ACS SyntheticBiology

Viewpoint

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Enabling a Next Generation of Synthetic Biology Community Organization and Leadership

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ABSTRACT: Synthetic biology seeks to make engineering of complex biological functions more efficient, reliable, and predictable. Advancing the process of engineering biology requires community organization and leadership. As synthetic biology matures into a globally significant enterprise, the community needs to enable a next generation of leaders to organize the field's responsible advancement. We discuss key points raised at a community meeting on these issues at SB6.0—the Sixth International Meeting on Synthetic Biology—and highlight opportunities to carry forward the conversation.

Over the past decade, activities recognized as 'synthetic biology' have emerged at the interface of a number of fields, including the biological sciences, engineering, and computation. Synthetic biology's vision focuses on developing foundational tools and processes for making biology easier to engineer.[1] For the engineering of biological functions to become routine, both technical and social change is required. Organizations and institutions need to evolve with the practice of engineering biology. As synthetic biology matures, it is critical to empower leaders who can conscientiously support continued innovation and value creation in an increasingly globalized world.

Synthetic biology's leaders often emphasize the importance of 'community' in biotechnology development. Community is both a means and an end. As a means, community is investing in shared infrastructure—technical, physical and human resources, and their linkages—to work on common problems. As an end, it is diffusion of knowledge and tools that allow a broader collection of people to contribute to, and benefit from, biology-based technologies. Further, fostering a community network of socially cognizant practitioners is noted as essential (though not sufficient) to ensuring increasingly distributed activities progress responsibly.[2] Within this vision, empowering a next generation of leaders is needed to advance higher-order successes. Synthetic biology's community vision therefore guides a movement that is as much social as it is technical.

This vision has yielded early successes. The number of people who identify as participants in synthetic biology (the community) has grown explosively.[3] Nowhere is this more evident than the international Genetically Engineered Machine (iGEM) competition (http://igem.org). Last year iGEM welcomed 215 teams and thousands of students from around the world, only nine years after the first 5 teams competed at MIT. This "iGEM generation", as noted in a recent Viewpoint in *ACS Synthetic Biology*,[3] represents the first wave of people who have never known about biology without its engineering counterpart. Many see synthetic biology as their primary professional identity.

Early signs of success are reflected across many other venues. In 2006, the National Science Foundation (NSF) established the Synthetic Biology Engineering Research Center (Synberc), a 10-year program to lay the foundation and create the culture of synthetic biology (http://www.synberc.org). Many other institutions across the globe have additionally invested in synthetic biology research programs. These investments have catalyzed a confluence of technologies that allow the manipulation of genetic functions with greater precision, scale, and speed. The first demonstrations are now appearing, such as the production of semisynthetic artemisinin,[4] the creation of genomically constructed[5] and edited[6] organisms, and precise and reliable gene expression through standardized genetic architectures.[7]

The synthetic biology community is maturing along with the technology. The field's preeminent conference, the Synthetic Biology (SB) x.0 series, held its sixth international meeting in London in July 2013. Its approximate one thousand attendees from around the world spanned academia, industry, policy, and amateur communities. New forms of public and private investment are being mobilized (*e.g.*, the DARPA Living

Special Issue: SB6.0

Received: November 2, 2013
Published: March 11, 2014

   dx.doi.org/10.1021/sb400180p | *ACS Synth. Biol.* 2014, 3, 117−120

Foundries Program). New and existing companies are entering the synthetic biology space, and trade organizations are emerging. Policy communities are directing and overseeing activities that have effects across a diverse array of institutions.[8] Many countries are laying out national strategies for biotechnology that emphasize the role of synthetic biology.[9] Together, these reflect a transition to synthetic biology being recognized as a socially, politically, and economically significant field.

Yet the widespread growth of the synthetic biology community and its vision presents critical questions. Who is now *leading* the community? How are the community's identity and boundaries—its membership, activities, values, and norms—being negotiated? Is the direction of the field creating the most value? Synthetic biology's culture of creativity, grand visions, and inclusion has fueled rapid community growth and innovation. Yet its byproduct is an increasingly diverse and distributed practitioner community vying for attention and resources, and an expanding and often ambiguous definition of what *counts* as synthetic biology. Less defined boundaries may risk diluting a meaningful focus and ability to move forward in a coherent manner.

Having early success, yet an uncertain future, the synthetic biology community needs to revisit its approach to organization and leadership. The history of scientific and technical fields provides many examples of how organization and leadership decisions shape research agendas, industries, and professions, and in turn the emergence, stability, and death of fields and industries. For instance, the world's largest professional technical organization, the Institute of Electrical and Electronics Engineers (IEEE) (http://www.ieee.org), navigated several periods of community division and merging. In synthetic biology, and biological engineering more broadly, potentially competing efforts could either set a path for community diffusion or cohesion. Biology is inherently a distributed technology, and synthetic biology will therefore require evolution of distributed forms of leadership, organization, and control to enable both its practice and oversight (i.e., governance). However, a core uncertainty—one that deserves better articulation—is how to strike a productive balance between centralized and decentralized coordination of goals and activities during the field's ongoing development.

NEXT GENERATION NEEDS

In response to these uncertainties, we organized a satellite meeting at SB6.0 to discuss challenges and opportunities in next-generation organization and leadership. The open-invitation meeting gathered 68 representatives from academic, industry, government, and amateur (DIY) organizations who self-identified as active in community leadership activities. Notably, more than two-thirds of the participants were early career practitioners: assistant professors or career equivalents. The meeting centered on identifying *needs* and *strategies* to responsibly grow, organize, and leverage the network of people and groups now working in synthetic biology.

This small yet broadly experienced group of existing and emerging community leaders discussed key elements of enabling a thriving community—and individuals within it—to best advance synthetic biology. We summarize here some of the key attributes and functions raised:

Vision. Galvanizing a growing practitioner community requires renewed strategic visions for synthetic biology and its intersection with broader advances in engineering and the life sciences. In 2003, a DARPA Information Science and Technology (ISAT) study laid out a vision for investing in biology as technology, including a 10-year "best case scenario" roadmap for synthetic biology.[10] While forecasts such as these are inevitably imperfect, their development process creates momentum and establishes mutual accountability among diverse groups critical to supporting innovation. A decade later, continued efforts are needed to cultivate an expanded and diversified set of creative ideas for where biological technologies may offer unique capacities and value.

Leadership. Developing vision into collective action across a diverse and distributed community takes smart leadership. Leading in today's global environment requires more than technical savvy; it requires the social and political astuteness to connect the goals of diverse stakeholders. Synthetic biology needs to build a cadre of practitioners who can serve as effective brokers across organizations and foster a culture of innovation and social responsibility. Developing leadership requires investments in *people*. There needs to be investment in training leaders to lead. This includes creating programs that incentivize collaboration and mentorship between junior and senior leaders, and reward community service roles.

Resources. Ultimately, people are brought together to work creatively on common challenges through reliable and sustained resources. Continued innovation within a distributed community requires directed funding streams focused on foundational tools and critical infrastructure development. Mechanisms that drive high-risk, high-reward research also need to be an essential part of national and international research strategies. Moreover, new funding and organizational models are required that (i) cross disciplines and nations, (ii) connect young investigators, and (iii) focus on scaling, development, and industrialization of synthetic biology processes and techniques. Investing in community organization of parties engaged in synthetic biology activities will be essential to the success of such efforts.

Responsibility. Ensuring the responsible development of synthetic biology requires approaches that scale beyond organizations and borders and can diffuse and adapt along with technical capacities. Positioning safety, security, ethics, environmental health, and sustainability as central challenges driving—not simply responding to—synthetic biology research and training programs is essential. iGEM's approach of creating incentives for practitioners to explore and address the "human practices" of synthetic biology serves as a powerful model. Connecting with partners that have complementary expertise and jurisdiction for responding to challenges 'beyond the bench' is also vital. In the U.S., funders such as the Alfred P. Sloan Foundation and the NSF, among others, have provided early support for dedicated research and integration of the societal aspects of synthetic biology. This work needs to continue to be supported to mature alongside the field and not revert to more reactive models.

Expectations. The synthetic biology community needs to cultivate honest expectations about the complex and often uncertain nature of biotechnology development, and develop its capacity to respond to surprises. Sustained conversation among and between practitioner communities and broad publics will be essential to fostering mutual understanding regarding our public roles and responsibilities. Accounts of the real-world successes—and failures—at the academic and industrial level, beyond hope and hype, are required to convey the public value of investments in biotechnology. Broadening expertise in the

social sciences and policy can help inform discussions. Strong communication platforms need to be built to serve as reputable sources of information within and outside the community.

Metrics. To individually and collectively make smart decisions, the community needs improved information and metrics on how biotechnology-related activities are adding up to create value, or vulnerability. It is notable that the recent U.S. National Bioeconomy Blueprint[11] acknowledges a dearth of publicly available current and future projections for the scale and economic impact of synthetic biology and biotechnology more broadly. Practitioners and policy makers need better tools for navigating an increasingly complex space of activities and surveying emergent properties of the community and the growing industry.

Venues. Most critically, synthetic biology must create sustaining venues for the community to gather and cultivate new visions and leadership, as well as develop strategies for coordinating activities and discussing goals. Organizing models need to span both local and specialized communities, and more global participation. Venues also need to include both physical and virtual spaces. The most spectacular ideas happen when someone sees connections between two different fields that no one saw as connected before. Finding the intersection of problem and possibility requires a willingness to work with partners in different fields and the venues to do so.

EMERGING OPPORTUNITIES

Beyond discussing key needs and strategies, meeting participants shared efforts they are leading to foster leadership and community among a next generation of synthetic biology practitioners. Activities discussed included new conferences, educational programs, research collaborations, industry associations, start-up accelerators, community laboratories, policy initiatives, and other diverse activities we will not attempt to fully catalogue here. With so many opportunities, a core tension was determining how best to enable a next generation of leaders to work together over many different geographic and organizational scales. Strikingly, participants identified scarce venues for developing the strategies to do so. This was especially true for early career practitioners trying to align prospective leadership roles (directly and indirectly related to synthetic biology) with their individual career plans. Here, we highlight one example effort that helped catalyze the meeting at SB6.0, noting that there are many emerging opportunities.

The Synthetic Biology Leadership Excellence Accelerator Program (LEAP) is an initiative to enable a next generation of responsible biotechnology leadership. Piloted in 2012 in collaboration with the Alfred P. Sloan Foundation, the NSF, Synberc, the Woodrow Wilson Center, and the BioBricks Foundation, LEAP is an intensive fellowship program for synthetic biology practitioners at key transitional stages in their careers—generally new professors and career equivalents. The program was designed to do three things: (i) invest in the people who will ultimately shape and help govern biotechnology development, (ii) provide them with skills, networks, and commitments to action essential to promoting responsible innovation in practice, and (iii) act as a sustaining nexus of resources and support. In essence, LEAP aims to prepare leaders to lead.

The first class of twenty LEAP Fellows are a diverse group of emerging leaders from across the synthetic biology community, including universities, national laboratories, government, industry, think tanks, and amateur laboratories. The inaugural program centered on a weeklong workshop that provided focused time for Fellows to reflect on technical and social challenges shaping their individual and collective goals. Joining them were experts from across disciplines and sectors who shared real-world lessons in leading technology development and social change. Together, they worked to outline and develop actionable strategies to address Fellows' own top challenges for the practice of synthetic biology. At the end of the week plans were presented to program partners, and Fellows subsequently developed their ideas into 'strategic action plan' white papers. A year later, the program and these plans have catalyzed many new collaborative efforts, including grants, organizations, workshops, programs, papers, and international policy input. More information can be found at www.synbioleap.org.

LEAP is designed to foster a self-catalyzing community that can empower synthetic biology practitioners to recognize their individual and collective roles in shaping the future of biotechnology development. Supporting this, and other emerging opportunities and venues, is essential to enabling a next generation practitioners seeking to build and sustain the social and technical infrastructure critical to fostering synthetic biology's responsible development.

SUMMARY

Through its focus on advancing the process of engineering biology, synthetic biology offers many opportunities to meet key challenges of the 21st century. Ushering the field forward demands attention to higher-level structure and strategy for organizing collective efforts. The synthetic biology community must implement approaches that can address ongoing tensions between distribution and cohesion in the community's leadership and organizational structure. Within this, creating sustaining venues to cultivate leadership and strategy development among a next generation of practitioners is essential. Investing in community organization and leadership creates (i) networks that connect biotechnology development on a global scale, (ii) strategies to promote responsible development in practice, and (iii) ongoing identification of priority issues that merit further engagement and dialogue among practitioners and the public. These outcomes will enable new research directions, valuable collaborations, and creativity. In turn, this will enable synthetic biology to become a driver of global innovation and societal value in years to come.

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Notes

The authors declare no competing financial interest.

ACKNOWLEDGMENTS

We thank Drew Endy, Richard Murray, Jay Keasling, Kevin Costa, Christina Agapakis, Michael Fisher, Ryan Ritterson, Nina DiPrimio, Peter Ackermann, Stephen Comello, Skye Schuchman, and Jenny Rooke for helpful advice and comments. M.J.P. gratefully acknowledges funding from the National Science Foundation (NSF) (Synberc; EEC-0540879) and the Alfred P. Sloan Foundation (2013-06-05). M.C.J. thanks the National Science Foundation (MCB-0943393), the Office of Naval Research (N00014-11-1-0363), the DARPA YFA

Program (N66001-11-1-4137), the Army Research Office (W911NF-11-1-044), the NSF Materials Network Grant (DMR-1108350), the DARPA Living Foundries Program (N66001-12-C-4211), the David and Lucile Packard Foundation (2011-37152), and the Chicago Biomedical Consortium with support from the Searle Funds at the Chicago Community Trust for support.

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