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Introduction to the Special Issue on BioFoundries and Cloud Laboratories

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1 INTRODUCTION

Biology in the 21st century presents us with tremendous potential to harness the natural world to address key global challenges. In particular, our ability to engineer new therapeutics, energy solutions, agriculture, materials, and diagnostics [1] all have been accelerated by the forward engineering of biological systems using new experimental technologies, artificial intelligence [2], bioinformatics, cloud computing, and laboratory robotics [3]. One need look no further than the rapid development of vaccines during the COVID-19 pandemic to see examples of our need and ability to respond rapidly to new global challenges using engineered biological solutions.

One of the key fields involved in this revolution is Synthetic Biology [4]. Synthetic biology attempts to modularize biology and create "functional modules" that can be composed to create new complex behaviors. It is a very interdisciplinary field drawing on techniques in bioengineering, computer science, material science, and even public policy [5].

One of the core concepts that is being developed is that of "Biofoundries" or "Cloud Laboratories" [6]. These organizations would exist to support the large-scale, reproducible, and formalized manufacturing processes required by Synthetic Biology. These organizations would act as foundries do in other disciplines. They would allow users to submit specifications and then manufacture those

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specifications reliably and effectively. This would not only standardize the process but also make the process more democratized and widely deployed [7].

This special issue presents two papers related to concepts that would be required to support a paradigm shift to a biofoundry-based manufacturing ecosystem. The first paper is entitled "Virtualizing Existing Fluidic Programs" by Caleb Winston, Max Willsey, and Luis Ceze from the University of Washington. In this work, the authors provide a framework that can be used by biofoundries to automate and systematize the movement of reagents during experiments using liquid-handling robotics. It addresses issues of abstraction, primitive operations, hardware agnostic operation, virtualization, and programmatic interfaces. Having techniques and tools like this will allow biofoundries to be more productive, efficient, and standardized.

The second paper, entitled "Building an Open Representation for Biological Protocols," is a collaborative paper with authors at a diverse set of institutions. Appropriately they have developed a model for researchers at different locations to formally capture experimental protocols. Adopting techniques like this will allow biofoundries to standardize the services they offer and allow "customers" to unambiguously specify their manufacturing needs. This is also an important example of how this community must establish initiatives to create standardized processes, data models, and algorithms. This paper presents the Laboratory Open Protocol language (LabOP) and details many of its features, syntax, and use cases.

As our ability to manipulate biology expands, it will be key to have techniques from the computing community become increasingly involved in developing the design-build-test cycle promoted by Synthetic Biology. Biofoundries and Cloud Laboratories will be key components. These papers hopefully will provide an introduction to some of these concepts and help to introduce new potential contributors to the field.

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