3.

[75] *Bayh-Dole Act*, *supra* note 72.

[76] COOPER, *supra* note 74, at 27; SUNDER RAJAN, BIOCAPITAL, *supra* NOTE 73, AT 12.

[77] COOPER, *supra* note 74, at 26.

[78] Sunder Rajan, LIVELY CAPITAL, *supra* note 71, at 7.

[79] Patterson, *supra* note 38.

[80] *See* SARA GIORDANO, "LABS OF OUR OWN": POST/FEMINIST TINKERINGS WITH SCIENCE (forthcoming) (manuscript at 15-16) (on file with author).

the constraints of institutional science is therefore figured as white, U.S.-born, and male.[81]

C. The New Frontier Thesis

Both explicitly political and nostalgic accounts describe institutional science as rigidly structured and bureaucracy-bound. This emphasis suggests that DIY bio serves as open space — a new frontier crafted in mostly urban areas, by science enthusiasts. An account of DIY as a new frontier aligns nicely with the political and nostalgic accounts. In the frontier account, however, the space that DIY bio provides is less an alternative space for the merely bio-curious, and more a space where new territory (products) or breakthroughs (patentable processes) may be claimed. Here, I point to ways in which DIY bio serves institutional interests.

In 1893, historian Frederick Jackson Turner presented a paper titled, *The Significance of the Frontier in American History*.[82] Turner asserted that the American frontier provided sustenance and outlet for rugged individualism. The undeveloped and unpopulated (ignoring Native Americans and Mexicans) West acted as a safety valve.[83] The availability of open space drew people from the eastern cities, thus alleviating social, political, and economic pressures that might otherwise have destabilized the relatively new U.S. government.[84] DIY bio may serve a similar purpose. It provides some space and an outlet for those frustrated with institutional science. While some trained scientists have eschewed institutional science for DIY bio, many do both. It diverts the institutional science discontents to pursue their science interests and provides an outlet for career scientists[85] to pursue science for fun in a "natural," unconstrained space. The fact that DIY bio exists may be as effective a safety valve as its actual use. If DIY bio operates as a safety valve, then it protects institutional science, as Turner claimed the undeveloped, unpopulated West protected the settled United States.

DIY bio, as noted, owes its origins to institutional science. DIY bio as frontier also bears big bio's imprint. Synthetic biologists have

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[81] *See id.* at 11, 16.

[82] Frederick Jackson Turner, *The Significance of the Frontier in American History*, NAT'L HUMAN. CTR., May 2005, http://nationalhumanitiescenter.org/pds/gilded/empire/text1/turner.pdf.

[83] *See id.* at 9.

[84] *See id.* at 2-3.

[85] *See* GRUSHKIN ET AL., *supra* note 3, at 4.

organized a very specific open source approach to research and development. Open source science is one element of the open science approach that DIY biologists support. The open source principle calls for public availability and free reusability of science and technology data.[86] BioBricks™ and iGEM, two synthetic biology organizations, have become the standard-bearers of synthetic biology and open source science.[87] The BioBricks Foundation, formed as a non-profit organization, has the stated purpose of standardizing biological parts to enable quick and easy assembly of gene sequences.[88] Its name draws on the Legos™ image to convey the standardization concept. The International Genetically Engineered Machine Foundation or iGEM promotes synthetic biology by sponsoring competitions, primarily for undergraduate students.[89] Both BioBricks and iGEM support open source technology use in specific ways. BioBricks has put forth a BioBricks Public Agreement that allows inventors to claim patents and permits users free access to those parts.[90] iGEM maintains the Registry of Standard Biological Parts, which iGEM claims as "the world's largest open-source community collection of standard parts, commonly called BioBricks."[91] Institutional synthetic bio has deliberately constructed a play-space frontier for DIY bio.

Turner's thesis posited an archetypal American individualism that he deemed essential to the American expansion and intertwined with the availability of frontier. Whether or not Turner's thesis was accurate, it centered a particular version of white, masculine individualism as its heroic driving force. Contemporary U.S. bio-science has its own archetypal individualism, which is implicitly masculine and predominantly white. The bio-individualist is the biotech success story. Key words and phrases include not only M.D./Ph.D, but as importantly, entrepreneurial, able to attract venture capital, and executive skillset. Herb Boyer,[92] Leroy Hood,[93] and Craig

[86] Gezelter, *supra* note 30 (defining open source science as one of four elements of open science).

[87] Christina D. Smolke, *Building Outside of the Box: iGEM and the BioBricks Foundation*, 27 NATURE BIOTECHNOLOGY 1099, 1099 (2009).

[88] *See Programs/BIONET*, BIOBRICKS FOUND., https://biobricks.org/bionet (last visited Sept. 9, 2017).

[89] *About*, iGEM, http://igem.org/About (last visited Sept. 9, 2017).

[90] *The BioBrick Public Agreement (BPA)*, BIOBRICKS FOUND., https://biobricks.org/bpa (last visited Sept. 9, 2017); *see* Smolke, *supra* note 87, at 1102 (describing the formation and concept of the BioBricks Public Agreement).

[91] *Labs Program*, iGEM, http://igem.org/Labs_Program (last visited Sept. 9, 2017).

[92] *Our Founders*, GENENTECH, https://www.gene.com/about-us/leadership/our-founders (last visited Sept. 9, 2017) (explaining that Genentech, regarded as an iconic

Venter[94] embody the bio-individualist.[95] DIY biology attracts a wider range of people and projects than the archetype. But so did the nineteenth century frontier. My point is that DIY bio, as a new frontier, serves institutional science by sustaining bio-individualism. The biohacker and outlaw are roomy enough for the entrepreneurial science geek whose participation in constructing the new frontier may expand the market.

III. PREDICTIVE ACCOUNTS

DIY bio appears in most policy work as a subsection or sub-subsection[96] of an assessment about other emerging technologies such as synthetic biology,[97] open source strategies in biotechnology,[98] or biosecurity.[99] Predictably, most analyses frame DIY bio in terms of

early biotechnology company and now a Roche subsidiary, was founded in 1976 by Herb Boyer, a biochemist, and venture capitalist, Robert Swanson).

93 *See Leroy Hood*, NAT'L ACAD. SCI., http://www.nasonline.org/programs/awards/2017/Leroy-Hood.html (last visited Sept. 9, 2017) (describing Leroy Hood as a biologist who started in academia and played a key role in the Human Genome Project by automating DNA sequencing, as well as founding or co-founding over a dozen biotechnology companies).

94 *See Biographies: J. Craig Venter, Ph.D.*, J. CRAIG VENTER INST., http://www.jcvi.org/cms/about/bios/jcventer (last visited Sept. 9, 2017) (describing Craig Venter, a scientist in Physiology and Pharmacology, who started in academia and then funded Celera Genomics while working on the Human Genome Project ("HGP"), then eventually leveraged a role for Celera in the HGP which expanded privatization of public science projects).

95 *See also* Luke Timmerman, *12 Serial Entrepreneurs Who've Created Value in Biotech Over, and Over, Again*, PARTNERING360 (Aug. 2, 2016), http://www.partnering360.com/blog/2016/08/02/12-serial-entrepreneurs-whove-created-value-in-biotech-over-and-over-again.

96 *But see* GRUSHKIN ET AL., *supra* note 3, at 14; Brian J. Gorman, *Patent Office as Biosecurity Gatekeeper: Fostering Responsible Science and Building Public Trust in DIY Science*, 10 J. MARSHALL REV. INTELL. PROP. L. 423, 449 (2011) [hereinafter *Patent Office*] (focusing on DIY bio).

97 *See, e.g.*, BALMER & MARTIN, *supra* note 50, at 19-20 (discussing biohacking or 'garage biology' in one paragraph of a twenty-nine page report); JOYCE ET AL., *supra* note 46, at 2, 28-29. *See generally* NAT'L ACADEMIES OF SCI. ENG'G & MED., PREPARING FOR FUTURE PRODUCTS OF BIOTECHNOLOGY (2017) [hereinafter PREPARING FOR FUTURE PRODUCTS] (mentioning DIY bio throughout this report); NAT'L RESEARCH COUNCIL, *supra* note 53 (discussing DIY bio in the Appendix).

98 *See, e.g.*, Lucas S. Osborn, Joshua M. Pearce & Amberlee Haselhuhn, *A Case for Weakening Patent Rights*, 89 ST. JOHN'S L. REV. 1185, 1208 (2015); Andrew W. Torrance, *Planted Obsolescence*, 48 IDAHO L. REV. 321, 322, 342-45 (2012).

99 *See, e.g.*, Brian J. Gorman, *Biosecurity and Secrecy Policy: Problems, Theory, and a Call for Executive Action*, 2 I/S: J.L. & POL'Y FOR INFO. SOC'Y 53, 55-58 (2006) [hereinafter *Biosecurity*]; H. Rachael Million-Perez, *Addressing Dual-Use Technology in*

potential benefit and risk. Just as predictably, they tend to identify a very narrow set of benefits and risks. These analyses foretell two possible futures: market promise or hacker peril. The benefits include those woven into the explanatory accounts, but policy discourse emphasizes the interplay between DIY bio, patent law, and the market. This valorizes DIY bio's commercial prospects as its primary benefit. Risk analyses identify a short list that map onto the narrow risk standards used to assess new technologies emerging from institutional science.

A. Market Promise

Most predictive accounts cast DIY bio's beneficial activities through the prism of commercial potential. The resulting spectrum ranges from pure hobbyist to intentional entrepreneur. The pure hobbyist is in it solely for fun, perhaps happy to work in the home garage, sharing successes and failures with virtual colleagues online, or working side by side in a community lab with others. The intentional entrepreneur, at the spectrum's other end, might use DIY bio expressly for product development or simply be open to any opportunity to commercialize.

The policy accounts assume that product development is a natural outcome of biology. In other words, the pathway between life science research and market is so well established that is has naturalized commercialization, even in a space defined as outside institutional science. As a result, the DIY bio entrepreneur might come from anywhere on the spectrum. Though the intentional entrepreneur might be more likely to pursue commercial opportunities, the pure hobbyist also might become a market success. Or, either might fail. The market success story might be someone like Zayner, who launched The Odin, through which he vends the DIY CRISPR and glow-in-the-dark mead kits. Or it might be someone like Kay Aull, who created a low-cost genetic test for hemochromatosis after her father's diagnosis.[100] It might be someone whose innovation uses registered BioBricks. The naturalization of commercialization makes any of these success stories seem predictable and inevitable.

an Age of Bioterrorism: Patent Extension to Inspire Companies Making Dual Use Technology to Create Accompanying Countermeasures, 44 AIPLA Q.J. 387, 399-401 (2016).

[100] Alper, *supra* note 62, at 1077.

B. Hacker Peril

1. Harmful Products and Biosecurity Risk

The two sources of harm that law and policy identify are from dangerous products or uncontrolled release of a genetically engineered organism. By far, analyses weigh uncontrolled release and any resulting biosecurity risks as the greatest threat. Concerns include accidental release from one without proper training in laboratory safety protocols as well as bioterrorism. The potential harms are to human health, environment, and property.

The predicted biosecurity risks of DIY bio echo broader concerns about biotechnology research. Key words used to express those concerns include biosecurity,[101] dual use,[102] uncontrolled release,[103] and bioterrorism.[104] In other words, a DIY biologist might use genetic engineering or synthetic biology to create and distribute an organism that causes harm, for example by reducing biological diversity, weakening an existing population of plant or animal life, making people sick, destroying crops, threatening the food supply, or deterring tourism. Risk analysis bundles these potential effects into three categories: physical environment, human health, and property.

2. Regulatory Gaps

While the discourse of DIY's possible risks follows a familiar pattern,[105] policy work describes regulatory issues that DIY bio raises as novel. Commentary focuses on regulatory gaps.[106] It notes that existing law is aimed at academic and commercial science — institutional science. DIY bio's ad hoc, idiosyncratic set of practices, along with its lack of government funding do not clearly trigger federal laws applicable to biotechnology. As a result, agencies such as

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101 *See, e.g.*, Gorman, *Patent Office*, *supra* note 96, at 427-28.

102 *See, e.g.*, *id.* at 425.

103 *See, e.g.*, Gorman, *Biosecurity*, *supra* note 99, at 83-84; Million-Perez, *supra* note 99, at 400-01.

104 *See, e.g.*, BALMER & MARTIN, *supra* note 50, at 20.

105 *See* Stephen J. Collier, Andrew Lakoff & Paul Rabinow, *Biosecurity: Towards an Anthropology of the Contemporary*, 20 ANTHROPOLOGY TODAY 3, 3-4 (2004) (arguing that "biosecurity risk" should be understood as a set of tensions resulting from relevant political and cultural valences, which asserts that "biosecurity risk" used in connection with DIY bio is shaped by the politics arising from 9/11 and from twenty-first century biotechnology).

106 *See* PREPARING FOR FUTURE PRODUCTS, *supra* note 97, at 72, 78-80; Meyer, *supra* note 2, at 117-18.

the FDA, the EPA, and the FBI cannot easily regulate DIY bio's activities.[107]

Policy analysis identifies open science, including open source practices as a risk factor. The open science movement formed as a response to Bayh Dole's effects on academic research — the pressure researchers experience to guard any data and methodology necessary to obtain patent protection and commercialization opportunity.[108] Thus, the open science movement can be seen as a nostalgic account of authentic science. Open science, as mentioned, includes open source practices along with transparency in scientific methodology, and data sharing.[109] The concern is that DIY bio, using open science practices, is more likely to result in accidental release or the lone biologist whose goal is bioterrorism. Debate prompted by open science typically pits open science against patent rights and commercialization.[110] Some see open science practices as threat to property interests. For example, open source scientists like DIY biologists might misuse a patent.[111]

3. Cautionary Tales

Despite the regulatory gaps, several regulatory interventions have emerged as cautionary tales for DIY biologists.[112] In 2004, Steven Kurtz, a member of Critical Art Ensemble and a SUNY Buffalo faculty colleague, was arrested and investigated for bioterrorism after police found he had purchased and used non-pathogenic bacteria in museum installations.[113] Despite the fact that the bacteria were inert, that they

107 *See* PREPARING FOR FUTURE PRODUCTS, *supra* note 97, at 72 (citing ALBERT C. LIN, PROMETHEUS REIMAGINED: TECHNOLOGY, ENVIRONMENT, AND LAW IN THE TWENTY-FIRST CENTURY (2013)).

108 *See* SUNDER RAJAN, BIOCAPITAL, *supra* note 74, at 12.

109 Gezelter, *supra* note 30.

110 For an excellent analysis of the debate and a challenge to the claim that open science and commercialization are in conflict, see Timothy Caulfield, Shawn HE Harmon & Yann Joly, *Open Science Versus Commercialization: A Modern Research Conflict?*, GENOME MED., 2012, at 2-8, https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3392762/pdf/gm316.pdf.

111 *See, e.g.*, Robin Feldman, *The Open Source Biotechnology Movement: Is It Patent Misuse?*, 6 MINN. J.L. SCI. & TECH. 117, 118-19 (2004) (assessing the patent misuse question and concluding that open source science is not likely to result in patent misuse).

112 *See, e.g.*, Charisius et al., *supra* note 6 ("Mention scare stories, and the name of Steve Kurtz will undoubtedly crop up.").

113 Amy Goodman, *Art in a Time of Terror: Acclaimed Art Professor Steve Kurtz on How He Became a "Bioterrorism" Suspect After His Wife Died in Her Sleep*, DEMOCRACY NOW!

were used solely for artistic expression, and that public health authorities determined that their use posed no environmental or safety risk, the Department of Justice sought to prosecute on charges of bioterrorism, mail fraud, and wire fraud. The prosecution effort ultimately failed, but the process took four years.[114]

Two other cautionary tales illustrate both the regulatory gaps and a softer approach to government intervention. In 2013, a Kickstarter campaign raised $484,013 to create glow-in-the-dark plants using synthetic biology.[115] The plan called for inserting genes from fireflies or bioluminescent bacteria into plants. Kickstarter donors were promised a plant within twelve months. Concerns about uncontrolled release produced two responses. One was law-based. The Glowing Plant project fell into a regulatory gap, but project developers encouraged others, in the spirit of open science, to use an existing DIY bio kit to make plant genome modifications of their own. Yet, using the kits would trigger regulatory oversight.[116] In addition, the possibility of uncontrolled release of genomically modified plants prompted environmentalists to pressure Kickstarter. [117] In response to both the legal and environmental concerns, Kickstarter banned DIY bio kits. As of July 2017, the developers have not produced a glowing plant.[118] As a result, this project has not raised the secondary regulatory oversight issues. In 2016, DIY biologist Josiah Zayner began selling kits for DIY fluorescent mead.[119] FDA staff argued that the protein for florescence was a "color additive" not recognized as safe

(June 16, 2008), https://www.democracynow.org/2008/6/16/art_in_a_time_of_terror.

114 *Id.*

115 Antony Evans, *Glowing Plants: Natural Lighting with No Electricity*, KICKSTARTER (2013), https://www.kickstarter.com/projects/antonyevans/glowing-plants-natural-lighting-with-no-electricit.

116 PREPARING FOR FUTURE PRODUCTS, *supra* note 97, at 94 ("The Growing Plant: A Product Without a Regulatory Hook . . . If kit recipients used the kit-supplied *Agrobacterium* plant-pest components to further modify the plant genome, regulation by USDA–APHIS would be triggered, which would mean that the secondary developer would need to interact with USDA–APHIS to determine what regulations would apply to the specific situation. Further, shipping of GE glowing-plant seeds across state lines could require a downstream notification to EPA.").

117 Sarah Zhang, *Whatever Happened to the Glowing Plant Kickstarter?*, ATLANTIC (Apr. 20, 2017), https://www.theatlantic.com/science/archive/2017/04/whatever-happened-to-the-glowing-plant-kickstarter/523551. *But see* PREPARING FOR FUTURE PRODUCTS, *supra* note 97, at 43.

118 Antonio Regalado, *Why Kickstarter's Glowing Plant Left Backers in the Dark*, MIT TECH. REV. (July 15, 2016), https://www.technologyreview.com/s/601884/why-kickstarters-glowing-plant-left-backers-in-the-dark; Zhang, *supra* note 117.

119 Lee, *supra* note 41.

for consumption. In response, Zayner issued a statement about the safety of the engineered yeast that included a claim about safety testing and an "Argument Against Regulation,"[120] and proceeded with sales.[121] Zayner's brash response may or may not counter the fact that the FDA was watching.

The three activities — art, glowing plants, and fluorescent mead — triggered a range of regulating actions. The government brought criminal law to bear on Critical Art Ensemble, in the wake of 9/11. The glow-in-the-dark plant project yielded the threat of regulation to plant recipients and a non-legal rule change by its funding platform. Josiah Zayner's mead recipe with genetically engineered yeast prompted informal FDA intervention. In public discourse, the prosecution of bio-artist Steven Kurtz resulted in well-deserved negative commentary on government overreach in the name of national security and its effects on free expression.[122] Around the time the court dismissed the government's case against Kurtz and the first DIYbio network meeting, the FBI initiated a collaborative approach, with DIY bio communities, to prevent biosecurity problems.[123] In the meantime, the plant and mead projects have produced an I-told-you-so-tinted discourse on science overreach. Perhaps the regulatory gaps are huge. Perhaps soft enforcement is proving effective. It also may be that the cautionary tales and the FBI's outreach have prompted self-regulation.[124] DIY bio's production of Codes of Ethics may evidence

[120] Josiah Zayner, *Our Statement About Beer Brewing Using Our Yeast Kits*, ODIN (Dec. 5, 2016), http://www.the-odin.com/blog/our-statement-about-beer-brewing-using-our-yeast-kits.

[121] The kit to "Genetically Engineer Any Brewing or Baking Yeast to Fluoresce" sells for $159.00 USD on The Odin's website, *Genetically Engineer Any Brewing or Baking Yeast to Fluoresce*, ODIN, http://www.the-odin.com/ge-yeast (last visited Oct. 27, 2017), and on Amazon. *Fluorescent Brewing Yeast Science Genetic Engineering Kit*, AMAZON, https://www.amazon.com/Brewing-Yeast-Genetic-Engineering-Kit/dp/B01NCU01GD (last visited Oct. 27, 2017).

[122] See, for example, an account of Marnia Johnston's experience with and response to the FBI's use of her artistic vision in constructing bioterrorism scenarios, Marnia Johnston, *Life in the Age of Biotechnology*, *in* THE MULTISPECIES SALON, *supra* note 63, at 202-05; Bolton & Thomas, *supra* note 1, at 218; Gregory Sholette, *Disciplining the Avant-Garde: The United States Versus the Critical Art Ensemble*, 112 CIRCA 50 (2005).

[123] *See* Tocchetti & Aguiton, *supra* note 69, at 827; Edward W. Lempinen, *FBI, AAAS Collaborate on Ambitious Outreach to Biotech Researchers and DIY Biologists*, AM. ASS'N FOR ADVANCEMENT ARTS & SCI. (Apr. 1, 2011), https://www.aaas.org/news/fbi-aaas-collaborate-ambitious-outreach-biotech-researchers-and-diy-biologists.

[124] The FBI's approach has included presenting a friendly and persistent presence at DIY conferences, and intentionally forming cooperative relationships with community labs and individuals. Some observers see this tactic as an effective prompt of self-regulation. *See* JOYCE ET AL., *supra* note 46, at 28; Tocchetti & Aguiton, *supra*

this.[125] Or it may be that the Codes are simply window dressing for self-regulation.[126]

The regulatory actions and the discourse that followed suggest another, more significant disciplining effect. Public discourse stayed within the narrow, prescribed set of identified harms. That is, both the official interventions and public discourse largely accepted or criticized regulatory action on bio art, fluorescent mead, and glow-in-the-dark plants in terms of risk to health, environment, or property interests. Apart from commentary about harm to free expression, most commentary accepted those risks as the understood range of potential problems that DIY bio might create.

IV. IN BIOTECH'S BACKYARD

DIY bio defines itself as distinct from and outside institutional science. Yet while DIY biologists use labs outside of academic and commercial science spaces, the preceding sections of this paper sketch the close connections between U.S. DIY bio and big bio. DIY bio's origins and many of its practitioners come from big bio.[127] DIY bio's explanatory accounts show that while DIY bio may criticize big bio, it sees itself as part of the same set of traditions; it is not ahistorical. Further, law and policy accounts assess DIY bio within the larger discourse about biotechnology, including its acknowledged benefits and risks. In fact, biotechnology, as a set of norms and practices and as a political economy, pervades DIY bio. The new frontier of DIY bio is not outside big bio. Rather, DIY bio operates in biotech's backyard.

DIY bio uses and valorizes open science, citizen science, and democratization of science. Many describe DIY bio as a community of citizen scientists. Yet DIY bio has not crafted a vision of what science should be. Instead, it has tacitly accepted the narrow, compliance-based standards that institutional science has negotiated as "oversight." The absence of a substantive vision may make DIY bio vulnerable to full annexation by biotech. Yet, as an emergent and aspirational community, DIY bio could serve as a laboratory for a new science of the people.

note 69, at 827; Howard Wolinsky, *The FBI and Biohackers: An Unusual Relationship*, 17 EMBO REP. 793, 794 (2016).

[125] *See* PREPARING FOR FUTURE PRODUCTS, *supra* note 97, at 36.

[126] Some see ethical codes as compliance tools that establish legal protection against legal risk. *See* Jathan Sadowski, *Learning on the Ethical Crutch: A Critique of Codes of Ethics*, IEEE TECH. & SOC'Y MAG., Winter 2014, at 44, 46.

[127] *See* Kelty, *supra* note 66, at 6 (suggesting that DIY bio is merely "slightly less elite than traditional science").

A. Annexation

Is the full annexation of DIY bio by big bio inevitable? If so, what is at stake? For many, the possibility of implementing democratizing goals through open science practices is at stake. "The question is therefore whether such overlapping features as transparency and openness, participation and sharing, co-production of experts and lay people, grassroots entrepreneurship et cetera add up to something like a novel, alternative paradigm of knowledge production outside of the academia and industry walls."[128] Certainly, many DIY bio enthusiasts see DIY bio as a pathway to an alternative paradigm.

Yet, skepticism abounds. It starts with my point — that DIY bio is not "outside" institutional science. Neither, perhaps, is open science. Rather, "open biology is participating in the evolution of neoliberal sciences."[129] Consider synthetic biology's version of open science. The Biobricks Public Agreement and the Registry of Standard Biological Parts are consistent with market logic. The Public Agreement and Registry do not foster public science, but a privatized commons by contract. The parts subject to the Public Agreement and Registry are subject to patent and the limited Agreement to share. The effect is to thin the patent thicket and other costs, thus facilitating downstream product development. Science and technology scholar Kaushik Sunder Rajan called this "strategic decommodification."[130] Because DIY bio is more "conventional" than "novel,"[131] it remains subject to the same forces that have become integral to big bio. These forces include the now-naturalized logic of market that neoliberalism and its legal facilitator, the Bayh-Dole Act, launched. The logic of market makes product development, patent protection, and profit seem like the only credible validation standards for research. In the skeptic's view, DIY bio will continue as adjunct to biotechnology.

The path of DIY bio in biotech's backyard or, perhaps, fully annexed to biotech, might look something like this.[132] First, DIY biology would take steps to make itself more attractive to big bio and corporate sponsors. For example, community lab Biocurious offers corporate workshops.[133] As big bio expands its presence in DIY bio, DIY bio

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128 Keulartz & van den Belt, *supra* note 55, at 2.

129 DELFANTI, *supra* note 55, at 14.

130 SUNDER RAJAN, BIOCAPITAL, *supra* note 74, at 46.

131 Giordano, *supra* note 80, at 37.

132 This is intended to illustrate, not predict.

133 *Corporate Workshops*, BIOCURIOUS, http://biocurious.org/workshops (last visited Sept. 10, 2017).

would gravitate toward institutional science's validation standards. The DIY bio success story would look increasingly like the biotech success story — entrepreneurial professional scientists, trained at elite universities.[134] The emerging DIY biology success, drawn from the same pool under the same standards as institutional science, is likely, then, to be white or Asian, and male. Second, DIY bio would shift from a community model to variations of institutional labs. Other bridges or formal relationships between institutional science and DIY bio might form to facilitate technology transfer and product development.[135] This shift would not require a rejection of open science practices. However, it might follow leads that synthetic biology and software companies like Redhat have set.[136] They use open source practices to garner efficiencies[137] and avoid costly patent thickets,[138] and their other practices reflect dominant biotechnology values, as well. Third, as DIY bio gains attention as a site of emerging technology use, investment will follow. A gold rush may ensue.[139] Fourth, policy makers will continue to propose regulatory approaches to fix the regulatory gaps. But the gaps may close or appear to as DIY bio pivots toward the market. Arrangements using a mix of liberal patent and contract practices may then seem sufficient to address public concerns, thus forestalling significant regulation.[140] While these legal arrangements might seem like a step toward open science, they would instead complete DIY bio's transformation from aspiring science-for-the-people to newest privatized frontier.

This path is not a prediction. It illustrates the point that the scenario seems plausible, even likely, in the absence of an alternative vision. Beyond declaring its embrace of open science and citizen science, DIY

134 *See* Giordano, *supra* note 80, at 18-19.

135 *See* Delgado, *supra* note 13, at 72 ("DIYbio might turn into a transfer of materialities and temporalities from public domains to science.").

136 *See* Robert W. Gomulkiewicz, *Entrepreneurial Open Source Software Hackers: MySQL and Its Dual Licensing*, 9 COMPUTER L. REV. & TECH. J. 203, 205-06 (2004) (reviewing open source software models, including Redhat's).

137 David L. Olson, Bjorn Johansson & Rogerio Atem de Carvalho, *Open Source ERP Business Model Framework*, ROBOTICS & COMPUTER INTEGRATED MANUFACTURING, Oct. 2015, at 2, http://www.sciencedirect.com/science/article/pii/S0736584515000927.

138 Feldman, *supra* note 111, at 123-24.

139 Gorman, *Patent Office*, *supra* note 96, at 428-29 (discussing the possibility and effects of a biotech gold rush that involves DIY scientists).

140 *See, e.g.*, Gorman, *Patent Office*, *supra* note 96, at 434; Keulartz & van den Belt, *supra* note 55 (explaining "rapprochement between DIY-Bio and BIG-Bio is by Biologigaragen in Copenhagen and the Danish biotech multinational Novozymes, the world's largest producer of enzymes").

bio has not articulated what science could be. DIY bio's most valorized notion of citizen science claims the ability to do science, rather than wait for the knowledge to be handed down from on high. It is premised on a participatory version of science knowledge formation. That is a bullet point, perhaps even a big bullet point. Yet it does not address key questions. On a DIY bio scale, rethinking the relationship between science and society might seem too big a task. Yet, it might be possible, as the Biopunk Manifesto asserts, to consciously challenge the role of white masculinity in the DIY bio community, and even refigure bio-individualism into something more bottom-up than top-down.

B. DIY Bio's Risk Calculus

For the most part, DIY bio has responded to concerns about potential harm to health, environment, and property in two ways. First, DIY bio has rejected claims that its activities might result in serious harm. For example, reports of recent DIY bio activities conclude that DIY biology lacks the sophistication necessary to produce significant harm.[141] Second, DIY communities claim to self-regulate. Community labs, for example, train biologists in lab safety to address concerns about uncontrolled release.[142] As mentioned, DIY bio has cooperated with the FBI's soft oversight approach.[143] DIYbio.org has facilitated draft codes of ethics issued by the United States and Europe delegations in 2011.[144] Like most industries, DIY bio claims that self-regulation precludes the need for external regulation.

Like big bio, predictive accounts of DIY bio define risk in ways that are vague and slippery and simultaneously narrow and limiting. The law and policy assessments use economic frames typical of contemporary science and technology analyses. While some assessments focus on benefit and some on risk, they rest on an understanding that the big picture analytical framework is a risk-benefit weighing. DIY bio's own response to risk assessment accepts the framework. Thus, "uncanny overlaps between the development of

[141] *See, e.g.*, GRUSHKIN ET AL., *supra* note 3, at 17-19.

[142] For example, DIYbio.org has an "Ask the Biosafety Expert" function on its website. *Ask a Biosafety Expert*, DIYBIO, http://ask.diybio.org (last visited Sept. 10, 2017).

[143] *See* DELFANTI, *supra* note 55, at 116.

[144] *See Codes*, DIYBIO, https://diybio.org/codes (last visited Sept. 10, 2017).

life-science epistemologies and the epistemologies of neoliberal economics"[145] characterize both big bio and DIY bio.

Narrow definitions of risk serve neoliberalism's agenda of assigning responsibility for risk to private entities, thus obviating the need for government intervention. Dominant understandings of health locate health and illness within the physical body and increasingly at the molecular level. DIY bio's focus on genomics maintains this body-bounded construct of health. This construct isolates the human body from any thing or relationship that is not within the body's cells and tissues; it minimizes the relevance of social and physical environment, while maintaining the salience of identity-based population to risk assessment. From the late twentieth century, personal responsibility has infused the concept of health risk, effectively identifying the individual as the primary authority for incurring or managing risk.[146] The resulting biomedical individualism filters out root causes of health risk that would justify regulation or other government intervention.[147]

The three risks — health, environment, and property — are co-constructed in the biotechnology context. In the late twentieth century, biotechnology transformed the life sciences. Biology became technology.[148] Life itself became both capital and a source of the raw materials of the biotechnology industry.[149] Property then, became the nexus between health and other life (environment). As biocapital,[150] health and environment are seen as resources — raw materials, subject to biotechnological capture and management. DIY bio taps into this process, without disrupting or challenging it.

Significant risks are ultimately those that threaten investment and capital value. More specifically, risks to health, environment, and property that cannot be privately managed are those likely to be deemed too great, unless the return on capital justifies the cost of potential regulation.

Thus far, DIY bio's approach of rejecting potential harm and claiming self-regulation signals acceptance of that calculus. That is, DIY bio has tacitly agreed to industry, law, and policy standards designed for institutional science. Those standards screen out

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145 Sunder Rajan, LIVELY CAPITAL, *supra* note 71, at 7.

146 *See* Elizabeth Fee & Nancy Krieger, *Understanding AIDS: Historical Interpretations and the Limits of Biomedical Individualism*, 83 AM. J. PUB. HEALTH 1477, 1478-79 (1993).

147 *See id.* at 1481.

148 *See* COOPER, *supra* note 74, at 126-27.

149 *See* SUNDER RAJAN, BIOCAPITAL, *supra* note 74, at 42-43.

150 *See id.* at 43.

concerns that are not economic, located within the body, or otherwise subject to discrete quantitative measures.[151] In doing so, DIY bio may be accepting the predictions about market potential, consumer harm, and biological release that those standards are designed to produce. This makes sense if the goal is solely regulation-avoidance.

If, on the other hand, DIY biologists, or some group of them, takes seriously the question of visioning science for the people, the visioning process should suggest alternatives to or expansions of the risk calculus. Developing a new framework that extends beyond risk-benefit might start by challenging the naturalization of commercialization. What might happen if commercialization became one possible means, rather than the driver? If we remove "health" from the confines of the body and expand responsibility beyond the individual, what additional factors come into consideration? In other words, what might DIY science become if the framework formed by the nexus between institutional science and neoliberalism did not apply?

C. The Ethics Gap and Its Potential

As yet, DIY bio has not expressed a commitment to ethical science activity, nor developed a robust ethos. Perhaps, its tacit acceptance of the risk-benefit framework means that its view of ethics aligns with that of institutional science. That is, it conflates a risk-benefit weighing with ethical standards or views ethics as a compliance obligation.

The risk calculus is not devoid of ethical concerns. It maps onto a standard ethical test used in institutional science. The test highlights three criteria — safety, efficacy, and autonomy.[152] That test derives from the Belmont Report's principlist framework, the FDA's drug and device approval standards, and neoliberalism's effects on the life sciences and autonomy. The Belmont Report states four principles — autonomy, beneficence, non-maleficence, and distributive justice.[153] Autonomy's application is informed consent. The non-maleficence principle is addressed by weighing risk to human health against

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[151] *See also* Sheila Jasanoff, *Technologies of Humility: Citizen Participation in Governing Science*, 41 MINERVA 223, 238-39 (2003).

[152] Compare the risk calculus with a slightly more robust ethical analysis, one which uses safety, efficacy, and autonomy as baseline criteria or a first step to be followed by rigorous consideration of distributive justice and social implications.

[153] *See* NAT'L COMM'N FOR THE PROT. OF HUMAN SUBJECTS OF BIOMEDICAL & BEHAVIORAL RESEARCH, THE BELMONT REPORT 4-5 (1979).

benefits. Benefits refer to efficacy or improvements to human health. The FDA uses safety and efficacy as its criteria in the drug and device testing requirements for market approval.[154] Efficacy, like safety or risk to human health, is narrowly defined. The FDA requires that the product work, but does not require that it work well or better than existing therapeutics. Market thinking has infiltrated these criteria. Claims that individual choice should trump agency standards in determining access to drugs have gained credence.[155] This indicates that traditional bioethics' first principle, autonomy, may now be understood as a form of free market individualism. In addition, the pharmaceutical industry has leveraged that version of autonomy to maximize the role of drugs in medical care, and the sale of particular products.[156] While big bio's risk calculus is not the end-all and be-all of ethics in institutional science, it is part of an impoverished ethical framework.

In 2011, the North American and European DIYbio Congresses issued Draft Codes of Ethics. The codes incorporate principles of open science — open access, transparency, and education; and self-regulation — safety (adopt safe practices), environment (respect the environment), and peaceful purposes (biotechnology should only be used for peaceful purposes).[157] As discussed, the North American Code has one more element — Tinkering. The Code elements are general. As my characterization suggests, the Code elements, like the Belmont Report principles, lend themselves to narrow or broad readings. Read more generously, safety, environment, and peaceful purposes might move DIY bio beyond the issue of forestalling regulation to situating science as a tool for social justice. On the other hand, open access could be read as a right to access, premised on free market individualism. Tinkering invokes the individual, as the

154 *The FDA's Drug Review Process: Ensuring Drugs are Safe and Effective*, U.S. FOOD & DRUG ADMIN., https://www.fda.gov/drugs/resourcesforyou/consumers/ucm143534.htm (last visited Oct. 15, 2017).

155 *See About Right to Try*, RIGHTTOTRY, http://righttotry.org/about-right-to-try (last visited Oct. 15, 2017). For example, state Right to Try laws ostensibly give patients diagnosed with terminal conditions the right to try drugs that have passed phase 1 testing. *FAQ*, RIGHTTOTRY, http://righttotry.org/faq (last visited Oct. 15, 2017). Thirty-seven states have Right to Try laws by legislation or ballot initiative. *Id.*

156 *See generally* JOE DUMIT, DRUGS FOR LIFE: HOW PHARMACEUTICAL COMPANIES DEFINE OUR HEALTH (2012).

157 *See supra* note 67 and accompanying text. For a detailed comparison of the differences in ordering, wording, and content of the two codes, see Kathleen Eggleson, *Transatlantic Divergences in Citizen Science Ethics — Comparative Analysis of the DIYbio Code of Ethics Drafts of 2011*, 8 NANOETHICS 187, 188-92 (2014).

nostalgic accounts show. If DIY bio is first and foremost an individualist vision of science, it stands little chance of evolving into a new understanding of science.

The open science principles suggest that DIY bio's ethos differs from big bio's, and that DIY bio is not bound by big bio's norms. Yet, open science goals do not translate to an ethics of science. Open science can be used for different goals,[158] including forms of commercial distribution that are exploitative. In addition, the Code states the elements as universal principles, which in itself is problematic.[159] Typically, dominant readings of so-called universal principles are used to maintain boundaries, and identify the out-group as non-compliant. It is very possible that the universal principles may be used to undercut the inclusive goals that open science asserts.

My comments in the previous subparts suggest, without prescriptive detail, the possibility of using DIY bio to redefine the possible relationship between science and society. Contemporary accounts indicate that DIY bio projects are typically small-scale and are relatively unsophisticated.[160] As such, DIY bio seems underpowered as a platform for re-thinking the political economy of the life sciences. What I suggest here is not that DIY biologists directly challenge or redesign institutional science. Rather, DIY bio might provide an opportunity to create, by deliberate experimentation, a set of practices that are ethos-based and originate from critical social inquiry. The most valorized explanatory accounts speak, in bits and pieces, of social justice goals. Using these as a starting point, DIY bio might craft ways of doing science that embed justice-based ethics into inquiry and practice. Ethics, then, could become not a compliance checklist, but constitutive of good science.

CONCLUSION

DIY bio is many things to many people. That is, undoubtedly, part of its appeal. What is it not, however, is separate and apart from institutional science. Its location in biotech's backyard, without a fence or substantive alternative vision of DIY bio's role, makes it vulnerable to annexation. In that scenario, DIY bio and its dream of a new science by the people might disappear. This Essay maps the relationships between DIY bio and institutional science. The mapping

158 *See* DELFANTI, *supra* note 55, at 19 (discussing use of open source and open science incorporated into new models for profit extraction).

159 Giordano, *supra* note 80.

160 *See* DELFANTI, *supra* note 55, at 115.

also critiques aspects of biotechnology that are inconsistent with DIY bio's stated goals of access and participatory knowledge formation. If DIY bio takes those goals seriously, this Essay suggests that it move beyond compliance-based thinking, and beyond experimentation using plasmids and pipettes. Acknowledging that science is a social practice, followed by scientific-social inquiry about how and why we engage with plasmids and pipettes, and willingness to experiment with new social methods of doing science, might move DIY bio out of biotech's backyard, and into society.