Notes on the Visions for Computational and Systems Biology Workshop for the Genomes to Life Program[1]

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Executive Summary

On September 6–7, 2001, the U.S. Department of Energy's (DOE) Genomes to Life program (DOEGenomesToLife.org) brought together 120 biologists and computational scientists in Washington, D.C., for the "Visions for Computational and Systems Biology" workshop. The clear conclusion of participants was that an exciting era is dawning in which the biological and information sciences will combine forces to solve critical problems facing the environment, energy production, and human health.

From the foundation of whole-genome sequences, investigators will seek to build a comprehensive and profound understanding of complex living systems. A central goal of Genomes to Life is to establish a national infrastructure to transform the tremendous outpouring of data and concepts into a computationally based, systems-level biology. Success in this quest will require powerful and revolutionary biological, mathematical, computational, engineering, and physical approaches and technologies as well as the capabilities of other federal agencies, research and educational institutions, industries, and disciplines. With this meeting, Genomes to Life took a first step in creating a common language and set of goals across the many scientific disciplines and agencies that must work together to achieve the vision.

The workshop's central theme was that the current paradigm in biology—variously described as "single gene," "reductionist," or "linear"—is not likely to be successful on its own in providing the necessary data and understanding to permit quantitative predictions or de novo design of biological systems. Instead, existing research methods will be augmented by a systems approach in which comprehensive data sets will be collected and assembled into predictive computational models. This new standard grows out of rapid advances in instrumentation for the biosciences, vast improvements in computing speeds and modeling capabilities, growing interest from physical and information scientists in biological problems, and recognition that new procedures and techniques are needed for biology to achieve its full promise in improving human well-being.

There are many challenges to the full realization of the new biology. Many experimental methods must be devised to provide comprehensive, highly accurate data sets; and necessary computational infrastructure, software, and algorithms must be formulated to use these data

[1]These are the best available notes and do not represent a verbatim or consensus document of the workshop. Remarks made by individuals are believed to be correct but have not been verified.

sets effectively. A new generation of life scientists must be trained who are facile with the methods of both experimental biology and computational science. Finally, new models for organizing, managing, and funding the biosciences must be created to enable large-scale, multidisciplinary research projects in biology. Despite these challenges, the promise of the new biology for nearly all aspects of human endeavor, combined with the enthusiasm of investigators from the physical, natural, and informational sciences, means that there are excellent prospects for rapid progress.

Introduction

On September 6–7, 2001, the U.S. Department of Energy's (DOE) Genomes to Life program (DOEGenomesToLife.org) brought together 120 biologists and computational scientists in Washington, D.C., for a workshop entitled "Visions for Computational and Systems Biology." The clear conclusion of participants was that we are on the threshold of an exciting new era in which the biological and information sciences will combine forces to solve critical problems facing the environment, energy production, and human health. From the foundation of whole-genome sequences, the aspiration of the new biology is to build a new, comprehensive, and profound understanding of complex living systems. A central goal of Genomes to Life is to establish a national infrastructure to transform the tremendous outpouring of data and concepts into a new computationally based biology. Success in this quest will require powerful new biological, mathematical, computational, engineering, and physical concepts, approaches, and technologies such as modeling, as well as the capabilities of other federal agencies. With this meeting, Genomes to Life took a first step by starting to create a common language and set of goals across the many scientific disciplines and agencies that must work together to achieve the vision. This objective can be achieved only by joining revolutionary technologies for systems-level and computational biology.

The workshop's central theme was that the current paradigm in biology—variously described as "single gene," "reductionist," or "linear"—is not likely to be successful on its own in providing the necessary data and understanding to permit quantitative predictions or de novo design of biological systems. Instead, the existing research approaches will be augmented by a "systems" approach in which comprehensive data sets will be collected and assembled into predictive computational models. The new paradigm grows out of the rapid advances in instrumentation for the biosciences, the vast improvements in computing speeds and modeling capabilities, the growing interest from physical and information scientists in biological problems, and the recognition that new approaches are needed for biology to achieve its full promise in improving human well-being. This report summarizes the key findings from this workshop. It describes long-term goals and major scientific drivers behind computational and systems biology, as well as discussions related to overcoming the existing barriers in biosciences research.