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Valparaiso University

WHO LET THE HUMANISTS INTO THE LAB?

Eleonore Pauwels[*]

[W]e don't assemble because we agree, look alike, feel good, are socially compatible or wish to fuse together but because we are brought by divisive matters of concern . . . .[1]

I. ENGINEERING LIFE OR ENGINEERING FOR BETTER LIFE

This quote from Bruno Latour suggests that we might be more connected to each other by our doubts, our questions, our ignorance, and the issues we care for, than by any other set of values, opinions, attitudes, and principles. The experiment is certainly easy to make. Just brainstorm over any set of contemporary issues: the financial crisis and its economic and political ramifications, the revolutions erupting in Maghreb and Machreq, the spread of genetically modified organisms in Brazil, nuclear proliferation, research around bio-energy including the development of synthetic engineered algae, controversies about acid rain, and climate change itself. Around every one of these areas of concern we see growing entanglements of passions, indignations, and controversies within a complex web of stakeholders and opponents.

These "matters of concern" bring us together in ways that create a public discourse profoundly different from the monologue offered through election polls or traditional media coverage. Matters of concern create an "agora"; they create political conditions for dissenting imaginations.[2] It is the unveiling of these matters of concern outside of

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[*] Public Policy Scholar, Woodrow Wilson International Center for Scholars, Washington D.C. The author was Co-Principal Investigator within the NSF grant SES-0925449 which was aimed at organizing a transatlantic exploratory workshop on synthetic biology, sustainability science and science & technology studies (STS). The workshop brought together researchers in the fields of STS, sustainability science and synthetic biology from Europe and the United States to initiate an open discussion on the implications of synthetic biology for sustainability research and policy. The workshop explored how to create and coordinate interdisciplinary research activities that deal with the economic, environmental, social, political, and ethical impacts and implications of synthetic biology from long-term and local-to-global perspectives. The author played a substantial role in conceptualizing the meeting as well as the related outputs.

[1] Bruno Latour, *From Realpolitik to Dingpolitik or How to Make Things Public*, *in* MAKING THINGS PUBLIC: ATMOSPHERES OF DEMOCRACY 14, 23 (Bruno Latour & Peter Weibel eds., 2005).

[2] Eleonore Pauwels, Woodrow Wilson Int'l Ctr. for Scholars, The Value of Science and Technology Studies (STS) to Sustainability Research in Europe: A Critical Approach Toward Synthetic Biology Promises, Presentation to the European Commission (May 26–28, 2009), *available at* http://ec.europa.eu/research/sd/conference/2009/presentations/21/eleonore_pauwels_-_the_value_of_science_and_technology_studies.pdf#view=fit&pagemode=none.

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the laboratory to different *publics*—including, beyond the traditional notion of "public," the natural and social sciences—that I wish to explore in this contribution.

Synthetic biology inspires controversy by claiming it can "engineer life." The claim is unprecedented among major scientific disciplines and suggests a commensurately unprecedented change to the way that people understand and value nature. By virtue of its transformative objective, synthetic biology is at the forefront of what has been termed the "Molecular Economy"[3] as this integrative science borrows techniques and methodologies from a variety of disciplines, including from genetics, molecular biology, information technology, and nanotechnology. Synthetic biology harnesses these fields in pursuit of the design and development of biological systems, frequently of high complexity, which do not occur in nature; the technology offers wide application in fields as diverse as energy, medicine, and materials engineering.[4] Although promising great scientific innovation, particularly in the spaces between traditional disciplines, synthetic biology also presents serious challenges. The emerging technology's regulation and development, its ability, or lack thereof, to control for unintended consequences, and its very identity, especially its communication and relationship with non-scientific audiences, all represent significant contemporary obstacles.

Paralleling the field's burgeoning development and applications—in particular at the interfaces between individual disciplines—new and still unimagined ethical, legal, and social dilemmas likely will emerge in the near future and significantly challenge the existing frameworks that guide scientific practice. While synthetic biology will no doubt blaze its own trail, the pathway it follows likely will track in important ways that of another pillar of the molecular economy: recombinant DNA

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[3] The concept of "Molecular Economy" relies on a two-fold phenomenon: the convergence of nanotechnology and cutting-edge biotechnologies and the subsequent promises of manufacturing at the atomic scale. David Rejeski, *The Molecular Economy*, 27 ENVTL. F. 36, 36 (2010).

[4] *See generally* MICHAEL RODEMEYER, NEW LIFE, OLD BOTTLES: REGULATING FIRST-GENERATION PRODUCTS OF SYNTHETIC BIOLOGY 18–20 (March 2009), *available at* http://www.synbioproject.org/process/assets/files/6319/nano_synbio2_electronic_final.pdf (offering additional illustrations of the application of synthetic biology); Drew Endy, *Foundations for Engineering Biology*, 438 NATURE 449, 453 (2005) (providing further information on the development of biological systems and their application); Luis Serrano, *Synthetic Biology: Promises and Challenge*, MOLECULAR SYS. BIOLOGY, Dec. 2007, *available at* http://www.nature.com/msb/journal/v3/n1/pdf/msb4100202.pdf (providing more material on the development of biological systems).

technology. Its emergence similarly sparked unimagined ethical, legal, and public health concerns, not all of which are yet resolved.[5]

Above all, in the scientific and public spheres, synthetic biology fits into a regime of innovation based on techno-scientific promises and therefore is epitomized through metaphors and narratives that involve the articulation of a vision.[6] Often this articulation takes the form of hype. Vision and hype are both types of discourse that look toward the future. The vision of synthetic biologists is a future where humans engage in the large-scale design and creation of new life forms that are exquisitely tailored for human purposes.[7] The genetic engineering of organisms and the extensive design and manufacture of living things from virtual genetic sequences blurs the line between machine and organism, life and non-life, and the natural and the artificial, and thus transforms the relationship between human kind and nature in ways that are exciting to some people but troubling for others.[8]

In the near future, there might be a need to explore the readiness of the engineering profession to address the ethical and social issues associated with our bio-technical futures. The possibility of error, human and otherwise, is why history is important when we think about

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[5] *See generally* Susan Wright, *Molecular Biology or Molecular Politics? The Production of Scientific Consensus on the Hazards of Recombinant DNA Technology*, 16 SOC. STUD. SCI. 593 (1986) (offering additional background information); Susan Wright, *Recombinant DNA Technology and Its Social Transformation, 1972-1982*, 2 OSIRIS 303 (1986) (giving a historical analysis of how recombinant DNA technology became a cornerstone of our technological landscape and the implications raised by the public-private collaboration that emerged in the aftermath).

[6] At the core of the regime of innovation based on techno-scientific promises lies the observation that Western nations have tied their visions of scientific research to that of economic competitiveness through continual technological innovation. *See generally* Brian Wynne et al., *Taking European Knowledge Society Seriously: Report of the Independent Expert Group on Science and Governance to the Science, Economy and Society Directorate, Directorate-General for Research, European Commission* (2007), *available at* http://ec.europa.eu/research/science-society/document_library/pdf_06/european-knowledge-society_en.pdf (reporting extensively on the issue); Pauwels, *supra* note 2 (delving into a more in-depth analysis).

[7] *See generally* Victor de Lorenzo, *Beware of Metaphors: Chasses and Orthogonality in Synthetic Biology*, 2 BIOENGINEERED BUGS 3 (2011) (articulating additional information on the vision of synthetic biologists); Rob Carlson, *Open-Source Biology and Its Impact on Industry*, IEEE SPECTRUM, May 2001, at 15 (reiterating the same); Michael Specter, *A Life of Its Own: Where Will Synthetic Biology Lead Us?*, NEW YORKER, Sept. 28, 2009, http://newyorker.com/reporting/2009/09/28/090928fa_fact_specter?currentPage=all (reiterating the same).

[8] *See generally* Marc Bedau et al., *Social and Ethical Checkpoints for Bottom-Up Synthetic Biology, or Protocells*, 3 SYSTEMS & SYNTHETIC BIOLOGY 65 (2009) (conducting an investigation into the extent to which some of the paradigm changes in synthetic biology could trigger ethical concerns and public distrust); Eleonore Pauwels, *Review of Quantitative and Qualitative Studies on U.S. Public Perceptions of Synthetic Biology*, 3 SYSTEMS & SYNTHETIC BIOLOGY 37 (2009) (discussing additional concerns regarding ethics and the public).

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future technologies. How well have we managed the introduction of other technologies? Have we, as a society, learned anything?

Synthetic biology thus crosses important technological frontiers, like the boundary between science and engineering, and is part of what has been called the "New Biology."[9] Such a revolution in the life sciences, its nature and goals, preferably would require parallel adaptations in societal governance, but despite the efforts of visionary researchers to overcome the divisions between the two cultures of humanities and natural sciences,[10] the New Biology has been imagined mainly under the auspices of biologists, other natural scientists, mathematicians, and engineers. A comprehensive understanding of the epistemic, ontological, and normative changes induced by this New Biology paradigm would benefit from the involvement of researchers from humanities, including social sciences and bioethics.

This Article briefly reviews the dynamics through which life sciences progressively became part of a new social contract between science and national politics, and how these dynamics shape what bio-technical futures the New Biology will inspire. More importantly, these promissory futures attribute a value to biological artifacts—a "biovalue"—and, ipso facto, transform the relationship between these biological constructs and citizens under the umbrella of a new "economy of hope."[11] This retrospective analysis will help us understand how life sciences are becoming increasingly foundational epistemologies of our times. The overall objective is to reflect critically on the extent to which this production of epistemologies influences and limits who gets to imagine, anticipate, and configure human futures, as well as to reflect critically on the matters of concern, which are emerging in the aftermath.

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[9] The "New Biology" aims at better integrating different sectors of the life sciences, engineering, and natural sciences in general, with the view of harnessing these scientific forces towards societal goals as referenced here. *See generally* NAT'L RESEARCH COUNCIL OF THE NAT'L ACADEMIES, A NEW BIOLOGY FOR THE 21ST CENTURY (2009) [hereinafter A NEW BIOLOGY].

[10] Sheila Jasanoff is noted for her work on co-production: the analytical framework of co-production directly pertains to governance issues by exploring how the objects and practices of scientific research are embedded in larger moral, legal, and social environments, and vice versa. Sheila Jasanoff, *The Idiom of Co-Production*, *in* STATES OF KNOWLEDGE: THE CO-PRODUCTION OF SCIENCE AND SOCIAL ORDER 1 (Sheila Jasanoff ed., 2004).

[11] *See* Nikolas Rose & Carlos Novas, *Biological Citizenship*, *in* GLOBAL ASSEMBLAGES: TECHNOLOGY, POLITICS, AND ETHICS AS ANTHROPOLOGICAL PROBLEMS 439, 452 (Aihwa Ong & Stephen J. Collier eds., 2005) (explaining that the two concepts of "biovalue" and "economy of hope" build on the increasing tendency to consider "life" as having a potential economic value to be regulated and compensated within a regime of bio-techno-scientific promises).

II. THE RISE OF THE "NEW BIOLOGY"

Narratives of techno-scientific progress, such as those that combine general societal "progress" with technological advances, have existed for decades in our polities. In this context, the life sciences are not an exception. Synthetic biology, with its aim to engineer biological pathways, lies at the heart of what the U.S. National Research Council ("NRC") has called *A New Biology for the 21st Century*.[12] This report recommends that a "New Biology" approach—one that depends on greater integration within biology and closer collaboration with physical, computational, and earth scientists, mathematicians, and engineers—be used to find solutions to four key societal needs. These societal needs are sustainable food production, ecosystem restoration, optimized biofuel production, and improvement in human health.

Interestingly, this vision has been reinforced by two deliberations within Congress: one was concerned with the potential implications of synthetic biology for the production of renewable energy;[13] the other dealt with the necessary steps to promote the emergence of this New Biology.[14] Similarly, the European Commission mantra, the "Knowledge based bio-economy,"[15] is intended to chart a path forward that nurtures innovation in biotechnology while avoiding serious safety, security, and ethical pitfalls, so that it will fulfil its promises as a mechanism for economic growth and competitiveness. In both the United States and the European Union, the dynamics of synthetic biology design are presented as a domain of practice through which policy actors, in partnership with public and private support, anticipate and configure human futures.

Under the heading "New Biology," biosciences and biotechnologies have begun to target social problem solving as an explicit purpose of research, producing new challenges for governance. This is actually a late chapter of an old story that started just after World War II. The

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12 A NEW BIOLOGY, *supra* note 9.

13 *See Hearing on Developments in Synthetic Genomics and Implications for Health and Energy: Hearing Before the Comm. on Energy & Commerce*, 111th Cong. (2010), *available at* http://democrats.energycommerce.house.gov/index.php?q=hearing/hearing-on-developments-in-synthetic-genomics-and-implications-for-health-and-energy (statements of J. Craig Venter, Ph.D., Founder, Chairman, and President, J. Craig Venter Institute; Jay D. Keasling, Ph.D., Acting Deputy Director, Lawrence Berkeley National Laboratory; and Drew Endy, Ph.D., Assistant Professor, Stanford University).

14 *See 21st Century Biology: Hearing Before the Subcomm. on Research & Sci. Educ. of the H. Comm. on Sci. & Tech.*, 111th Cong. (2010), *available at* http://gop.science.house.gov/Media/hearings/research10/jun29/Collins.pdf (statement of Dr. James P. Collins, Professor of Natural History and the Environment, Arizona State University).

15 *Knowledge Based Bio-Economy*, EUR. COMMISSION (Dec. 25, 2008), http://ec.europa.eu/research/biosociety/kbbe/kbbe_en.htm.

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monumental enterprises that targeted space technologies or the deciphering of the human genome are milestones that characterize how the force of science is harnessed to serve national narratives of progress in a context of global competition. Along that road, institutional avenues opened for those who study the moral and social implications of cutting-edge scientific ventures, creating a myriad of new professions including the bioethicist.[16]

Science, and life sciences in particular, thus became part of a regime of techno-scientific promises; life sciences came to be seen as an economically productive and fertile source of medical, agricultural, and environmental innovation for a world straining to overcome limits to growth. Life sciences emerged as what some have called Mode 2 science.[17] They are increasingly interdisciplinary and "applied" in order to promote social goals; they now develop within a web of stakeholders that go far beyond the usual machinery of public science to reach non-institutional actors such as private laboratories, start-up companies, and more recently, "amateurs." With this shift toward Mode 2 science, the life sciences have become progressively subject to policy narratives and strategies that aim to fuel the innovation machine and find pathways to realize the nascent techno-scientific promises.[18] More and more, responsibility and integrity in the life sciences is associated with new forms of social accountability. Hesitant attempts to educate "the public," communicate the goals of scientific enterprise, and even involve citizens in the shaping of technological progress are indications of a move toward Mode 2 science.

However, what policy actors might have forgotten on this transformative pathway is that life sciences, and obviously the New Biology, are situated at the intersection of two transformations with deep

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16 Biological & Envtl. Research Info. Sys., *Ethical, Legal, and Social Issues*, HUM. GENOME PROJECT (Sept. 16, 2008), http://www.ornl.gov/sci/techresources/Human_Genome/elsi/elsi.shtml. In resorting to bioethics as a concurrent form of policy discourse, we have opened new spaces for the politics of life in the twenty-first century. *See generally* Mariachiara Tallacchini, *Governing by Values. EU Ethics: Soft Tool, Hard Effects*, 47 MINERVA 281 (2009) (discussing such ethical issues).

17 The concept of Mode 2 science shows the extent to which changes in the modes of knowledge production have made science more embedded in society and more closely tied to its applications. *See generally* MICHAEL GIBBONS ET AL., THE NEW PRODUCTION OF KNOWLEDGE: THE DYNAMICS OF SCIENCE AND RESEARCH IN CONTEMPORARY SOCIETIES (1994).

18 Several leading science and technology studies ("STS") academics such as Sheila Jasanoff have delivered commendable analyses of the narratives that shape the interactions between science, expertise, law, and democracy, providing us with a critical approach toward the growing uneasiness that affects the relations between science and society. *See generally* SHEILA JASANOFF, DESIGNS ON NATURE: SCIENCE AND DEMOCRACY IN EUROPE AND THE UNITED STATES (2005).

ramifications for how we conceive the world: one regarding the production and assessment of knowledge and the other about the very foundations of politics.

Issues of social and policy concern, like notions of societal progress, conventionally are assumed to be knowable through science, awaiting only "technical fixes." Yet, this Article argues that the meaning and implications of progress as a policy issue are not intrinsic, but, for the most part, they are a human construction. In the case of technological governance, for example, measures for dealing with uncertainty and precaution, methods for storing and assessing data, and more generally, approaches to understanding the dynamics of the human-nature relationship are not only structured and constrained by natural realities but also are socially and normatively shaped. And when, in presidential speeches, promises are made to "restore science to its rightful place"[19] or to "unleash[] a wave of innovation that create[s] new industries and millions of new jobs,"[20] there is room for skepticism that the "fix" is just around the corner and, even more, that it will be a "technological fix."

On the political front, the increasing focus on global politics has largely changed the way we frame, conceive, and discuss politics. According to Ulrich Beck, "[w]e require new, exploratory ideas and schemata, for example, 'reflexive governance', in order to describe, understand, observe and explain the shifts now occurring in the very foundations of political action."[21] Indeed, we are witnessing a progressive weakening of the authority of nation-states, coupled with disruptive global economic dynamics, which both require rethinking and reorganizing the space and contours of collective political action. This shift has "attenuated the connections between states and citizens, calling into question the capacity of national governments" to handle their citizens' expectations.[22] Although supranational concerns, such as the demand for sustainable development or for more accountability and

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19 President Barack Obama, Presidential Inaugural Address (Jan. 20, 2009), *available at* http://www.whitehouse.gov/blog/inaugural-address. In both his Inaugural Address and State of the Union Address, President Obama made note of the importance of science to our success and the need to encourage science education and innovation. *See* President Barack Obama, State of the Union Address (Jan. 25, 2011), *in* 157 CONG. REC. H457, at H458 (daily ed. Jan. 25, 2011);; Presidential Inaugural Address, *supra*.

20 State of the Union Address, 157 CONG. REC. H457, at H458.

21 The phrase "'reflexive governance'" is used to denote the idea that there is a need for critically analyzing the dynamics of knowledge production, successes, and failures within the functioning of our large-scale socio-technical systems. *See* Ulrich Beck, *Reflexive Governance: Politics in the Global Risk Society*, *in* REFLEXIVE GOVERNANCE FOR SUSTAINABLE DEVELOPMENT 31, 31 (Jan-Peter Voß, Dierk Bauknecht & René Kemp eds., 2006).

22 *See* JASANOFF, *supra* note 18, at 14.

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equity, are gaining political salience, policy leaders and officials fear that the necessary civic confidence may fail to transpire.

These are complex challenges emerging from powerful and pervasive socio-political forces. As such, this Article argues that collective and critical approaches must be developed to understand the multiple meanings and normative dimensions of the notion of progress. There needs to be deliberate collective exploration of the socially and normatively constructed dimensions of progress, especially while defining the trajectories for research and innovation.

This retrospective analysis has highlighted how life sciences are becoming increasingly foundational epistemologies of our times. I will now turn to more specific developments in synthetic biology and reflect on the extent to which this production of epistemologies influences and limits the contours of our bio-technical futures.

III. A GLANCE AT OUR BIO-TECHNICAL FUTURES

Approximately thirty years ago, the eminent scientists Waclaw Szybalski and Anna-Marie Skala pointed to new developments in science that they suggested were giving birth to a "synthetic biology," a genetic frontier they placed beyond the mere analysis and description of existing genes to encompass the design of novel gene arrangements.[23] Although Szybalski and Skala's 1978 assessment smacked then of prognostication, developments in genetics in the past two decades have made their vision a more concrete reality. In particular, advancements in DNA synthesis and sequencing have enabled the engineering of micro-organisms from discrete, or off-the-shelf, chemical parts, even allowing scientists to "design to specification" micro-organisms capable of performing novel functions. In 2006, for example, University of California, Berkeley researcher Jay Keasling and his colleagues at Amyris Biotechnologies succeeded in engineering a microbe to produce artemisinin, an ingredient in anti-malarial drugs.[24] Another milestone was achieved in May 2010 by J. Craig Venter—an important figure in deciphering the human genome—and his research team when they successfully

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[23] *See generally* Waclaw Szybalski & Ann Skalka, *Nobel Prizes and Restriction Enzymes*, 4 GENE 181 (1978).

[24] Lynn Yarris, *An Age-Old Microbe May Hold the Key to Curing an Age-Old Affliction*, SCIENCE@BERKELEY LAB (May 30, 2006), http://www.lbl.gov/Science-Articles/Archive/sabl/2006/May/02-antimalarial.html (discussing Amyris, a leader in the emerging field of synthetic biology, which is well known for developing a strain of yeast for the large-scale manufacture of a precursor to the antimalarial drug artemisinin, for which the Asian plant source is in short supply).

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assembled the first synthetic bacterial genome and used it to take over a cell.[25]

Thus, by promising a range of applications from bioenergy to biosensors, synthetic biology promises to have a transformative impact on the ways we engineer and manufacture biological matter. In brief, this new technology could turn specialized molecules into tiny, self-contained factories, creating cheap drugs and clean fuels. The following vision, described by Rob Carlson in an article in the *IEEE Spectrum*, is a good example of the potential ontological changes we may be facing in this journey toward the molecular economy:

> In 50 years, you may be reading *IEEE Spectrum* on a leaf. The page will not actually look like a leaf, but it will be grown like a leaf. It will be designed for its function, and it will be alive. The leaf will be the product of intentional biological design and manufacturing.
>
> Rather than being constantly green, the cells on its surface will contain pigments controlled by the action of something akin to a nervous system. Like the skin of a cuttlefish, the cells will turn color to form words and images as directed by a connection to the Internet of the day. Given the speed with which the cuttlefish changes its pigment, these pages may not change fast enough to display moving images, but they will be fine for the written word. Each page will be slightly thicker than the paper *Spectrum* is now printed on, making room for control elements (the nervous system) and circulation of nutrients. When a page ages, or is damaged, it will be easily recycled. It will be fueled by sugar and light.
>
> Many of the artifacts produced in 50 years and used in daily living will have a similar appearance and a similar origin. The consequences of mature biological design and manufacturing will be widespread, and will

25 Press Release, J. Craig Venter Inst., First Self-Replicating Synthetic Bacterial Cell (May 20, 2010), http://www.jcvi.org/cms/press/press-releases/full-text/article/first-self-replicating-synthetic-bacterial-cell-constructed-by-j-craig-venter-institute-researcher/. Researchers at the J. Craig Venter Institute reported the design, synthesis, and assembly of the 1.08 million base pair *Mycoplasma mycoides* JCVI-syn1.0 genome, starting from digitized genome sequence information and its transplantation into a *M. capricolum* recipient cell to create new *M. mycoides* cells that are controlled only by the synthetic chromosome. *Id.*

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> affect all aspects of the economy, including energy and resource usage, transportation, and labor.[26]

This vision is simultaneously futuristic and foreseeable, reminding us that synthetic biology is ultimately part of a technological continuum anchored in the Enlightenment and constantly progressing through techno-scientific breakthroughs, such as recombinant DNA technologies.

Behind this impression of a continuum, however, there is something salient in the visions populating synthetic biology; through intentional biological design and manufacturing, engineered life forms—from engineered yeast to Venter's synthetic cell—are becoming "factories" on their own. In short, while laboratories have grown into "factories" through the twentieth century's collective imaginaries, today synthetic biology design turns the living cell itself into a factory. To this effect, Peter Galison remarkably analyzed how scientific practices and understandings have evolved through the nineteenth century from an Enlightenment culture seeking to unveil nature's true face, to a regime of "mechanical objectivity."[27] Scientific practices have progressed from those of intervening genial individuals to ones at ease building and supervising precise machines. The below excerpt depicts the transformations occurring within the sanctuary of the laboratory:

> Many features of the laboratory and factory coincide; they are deeply linked, and often co-produced. One can point, for example, to worker discipline, centralized power sources, and architecture—as well as shared political economic ideals of maximizing work and minimizing waste. But for our purposes here, the key commonality is the joint fascination with the reduction of individual variability through the use of machines: the production of regularity as a positive virtue that was simultaneously moral and epistemic. It was here that the quieting of the will met the discipline and self-restraint of the factory.
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> . . . .
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> . . . Scientific laboratory workers had long taken on the mantle of self-disciplined supervisors of machine. When scientists announced with pride in objectivity that they would do nothing to impose individual variation on the

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26 Carlson, *supra* note 7, at 15.

27 Peter Galison, *Objectivity is Romantic*, *in* THE HUMANITIES AND THE SCIENCES 15, 22–23 (ACLS Occasional Paper, No. 47, 2000).

> regular, uniform, and reliable output of their machines, they were testifying not only to the power of science in industry, but to the conjoint understanding of laboratory and factory.[28]

The vision of a future inhabited by "living factories" constitutes a significant and symbolic pace on the road to the molecular economy. It epitomizes and reinforces what some have called the production of "biovalue" within a "moral economy of hope":

> Biology is no longer blind destiny, or even a foreseen but implacable fate. It is knowable, mutable, improvable, eminently manipulable. Of course, the other side of hope is undoubtedly anxiety, fear, and even dread at what one's biological future, or that of those one cares for, might hold. But whilst this may engender despair or fortitude, it frequently also generates a moral economy of hope, in which ignorance, resignation, and hopelessness in the face of the future is deprecated. This is simultaneously an economy in the more traditional sense, for the hope for the innovation that will treat or cure stimulates the circuits of investment and the creation of biovalue.
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> . . . .
>
> . . . It also tries to encapsulate the ways in which life itself is increasingly locked into an economy for the generation of wealth, the production of health and vitality, and the creation of social norms and values.[29]

This transition toward increasing reliance on the production of biovalue and the techno-scientific promises that surface in the aftermath presents a kaleidoscope of interesting epistemological and ontological claims. These claims predominantly rely on metaphors borrowed from engineering imaginaries and practices. For example, the influence of materials and computer engineering helps to explain synthetic biology's dominant vocabulary, with frequent references made to bricks, building blocks, fabs, open source, debugging, and plug-ins.[30] The extensive use of engineering concepts and metaphors in the emergence of synthetic biology portrays the field as one easy to grasp and, at the same time, a

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[28] *Id.* at 33–34.
[29] Rose & Novas, *supra* note 11, at 442, 452.
[30] *See* Serrano, *supra* note 4, at 1.

very appealing and promising endeavor.[31] These mechanistic representations are anything but new in biotechnology and genetic engineering, where metaphors or images constructed to represent new processes, products, and their potential effects have widely adopted mechanistic models. Beyond the need to sketch the functioning of biological systems, these models also convey the implicit reassurance that these systems can be optimized and that they are reliable and under control; their behavior is predictable. This reassuring concept has also affected the design of regulation; mechanistic metaphors have been used as examples of mitigating uncertainties and managing safety aspects.[32] Additionally, the effects of these images and metaphors are amplified by the fact that, as with most emerging sciences, the practitioners in charge of mapping synthetic biology are also concurrently inventing it.[33]

There is no doubt that a lot of innovation will occur in the interstitial spaces between the disciplines involved in synthetic biology. But this emerging multidisciplinary smorgasbord will provide challenges in terms of the ability of new fields to regulate their own actions, anticipate unintended consequences, communicate effectively with each other and the public, and solve what some political scientists call "collective actions." There likely will be new challenges in managing ethical, social, and legal issues at the boundaries between disciplines. These emerging entanglements will give rise to questions and controversies—matters of concern—that we propose to address in the following point.

IV. MATTERS OF CONCERN AT THE BOUNDARIES BETWEEN DISCIPLINES

Through the above exploration of past and present imaginaries that have inspired synthetic biology, this Article has attempted to demonstrate how the field is emerging from a technological continuum, well epitomized by the New Biology, but also where ruptures with the past are likely to appear. Indeed, this New Biology suggests a significant reformulation of the nature and objectives of the life sciences and, ipso

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31 Specter, *supra* note 7, at 16.

32 In 1989, almost coincidentally with the release of the first U.S. patent on a complex organism, the Oncomouse, the Office of Technology Assessment ("OTA") published the report entitled *Patenting Life*. To stress the analogy between mechanical and biological inventions, and thus the inevitable patentability of organisms, the OTA showed, side by side, the two drawings accompanying, respectively, the Mousetrap (patented in 1900) and the Oncomouse. OFFICE OF TECH. ASSESSMENT, U.S. CONGRESS, NEW DEVELOPMENTS IN BIOTECHNOLOGY: PATENTING LIFE—SPECIAL REPORT, OTA-BA-370, 19 (1989), http://www.fas.org/ota/reports/8924.pdf.

33 *See* Meera Lee Sethi & Adam Briggle, *Making Stories Visible: The Task for Bioethics Commissions*, 27 ISSUES SCI. & TECH. 29, 44 (2011) (illustrating how the narrative dimension is used to convey much more than specific functions and chart a new scientific territory).

facto, reveals several ruptures. Not only is this New Biology inherently interdisciplinary—incorporating biology, engineering, and computer science—and purposefully oriented toward problem solving, but also it crosses the boundaries between discovery and invention (science versus engineering) and life and non-life. Additionally, life sciences are increasingly organized around multiple sectors and entangle the interests of institutional and non-institutional actors such as Congress, federal agencies, private laboratories (e.g., the J. Craig Venter Institute), the Do-It-Yourself Biology ("DIYBio") community, non-governmental organizations ("NGOs"), and different layers of the public through early participatory debates.

A. Rupture 1: Unity and Disunity Across Life Sciences

In its "Vision of the Future," the NRC Report envisages a drastic integration of several fields that are thought to be key in solving sustainability challenges confronting our societies:

> Given the fundamental unity of biology, it is our hope and our expectation that the New Biology will contribute to advances across the life sciences. . . .
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> . . . .
>
> . . . [T]he life sciences have the potential to provide a set of tools and solutions that can significantly increase the options available to society for dealing with problems. Integration of the biological sciences with physical and computational sciences, mathematics, and engineering promises to build a wider biological enterprise with the scope and expertise to address a broad range of scientific and societal problems.[34]

Such a vision postulates a form of unity within biology, which is contested and might therefore create a potential for fragmentation and disillusion along the road. Since the beginning of the twentieth century, and probably earlier, researchers in biology have been tussling over numerous controversies such as that witnessed by the following argument published in 1913 on the mechanisms of life:

> The camp of biologists is divided. There are those who hold that the phenomena of life involve a separate principle which does not operate in non-living matter.

34 A NEW BIOLOGY, *supra* note 9, at viii, 10.

> Another school seeks to interpret all actions or functions of the living organisms in terms of the general laws of nature which are known to apply to all matter living or dead.[35]

The controversies that animated the laboratories of the nineteenth century have barely disappeared only to be replaced by new arguments and uncertainties. Results from laboratory interactions between practitioners in synthetic biology and philosophers of science have given insight into how synthetic biologists, by making use of synthetic systems, attempt to disentangle and identify the different forms of biology specific fluctuations, their sources, and consequences for the dynamics of the system.[36] These results point out important methodological and conceptual difficulties of synthetic biology that will influence the technical success of the field. For example, theory-building in biology largely takes the form of modeling while it lacks a unifying theoretical framework to ground the modeling enterprise and its empirical evaluation. The data in this field is often limited, ambivalent, and the parameter values are difficult to measure. Therefore, models in biology often give only qualitative results, and due to the complexity of biological systems, they might convey idealized conjectures in terms of predictability and control. Laboratory observations thus show that it is crucial to better understand and analyze the important metaphorical notions often used in synthetic biology, such as "noise," "robustness," "orthogonality," "modularity," "feedback loops," "circuits," and "chassis."[37] Beyond an adoption of a better understanding of these notions by synthetic biology practitioners, there will be a need to help frame other more trivial, but still controversial, concepts such as "artificial cells" and "synthetic life."

B. Rupture 2: The Future of Biological Constructs

Ahead of concerns over predictability and optimization within biological design, further ethical and social issues can be disclosed by reflecting on the metaphors, narratives, and imaginaries of engineering life.

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35 *Vitalism and Mechanism*, SCI. AM., Aug. 2, 1913, at 82.

36 *See* Michael B. Elowitz & Stanislas Leibler, *A Synthetic Oscillatory Network of Transcriptional Regulators*, 403 NATURE 335, 335–38 (2000) (providing more information related to this research on the meaning and conditions for biological fluctuations).

37 *See* de Lorenzo, *supra* note 7, at 3 (discussing the metaphors of chasses and orthogonality); Andrea Loettgers, *Synthetic Biology and the Emergence of a Dual Meaning of Noise*, 4 BIOLOGICAL THEORY 340, 341 (2009) (giving an analysis from a philosopher of science's point of view of the meaning of noise within biological systems).

In many ways, synthetic biology represents the convergence of biology and engineering. In practice, it can be described as "biology by engineers," as both fields represent important methodological cornerstones. More technically speaking, synthetic biology affects the intertwined social and technological arrangements—what some researchers label "socio-technical systems"—that order relationships between human beings and nature. Considering all this, synthetic biology appears to stand poised to effect long-term ontological changes and reclassifications, to generate new entities, and to devise new understandings of old ones.

Going beyond the immediate realm of synthetic biology, such changes may prompt a fundamental rethinking of the identity of the human self and of its place within the existing natural, social, and political orders.[38] How does this new science test society's dominant understandings about life, nature, the role of science, and the proper order of things? What is the impact of the engineering community and its collective practices on social or biological systems? What would it mean to live in a world where humans synthesize life?

More immediate questions arise from our current technical capabilities to create novel biological entities such as the "synthetic cell."[39] What are their ethical status, potential applications, and policy implications? These novel objects are conceptualized differently—from raw data to "scientific facts"—and will be treated differently according to institutional and non-institutional settings: from the laboratory, the courtroom, and national patent offices to more diffuse structures such as DIYBio laboratories or public media.[40] As stressed by researchers in the

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38 The following articles remarkably anticipate some of the concerns likely to be raised on the future pathways of synthetic biology. *See generally* Bedau et al., *supra* note 8, at 65 (examining the unique "ethical, social and regulatory issues concerning bottom-up synthetic biology"); Peter Dabrock, *Playing God? Synthetic Biology as a Theological and Ethical Challenge*, 3 SYSTEMS & SYNTHETIC BIOLOGY 47, 47 (2009) (analyzing and criticizing the usage of the formula "playing God" with "respect to the theological concepts of creation, sin and humans as created in the image of God"); Anna Deplazes & Markus Huppenbauer, *Synthetic Organisms and Living Machines: Positioning the Products of Synthetic Biology at the Borderline Between Living and Non-Living Matter*, 3 SYSTEMS & SYNTHETIC BIOLOGY 55, 55 (2009) (analyzing the blurred border between living and non-living matter and where to "position the future products of synthetic biology that belong to the two hybrid entities 'synthetic organisms' and 'living machines'"); Rose & Novas, *supra* note 11, at 439–42 (analyzing the "biologization of politics" from the perspective of citizenship).

39 *See* Mildred K. Cho & David A. Relman, *Synthetic "Life," Ethics, National Security, and Public Discourse*, 329 SCI. 38, 38–39 (2010) (presenting the limited potential ethical and policy implications of the scientific breakthrough achieved by the J. Craig Venter Institute on May 20, 2010).

40 *See* KAUSHIK SUNDER RAJAN, BIOCAPITAL: THE CONSTITUTION OF POSTGENOMIC LIFE 12–13 (2006) (contributing another valuable analysis of this issue); Stephen Hilgartner,

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past,[41] the traditional distinction between discoveries and inventions is decisive here. What are the different models of ownership that are tacitly emerging both inside and outside the laboratory and within the public-private partnerships surrounding the development of synthetic biology? What are the implications of these different ownership models for our socio-technical systems, socio-ecological systems, and socio-economic systems? Do scientists see themselves as "discovering" something that is already in nature and "modifying" it or "inventing" totally new artifacts? This distinction is not only relevant for philosophy of science, epistemology, and patent law, but it also relates historically to different types of social contracts: fundamental research versus applied research.

Furthermore, the distinction between discovery and invention directly relates to the issues of sustainability and equity as it prescribes different paths for the appropriation of nature. To this effect, the urgency of "making something of life" with the perspective of promoting sustainability raises an array of additional potential concerns and contradictions. To date, there is no solid reason to deny or question that synthetic biology may offer an unprecedented opportunity to transform modern medicine, generate clean biofuels, and promote more sustainable infrastructures. However, several voices from the academic sector have warned that the technology may develop in an unsustainable way in regard to environmental and societal concerns. In a report published in 2009, Michael Rodemeyer identified specific cases where research processes and infrastructures used to develop synthetic biology products of first, second, and third generations will need more sophisticated risk assessment procedures than those on which U.S. federal agencies currently rely.[42] In her 2010 testimony to the U.S. Presidential Bioethics Commission, Allison Snow systematically described how ecosystems might be impacted by the environmental release—intentional or unintentional—of synthetic organisms.[43]

However, too often these concerns are marginalized and the pathway toward advancing sustainability goals is presented in a simplified light. To that effect, the following excerpt from the NRC Report is eloquent: "Fortunately, advances in the life sciences have the

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Mapping Systems and Moral Order: Constituting Property in Genome Laboratories, *in* STATES OF KNOWLEDGE, *supra* note 10, at 131, 132–33 (analyzing the value of biological constructs within public-private research partnerships in the United States).

41 JASANOFF, *supra* note 18.

42 RODEMEYER, *supra* note 4, at 8–9, 27–28.

43 Allison Snow, Dep't of Evolution, Ecology & Organismal Biology, Ohio State Univ., Speech on Benefits and Risks at the Presidential Commission for the Study of Bioethical Issues (July 8, 2010), *available at* http://www.tvworldwide.com/events/bioethics/100708.

potential to contribute innovative and mutually reinforcing solutions to reach all of these goals and, at the same time, serve as the basis for new industries that will anchor the economies of the future."[44] Current reflections and disagreements about the governance of synthetic biology make it a particularly apposite lens through which to analyze the wider uncertainties about the relationship between the molecular economy and sustainability.

C. Rupture 3: Life Sciences Outside of the Laboratory

This Article previously described the rise of the molecular economy and the status that life is acquiring as a new potential value to be negotiated in a whole range of practices of production, regulation, and compensation. These transformations were accompanied by the growth of a number of economic actors largely investing in the promises of the molecular economy.[45] These transformations have also shaped the practitioners of the life sciences themselves. As analyzed by Steven Shapin, the scientific persona itself is progressively evolving into one of entrepreneurship.[46] This, however, is only one facet of a web of private laboratories, start-up companies, and ventures developing around the promises of the life sciences. These dynamics not only reinforce the notion that the engineering of life has value (bio-value) but also nurture the related regime of techno-scientific promises supposed to advance societal goals. How these common goals and other domains of public good are actually defined and negotiated is a Pandora's box that has only occasionally been opened to public scrutiny.

As a corollary to the development of the molecular economy, anthropologists and sociologists of science have described the emergence of novel forms of "biosociality" that coalesce around a biological conception of a shared identity.[47] A good example of these nascent biosocial groupings is the DIYBio movement. With the motto of "citizen science," the DIYBio movement has linked communities electronically through e-mail lists and websites, thus developing what Nikolas Rose

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[44] A NEW BIOLOGY, *supra* note 9, at 9.

[45] *See* RAJAN, *supra* note 40, at 21–30.

[46] *See generally* STEVEN SHAPIN, THE SCIENTIFIC LIFE: A MORAL HISTORY OF A LATE MODERN VOCATION (2008).

[47] *See* PAUL RABINOW, *Artificiality and Enlightenment: From Sociobiology to Biosociality*, *in* ESSAYS ON THE ANTHROPOLOGY OF REASON 91, 91–93 (1996) (explaining how the author's concept of "biosociality" refers to a transformative condition under which both nature and scientific work in the life sciences become increasingly revealed as cultural practice).

termed "digital bio-citizenship."[48] This new digital bio-citizenry is increasingly active, playing a larger role in the enhancement of their own scientific literacy. Though the members of a "community laboratory" interact primarily through network groups and the internet, they are coming to understand and describe themselves in an increasingly biological language.

The following comment from Jason Bobe, co-founder of DIYbio.org, gives a better perspective on how this movement actively engages in the processes of self-education of active and "ethical" biological citizens: "The DIYbio community is positioned better than any other organization to develop a positive culture around citizen science and to 'set the pattern' for best practices worldwide by establishing a code of ethics, developing norms for safety, and creating shared resources for amateur biologists."[49] According to this vision, the DIY biologists are also in a constant process of re-imagining and repositioning themselves relative to those to whom they are responsible, including their co-citizens, their community, and their society. While they are developing a new kind of active bio-citizenship, they are also engaging in a new informed set of ethical practices.

These developments are not without important questions. A potential concern may be that amateurs entering the domain of biology have different ethical norms, standard practices, and expectations vis-à-vis regulators and the public. Many of them might have little training in biology, toxicology, environmental sciences, and ecology, all of which are crucial for impact assessments of new biological organisms. The practice of bio-engineering outside of the traditional laboratory potentially creates new spaces of public dispute about the implications of "tinkering" at the molecular level. It generates new objects of contestation such as the "synthetic cell," the synthetic algae growing in Californian ponds, and even the "homemade" centrifuge partially built with pieces ordered on eBay, an online marketplace. These objects of contestation only become what Bruno Latour calls "matters of concern" when they are analyzed in the light of the respective powers and responsibilities of public agencies, private laboratories and companies, bio-amateurs, and citizens themselves. Next, this Article will critically

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48 Rose & Novas, *supra* note 11, at 442; *see also* NIKOLAS ROSE, THE POLITICS OF LIFE ITSELF: BIOMEDICINE, POWER, AND SUBJECTIVITY IN THE TWENTY-FIRST CENTURY 131–54 (2007) (providing an in-depth analysis of the concept of biological citizenship).

49 *Responsible Science for Do-It-Yourself Biologists: New Initiative Launched on Biosafety*, SYNTHETIC BIOLOGY PROJECT (June 29, 2010), http://www.synbioproject.org/news/project/6424 (quoting Jason Bobe).

reflect on the possible means to unveil these matters of concern on the public stage of our technological democracies.

V. THE "TWO CULTURES" GAP REVISITED

The successive reformulations of the nature and objectives of the life sciences—described earlier in this Article—would gain from being accompanied by corresponding changes in the way synthetic biology is governed by and introduced into society. Thus far, policy responses to the development of new hybrid biological constructs have been quite limited in scope. Responses often take the form of creating ethics committees to study the implications of particular trajectories of research.[50] This contribution argues in favor of a more comprehensive approach, addressing synthetic biology's full potential to influence human futures.

Too often, the public and policy debates surrounding synthetic biology have been narrowly focused around a utilitarian calculation of its technological benefits versus its potential regulatory risks. Although the technical aspects of synthetic biology policy are immensely important, spanning from controversies on ownership to socio-technical implications to biosecurity and biosafety concerns (nobody would like the re-engineered flu virus to mysteriously escape from the lab), fundamental questions about *what* applications of synthetic biology would advance societal goals and be considered sustainable are ignored, and thus limit the discussion to the opinions of a few technocratic elites.

Some recent research initiatives, though, have started to revisit what C.P. Snow called "the Two Cultures."[51] Snow saw a growing divide between the cultures of the sciences and the humanities, a divide that continues to present an obstacle to responsible education and problem

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[50] In November 2009, the European Group on Ethics in Science and New Technologies published a year-long study of the ethical and social implications of synthetic biology. *Opinion of the European Group on Ethics in Science and New Technologies to the European Commission, Ethics of Synthetic Biology*, Opinion No. 25 (Nov. 17, 2009), *available at* http://ec.europa.eu/european_group_ethics/docs/opinion25_en.pdf. In December 2010, the U.S. Presidential Commission for the Study of Bioethical Issues published the results of its one-year study. PRESIDENTIAL COMM'N FOR THE STUDY OF BIOETHICAL ISSUES, NEW DIRECTIONS: THE ETHICS OF SYNTHETIC BIOLOGY AND EMERGING TECHNOLOGIES (2010), http://www.bioethics.gov/documents/synthetic-biology/PCSBI-Synthetic-Biology-Report-12.16.10.pdf.

[51] C.P. SNOW, THE TWO CULTURES (Cambridge Univ. Press 1993) (1960). Several influential thinkers within the field of STS have begun to revisit C.P. Snow's exploration into the divide between the sciences and the humanities. *See* Jasanoff, *supra* note 10, at 1–13 (explaining through the analytical framework of co-production how the objects and practices of scientific research are embedded in larger moral, legal, and social environments, and vice versa).

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solving. The research initiatives discussed above promote different ways in which the cultures of science—far from standing apart from the rest of the academic disciplines—are in timely conversations with the cultures of the humanities, the social sciences, the arts, and the law.

One of these initiatives is called "lab-scale intervention."[52] Nanotechnology—and to a limited extent, synthetic biology—has witnessed the development of these new modes of cross-disciplinary collaboration between natural sciences and humanities that help develop reflective scientific practices.[53] The rationale behind these collaborative ventures is to identify moments of ethical uncertainty and social controversies high upstream in the research and development ("R&D") process. These collaborations are also supposed to promote a more rapid transmission and translation of ethical and regulatory insights from the social sciences and bioethics component back to the laboratory. Encouragingly, recent studies show that it is possible to form an interdisciplinary trading zone in which a scientist and a humanist jointly explore a cutting-edge topic in nanotechnology.[54] Concretely, engineers and humanists become actively involved in the process of knowledge-exchange, better described as "knowledge-trading,"[55] with the consequent result that some engineers and humanists develop long-term interactions, building trust and enabling mutual learning by working together in hybrid collectives.

These long-term, cross-field collaborations are important for two reasons. On the one hand, such collaborations promote continuing communication "inside-and-out" the laboratory, which helps to ensure that there is mutual understanding and validation of the data produced. This refers to what Kim Fortun and Mike Fortun have described as the

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[52] The term "lab-scale intervention" refers to "new forms of interaction . . . developing [in the laboratory] between social and natural scientists to strengthen the connections between science and society." Daan Schuurbiers & Erik Fisher, *Lab-Scale Intervention*, 10 EMBO REP. 424, 424 (2009).

[53] Erik Fisher has done a great deal of research on the collaboration between natural science and humanities. *See, e.g.*, Erik Fisher, *Ethnographic Invention: Probing the Capacity of Laboratory Decisions*, 1 NANOETHICS 155 (2007); Erik Fisher et al., *Midstream Modulation of Technology: Governance from Within*, *26* BULL. SCI. TECH. & SOC'Y 485 (2006); Schuurbiers & Fisher, *supra* note 52, at 424.

[54] Michael Gorman et al., *Societal Dimensions of Nanotechnology as a Trading Zone: Results from a Pilot Project*, *in* DISCOVERING THE NANOSCALE 63, 66–68 (Davis Baird, Alfred Nordmann & Joachim Schummer eds., 2004); *see also* Fisher et al., *supra* note 53, at 486 (discussing the role of "scientists and engineers in the larger task of shaping technoscience given an increasing awareness of how societal concerns can affect innovation enterprises").

[55] The expression "knowledge-trading" assumes that a two-way learning process is possible and that both fields involved in the trading zone benefit from the exchange of knowledge.

"ethnography of ethics"[56]—assuming that reflexivity should also apply to social sciences—and "friendship with the sciences,"[57] which pictures a more positive collaborative engagement between lab scientists and embedded humanists. On the other hand, these collaborations sometimes function as forms of extended peer review, which favor cross-fertilization of knowledge.[58]

In the future, these binomes of researchers from different disciplinary cultures could act as spaces for the articulation of plural narratives and metaphors that promote the transmission of scientific, ethical, and regulatory controversies from the social sciences to the lab and vice versa. This would function as a mirror or a "reflexivity tool" for the life sciences involved in synthetic biology design and the social sciences interested in the related implications. In a "knowledge-society," this "reflexivity tool" could also be extended to the public sphere by including policymakers, NGOs, investors, and science journalists.

Ideally, such collaborative practices will require continual conversations with those outside the lab, including policymaking communities and non-institutional networks such as DIYBio and private conglomerates. Such an early dialogue between researchers and policymakers, for example, would help identify moments of safety or regulatory uncertainties in synthetic biology trajectories, or what Brian Wynne calls "epistemic other": "It is difference manifesting itself as an unknown set of realities, acting themselves as unknowns and beyond our control (but not beyond our responsibility), into a world we thought we controlled."[59] Indeed, policymaking communities do not need only a clear perspective on the challenges posed by synthetic biology to ethics and politics but must also promote, inside public policy communities, more reflexive thinking on the social and normative dimensions of synthetic biology design.

Though these cross-disciplinary attempts are still nascent, they already raise questions and require us to be critical: to what extent do these lab-scale studies lead to better capacity to critically analyze the relevance of synthetic biology promises to societal goals? To what extent

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56 Kim Fortun & Mike Fortun, *Scientific Imaginaries and Ethical Plateaus in Contemporary U.S. Toxicology*, 107 AM. ANTHROPOLOGIST 43, 50 (2005).

57 *Id*.

58 *See* Ângela Guimarães Pereira & Silvio Funtowicz, *Quality Assurance by Extended Peer Review: Tools to Inform Debates, Dialogues and Deliberations*, THEORIE UND PRAXIS, June 2005, at 74, 75–76 (2005) (Ger.) (providing more information on the concept of "extended peer review").

59 Brian Wynne, *Daring to Imagine*, INDIA-SEMINAR (May 2009), http://www.india-seminar.com/semframe.html (follow "2009" hyperlink; then follow the "Knowledge in Question" hyperlink; and then follow the "Daring to Imagine" hyperlink).

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do they allow us to collectively experiment with possible alternatives within synthetic biology? To what extent will they succeed in developing co-production among multiple disciplines and perspectives from the outset as opposed to downstream reflection upon the ethical, legal, and social implications of synthetic biology?

As a tentative answer to the above interrogations, this Article summarizes a few empirical reflections which arise from the discussions of a group of experts in sustainability science, synthetic biology, and science and technology studies ("STS") held at the Woodrow Wilson International Center for Scholars.[60] The discussions led to intense cross-field reflections and debates about the controversies of knowledge production, the impact of policymaking, cross-national differences in the way research cultures reproduce, and how emerging technologies—like synthetic biology—interact with societies. It began to shed light on potential collaborations as well as research, education, and policy initiatives at the crossroad between science, technology, and society. Key aspects and questions concerning these research initiatives and infrastructure include the inputs listed below.

A. Input 1: The Development of Long-Term Collaborative Research Groups

These research groups would collectively pursue research at the crossroad between life sciences and society, combine their findings, and cooperate with colleagues in technical, civic, entrepreneurial, and policy communities to translate research into new approaches to meet the challenges facing society. The concept of "collaboration" provoked interrogations among the participants: how do you create the infrastructures so that complex ways of thinking from different fields can meet somewhere and learn from each other? How can we think about forms of "cohabitation," where researchers from different fields could reflect together on design, options, research questions, and trajectories? Is it possible for different socio-technical imaginations to cohabit? What are the necessary conditions (institutional, epistemic, political, and cultural) to develop different forms and places for reflexivity, at different

[60] This group of experts in STS, sustainability science, and synthetic biology, organized in part by this author, gathered on May 10 and May 11, 2010, at the Woodrow Wilson International Center for Scholars with the support of the U.S. National Science Foundation. *See* WOODROW WILSON INT'L CTR. FOR SCHOLARS, TRANSATLANTIC EXPLORATORY WORKSHOP ON SYNTHETIC BIOLOGY, SUSTAINABILITY SCIENCE AND SCIENCE & TECHNOLOGY STUDIES (STS) 2 (2010) http://www.synbioproject.org/process/assets/files/6402/_draft/nsf_workshop_booklet_final.pdf (providing the full agenda and list of participants for the workshop).

levels, in different contexts and networks such as the educational systems, the policy systems, or the laboratories?

B. Input 2: Novel Training Programs at the Boundaries

Novel training programs should be created and must be able to prepare the next generation of researchers in cross-field collaborations. Collaborations in the interstitial spaces between fields appeared as one of the key features on which novel training programs should be built. Additionally, the concept of cross-field education generated new questions. What are the barriers to developing cross-field research programs within universities or research centers that would foster the type of partnerships needed in the assessment and governance of emerging technologies like synthetic biology? What are the impacts of cost structure, pressure from departments, and power structure within universities? How should we re-think the roles, goals, and practices of knowledge-producers like universities, academies, and research centers when it comes to cross-field collaborations, especially with the aim of transitioning towards more sustainable socio-technical and socio-ecological systems?

C. Input 3: The Fostering of Networks Across Sectors

Networks are needed to bring practitioners, policymakers, and scholars together to promote the co-evolution of diverse forms of knowledge. The notions of "impact," "intervention," and "channels of action from academia to policymaking" were explored in terms of opportunities for: (1) theorizing systemic ways of critically assessing problems and producing knowledge about them, and (2) institutionalizing cross-field experiments. How can channels of influence on policymaking be maximized through cross-field collaboration? What are the obstacles? How can we build on funding schemes, publications, and public infrastructure to promote cross-field collaborations?

A subsequent challenge lies in finding practical ways to integrate complex forms of interdisciplinary knowledge-making and assessment with more inclusive forms of stakeholder engagement and citizen deliberation. One option is to work with the potential of stakeholders and citizens to become independently knowledgeable agents. Each stakeholder is capable of its own reflective thinking about collective rationalities, knowledge, and responsibilities. According to the 2007 Wynne report, this may lead "to develop the cultural and political conditions under which genuine widespread civic ownership of societal

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problems like sustainability, and climate change (amongst others), and real engagement with the salient science, might be achieved."[61]

This reminds us that the ultimate challenges are to prevent high-paced technoscientific politics from withdrawing from the democratic scene (*learning is forgetting*) and to cultivate the ability to "make things public" and to turn "matters of facts" into "matters of concern." In a vibrant call, Latour invites us to give a chance to what he names "Dingpolitik":

> The point of reviving this old etymology is that we don't assemble because we agree, look alike, feel good, are socially compatible or wish to fuse together but because we are brought by divisive matters of concern into some neutral, isolated place in order to come to some sort of provisional makeshift (dis)agreement. If the *Ding* designates both those who assemble because they are concerned as well as what causes their concerns and divisions, it should become the center of our attention: *Back to Things!*[62]

Finally, at the core of this vibrant call for returning to "Dingpolitik" lies the diagnosis that the *modus vivendi* between modern democracies and technosciences has become increasingly compromised. The transformative power of technosciences reshapes societies in destabilizing ways by imposing certain norms and replacing controversies with "safe and serious" forms of knowledge which have significant ramifications in how we conceive the world. However, if in the real world scientific and technological hubris encounter the wider societal context of values and aspirations, giving birth to novel constructions of technological artifacts and socio-organizational innovations, the case of synthetic biology might be a good example of such a long "hybridization" process.

VI. CONCLUSION

My hope is that, despite the complexity and ambiguity around the visions of our bio-technical futures, the reader feels like a participant on this voyage, if not on the same boat, at least part of the same flotilla. The ultimate question is how to navigate when, in front of us, there is an array of promising, though uncertain and intricate, trajectories.

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[61] Wynne et al., supra note 6, at 18.

[62] Latour, *supra* note 1, at 23.

https://scholar.valpo.edu/vulr/vol45/iss4/5

Pauwels: Who Let the Humanists into the Lab?

This Article briefly depicted how, under the heading "New Biology," life sciences have begun to target social problem solving as an explicit purpose of research, thus producing imagined visions of our bio-technical futures and new challenges for governance. It initiated an analysis of the epistemic machineries of contemporary life sciences and, ipso facto, aimed at problematizing our systems of production of epistemologies as a subject of historical and sociological inquiry.

Eventually, through this diagnosis, we aim at unveiling the dynamics that promote the constant weaving of the life sciences with a political regime of techno-scientific promises. The overall objective is to reflect critically on who gets to imagine, anticipate, and configure human futures, as well as to reflect critically on the matters of concern that emerge in the aftermath.

As the central hypothesis, this Article then proposes that society would gain from developing new ways of assessing innovations in life sciences that are pluralist, inclusive of multiple disciplines, and, to a greater extent than at present, capable of implementing reflexive change and mutual learning, while maintaining a common focus on social robustness and sustainable, meaningful, and responsible developments. To this end, this Article began to explore the potential of using collaborative epistemic networks such as lab-scale interventions or interdisciplinary trading zones among scientists, engineers, ethicists, and social scientists/humanists upstream in the R&D process.

Finally, this Article is an invitation to challenge the assumptions behind the issues that matter, the issues that create a public around them. Though this will raise many questions some more difficult than others, we should dare to ask them. Interestingly, when it comes to science and politics, the most important controversies might be prosaic. Given that we live in social systems which are organized, for the most part, around a plurality of values, the question revolving around science and politics might become the following: are there ways for all of us to think, share, and collectively make choices without silencing any dissenting voices and imaginations?

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