

Final Technical/Scientific Report

DOE award number: DE-SC0007069

Recipient: National Academy of Sciences

Project title: Assessing the Importance and Impact of Glycomics and Glycosciences Phase II

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Executive Summary

Glycans form one of the four basic classes of macromolecules in living systems, along with nucleic acids, proteins, and lipids. They are composed of individual sugar units that can be linked to one another in multiple ways, enabling them to form complex three-dimensional structures. In living systems, glycans are involved in myriad processes that are part of normal cellular physiology, development, and signaling, as well as in the development of both chronic and infectious diseases. Because of their ubiquity on cell surfaces, they are key components of biological interfaces and are involved in molecular recognition and signaling. They are also important molecules in cell adhesion and cell movement. Meanwhile, glycans on proteins inside cells participate in the cell's responses to incoming signals, for example by helping to modulate gene expression and protein functions. Glycan polymers such as cellulose are important components of plant cell walls. Understanding how such walls are assembled and how they can be deconstructed is fundamental to basic plant biology, but also in the development of applications such as efficient conversion of biomass into fuels. Glycan polymers derived from plants and other organisms can also serve as sources of new materials with wide-ranging applications from tissue engineering scaffolds to flexible electronic displays.

Achieving an understanding of the structures and functions of glycans is fundamental to understanding biology. The National Research Council report resulting from this project, *Transforming Glycoscience: A Roadmap for the Future*, discusses the impact glycoscience can have across health, energy, and materials science and lays out a roadmap of research goals whose achievement could help the field become a widely-recognized and integrated discipline rather than a niche area studied by a small number of specialists. Despite advances, gaps remain in the current suite of tools for investigating glycans and these tools often require expert users and facilities, presenting a barrier for many investigators. The field is poised to benefit from the pursuit of the framework laid out in the study, which incorporates not only human physiology and health but also plant, animal, and microbial research and efforts to improve tools for synthesis, analysis, data management, and other fundamental research infrastructure.

Goals, Objectives, and Accomplishments

Project Statement of Task

The National Research Council of the National Academy of Sciences will convene an ad hoc committee to assess the importance and impact of glycoscience and glycomics. Glycoscience is the confluence of scientific disciplines that study complex glycans and their relationships to other molecules. Glycans are involved in all phases of life, and an improved understanding could significantly impact diverse sectors of society, including health and energy. While genomics and proteomics have produced unparalleled discoveries that have advanced the understanding of biological processes, the picture these present is incomplete. Glycoscience and glycomics, the systematic analysis and characterization of the structure and function of glycans synthesized by a cell, tissue, or organism, could be a critical next step in building on genomics and proteomics, linking gene function to an observed phenotype, and decoding the molecular makeup of an organism.

In order to realize the potential of glycoscience and glycomics to build on genomics and proteomics and forge major new roads of discovery, the National Research Council of the National Academy of Sciences will convene an ad hoc committee to:

- Conduct an in-depth analysis of the current state of research in glycoscience and glycomics in the U.S.;
- Compare current U.S. and international research efforts in glycoscience;
- Discuss key challenges to the growth and development of the field of glycoscience and glycomics;
- Develop a roadmap with concrete research goals to significantly advance glycoscience and glycomics in the U.S., including the identification of metrics that may be used to help assess efforts to achieve these goals and objectives; and
- Articulate a unified vision for the field of glycoscience and glycomics.

The ad hoc committee will conduct workshops and other data-gathering activities to inform its findings and conclusions, which will be provided in the form of a consensus report.

The project's preliminary work schedule included 3 in-person meetings, a workshop, committee teleconferences, and production and dissemination of the report. The project successfully completed these milestones. Three in-person committee meetings and approximately 19 committee teleconferences were held over the course of the project, along with a public workshop (January 2012) and a public community discussion at the 2011 meeting of the Society for Glycobiology (November 2011).

The report resulting from this project was published through the National Academies Press and reflects the accomplishment of the goals and objectives in the statement of task. It is available for free download at http://www.nap.edu/catalog.php?record_id=13446.

The report was disseminated through briefings provided to the sponsoring agencies, at a 2-day symposium held during the August 2012 American Chemical Society national meeting, and at a discussion event at the November 2012 annual meeting of the Society for Glycobiology. It has also been featured in several articles and blogs (see list below).

Summary of Project Activities

The award was processed on July 19, 2011. An ad-hoc committee was appointed to address the statement of task and approved by the National Research Council Executive Office on August 24, 2011. The members were:

Chair:

David Walt, Tufts University

Members:

Kiyoko Aoki-Kinoshita, Soka University (Japan)

Brad Bendiak, University of Colorado, Denver

Carolyn R. Bertozzi, University of California, Berkeley

Geert-Jan Boons, University of Georgia

Alan Darvill, University of Georgia

Gerald Hart, Johns Hopkins University

Laura L. Kiessling, University of Wisconsin

John Lowe, Genentech

Robert Moon, Forest Products Laboratory, U.S. Forest Service

James Paulson, The Scripps Research Institute

Ram Sasisekharan, Massachusetts Institute of Technology

Ajit P. Varki, University of California, San Diego

Chi-Huey Wong, The Scripps Research Institute, Academia Sinica (Taiwan)

The committee held its first in-person meeting on October 10-11, 2011. This meeting included discussions with the study sponsors and an introduction to the statement of task, project goals, and timeline. It also included planning for a public data-gathering workshop to inform the committee's report.

The public workshop was held on January 12-13, 2012. Day one of this workshop discussed challenges and opportunities for glycoscience in the areas of public health, materials science, and energy, as well as

small group discussions on each of these topics. Day two of the workshop focused on key scientific challenges in glycoscience in the areas of synthesis, chemical analysis, biological analysis, and informatics and databases. Small group discussions in these topic areas were also held on day two. A second committee meeting was held following this workshop.

The committee held its final in-person meeting on March 19-20, 2012 and has also held multiple teleconferences to discuss its draft report.

The committee produced a written report. The report went through the NRC's formal review and response process and was made publicly available through the National Academy Press website on August 16, 2012.

The committee briefed sponsors as part of the NIST/FDA/NIH/NSF/DOD interagency meeting on glycoscience held at NIH on August 7, 2012.

Public dissemination of the report occurred during the symposium "Glycoscience at the Crossroad of Health, Materials, and Energy", held at the American Chemical Society National Meeting in August, 2012. The symposium showcased current glycoscience research, discussed the impacts of advances in glycoscience across health, energy, and materials science, and described a vision for future development of the field articulated in the committee's report. The symposium provided an opportunity to engage the broader chemical sciences community in celebrating the contributions of glycoscience, helped to provide increased recognition for the field and its cross-cutting significance, and allowed the committee to share the messages of its report. Symposium speakers included Carolyn Bertozzi, Laura Kiessling, Chi-Huey Wong, Samuel Danishefsky, Markus Pauly, and Ian Wilson.

Dissemination also occurred at the November 2012 meeting of the Society for Glycobiology. A discussion was held among members of the scientific community on how to move forward with the report's main messages. In particular, the discussion was centered on achieving the goals set forth in the report by involving the engagement of many members of the scientific community to further the fundamental biological and chemical understanding of glycans, help solve technical challenges in areas such as glycan synthesis and analysis, and develop new applications.

Products developed under the award

a. Publications

Transforming Glycoscience: A Roadmap for the Future. Committee on Assessing the Importance and Impact of Glycomics and Glycosciences, National Research Council. Washington, DC: The National Academies Press, 2012.

Available for free download at http://www.nap.edu/catalog.php?record_id=13446

Several publications also discussed the report, including:

- Service, R. F. 2012. Looking for a Sugar Rush. *Science*, 338:321-323.
- Borman, S. 2012. Renewed Focus On Glycoscience. *Chemical & Engineering News*, 90:28-29.
- Hart, G.W. 2012. National Academy Report Concludes that Major Investments in Glycoscience Are Required to Advance Medicine and to Ensure Mankind's Future Sustainability in both Energy and Materials. *Glycobiology* 22(11):1399–1401.
- Bowman, K. and Friedman, D. 2013. Glycoscience: Integrating a Key Macromolecule More Fully in the Curriculum. *CBE Life Sciences Education* (in press).

b. web site or other Internet sites that reflect the results of this project;

The report may be downloaded free of charge at: http://www.nap.edu/catalog.php?record_id=13446

The report was featured online on several science blogs:

- InsideScience. U.S. National Academy Report Sweet on Sugars. Available at: <http://news.sciencemag.org/scienceinsider/2012/08/us-national-academy-report-sweet.html>; Accessed Dec 18, 2012.
- ASBMB Today. Tackling challenges in glycoscience. Available at: <http://wildtypes.wordpress.com/2012/08/16/roadmap-for-glycoscience/>. Accessed January 4, 2013.

c. Networks or collaborations fostered

As part of the project, a public workshop was held in January, 2012 that sought to gather researchers from multiple areas in which glycoscience is relevant, including health, biofuels, and materials science. It provided an opportunity for different research communities to explore common challenges, tools, and needs and featured active discussion among participants to help develop new networks.

The events held at the 2011 and 2012 meetings of the Society for Glycobiology also served to foster the network of interested researchers in the field. The meetings discussed ways to engage the broader scientific community in collaborations to advance glycoscience and address some of the roadmap goals identified in the report.