IDA

SCIENCE & TECHNOLOGY POLICY INSTITUTE

Process Evaluation of the Large-Scale Collaborative Project Awards (Glue Grants) of the National Institute of General Medical Sciences (NIGMS)

Brian Zuckerman, Project Leader
Christina Viola Srivastava

July 2010

IDA Document NS D-4051
Log: H 10-000012

INSTITUTE FOR DEFENSE ANALYSES
SCIENCE & TECHNOLOGY POLICY INSTITUTE
1899 Pennsylvania Ave., Suite 520
Washington, DC 20006-3602

The Institute for Defense Analyses is a non-profit corporation that operates three federally funded research and development centers to provide objective analyses of national security issues, particularly those requiring scientific and technical expertise, and conduct related research on other national challenges.

About this Publication

This work was conducted by IDA's Science and Technology Policy Institute under contract OIA-0408601, Task OSTP-20-0002.46, "Process Evaluation of the NIGMS Glue Grant Program," for the National Institute of General Medical Sciences. The views, opinions, and findings should not be construed as representing the official position of the sponsoring organization, the National Science Foundation, or the Office of Science and Technology Policy in the Executive Office of the President.

Process Evaluation of the Large-Scale Collaborative Project Awards (Glue Grants) of the National Institute of General Medical Sciences (NIGMS)

FINAL REPORT

July 2010

Prepared for:

Juliana Blome, Ph.D.
Office of Program Analysis and Evaluation
National Institute of General Medical Sciences
National Institutes of Health

Prepared by:

Christina Viola Srivastava

Brian Zuckerman, Ph.D.

Science and Technology Policy Institute
1899 Pennsylvania Avenue NW, Suite 520
Washington, DC 20006

Foreword

This project was performed by the Science and Technology Policy Institute (STPI) of the Institute for Defense Analyses (IDA) under Contract Number OIA-0408601 in support of the National Institute of General Medical Sciences (NIGMS) of the National Institutes of Health (NIH). STPI is a federally funded research and development center that provides technical and analytic support to the Office of Science and Technology Policy and the Federal R&D community. The financial sponsor for this task is the National Science Foundation (NSF).

Table of Contents

Summary

The Large-Scale Collaborative Project Awards initiative of the National Institute of General Medical Sciences (NIGMS), commonly known as the Glue Grants program, was launched in 1999. Its purpose was to facilitate collaboration among groups of independently funded investigators in order to solve complex biomedical research problems. Between FY 2000 and FY 2008, a total of nine R24 Phase I planning awards and five U54 Phase II consortia were funded under the initiative. During the same period of time, National Institutes of Health (NIH) investment in the Glue Grants through 2008 totaled $295 million in direct costs, of which NIGMS supplied approximately $280 million.

In early 2008, NIGMS Director Jeremy Berg, Ph.D., requested that a Process Evaluation be conducted in order to assess program design, management, and implementation. The Science and Technology Policy Institute (STPI), a federally funded research and development center, was selected to conduct this Process Evaluation as an independent evaluator with guidance from an Advisory Committee consisting of senior NIGMS staff members. The Process Evaluation focused specifically on three main areas of interest: (1) program planning and design; (2) consortium-level implementation and management; and (3) program-level implementation and management. The most important source of empirical data was a series of semi-structured interviews conducted with Glue Grant Principal Investigators (PIs) and NIGMS staff members between July 2008 and June 2009. Additional data sources included internal NIGMS planning documents, the Glue Grant Funding Opportunity Announcements (FOAs), application materials, annual progress reports submitted by the PIs, NIH databases, and a book chapter authored by Glue Grants program staff members.

Program Origin and Design

The Glue Grants concept originated during a series of subcommittee meetings of the NIGMS Advisory Council held in early 1998. Participants identified a series of topics (e.g., functional biology, bioinformatics) that they believed would require new funding mechanisms designed to promote multidisciplinary collaboration. The first Glue Request for Applications (RFA-GM-99-007) was released on May 26, 1999. Its stated purpose was "to enable the solution of major problems in biomedical research and to facilitate the next evolutionary stage of integrative biomedical science," but it provided few details regarding the types of problems appropriate for solution via this mechanism.

Key program design features included the following:

- Each proposal was expected to include a large number of participating investigators, and multi-institutional collaborations were particularly encouraged.
- All topics in areas of research supported by NIGMS were potentially eligible.
- A mandatory Phase I planning award was required prior to submission of a more extensive Phase II application. Phase I awards used the R24 mechanism, providing a maximum of $25,000 in direct costs for a maximum of one year.
- Phase II consortium awards used the U54 Specialized Center (Cooperative Agreement) mechanism. The maximum was $5 million in annual direct costs for a maximum of five

years with eligibility for one competing renewal. After 2004, there was a shift from a fixed annual funding level of $5 million per year in direct costs to a five year total of $25 million, with a maximum of $7 million available in any given year.

- Consortium funds were to be used to extend the already-funded research efforts of individual investigators in order to form an integrated consortium; requests for funds to support new individual research projects were excluded.
- Funds could be requested for three types of Collaborative Project Resources:
    - Core resources were envisioned as a means of developing new technologies or standardizing data across research teams. Each application was required to include an administrative core and a core resource devoted to information collection, analysis, and dissemination.
    - Bridging projects were originally intended to support collaboration enhancement activities in the laboratories of participating investigators to assist them in integrating their R01-funded research with the work of the consortium. Beginning with the 2002 RFA, the definition was expanded to include data collection, research, or technology development projects that would serve the needs of the consortium as a whole as well as to include technology validation or laboratory exchanges between participating investigators to transfer technology among investigators.
    - Pilot projects were intended to support investigators who did not themselves have independent support or to involve investigators with necessary skills who were new to the field in the consortium's activities.
- Responsibility for consortium leadership was to be shared by the PI and a Steering Committee composed of participating investigators and including one NIGMS program staff member as a voting member.
- Each Glue Grant consortium was required to convene an External Advisory Committee in order to provide strategic advice to the PI and Steering Committee on an annual basis.

The Glue Grants solicitation was re-issued in 2001 (RFA-GM-01-004), 2002 (RFA-GM-02-007), 2004 (PAR-04-128), and 2007 (PAR-07-412). The changes to the definition of bridging projects and flexibility of annual maximum award size described above were the most significant adjustments to program design over time.

Consortium-Level Implementation

The Alliance for Cellular Signaling (AfCS) was the first consortium to receive Phase II funding in 2001, and it was followed by the Cellular Migration (Cell Migration) consortium, the Consortium for Functional Glycomics (CFG), and Inflammation and Injury (Inflammation) consortium. The fifth consortium, Lipid Metabolites and Pathways Strategy (LIPID MAPS), received Phase II funding in 2003. The Cell Migration consortium, the CFG, the Inflammation consortium, and LIPID MAPS successfully competed for five year renewals, while the AfCS received three years of funding to complete current work and phase down operations gradually after the competitive renewal.

Key differences among the five funded consortia with respect to implementation include the following:

- Total number of collaborators participating (defined as institutions receiving consortium funds) varied from a low of eight (AfCS) to a high of 22 (Inflammation).

- Three of the five consortia incorporated specific mechanisms to involve investigators who did not receive direct monetary support from the award:
    - The AfCS recruited over 800 members with expertise on particular molecules to develop and review "Molecule Pages" for the consortium's Web site.
    - The CFG recruited over 400 investigators with funded research programs falling within the scope of the consortium to provide data to the consortium in exchange for receiving access to consortium resources. Participating investigators were organized into subgroups to facilitate networking and coordination and to represent the interests of the participating investigators to the Steering Committee.
    - The Inflammation consortium's Membership Program was established to facilitate sharing of clinical data and other outputs with interested investigators. After registering with the consortium, members became eligible to request access to the de-identified clinical datasets after providing evidence of approval from their local Institutional Review Boards.
- Each of the five funded consortia can be regarded as addressing a complex biological problem, but there were substantial differences in the strategies they employed to address these questions:
    - The AfCS and the Cell Migration consortium each aimed to develop a comprehensive and holistic understanding of a cellular process. Both consortia organized their cores as a set of integrated but semi-autonomous research initiatives, each of which was essentially working on its own sub-question or perceived barrier to progress.
    - The Inflammation consortium and LIPID MAPS aimed to coordinate, standardize, and harmonize research methods across their respective fields to pool information from multiple sources. As a multi-site clinical trial, the Inflammation consortium aimed to collect samples and data from a geographically diverse patient population and analyze them to gain an integrated understanding of a biological process. Key challenges included developing consensus standards of care and sampling methods. Similarly, LIPID MAPS aimed to collect similar information about the role and function of various classes of lipids in the responses of macrophage cells (RAW264.7 cells, thioglycolate-elicited primary macrophages, and bone marrow-derived primary macrophages) to a variety of stimuli. Facilitating access to mass spectrometry technology, which had not previously been widely used to study lipids, and developing consensus on lipid nomenclature were key functions of the consortium. An interesting difference between Inflammation and LIPID MAPS, however, is that their core structures were organized differently. While the Inflammation cores were organized vertically as a "pipeline" for collecting and processing data, the LIPID MAPS Cores were organized horizontally, with cores studying each class of lipids conducting their own analyses.
    - The CFG employed a variety of different strategies. The research-driven subgroups, especially as re-organized after the renewal, seem to reflect a problem-driven approach similar to the AfCS and the Cell Migration consortium. Other elements of the consortium—especially the contribution of data from over 400 members and the efforts to develop consensus nomenclature for lipids—

resemble a standardization approach similar to Inflammation and LIPID MAPS. A third strategy, which appears to be unique to the CFG among the funded Glue Grants, was to establish service-oriented cores that analyzed samples using high-throughput technologies for community members upon request and also produced resources such as knockout mice for the community.

- The AfCS was the only consortium to attempt to incorporate pilot projects, and only three of the five consortia incorporated bridging projects (AfCS, CFG, and LIPID MAPS). In all three cases, the primary goal of the bridging projects was either to develop specific technologies or to overcome technical bottlenecks.
- The CFG appears to have enthusiastically embraced the use of milestones as a management tool, electing to set and review milestones quarterly.

NIGMS Management Processes and Program-Level Implementation

Because the Glue Grants were awarded in phases, applications were reviewed at the beginning of Phase I, the beginning of Phase II, and at the competing renewal for Phase II. As with other large-scale NIGMS awards, the Glue Grant applications underwent peer review by a Special Emphasis Panel (SEP) followed by individual review by the NIGMS Advisory Council at each stage. Issues and challenges identified during review include the following:

- Phase I applications may not have been sufficiently detailed for reviewers to adequately judge the merit of the concept being proposed.
- For some fields, extraordinary effort was required to identify peer reviewers with sufficient expertise who did not have conflicts of interest with any of the proposed consortium members and who expressed willingness to keep an open mind about the Glue Grants as a mechanism.
- The size and complexity of the Glue Grant applications appeared to influence priority scores in that additional components introduced additional opportunities for reviewers to identify major or minor flaws.
- Conflicts of interest were also an issue during review of the Glue Grant applications by Council, and it was often the case that the Council members with the most knowledge and experience in the fields relevant to the application being discussed did not participate because of conflicts of interest with institutions participating in the proposed consortium.
- Review of competing renewal applications was particularly challenging because there were no standards to help the panels to judge whether progress made during the first few years had been sufficient to justify continuation of the cooperative agreement; this was described as a particular concern for consortia that experienced delays in “ramping up” operations during the first few years.

The Glue Grants were unique at NIGMS in that Council received a summary of progress by each consortium every year. In most years, the Program Director submitted a two-page report to Council describing progress. In the third year, however, the PIs were brought before Council to make brief reports in an open session. At the time of the Process Evaluation, additional administrative review had been requested by Council for each of the three active Glue consortia that had reached the midpoint between competitive renewal and the end of the ten year funding period. Administrative review procedures were characterized differently for each of the three consortia:

- The Cell Migration review began with the consortium submitting a document to a panel of reviewers that described the consortium's progress toward its milestones during the previous two years. Next, the consortium's annual meeting was held at NIH, and several of the reviewers attended the meeting and had the opportunity to interact with attendees. Afterward, the reviewers developed a set of written questions for the consortium, and the consortium responded in writing. Finally, the reviewers provided a written report and made recommendations for the future that were presented to the Council.
- The CFG administrative review process was conducted by a panel of external reviewers who extracted information from the consortium's annual reports and prepared a written evaluation report for Council. No input from the consortium was sought, and the PI stated that he was unaware that the process was underway until the panel's evaluation had already been submitted to Council.
- Review for the Inflammation consortium was not yet complete at the time of the Process Evaluation, but it had so far consisted of the NIGMS Council itself posing a set of questions to the consortium, and the consortium had responded in writing.

Most interviewees described relatively little involvement by NIGMS program staff in the scientific and day-to-day management of the cooperative agreements. Most PIs interviewed described NIGMS program staff members as generally helpful and insightful voices on their respective Steering Committees who were especially helpful in clarifying the Institute's expectations, opinions, and requirements. Several PIs also confirmed that NIGMS program staff members effectively facilitated communication between the consortium and the larger research community. However, one consortium reported having been at odds with its Program Director on a number of different management issues, especially after the competitive renewal.

Dr. Michael Rogers, the Director of the Division of Pharmacology, Physiology, and Biological Chemistry (PPBC), is the coordinator for the Glue Grants program. In this capacity, Dr. Rogers mentors and advises program staff members involved with the Glue Grants. He also initiated and continues to lead monthly meetings with the Glue program staff that are referred to as the "G6" meetings. However, neither Dr. Rogers nor the "G6" group have authority to set or enforce policy across the program; consortium-level management decisions remain in the hands of the Program Director and/or more senior staff members in the Division to which the consortium is assigned.

Findings

Findings were developed in each of three categories corresponding to areas of interest for the evaluation: overall program planning and design (Findings 1 and 2); implementation and management at the level of the consortium (Finding 3); and implementation and management at the level of the program (Findings 4 through 7).

Finding 1: The program-level objectives of the Glue Grants were not clear.

Two program objectives were identified in the original (1999) Glue solicitation: (1) "to enable the solution of major problems in biomedical research"; and (2) "to facilitate the next evolutionary stage of integrative biomedical science." Of the two, problem-solving was more straightforward as an objective, but the meaning of neither "problem" nor "solution" was entirely clear in the context of the solicitation. With respect to the second objective, integrative activities were clearly important to program planners, but it was less clear what specific outcomes were to be achieved through integration. At least one interviewee suggested that the program-level objectives were

deliberately left open to interpretation so that objectives could be self-defined by applicants. Regardless of intent, however, the Institute's decision to state program objectives that were open to interpretation had consequences for management at the consortium and program level.

Finding 2: The program design as implemented was not entirely consistent with either of the stated program objectives.

The structure of the program as implemented was not entirely consistent with either of the program objectives described in the solicitations, let alone both. With respect to problem solving, if NIGMS actually intended for the Glue consortia to be exclusively dedicated to solving research problems, the "gluing" approach was not obviously the most direct and efficient means of achieving that goal. Facilitating collaboration between groups of independently funded researchers does not guarantee that their goals and incentives will be aligned with any larger vision or overarching set of questions. On the other hand, if integration was the primary objective, it is likely that the program design could have been more effective if it had focused on a particular mechanism by which integrative activities were expected to result in progress for a particular field and/or the biomedical research enterprise as a whole. Examples of possible mechanisms include:

- Overcoming specific technical barriers or bottlenecks that are currently impeding progress;
- Identifying and filling gaps in strategic research agendas in order to reach common goals more quickly and efficiently;
- Adapting concepts, tools, and technologies from other fields to open new frontiers;
- Harmonizing methods, standards, and reporting practices and centralizing data collection to accommodate analysis of large-scale patterns;
- Pooling the resources and expertise of multiple laboratories in order to address questions that are too large for a single group to tackle on its own.

Various components of the program as implemented appeared to be consistent with several of these mechanisms for achieving progress through integration, but the program design overall was not optimized for any of them.

Finding 3: In the absence of clear program objectives, the Glue consortia were structured to meet needs and priorities as determined at the consortium level.

Awardees appear to have designed the Glue consortia to meet perceived need in their own fields. One PI stated that he had simply proposed to do as much to move his field forward as he felt could reasonably be accomplished for $5 million per year in direct costs, while another emphasized the ten year time frame as the most important constraint on consortium design. As might be expected, there were substantial differences in how the various consortia framed their objectives as well as how they organized and interpreted the structural elements of the program (e.g., cores, bridging projects). Some interviewees, particularly the PIs, identified the flexibility of the program with respect to both objectives and structure as a key strength.

Finding 4: The Glue Grants functioned as a funding mechanism rather than a cohesive program or initiative.

As implemented by NIGMS, the Glue Grants functioned as a funding mechanism rather than a true program or initiative with its own vision, goals, and management structure. Interviews with individuals who participated in the planning stages made it clear that the original concept was

motivated in part by a desire to experiment with alternatives to the R01 Research Project Grant, which, at the time, made it difficult to support collaborative projects. Instead of creating a unified management structure for the Glue Grants as a program, each cooperative agreement was placed into the portfolio of an existing NIGMS Division with relevant interests. The program staff members from different Divisions who were assigned to Glue Grants did meet regularly, and senior NIGMS leaders were involved in those discussions as needed. However, neither the "G6" group nor any central authority below the level of the Institute Director was authorized to set or enforce policy for the Glue Grants as a group. Instead, responsibility for decision-making was retained by the Program Directors and their respective Division Directors with input from the program staff.

Finding 5: The ten year timeframe posed a variety of challenges.

The Glue Grants were awarded for an initial term of five years with the possibility of one and only one competing renewal. Interviewees described a variety of challenges related to the ten year time frame and the sunset provision. These included: (1) the flat annual budget limit despite resource needs that varied over the course of ten years; (2) declining incentives for investigators to adhere to specific aims after renewal; and (3) uncertainty regarding post-award sustainability of collaborations and resources built by the consortia. Evidence received after the interviews were complete indicates that the Institute was actively making plans to address the sustainability issue towards the end of 2009.

Finding 6: Significant challenges for peer review were encountered because of the size and scope of the Glue Grants.

Several serious challenges for review of the Glue Grant applications were described by interviewees. At Phase I, SEPs may have been asked to review multiple proposals and to evaluate the importance and plausibility of concepts without sufficient information. At all phases of peer review, staff members had to expend considerable (and sometimes extraordinary) effort to recruit reviewers with appropriate expertise and seniority who were free of conflicts of interest and strong bias or pre-conceptions about the Glue Grants. Once assembled, the SEPs faced challenges in fairly assessing applications with an unusually large number of components. Competing renewal applications were even more difficult to assess because there were no accepted standards for how much progress it was reasonable to expect from the Glue consortia after only a few years of operating at full scale. After peer review, Council faced challenges in deciding how to interpret all of the input it received regarding the merit of each application, and these challenges were often made more daunting by the absence of the Council members with the most knowledge and experience in the relevant areas of science, because these individuals were most likely to have conflicts of interest with the application under consideration. It is worth noting that the most serious challenges described above arose from the size, scope, and nature of the Glue Grant applications rather than from any inappropriate actions on the part of NIGMS staff members, the SEPs, or Council. Evidence indicates that appropriate efforts were made by all participants to meet the unique needs of the Glue Grants while working within the confines of NIH requirements for peer review.

Finding 7: The Institute's approach to management of the Glue cooperative agreements was not clearly defined.

Two potential problems were identified in the Institute's approach to managing the Glue cooperative agreements. The first was that mechanisms for ensuring that the consortia and

NIGMS developed and maintained a common vision for the objectives and strategic direction of the consortia were inadequate. Interviewees tended to raise this concern most often by observing that they received inconsistent feedback from NIGMS regarding the relative importance of creating resources for and involving the entire research community as opposed to solving a complex biological problem.

The second potential problem with the Institute's management approach was a lack of clarity surrounding the role for NIGMS in consortium management. Although the Institute clearly had the authority to involve itself to the extent it saw fit, truly active direction by program staff of extramural research is not the cultural norm at NIGMS. The default approach to management of the Glue Grants appears to have been mostly passive, with NIGMS program staff members providing advice and answering questions but leaving scientific direction and day-to-day management to the PIs and Steering Committees. In the case of one consortium, however, an escalating series of disagreements after the competing renewal seems to have resulted in a shift to increasingly active involvement in consortium management by program staff.

I. Introduction and Evaluative Approach

A. Introduction

The Large-Scale Collaborative Project Awards initiative of the National Institute of General Medical Sciences (NIGMS), commonly known as the Glue Grants program, was launched in 1999. Its purpose was to facilitate collaboration among groups of investigators with existing research funding to solve complex biomedical research problems. Between FY 2000 and 2008, a total of nine Phase I planning awards and five Phase II consortia were funded. During the same period, NIGMS invested approximately $280 million in the Glue Grants program, and four other NIH Institutes and Centers plus the Office of the Director contributed an additional $15 million.[1]

In early 2008, NIGMS Director Jeremy Berg, Ph.D., requested a Process Evaluation of the Glue Grants to assess program design, management, and implementation. The Science and Technology Policy Institute (STPI), a federally funded research and development center, was selected to conduct this Process Evaluation under contract to NIGMS. STPI was tasked with conducting an assessment of the program from the standpoint of an independent evaluator with no stake in the outcome of the Process Evaluation. An Advisory Committee composed of senior NIGMS staff members reviewed and approved the study design and data collection instruments and provided input as needed. Advisory Committee members included:

- Dr. Juliana Blome, Chief, Office of Program Analysis and Evaluation;
- Dr. Catherine Lewis, Director, Division of Cell Biology and Biophysics;
- Dr. Rochelle Long, Chief, Pharmacological and Physiological Sciences Branch, Division of Pharmacology, Physiology, and Biological Chemistry;
- Dr. Michael Rogers, Director, Division of Pharmacology, Physiology, and Biological Chemistry.

B. Evaluative Approach

The first step in the evaluation design process was to develop a preliminary program logic model describing program inputs; supported activities; and their intended outputs, outcomes, and impacts (see Appendix A). During the logic modeling process, two primary target outcomes were identified for the Glue Grants: (1) facilitating multi-institutional research collaboration; and (2) finding solutions to complex biological problems. Early evidence indicated that these outcomes were to be achieved through large-scale cooperative agreements that would "glue" together groups that already had research funding to form research consortia, but there was considerable ambiguity with respect to the intended theory of action (the mechanism through which supported activities were expected to generate intended outcomes). Investigating the origins and implications of this potential ambiguity in the program logic became one of the focal areas for the

[1] In order of contribution size: National Institute of Allergy and Infectious Diseases (NIAID), $9.6 million; National Cancer Institute (NCI), $5.0 million; National Center for Research Resources (NCRR), $160,000; Office of the Director (OD), $70,000; and National Institute of Dental and Craniofacial Research (NIDCR), $3,000.

Process Evaluation. The logic modeling process also suggested that management and implementation processes should be examined at both the program and consortium levels.

A literature review was conducted to identify additional process issues with potential relevance for programs intended to support large-scale collaborative research. Borrowing from a multi-level framework for assessing large-scale, multi-institution research collaborations developed by Boardman and Bozeman,[2] the review of literature focused on: (1) processes and management attributes at the consortium level; and (2) attributes of the NIGMS large-scale projects awards program. Factors identified in the literature as potentially significant at the consortium level include the following:

- *Planning.* Planning has been demonstrated to be important to multi-institution collaboration success, specifically the coordination of goals across participants and stakeholders.[3, 4, 5]
- *Structure and rules.* Structure and rules have been shown to be important for explaining why collaborations persist rather than disintegrate into the pursuit of disparate activities and goals of the self-interested individuals and organizations that engage in collaboration.[6, 7]
- *Communication.* Communication has been demonstrated to play a significant role in the success of inter-organizational collaborations.[8, 9, 10, 11] Communication is enhanced with the geographical proximity of the collaborating organizations.
- *Geographic distribution.* There can be a negative relationship between the geographic distance separating collaborators and the frequency with which they collaborate.[12, 13]

---

[2] C. Boardman and B. Bozeman (2006). "The Emergence and Impact of 'Organic' Research Collaboration." *Economics of Innovation and New Technology*. 15(1), 51-69.

[3] F. Scharpf (1978). "Interorganizational Policy Studies: Issues, Concepts, and Perspectives." In K. Hanf and F. Scharpf (Eds.), *Interorganizational Policy Making*. London: SAGE.

[4] B. Gray (1989). "Collaborating: Finding Common Ground for Multiparty Problems." San Francisco: Jossey-Bass.

[5] M. Landau (1991). "Multiorganizational Systems in Public Administration." *Journal of Public Administration Research and Theory*, 1, 5–18.

[6] M. Crozier and J. Thoenig (1976). "The Regulation of Complex Organized Systems." *Administrative Science Quarterly*, 21, 547–570.

[7] H. Leblebici and G. R. Salancik (1982). "Stability in Interorganizational Exchanges: Rulemaking Processes of the Chicago Board of Trade." *Administrative Science Quarterly*, 27, 227–242.

[8] E. Von Hippel (1988). *The Sources of Innovation*. New York: Oxford University Press.

[9] M. R. Lind and R. W. Zmud (1995). "Improving Interorganizational Effectiveness Through Voice Mail Facilitation ff Peer-to-Peer Relationships." *Organization Science*, 6(4), 445–461.

[10] L. Y. Doz (1996). "The Evolution of Cooperation in Strategic Alliances: Initial Conditions or Learning Processes?" *Strategic Management Journal*, 17, 55–83.

[11] M. D. Santoro and P. A. Saparito (2003). "The Firm's Trust in its University Partner as a Key Mediator in Advancing Knowledge and New Technologies." *IEEE Transactions on Engineering Management*, 50(3), 362–373.

[12] R. E. Kraut, C. Egido, and J. Galegher (1990). "Patterns of Contact and Communication in Scientific

Moreover, there is evidence that collaborators who work in the same building or laboratory are more productive than those who use electronic media to compensate for geographical distance.[14, 15, 16] Geographic co-location can also enhance inter-partner trust[17] and learning.[18, 19]

Program-level attributes identified as potentially significant include:

- *Resources.* Resources are important for bringing together "sticky and difficult to imitate" research capacity that is otherwise unattainable.[20] Resources here entail human capital as well as research funds and equipment.
- *Role clarity.* Role clarity refers to how well the program communicates the core functions and goals for research collaborations, which helps to avoid research priority and goal conflicts among collaborating organizations and enhances the productivity of the collaborations.[21]
- *Culture.* Culture is just shorthand for "the distinctive or unique features of the organization."[22] These characteristics—such as the basic assumptions of an organization[23]—have been demonstrated to lead to barriers to scientific productivity and future collaborations among the partners.[24]

Research Collaborations." In J. Galegher, R. E. Kraut, and C. Egido (Eds.). *Intellectual Teamwork: Social and Technological Foundations of Cooperative Work*. Hillsdale, NJ: Lawrence Erlbaum Associates, 149–171.

[13] G. M. Olson and J. S. Olson (2002). "Mitigating the Effects of Distance on Collaborative Intellectual Work." *Economics of Innovation and New Technology*, 12(1), 27–42.

[14] J.S. Katz (1993). "Bibliometric Assessment of Intranational University-University Collaboration" Ph.D. Thesis. Science Policy Research Unit, University of Sussex, Brighton.

[15] L. M. Covi, J. S. Olson, and E. Rocco (1998). "A Room of Your Own: What Do We Learn About Support of Teamwork from Assessing Teams in Dedicated Project Rooms?" In N. Streitz, S. Konomi, and H. J. Burkhardt, (Eds) *Cooperative Buildings*. Amsterdam: Springer-Verlag, 53–65.

[16] S. Teasley, L. Covi, M. S. Krishnan, and J. S. Olson (2002). "Rapid Software Development Through Team Collocation." *IEEE Transactions in Software Engineering*, 28(7), 671–683.

[17] M. D. Santoro and P. A. Saparito (2003). "The Firm's Trust in its University Partner as a Key Mediator in Advancing Knowledge and New Technologies." *IEEE Transactions on Engineering Management*, 50(3), 362–373.

[18] Doz (1996).

[19] R. Kumar and K. O. Nti (1998). "Differential Learning and Interaction in Alliance Dynamics: A Process and Outcome Discrepancy Model." *Organization Science*, 9(3), 356–367.

[20] D. C. Mowery, J. E. Oxley, and B. S. Silverman (1998). "Technological Overlap and Interfirm Cooperation: Implications for the Resource-Based View of the Firm." *Research Policy*, 27, 507–523.

[21] A. Nygaard and R. Dahlstrom (2002). "Role Stress and Effectiveness in Horizontal Alliances." *Journal of Marketing*, 66(2), 61–83.

[22] E. Schein (1992). *Organizational Culture and Leadership*. San Francisco: Jossey-Bass.

[23] H. Trice and J. Beyer (1993). *The Cultures of Work Organizations*. Upper Saddle River, NJ: Prentice Hall.

[24] E. Schein (1992). *Organizational Culture and Leadership*. San Francisco: Jossey-Bass.

- *Leadership and management style.* Leadership and management styles that do not "match" the work scenario have been shown to undermine organizational performance.[25]

Finally, insights from the initial discussions, logic modeling process, and literature review were used to develop a set of process-related study questions to guide evaluation data collection (Table 1).

Table 1: Process Evaluation Study Questions

1. Program Planning and Design
1.1. Where did the idea for the program come from, and how did it evolve prior to implementation? After implementation? Which stakeholders had input?
1.2. What were the program goals and desired outcomes (explicit and implicit)? Were they understood in the same way by all stakeholders?
1.3. How were the following activities expected to support the program goals: (a) bridging projects, (b) pilot projects, and (c) core resources?
1.4. How were the following structural components expected to support the program goals: (a) U54 mechanism, (b) integration of NIGMS program staff into steering committees, and (c) milestones?
1.5. Were other program design models or approaches considered? If yes, why was this one preferred? Is there evidence that expected benefits were realized?
2. Consortium-Level Implementation and Management
2-1. Were there differences among the funded consortia in the way funds were allocated and supported activities were implemented?
2-2. What processes and mechanisms were used to recruit or select consortium members?
2-3. Were the administrative, project management, and data sharing/intellectual property plans adequate and appropriate?
2-4. What plans have been put in place (if any) for sustainability of the consortia beyond the period of Glue Grant support?
2-5. How were consortium-generated information and resources shared and disseminated among consortium members and beyond?
2-6. How did awardees define the complex biomedical problems they were addressing, and did these definitions evolve over time?
2-7. Have some consortia made more progress than others? If yes, is there evidence that success is attributable to one or more identifiable factor(s) (e.g., good management, luck, the type of biological problem, maturity of the field, etc.)?
2-8. Overall, were stakeholders satisfied with consortium management? Were there any award-level management strategies that appear to have been particularly effective or ineffective?
2-9. Is there evidence that consortium-level activities and processes supported program goals as expected?
3. Program-Level Implementation and Management
3-1. Was the application review process implemented as planned? Were any significant problems encountered?
3-2. Were the following components implemented and managed as planned: (a) U54 mechanism, (b) integration of NIGMS program staff into steering committees, and (c) milestones? Were any significant problems encountered?
3-3. Was the overall program management approach and level of involvement by NIGMS appropriate for these cooperative agreements? Was the management approach consistent across the program and over time?
3-4. Overall, were stakeholders satisfied with program management? Were there any program-level management strategies that appear to have been particularly effective or ineffective?
3-5. Is there evidence that program-level activities and processes supported program goals as expected?

[25] Peter G. Northouse (2007). *Leadership: Theory and Practice* (4th ed.). London: Sage.

C. Empirical Methods

Because initial discussions indicated that each of the five funded consortia was unique, a case-based approach (structured effort to understand the implementation and management of each consortium in context) was employed for most data collection related to consortium-level management and implementation. Semi-structured interviews were conducted with the following individuals via telephone between July 2008 and June 2009:

- The Principal Investigator (PI) of four of the five funded Glue consortia (the fifth PI responded to an abbreviated version of the interview questions via email);
- A senior administrator for one consortium (this interview was conducted in order to reduce the length of the subsequent interview with the consortium's Principal Investigator);
- The NIGMS program staff member with the longest history of involvement with each of the five Glue consortia (generally the original Program Director);
- Four members of the NIGMS scientific review staff with knowledge of the review process for the Glue Grants;
- Three additional current or former senior officials at NIGMS who have participated in planning for or oversight of the Glue Grants.

Interview subjects were given the opportunity to review and correct the notes taken during each interview, and only the revised notes were used in further analyses.

Additional data sources included internal NIGMS planning documents, the Glue Grant Funding Opportunity Announcements (FOAs), application materials, investigator progress reports submitted annually by the PIs, NIH administrative databases, a book chapter authored by Glue Grants program staff members, and PubMed.

Initial drafts of the evaluation report were reviewed iteratively by NIGMS staff members, including the Advisory Committee and many of the NIGMS interviewees. Additional comments and factual corrections offered by these individuals were incorporated into the document as appropriate.

D. Structure of This Report

Section II of this report describes the genesis of the Glue Grants concept and design of the program in detail. Section III describes aspects of program implementation at the consortium level. Section IV describes management processes controlled by NIGMS or NIH, including application review and involvement in management at both the consortium and the program level. The final two sections describe evaluation findings and recommendations.

II. Program Origin and Design

The purpose of this section is to describe the planning process for the Glue Grants as well as the overall design and structure of the program as implemented.

A. Origin of the Glue Grants Concept

In the spring of 1998, under the direction of former NIGMS Director Dr. Marvin Cassman, three subcommittee meetings of the NIGMS Advisory Council were convened to discuss options for investing funds that were newly available due to the projected doubling of the NIH budget. The subcommittees corresponded to three NIGMS Divisions: Cell Biology and Biophysics (CBB); Genetics and Developmental Biology (GDB); and Pharmacology, Physiology, and Biological Chemistry (PPBC). At the GDB Subcommittee meeting, participants identified a series of topics (e.g., functional biology, bioinformatics) they believed would require creative funding mechanisms, long-term projects, and interdisciplinary collaborations.[26] The PPBC Subcommittee made more specific recommendations for investment of the newly available funds:

- Fund integrative, multidisciplinary, and multi-institutional consortia;
- Make chemistry, physics, applied math, and/or computer science central elements;
- Organize awards around a central problem (e.g., regulation and function of G-protein coupled signal transduction pathways);
- Encourage interaction via electronic media;
- Impose a sunset provision to limit lifespan of the awards.[27]

B. Planning Process

Following the subcommittee meetings, NIGMS began to formulate plans for a new initiative responsive to this vision. PPBC Director Dr. Michael Rogers took a lead role in the planning process, but he consulted extensively with senior staff members from across the Institute. Dr. Rogers recalled that he began by conducting a scan of large-scale programs at NIH and other agencies to identify potential models, but he found few programs with potential relevance. However, conversations with the program staff members who manage the National Science Foundation's Science and Technology Centers were particularly helpful.

By the summer of 1998, the new initiative had begun to take shape with a focus on integrating already-funded investigators into consortia rather than funding new research. Accordingly, it was dubbed the "Glue Grant."[28]

---

[26] "Report of the National Advisory General Medical Sciences Council Subcommittee for the Division of Genetics and Developmental Biology." May 13, 1998.

[27] "Report of the National Advisory General Medical Sciences Council Subcommittee for the Division of Pharmacology, Physiology, and Biological Chemistry." May 13, 1998.

[28] Michael E. Rogers and James Onken (2008). "The National Institute of General Medical Sciences Glue Grant Program." In Gary M. Olson, Ann Zimerman, and Nathan Bos (Eds.). *Scientific Collaboration on the Internet Cambridge*, MA: The MIT Press.

A group of outside consultants convened in November of 1998 recommended developing two separate programs to support collaborative efforts: one to support large-scale collaborations with a budget limit of up to $5 million per year in direct costs, and one to support collaborative efforts on a much smaller scale with a limit of $300,000 per year in direct costs. [29] NIGMS adopted this recommendation, with the Glue Grants serving as the large-scale component. A different program (see Program Announcement GM-00-099, Integrative and Collaborative Approaches to Research) was launched to fill the smaller-scale niche, but that effort was not included within the scope of this Process Evaluation.

Once the draft concept for the Glue Grants was sufficiently developed, all NIGMS staff members were given an opportunity to comment. The next step was to draft and vet a Funding Opportunity Announcement (FOA). The final Request for Applications (RFA-GM-99-007), officially titled "Large-Scale Collaborative Project Awards" was released on May 26, 1999.

C. Program Goals and Objectives

The opening line of the original Glue FOA (RFA GM-99-007) was the following: "The purpose of this request for applications is to enable the solution of major problems in biomedical research and to facilitate the next evolutionary stage of integrative biomedical science." This language suggests strongly that NIGMS had two related objectives for the program. However, the solicitation offered little additional guidance on how either objective was to be interpreted.

Specifically, in lieu of a more general description of the types of problems appropriate for solution via the Glue Grants, the 1999 RFA offered the following four examples:

1. Working out all facets of particular cellular processes, both for the process itself and for its integration into and control of cellular function;
2. Determining structures and distilling global structure-function principles for organelles;
3. Quantitatively modeling interacting metabolic pathways in a model organism;
4. Determining the multi-level control mechanisms and their integration into the biological response to traumatic injury.

At least one interviewee stated that the types of problems appropriate for Glue Grants were left undefined deliberately to encourage applicants to identify problems for themselves. With respect to the second goal (integrative biomedical science), the FOAs offered no additional elaboration beyond a description of allowable activities. If, as some interviewees suggested, the objectives were related in the minds of planners such that integrative biomedical science was intended to result in problem-solving, neither the connection nor the theory of action were explained in the solicitations.

D. Key Program Design Features

The 1999 Glue Grants RFA included the following provisions and requirements for applicants:

- ***Eligibility.*** According to the 1999 Glue Grant RFA, institutions eligible to submit applications for Glue Grants included domestic non-profit organizations such as public and private institutions such as universities, colleges, hospitals, laboratories, units of State

[29] Ibid.

and local governments, and eligible agencies of the Federal government otherwise eligible for extramural support from NIH. Each proposal was expected to include a large number of participating investigators, but minimum and maximum numbers were not set. Multi-institutional applications were particularly encouraged, and investigators from foreign institutions and industry were welcome to participate as collaborators.

- ***Research Topics.*** The RFA did not limit the range of research topics eligible for a Glue Grant except to say that applications must fall into areas of research supported by NIGMS and that they must correspond with the major research activity of the proposed PI.
- ***Phase I.*** The purpose of the mandatory Phase I planning award was to provide resources for detailed planning to applicants who demonstrated the selection of an appropriate complex biological problem, an innovative plan, and appropriate commitments to its solution from participating investigators and institutions. Phase I applicants were to submit an overview of the proposed large-scale consortium concept for peer review. Successful Phase I applicants would receive an R24 award of up to $25,000 in direct costs for one year and would be eligible to submit a Phase II application.
- ***Phase II.*** The purpose of Phase II was to support the large-scale consortium itself. Phase II awards would use the U54 Specialized Center (Cooperative Agreement) mechanism and would be capped at $5 million per year in direct costs. Phase II awards were expected to last for a maximum of five years, with the possibility of one competing renewal for an additional five years. Funds were to be used to extend the research efforts of individual investigators to form an integrated consortium; requests for funds to support new individual research projects were excluded.
- ***Leadership and Governance.*** Leadership responsibility was to be shared by the PI and a Steering Committee. The PI was assigned overall responsibility for award administration, operations, and scientific and technical direction. The Steering Committee was to serve as the governing board of the consortium, working with the PI to establish the scientific and technical direction of the project, develop common guidelines and procedures, monitor operations, and recommend changes as needed to facilitate progress on the goals of the large-scale collaborative project. The PI was required to abide by the operating rules and guidelines developed by the Steering Committee.
- ***NIGMS Program Director.*** The NIGMS Program Director was required to serve as a voting member of the Steering Committee. Other responsibilities included facilitating interactions with NIGMS, providing advice and guidance on compliance with NIGMS requirements, and facilitating interaction with the scientific community.
- ***External Advisors.*** The RFA also required each funded consortium to convene an External Advisory Committee to provide strategic advice to the PI and Steering Committee on an annual basis. The Advisory Committee was to be composed of a minimum of three members not otherwise involved with the consortium.
- ***Collaborative Project Resources.*** Apart from disallowing requests to fund new research projects for individual laboratories, the Glue Grant RFA allowed considerable flexibility with respect to consortium structure. Although applicants were not required to limit themselves to only these, the 1999 RFA defined three specific types of collaborative project resources for which funds could be requested:
    - **Core resources** were envisioned as a means of developing new technologies or standardizing data across research teams, thereby speeding progress toward scientific goals or adding capabilities to those possessed by the research team. NIGMS required

each Glue Grant to include an administrative core as well as a core devoted to information collection, analysis, and dissemination. The information core could be combined with a bioinformatics core at the discretion of the applicant.

  - **Bridging projects** were originally intended to support collaboration enhancement activities in the laboratories of participating investigators to assist them in integrating their R01-funded research with the work of the consortium.
  - **Pilot projects** were intended to support investigators who did not themselves have independent support or to involve investigators with necessary skills who were new to the field in the consortium's activities.

- ***Milestones.*** As part of the Phase II application process, each consortium was required to develop a set of milestones, which were to be reviewed and adjusted annually.
- ***Data Sharing and Intellectual Property.*** The RFA required each applicant to propose a data sharing and intellectual property (IP) plan that would govern providing access to consortium-created data and resources to the investigator community as well as establish procedures within the consortium governing intellectual property rights.

E. Evolution of Program Design

The Glue Grant solicitation was reissued by NIGMS in 2001 (RFA-GM-01-004), 2002 (RFA-GM-02-007), 2004 (PAR-04-128), and 2007 (PAR-07-412). In general, few major changes to the program design were made over time. Perhaps the most significant changes were the following:

- Starting in 2002, the guidelines for bridging projects were expanded to include data collection, research, or technology development projects that would serve the needs of the consortium as a whole as well as technology validation or laboratory exchanges to facilitate transfer of technology between participating investigators.
- Starting in 2004, the fixed annual funding level of $5 million per year in direct costs was changed to a five year total of $25 million, with a maximum of $7 million available in any given year.

Other changes introduced after 1999 include the following:

- Starting in 2001, the FOA no longer explicitly encouraged participation by industry. In 2004, participating investigators were also required to disclose ties to industry.
- Starting in 2002, applicants were required to submit a more detailed plan for sharing data. In 2007, quality of the data sharing plan became part of review criteria/scoring.
- Starting in 2004, Phase I applications were subject to review by the NIGMS Advisory Council.
- Starting in 2004, applicants were required to submit plans for increasing the number of participating investigators from groups that are underrepresented in the biomedical, clinical, behavioral, and social sciences.
- Starting in 2004, the maximum for pilot projects was raised from $75,000 to $100,000 in annual direct costs.
- Starting in 2004, Steering Committee members were required to be chosen from those investigators actively involved in the functioning of the consortium.
- The 2004 and 2007 solicitations were issued as Program Announcements rather than RFAs. Shifting to a Program Announcement provided a regular schedule for applications

(one application date per year for three years), giving investigators more time to develop concepts than would an irregularly issued RFA with a short preparation period. The shift also meant than NIGMS would no longer set aside funding for Glue Grant applications, so that new proposals would be competing for resources with all other applications rather than against the applications in that cohort of Glue Grants.

- Starting in 2007, the FOA specified two separate NIGMS roles—the Program Director and the NIH Project Scientist. While the Program Director continued to be assigned roles related to the normal scientific and programmatic stewardship of the award, the NIH Project Scientist was to serve on the Steering Committee and facilitate interactions with the scientific community. The FOA also specified that, at the Institute's discretion, the assigned Program Director could also serve as the NIH Project Scientist.

III. Consortium-Level Implementation

This section describes the history, structure, and objectives of the five funded Glue consortia and explores program challenges as described by interviewees. The section is organized by process-related theme rather than by consortium to highlight key similarities and differences.

A. Funded Consortia

A total of nine Phase I R24 awards had been funded through FY 2009, and five of the awarded groups competed successfully for Phase II consortium funding. The Alliance for Cellular Signaling (AfCS) was the first consortium to receive Phase II funding in 2001, and it was followed quickly by the Cellular Migration (Cell Migration) consortium, Consortium for Functional Glycomics (CFG), and Inflammation and Injury (Inflammation) consortium. The fifth consortium, Lipid Metabolites and Pathways Strategy (LIPID MAPS), first received Phase II funding in 2003. The Cell Migration consortium, the CFG, the Inflammation consortium, and LIPID MAPS successfully competed for five year renewals, while the AfCS received three years of funding to complete current work and phase down operations gradually after the competitive renewal.

B. Consortium Development

The four Glue PIs who participated in interviews described a generally similar approach to consortium development. Each PI began with a general idea of what he wanted to achieve, but extensive input from collaborators helped to shape the full proposal. Informal meetings were generally held to develop the Phase I proposal, and more formal meetings between collaborators were held during the planning award to develop the Phase II proposal.

The total number of collaborators (defined as institutions receiving monetary support from the Glue Grant) varied from a low of eight (AfCS) to a high of 22 (Inflammation, Table 3). In the three cases where the relevant research communities were relatively small and well defined (CFG, Inflammation, and Cell Migration), the PIs reported drawing on personal connections and knowledge of the field to recruit suitable collaborators. The LIPID MAPS PI described a slightly more systematic approach to selecting collaborators from the larger and more fragmented community of lipid researchers; he began by listing all of the major classes of lipids and then selecting individuals with expertise in each area. He also recruited collaborators with expertise in mass spectrometry technology, macrophages, genomics, proteomics, synthesis, and bioinformatics.

The active involvement of an industrial collaborator, Avanti Polar Lipids, is a unique feature of the LIPID MAPS consortium; the PI explained that he sought participation from Avanti rather than an academic collaborator because he felt they were best suited to manufacture, distribute, and commercialize the lipids and other materials that would be required by the consortium. The PI observed that the company is extremely responsive and may well have spent more on consortium-related projects than they have received through the subcontract. There are currently approximately 300 compounds in the Avanti catalog that have been developed specifically for LIPID MAPS.

Table 2: Glue Consortia Funded Between FY 2000 and FY 2008

Consortium Name	PI	Lead Institution	Funding Period	Total Dollars Through FY 2008[a]	Co-funding ICs	Scientific Objective
Alliance for Cellular Signaling (AfCS)	Alfred Gilman	University of Texas Health Sciences Center at Dallas	2000 (Phase I); 2001–2007 (Phase II)	$63,714,926	NIAID, NCI	Assess complexity and dynamics of signal processing; develop predictive models
Cellular Migration	Alan Horwitz	University of Virginia	2000 (Phase I); 2001–2011 (Phase II)	$61,351,656	None	Elucidate the mechanisms underlying cell migration
Consortium for Functional Glycomics (CFG)	James Paulson	The Scripps Research Institute	2000 (Phase I); 2001–2011 (Phase II)	$64,944,465	NIDCR, NCRR	Define the paradigms by which protein-carbohydrate interactions mediate cell communication
Inflammation and Injury	Ronald Tompkins	Massachusetts General Hospital	2000 (Phase I); 2001–2011 (Phase II)	$62,232,737	None	Improve systems-level understanding of the key regulatory elements that drive the normal host response to serious injury and its accompanying severe systemic inflammation
LIPID MAPS	Edward Dennis	University of California-San Diego	2002 (Phase I); 2003–2013 (Phase II)	$42,824,372	OD	Identify and quantify lipids in mouse macrophages under basal and activated conditions

[a] Funding total includes Phase I planning grant.

Table 3: Glue Consortium Collaborators

Consortium Name	Research Sites
Alliance for Cellular Signaling (AfCS)	**United States (8)—CA:** California Institute of Technology; San Francisco Veterans Administration Medical Center; Stanford University; University of California-San Diego; University of California-Berkeley; **TX:** University of Texas Southwestern Medical Center; University of Texas Health Sciences Center at Dallas; **TN:** Vanderbilt University
Cellular Migration	**United States (18)—CA:** The Burnham Institute; The Scripps Research Institute; University of California-Davis; University of California-Irvine; University of California-San Diego; University of California-San Francisco; **CT:** University of Connecticut Health Center; **FL:** Florida State University; **IL:** Northwestern University; University of Illinois at Urbana-Champaign; **MA:** Harvard Medical School; Massachusetts Institute of Technology; **MD:** Johns Hopkins University; **NC:** University of North Carolina at Chapel Hill; North Carolina State University; **NJ:** Princeton University; **NY:** Albert Einstein College of Medicine; **VA:** University of Virginia **International (3)—Israel:** Weizmann Institute of Science; **UK:** Oxford University; University of Leicester
Consortium for Functional Glycomics (CFG)	**United States (6)—CA:** The Scripps Research Institute; University of California-San Diego; Palo Alto Research Center; **GA:** Emory University;[30] **IN:** Indiana University; **MA:** Massachusetts Institute of Technology **International (5)—Japan:** Institute for Chemical Research, Kyoto University; **Netherlands:** Vrije University Medical Center; **Russia:** Shemyakin Institute of Bioorganic Chemistry, Russian Academy of Sciences; ND Zelinsky Institute of Organic Chemistry, Moscow; **UK:** Imperial College of Science, Technology and Medicine
Inflammation and Injury	**United States (22)—AL:** University of Alabama at Birmingham; **CA:** Stanford University; **CO:** University of Colorado, Denver; **FL:** University of Florida, Gainesville; **IL:** Loyola University; **MA:** Massachusetts General Hospital; Harvard Medical School; Brigham and Women's Hospital; Massachusetts Institute of Technology; University of Massachusetts, Worcester; Shriners Burns Hospital; **MI:** University of Michigan; **MN:** Minneapolis Medical Foundation; **MO:** Washington University School of Medicine; **NJ:** University of Medicine and Dentistry of New Jersey; **NY:** University of Rochester Medical Center; **PA:** University of Pittsburgh Medical Center; **TX:** University of Texas Medical Branch; University of Texas Southwestern Medical Center; University of Texas at Houston; **WA:** University of Washington School of Medicine; Pacific Northwest National Laboratory

[30] The original collaborator was the University of Oklahoma Health Sciences Center, but one of the cores moved with a key collaborator to Emory University.

LIPID MAPS	**United States (12)—AL:** Avanti Polar Lipids Inc.; **CA:** University of California-San Diego; University of California-Irvine; **CO:** University of Colorado at Boulder; University of Colorado at Denver; National Jewish Medical and Research Center and University of Colorado Health Science Center; **GA:** Georgia Institute of Technology; **IN:** Indiana University; **NC:** Duke University Medical Center; **PA:** Pennsylvania State University; **TN:** Vanderbilt University Medical Center; **TX:** University of Texas Southwestern Medical Center

C. Organization and Structure

While each of the five Glue awardees made use of the structural elements outlined in the solicitation, there were substantial differences in how these structures were interpreted, implemented, and combined to organize the consortia. Organizational charts prepared by the consortia themselves (Appendix B) illustrate some of these differences. The following sections describe use of the various structural elements in more detail.

Structures for Consortium Leadership and Management

As required in the solicitation, all five consortia were led and coordinated by the PI, an Administrative Core, and a Steering Committee. In all five cases, the Administrative Core included at least one individual charged with assisting the PI in managing day-to-day operation of the consortium, although titles and responsibilities for this individual varied (AfCS, Chief Operating Officer; Cell Migration, Co-PI; CFG, Assistant Director; Inflammation, Program Manager; and LIPID MAPS, Project Manager).

With the exception of the first five years of the AfCS, Steering Committee members were either consortium sponsors or participating investigators. Consortium Steering Committees ranged in size, with 10 to 13 members being most common; frequency of scheduled Steering Committee meetings also varies widely (Table 4). The Consortium with the smallest Steering Committee, LIPID MAPS, established a larger group called the Operating Committee that included all core leaders and bridging project directors. The Operating Committee meets every two weeks via videoconference, and the PI described it as the central forum for discussion and decision-making for the Consortium. On the other end of the spectrum, the Inflammation consortium established an Executive Committee consisting of the core leaders only to facilitate decision-making by its very large Steering Committee.

In addition to the Steering Committee, the AfCS included two additional Systems Committees focused on the two cell types initially under investigation (B lymphocyte and cardiac myocytes). When the consortium switched cell types (see the next section for details), the two committees were consolidated into a single Macrophage Committee. According to the consortium Web site, the Systems Committees were originally intended to take a leadership role in data interpretation and integration across the consortia. However, primary responsibility for this task eventually fell to a Data Analysis Group consisting of the data analysts who were embedded within each of the research core facilities in addition to the data modeling and network analysis core. The data analysis group held monthly meetings and was overseen by a committee of senior researchers from the consortium.

Table 4: Consortium Governing Bodies

Consortium Name	Number of Steering Committee Members	Meeting Frequency	Other Governing Bodies
Alliance for Cellular Signaling (AfCS)	12 (initial)/ 10 (post-renewal)	Monthly	Systems Committees, Macrophage Committee, and Data Analysis Group
Cellular Migration	11	Twice per year or as needed	
Consortium for Functional Glycomics (CFG)	11 (initial)/ 13 (post-renewal)	Every two weeks	Six subcommittees: Glycan Analysis, Glycan Library and Glycan Array, Glycosyltransferase Database, Nomenclature, Mouse, and Publications)
Inflammation and Injury	15–18 (initial)/ 20+ (post-renewal)	Quarterly	Executive Committee
LIPID MAPS	7	Twice per year or as needed	Operating Committee

Core Facilities

Implementation of the core research areas, the most important organizational structure for the Glue Grants program, is described below for each individual consortium.

- ***AfCS.*** The AfCS defined its core resources around technologies/disciplines (cell preparation and analysis, macrophage biology, molecular biology, protein chemistry, microscopy, antibody, lipidomics, data modeling, and network analysis). The AfCS described itself as following a design model more common in industry than in academia; the cores were intended to function as independent facilities rather than being incorporated into the existing laboratories of participating researchers. A senior scientist was assigned as titular head of each core, and a more junior researcher was in charge of day-to-day operations.
- ***Cell Migration Consortium.*** During the initial five years, the Cell Migration consortium defined its core structure around five research initiatives (discovery, structure, biosensor, modeling, and transgenic/knockout mouse), each of which was devoted to overcoming a specific perceived barrier to progress. As the term "research initiative" suggests, the cores were intended to be interconnected but self-contained research enterprises. There were also four support facilities (protein production, biomaterials, imaging, and photomanipulation), plus the required administrative and information coordination and dissemination cores. During the renewal phase, the support facilities were integrated into the initiative structure, resulting in seven initiatives (discovery, proteomic, structure, biosensor, modeling, imaging and photomanipulation, and knockout mouse). According to interviewees, the support facilities had always been integrated into the laboratories of the participating investigators, so the shift was primarily intended to streamline the organizational structure.

- ***CFG.*** The CFG created several different types of cores. Two service-oriented cores (Gene Microarray and Protein-Glycan Interaction) were established to analyze samples using high-throughput technology at the request of glycomics community members. Two other cores focused on generating specific types of resources for the entire glycomics community: the Glycan Synthesis Core developed a glycan library and the Mouse Transgenics Core produced knockout mice. Three other cores were established to produce, organize, and analyze data for use by the consortium and the community: Bioinformatics, Analytical Glycobiology, and the Mouse Phenotype. Each core had a senior coordinator who was responsible for oversight and top-level management. Subordinate to that person was a full-time director (postdoctoral researcher level) to provide day-to-day leadership.
- ***Inflammation.*** During the first five years, the Inflammation consortium included six research cores: (1) Protein Analyses and Cell Biology (Proteomics); (2) Genomics; (3) Patient-Oriented Research; (4) Model Validation (Animal Models); (5) Information Dissemination and Data Coordination; and (6) Computational Analysis and Modeling. In the renewal submission, two of the original cores (Proteomics and Computational Analysis) were subdivided, while a third, Model Validation, was eliminated. The core structure was designed as a pipeline for data collection and analysis. The idea was for the Patient-Oriented Research Core to define standard operating procedures for patient care and sample collection, enroll patients, and collect samples; the Cell Separation and Sample Preparation Core to prepare those samples for analysis; the Genomics and Proteomics Cores to develop and apply the technologies and standard operating procedures required for analysis of the samples collected; the Clinical Biostatistics Core to make the patient data as clean as possible; the Data Interpretation Core to correlate the genomics and proteomics data with clinical trajectories and outcomes; and the Information Dissemination and Data Core to develop the computational tools required to analyze the data and to maintain the database in a format that can be used by others.
- ***LIPID MAPS.*** Like the CFG and Cell Migration consortium, LIPID MAPS organized most of its cores as semi-autonomous research initiatives with development goals of their own. The PI explained that he would not have been able to attract the same quality collaborators if the cores had been more service-oriented. However, LIPID MAPS had an unusually large number of cores—officially there were nine, although in practice there were eleven because the Synthesis Core consists of three separate sub-cores. In the initial application, the core structure included: (1) six lipidomics cores representing each of the major classes of lipids; (2) a combined Bioinformatics/Data Coordination Core, which has been responsible for the consortium's data system as well as developing a consensus nomenclature; (3) a Macrophage Biology/Functional Genomics Core, with responsibilities including development of standardized protocols for handling macrophage cell lines, characterizing gene expression patterns involved in lipid sensing and metabolism, and developing RNA interference reagents for inhibition of gene expression; and (4) a Lipid Synthesis and Biophysical Characterization Core responsible for both biosynthesis support and biophysical characterization. The three sub-cores of the Lipid Synthesis core included the Avanti group, which is responsible for synthesis of analytical standards as well as other reagents for the consortium; another group responsible for design of novel lipids; and a third group responsible for biophysical characterization. Each of the lipid cores is equipped with a mass spectrometer purchased through the consortium.

Pilot and Bridging Projects

The AfCS was the only consortium to attempt to incorporate pilot projects, but it was not clear from available information how they were used.

Three of the five consortia incorporated bridging projects (AfCS, CFG, and LIPID MAPS). In all three cases, the primary goal was either to develop specific technologies or to overcome technical bottlenecks. LIPID MAPS was the only consortium to convert a bridging project from the first five years into a core during the renewal; the bridging project in question focused on lipid imaging. Bridging projects generally accounted for a small percentage of direct costs requested by the consortia that used them (8–16%). In interviews, several PIs expressed confusion regarding the intended purpose of the bridging projects.

Structures to Facilitate Community Participation

All five consortia engaged in community outreach through their Web sites, participation at scientific meetings, and through other activities. In addition to these informal outreach activities, several of the consortia (AfCS, CFG, and Inflammation) incorporated more formal structures to facilitate participation by community members who were not receiving monetary support from the Glue Grants. These structures are described below.

- ***AfCS Membership and Editorial Board.*** The AfCS recruited more than 800 members with expertise on particular molecules to develop "Molecule Pages" for the Signaling Gateway Web site. Membership and Editorial Committees (composed of volunteers) were appointed to recruit members and oversee peer review of the molecule pages.
- ***CFG Participants and Subgroups.*** Interested investigators with programs of funded research falling within the scope of the CFG were offered the opportunity to become participating investigators. These individuals agreed to provide data to the consortium in exchange for receiving access to consortium resources. At the time of the renewal application, there were more than 400 participating investigators. The participating investigators were organized into "subgroups" to facilitate networking and coordination and to represent the interests of the participating investigators to the Steering Committee. The subgroups were originally aligned with the four families of glycan binding proteins. As the consortium grew, however, it became clear that these categories were not sufficient to capture the diverse research interests of the consortium members. At the request of NIGMS, the subgroups were reorganized in year seven as biological or technical interest groups. New leaders were appointed, and NIGMS also required the subgroups to hold three additional workshops per year. The PI described this development as positive in terms of engaging the participating investigators.
- ***Inflammation Membership.*** The Inflammation consortium's Membership Program was established to facilitate sharing of consortium data and products with investigators who were not affiliated with the cores. Members were required to agree to uphold the consortium's ethical and legal standards and to acknowledge NIGMS support on any publications making use of consortium data. Members were automatically granted access to the consortium's protocols and murine data, and they were eligible to request access to the de-identified clinical datasets. The Steering Committee required that all such requests be accompanied by approval from the member's local Institutional Review Board. Investigators affiliated with the cores were required to follow the same procedures if they wished to use consortium data in their own research. Approximately 40 such requests had been granted at the time of the Process Evaluation.

External Advisory Committee

As required in the solicitation, each of the five consortia established an External Advisory Committee (EAC) composed of at least three members. EACs were convened annually, typically during the consortium's annual meeting. Several PIs also described consulting with individual EAC members for advice as needed throughout the year. All of the PIs who were interviewed described input from the EAC as useful, especially while they were developing renewal applications. One PI explained that he viewed review by the EAC as an opportunity to identify and address issues that were likely to be raised during peer review.

However, several interviewees did express concern about a lack of clarity regarding the appropriate role for NIGMS in the EAC review process. Most PIs felt that the process was intended to create dialog between the consortium and the EAC only, without involvement by NIGMS. However, the LIPID MAPS consortium structured the process such that the NIGMS Program Director played a key role in presenting information to the EAC and soliciting advice.

D. Consortium-Level Objectives and Strategies

Each of the five funded consortia can be regarded as addressing a complex biological problem in that each ultimately sought to understand one of the following: (1) a complex biological process at the cellular level (AfCS, how cells signal; Cell Migration, how cells move); (2) a complex biological process at the organism level (Inflammation, normal host response to injury); or (3) the role and function of a class of molecules in cellular processes (CFG, glycan binding proteins; LIPID MAPS, lipids). There were substantial differences, however, in the strategies employed by the consortia to address these questions. To illustrate some of these differences, it is useful to define three groups or models of Glue consortia based loosely on how they conceptualized the "gluing" function of the consortium. The purpose of this categorization is to compare and contrast consortia that seemed to share dominant characteristics rather than to claim that any of the consortia behaved purely in the manner described.

Research Initiative Model: AfCS and Cell Migration

Of the five Glue consortia, the AfCS and the Cell Migration consortium were probably the most similar to each other in objectives and approach. Both ultimately aimed to develop a comprehensive and holistic understanding of a complex cellular process, and both seemed to internalize the notion of Glue Grants as mechanisms for problem-solving. Each was organized as a set of integrated but semi-autonomous research initiatives working on their own sub-questions. However, one key difference between the two was that the Cell Migration consortium set objectives that were more modest. While the AfCS aimed to develop a comprehensive mathematical model for the entire cellular signaling process, the Cell Migration consortium identified and attacked specific perceived barriers to progress towards an understanding of cell migration.

Standardization Model: Inflammation and LIPID MAPS

Inflammation and LIPID MAPS each sought to coordinate, standardize, and harmonize research methods across a research community to facilitate sharing of data and analysis of larger patterns. As a multisite clinical trial, the Inflammation consortium aimed to collect samples and data from a geographically diverse patient population to gain an integrated understanding of a biological process. Key challenges included developing consensus standards of care and sampling methods. Similarly, LIPID MAPS aimed to collect comparable information about the role and function of

various classes of lipids in the responses of macrophage cells (RAW264.7 cells, thioglycolate-elicited primary macrophages, and bone marrow-derived primary macrophages) to a particular stimuli. The intent was to unify and coordinate lipid researchers, who had previously worked on their own classes of molecules in relative isolation, as a single community working together with metabolomics and cell signaling researchers. Facilitating access to mass spectrometry technology, which had not previously been widely used to study lipids, and developing consensus on lipid nomenclature were key strategies of the consortium.

One interesting difference between these two consortia is that their core structures were organized very differently. The Inflammation cores were organized vertically as a pipeline for collecting, processing, and analyzing data. On the other hand, the LIPID MAPS cores were organized horizontally, with each of the lipid cores conducting parallel analyses. As the LIPID MAPS PI explained, it was believed to be more practical to teach all of the consortium members to use their own mass spectrometers than to have a centralized group attempt to become experts on all of the various classes of lipids. The Inflammation consortium did not have that problem, since treating patients in different geographic locations does not require substantially different types of expertise. The vertical-versus-horizontal organizational difference may also explain why LIPID MAPS used bridging projects for new technology development, while the locus of the Inflammation consortium's technology development activities lay within the analytical cores themselves.

Hybrid Model: CFG

The CFG appears to have incorporated both of the strategies described above as well as an unusually strong emphasis on providing resources and services to the entire community. The research-driven subgroups, especially as reorganized after the renewal, are consistent with a problem-driven approach similar to the AfCS and Cell Migration. Other elements of the consortium, most notably the pooling of data contributed by members and the efforts to develop standard nomenclature, resemble a standardization approach similar to Inflammation and LIPID MAPS. A third strategy, which appears to have been unique to the CFG, was to devote substantial time and effort to providing resources and services to the entire glycobiology community.

E. Mechanisms for Integration and Communication within Consortia

The Process Evaluation identified four general strategies for facilitating communication and integration across the Glue consortia.

In-Person Meetings

The AfCS, Cell Migration, and the CFG held consortium meetings annually. The AfCS and Cell Migration annual meetings were open to consortium members, EAC members, and selected other participants by invitation only. The CFG, with its broader membership encompassing a wide swath of the glycobiology community, held open annual meetings in conjunction with the Society for Glycobiology. The PI estimated that the satellite consortium meetings tended to be approximately two-thirds of the size of the main meeting.

The LIPID MAPS consortium held two sets of consortium meetings annually. In December of each year, the consortium held workshops that were attended by LIPID MAPS personnel only. These meetings involved review and discussion of the previous year's progress as well as instruction on particular methods and techniques employed by the consortium. For example, early workshops were used to develop, coordinate, and standardize mass spectrometry methods. The consortium

also held an open, conference-style annual meeting each spring that the PI described as intended to facilitate communication between consortium scientists and others.

The Inflammation consortium held quarterly in-person meetings, and the consortium covered travel costs for all participating investigators. The first day of the meetings typically involved a discussion of progress during the previous quarter and setting goals for the next one, while the Steering Committee typically met on the second day. Interviewees from both the consortium and NIGMS stressed the importance of frequent in-person meetings to create a common language and to build trust among consortium members. The in-person meetings were also described as essential in developing consensus around standard operating procedures and achieving acceptable standards of uniformity among the various clinical sites.

Routine Teleconferences and Videoconferences

In addition to the annual or quarterly in-person meetings, all five of the Glue consortia held regularly scheduled group meetings via teleconference or videoconference for the purpose of coordinating progress and discussing important issues. The Inflammation consortium reported holding the most frequent consortium-wide meetings; investigators hold a weekly teleconference; and some of the research cores schedule additional teleconferences regularly. Similarly, LIPID MAPS holds consortium-wide conferences every other week. At the other end of the spectrum, each initiative within the Cell Migration consortium meets quarterly via teleconference or videoconference, but the annual meeting (see above) is the only regularly scheduled consortium-wide meeting.

It is perhaps worth noting that the AfCS, CFG, and LIPID MAPS used consortium funds to purchase videoconferencing equipment to facilitate routine meetings and informal communication between investigators. The recent development of low-cost Web conferencing functionality should render investments like this unnecessary in the future; however, this development would have been difficult to anticipate when the first four Glue Grants were launched in 2000.

Data Systems and Web Sites

An information core was a required element for each of the Glue consortia, and in all five cases these cores were used to develop data systems intended to facilitate data sharing among consortium members and the relevant research communities as appropriate. Interviewees reported few problems with the consortium data systems themselves, although several commented that getting the data systems up and running was a limiting factor during consortium start-up. In all five cases, Web sites were built to provide access to consortium data systems and to facilitate sharing of resources such as protocols and structures. Public access to consortium Web sites ranged from completely open in the case of the Cell Migration consortium to highly restricted to protect human subjects in the case of the Inflammation consortium. The other three consortia fell somewhere in between, offering public access to validated data but restricting preliminary data and certain resources to consortium members only.

All of the Glue consortia except for the Inflammation consortium partnered with the Nature Publishing Group to add editorial content such as news updates to their Web sites. In addition, the AfCS and CFG produced a quarterly newsletter containing research highlights and consortium news. The Cell Migration consortium's leadership drafted a monthly email update for consortium members. In addition to communicating administrative information, the "Migration Memo" drew attention to highlights from consortium research and recent updates to the Web site. The CFG also offered an online forum for consortium members as part of the Nature Network.

Milestones

All of the Glue consortia were required to set annual milestones, but interviews suggested that there were differences among them in the emphasis placed on milestones. Several PIs expressed ambivalence about the use of milestones as a management tool, arguing that coordination is needed but that the milestone process can be too rigid and/or runs counter to scientific culture. On the other hand, the CFG appears to have enthusiastically embraced the use of milestones, electing to set and revise milestones on a quarterly basis instead of an annual one. The PI explained that he was used to working with milestones because of his experience in industry, and his goal was to use the milestones as a mechanism to ensure communication and coordination between the cores. He described some initial resistance to writing specific milestones and paying close attention to dependencies, but the consortium members eventually became comfortable with this approach. The CFG cores submit quarterly reports on progress relative to the milestones for review by the Steering Committee.

F. Preliminary Outcomes

Although the Process Evaluation was not designed to assess outcomes in a systematic fashion, limited data on key scientific and other accomplishments of the Glue consortia were collected to provide context for the process questions under consideration. Appendix C summarizes these findings. In general, the preliminary output and outcome data suggest that all of the Glue consortia achieved some degree of success, but the nature of their accomplishments varied widely.

G. Plans for Sustainability

All four of the PIs interviewed expressed enthusiasm about sustaining the large-scale collaborative relationships fostered by the Glue consortia beyond the ten year funding period, but none was certain that the consortium or its investigators would succeed in securing funds to do so. The experience of the AfCS, for which NIGMS funding ended in 2007, suggests that it will be difficult to keep the consortia together as functioning research units without dedicated funding for that purpose. Alternative sources of funding that are currently being explored by the consortia include the NIH Roadmap initiatives, other NIH Institutes and Centers with relevant interests, the Veterans Administration, and the pharmaceutical industry. Two consortia are also giving serious consideration to development of proposals for new Glue Grants to explore new research questions, although both PIs expressed uncertainty about how such proposals would be received by NIGMS.

Although the prospects for maintaining the consortia themselves are uncertain, there is reason to believe that some of the consortium-developed resources may be sustainable beyond the duration of the Glue Grants. For example, the Nature Signaling Gateway (http://www.signaling-gateway.org) has already outlasted the AfCS Glue Grant by three years. The Signaling Gateway began as a collaborative venture between Nature Publishing Group (NPG) and the AfCS, with startup funds (approximately $200,000) provided by NIGMS through a supplement to the Glue Grant as well as corporate sponsors. The original plan was for the AfCS to provide data and develop the molecule pages, while NPG agreed to develop content for the news-oriented "signaling update" section. After the AfCS Glue Grant ended in 2007, NPG continued to update the news portion and maintained the AfCS databases as a static resource. These efforts were supported in part by the sale of advertising space on the Web site. The molecule pages project has also been continued by a former AfCS collaborator at the University of California-San Diego.

Interviewees with knowledge of several of the current Glue Grants reported plans to continue offering reagents, protocols, and services to the relevant research communities at cost through investigators' personal Web sites. LIPID MAPS reported that its reagents and standards will remain available through the Avanti Polar Lipids catalog indefinitely. Alternatives are also being explored to find suitable long-term hosts for consortium databases; examples mentioned by interviewees include the National Center for Biotechnology Information (NCBI) at the National Library of Medicine (NLM) as well as niche industries (e.g., manufacturers of mass spectrometry equipment). However, at the time the interviews were conducted, there had not yet been any firm commitments made, and several PIs expressed serious concerns about the future of the information resources developed by the consortia.

It should also be noted that evidence received after the interviews were complete indicates that NIGMS was actively making plans to address the sustainability issue towards the end of 2009.

H. Implementation Challenges Identified by Interviewees

In addition to the issues discussed previously, interviewees described a number of implementation challenges faced by the various consortia. Those judged to be most significant are described in the following subsections.

Major Technical Challenges

Perhaps the most significant technical challenge encountered by any of the Glue consortia was the discovery that the two normal cell types (B lymphocytes and cardiac myocytes) originally proposed as model systems for the AfCS were unsuitable for the proposed research because they were resistant to manipulation of gene expression with RNA interference. The consortium's decision to abandon these cell lines in 2003 in favor of cultured RAW 264.7 macrophages was controversial because many researchers consider these cells to be less biologically relevant. Interviewees agreed that this serious technical problem was a major contributing factor in the Institute's decision to phase down funding for the consortium after year five.

The Inflammation consortium experienced technical difficulties related to using high-throughput genomics and proteomics in a large-scale clinical study. Several new technologies were developed to overcome these obstacles, and it appears likely that these technologies will have applications beyond the consortium study (see Appendix B for details). The Inflammation consortium also faced challenges in forging consensus among investigators on standards of care and clinical treatment protocols for trauma patients. Standards developed by the consortium have since been adopted widely.

Finally, both the CFG and LIPID MAPS faced serious challenges related to nomenclature and taxonomy in their respective fields. In the case of the CFG, the consortium convened a meeting at the request of NIGMS to develop consensus on a standard nomenclature for glycomics. The nomenclature chosen at the meeting and adopted by the consortium was a modified version of a system that had been developed by one of the CFG core directors. LIPID MAPS tackled the well-known problem of inconsistent nomenclature for lipids, which had not been addressed on a large scale since 1976. The consortium opted to coordinate with the national and international research communities to build consensus rather than adopting a new system on its own. Consensus was reached in under a year, and interviewees reported that the resulting system has been adopted as standard for the field. The consortium also helped to establish an International Lipid Classification and Nomenclature Committee to periodically review and revise the classification scheme.

Recruiting Qualified Staff

Interviewees familiar with the AfCS, CFG, and LIPID MAPS reported that all three consortia experienced varying degrees of difficulty in recruiting qualified individuals to staff the consortium, especially for the critical position of day-to-day manager for each of the research cores. Several interviewees suggested that the ten year sunset provision might have made the positions less attractive to junior investigators hoping to establish tenure-track research careers, but it is worth noting that positions of this nature would probably have been outside the traditional academic research career track regardless of the sunset provision. Efforts by the AfCS in particular to establish its cores as independent from any academic structure may have further exacerbated the recruiting problem, because potential employees could expect neither the long-term security and fringe benefits of an academic job nor the comparatively high salaries available in industry. LIPID MAPS also reported that it took longer than expected to identify staff scientists with appropriate expertise to run the mass spectrometer for each of the lipid cores. According to the PI, all of these positions were eventually filled with capable individuals; several came from industry, others were in non-tenure track positions, and one had worked in a mass spectrometry laboratory at the FBI.

Size of Consortium Budget

The AfCS was unique in that the Phase II consortium was initially budgeted at approximately $10 million per year in direct costs, which was twice the amount allowable under the RFA. The consortium proposed to obtain the balance of its funds from pharmaceutical companies. At the time the application was submitted, the consortium had commitments from Eli Lilly and Johnson & Johnson. Aventis and the Merck Genome Research Center eventually joined as sponsors, as did several nonprofits, but a large share of the extra funding during the first five years was eventually provided by NIAID and NCI. Several interviewees suggested that $5 million may have been too large a budget for the Glue consortia, and one interviewee commented specifically that a $10 million budget was almost certainly too big to be manageable.

Budget Flexibility

Several interviewees described the initial flat $5 million per year budget structure as an implementation challenge, noting that resource demands for a research enterprise at the scale of the Glue consortia are likely to fluctuate over the life of the project. Due to the technical challenges described above, as well as the typical course for a clinical study, the Inflammation consortium in particular experienced serious challenges with respect to cost structure and timing. During the ramp-up period, costs were substantially lower than the $5 million annual cap, but costs increased substantially during the active enrollment period. The PI's institution assisted with financing to meet resource demands as needed over the first five years, but the solution was not ideal. In the renewal application, budgets were fully itemized to justify the higher expected costs during open enrollment and the lower expected costs once enrollment is complete.

According to interviewees, the per-patient costs in the original Inflammation budget were also unrealistically low, as the standard operating procedures for clinical care and analytics had not been developed yet. For the renewal, the Program Manager headed an 18-month effort to quantify actual per-patient cost from enrollment through data reporting. The resulting figure, which was higher than anticipated, was used as the basis for developing the renewal budget.

The lack of discretionary funds to be allocated by the Steering Committee was also described as an implementation challenge by interviewees from several consortia. One interviewee described the administrative and hiring delays experienced by one of the consortia during the start-up

period as serendipitous, because the first month's funds plus unused salary funding became available as a discretionary fund for the Steering Committee to allocate to other projects as needed and to cover unforeseen expenses. Interviewees also reported that the External Advisory Committee for one of the consortia cited the lack of a discretionary budget as a weakness towards the end of the first year.

Data Sharing Issues

Interviewees familiar with the AfCS and CFG in particular described issues associated with implementation of each consortium's data sharing policy. According to interviewees, the AfCS had a policy of not publishing its work except on the consortium Web site during the first five years. After the renewal, however, that policy was changed, at which point data were withheld from the Web site until after publication. At the urging of NIGMS, the consortium did eventually post data to the Web site, but in some cases the relevant metadata were not made available.

The CFG's original data sharing plan stated that all consortium-funded data would be made public. According to interviewees, however, some consortium members became reluctant to share data, and the consortium requested permission to revise its data sharing plan such that the Steering Committee would have authority to decide which data to share. NIGMS denied this request. The consortium did continue to post validated data, but, as with the AfCS, interviewees reported that there were issues with reluctant members not providing sufficient metadata.

As the only clinically oriented consortium, Inflammation faced unique challenges in contending with regulatory and oversight requirements. Obtaining Institutional Review Board approval for the various sites was described as a difficult process, especially because standards for Web-enabled databases had not yet been established under the Health Insurance Portability and Accountability Act (HIPAA) at the time the consortium was initiated.

Relationship with Research Community

Interviewees reported that all of the Glue consortia experienced some degree of friction with the rest of the relevant research communities to some extent. For example, the Inflammation PI stated that he suspected that the investigators in his relatively small field who were not invited to participate in the consortium may have felt slighted. As another example, the Cell Migration PI described receiving unexpected feedback that the community was opposed to the consortium doing investigative research because of fears that it would become a juggernaut and that non-participants would be shut out. The consortium took these concerns seriously and imposed policies intended to minimize negative impacts on the community; granting full public access to consortium data is one such policy.

IV. NIGMS Management Processes and Program-Level Implementation

This section describes program-level implementation issues, including peer review processes, the role for NIGMS program staff in consortium-level management, oversight of the Glue Grants by the NIGMS Advisory Council, and coordination of management at the program level.

A. Application Review Processes

Because the Glue Grants were awarded in phases, applications were evaluated at the beginning of Phase I, the beginning of Phase II, and at the competing renewal for Phase II. As with other large-scale NIGMS awards, each stage of competition involved review by a Special Emphasis Panel (SEP) followed by individual review by the NIGMS Advisory Council. Issues and challenges identified by interviewees are described in the subsections that follow.

Phase I Review

As described by interviewees, the primary purpose of the Phase I review was to identify whether the proposed topic or problem was appropriate for the Glue Grants program, whether the proposed team of investigators (especially the PI) was sufficiently well qualified to address it, and whether there was sufficient evidence of a sound and cohesive plan to solve the chosen problem in a ten year time frame. Groups of several Phase I proposals were typically reviewed simultaneously by the same SEP. Perhaps because NIGMS's investment at this stage was small, the NIGMS Advisory Council's involvement with Phase I proposals was described by interviewees as minimal.[31]

Many interviewees who commented on the Phase I review process stated that it was insufficiently rigorous and that the actual concept being proposed may have received too little attention. One specific concern expressed was that the application format was too brief to provide sufficient information; Phase I applications consisted of a ten-page summary proposal, a two-page description of key personnel, and a three-page description of institutional resources. A second set of concerns were related to the composition of the SEPs, with some interviewees expressing doubt that a single SEP could possess sufficient expertise to review multiple Phase I applications.

Phase II Review: Special Emphasis Panel Phase

During 2000, the initial year in which Phase II applications were accepted, a SEP was assembled specifically for each application reviewed. In the three years that followed (2001–2003), all Phase II applications were reviewed by a single SEP. One interviewee stated that the subject matter of Phase II applications reviewed during this period varied widely, but the reviews were satisfactory. There were no additional Phase II applications reviewed until 2008, when a separate SEP was set up for each of the two applications reviewed.

As is standard practice for NIGMS review processes, review staff members arranged a teleconference prior to the review for the purpose of orienting panelists to the review process and criteria. Interviewees reported that senior NIGMS staff members, including the Institute

[31] No Council members were interviewed as part of the Process Evaluation.

Director, participated in some of these orientation meetings. Concerns about the process raised by interviewees included the following topics.

- ***SEP Recruiting.*** The general approach to recruiting reviewers described by review staff members who were interviewed was to start with experts in the most relevant fields who did not have conflicts of interest with the application under consideration—a particular challenge in smaller and more specialized fields due to the size and scope of the Glue applications. Additional reviewers with expertise in specific relevant areas such as bioinformatics were then added as needed. Review staff members explained that they also screened out otherwise qualified candidates who seemed to have strong biases regarding NIH support for large-scale collaborative research. Because of the high profile of the Glue Grants and the seniority of most applicants, interviewees also made an effort to ensure that potential reviewers were sufficiently well established in their careers that they would not be vulnerable to retaliation by applicants who did not like the outcome of the review. By all accounts, these various requirements made the process of recruiting reviewers for the SEPs unusually challenging.
- ***Complexity of Applications.*** Interviewees commented that the SEPs were diligent in working through the vast quantity of information provided in the Phase II applications, but the complexity of the proposed consortia made it challenging for the reviewers to assign a single priority score. Specifically, interviewees stated that the large number of components, each with potential for major and minor flaws, tended to negatively impact priority scores, even if the proposal as a whole was believed to be generally sound. Interviewees expressed doubts about the adequacy of the priority score as a mechanism for accurately conveying the SEP's assessment of Glue applications to NIGMS. It should be noted, however, that priority scores are one of several factors taken into consideration when applications are considered for funding. Furthermore, as is standard practice for peer review throughout NIH, the SEPs also provided summary comments in which they could elaborate on particular concerns.
- ***Desirability of Site Visits or Interviews.*** There were differences of opinion among interviewees (including review staff members, program staff members, and awardees) regarding the desirability of some form of direct contact between applicants and review panels (e.g., site visits, interviews) to supplement the written application materials. Those who were opposed tended to observe that the application page limits were generous enough to allow applicants to include all relevant information. Specifically regarding the possibility of site visits, it was also observed that the Glue consortia were geographically dispersed, so site visits would most likely have consisted of one or several meetings with leaders from each proposed consortium in a location selected for convenience. Interviewees who favored direct contact tended to argue that the consortia were so complex that it would have been difficult for applicants to anticipate all possible questions that reviewers might have had. During the first few review cycles, review staff members reported that arrangements were actually made for the PI to be available to answer questions from the SEP if necessary, but no such questions were ever posed. One review staff member mentioned soliciting questions from reviewers in advance of the review meeting for transmission to the PIs via email; a small number of questions were reportedly asked and answered in this manner.

Phase II Review: Advisory Council Stage

Interviewees reported that each scored Phase II application received careful consideration by the NIGMS Advisory Council. Interviewees' concerns with respect to the process of review by Council fell into three groups:

- ***Conflicts of Interest.*** Several NIGMS staff members commented that conflicts of interest with applications under consideration frequently required large numbers of Council members to refrain from participating in deliberations on Glue applications. They found this particularly troubling because the Advisory Council members in conflict with any given application were often those with the most relevant expertise. While the Council did have the option of appointing *ad hoc* members to review applications, interviewees worried that these appointees would not necessarily have had the breadth of experience and comfort level of regular Council members.
- ***Scoring and Decision-Making Processes.*** Interviewee opinions were mixed with respect to the Council's ability to understand and interpret the priority scores and comments assigned to applications by the SEPs. Some interviewees pointed to examples where the Council looked beyond relatively low priority scores to recognize merit in particular applications.

Review for Competing Renewals

In general, the process for review of competing renewal Phase II applications was similar to the process for review of the original applications. One difference was that individual SEPs were assembled for every competing renewal. Concerns raised by interviewees that were specific to competing renewals included:

- ***Timing and Ability to Assess Progress.*** One concern unique to renewal applications was the need to judge whether progress had been sufficient to justify continuation of the cooperative agreement. Several interviewees expressed concern that renewal applications, which were typically written during year four of the Glue Grant, may not have sufficiently reflected potential for future achievements. This was described as a particular concern for consortia that experienced early delays in "ramping up" their operations to full scale. Interviewees also noted that there was no common "yardstick" and little precedent to help reviewers judge how much progress to expect from consortia of this scale during the first few years.
- ***Consistency with Previous Review.*** Review staff reported that, in all five cases, members of the SEP that reviewed the initial Glue Grant application were also invited to participate on the SEP for the competing renewal. However, some of the original reviewers developed conflicts of interest with the funded consortia in the interim period (e.g., by participating as members of the EAC) that rendered them ineligible to participate. Interviewees observed that the two panels sometimes reached inconsistent conclusions regarding particular decisions or components of Glue consortia. Some of these interviewees suggested that some of the inconsistencies may have been attributable to a failure on the part of NIGMS and the consortia to adequately address concerns raised during the initial review. Others attributed apparent inconsistencies to differences in SEP composition or to members changing their minds about particular issues.

B. Role of NIGMS in Consortium-Level Management

The Glue Grant solicitations describe three specific roles for NIGMS in managing the cooperative agreements:

1. Serving as a voting member of the Steering Committee and playing an active role in meetings;
2. Facilitating communication with the scientific community and conveying any concerns raised by the community to the Steering Committee and Advisory Committee; and
3. Normal stewardship and administration of the award.

Initially, the NIGMS Program Director for each consortium was assigned to perform all three roles. After the first few years, however, concerns arose regarding potential for conflict of interest between the Program Director's role as a scientific participant and administrator and, to a lesser extent, the amount of time required for a single individual to fill both roles. In response to these concerns, a second program staff member was assigned to three of the five Glue Grants. This individual assumed responsibility the third role.

For most of the Glue consortia, interviewees described relatively little involvement by NIGMS program staff in the scientific and day-to-day management of the cooperative agreements. Most PIs interviewed described NIGMS program staff members as generally reasonable and insightful voices on their respective Steering Committees who were especially helpful in clarifying the Institute's expectations, opinions, and requirements. Several PIs also confirmed that NIGMS program staff members effectively facilitated communication between the consortium and the larger research community. These PIs acknowledged that minor disagreements had arisen on occasion, but they stated that these had been easily resolved through mutual discussion.

However, one PI expressed confusion over the intended role of the NIGMS program staff member on the Steering Committee. Until the renewal, he stated, it had been his understanding that all Steering Committee members had one vote and an equal voice. However, the consortium later found that it was required to reverse a Steering Committee decision on which the NIGMS representative had been the only voice of dissent as a condition of continued funding. The PI concluded that, in the future, the NIGMS vote should be treated as a veto rather than a single voice among many. The same consortium and NIGMS staff members were also at odds on a number of different management issues, especially after competitive renewal. Specific issues mentioned as sources of conflict include: approval of a new Core director; budgets and resource allocation across the consortium; interpretation of the consortium's data sharing policy; and the consortium's relationship with the larger research community. Interviewees from the consortium and NIGMS agreed that the Institute involved itself more actively in consortium management after the renewal and uncertainty associated with the shift strained the relationship on both sides.

C. Oversight by Council and Administrative Review

The Glue Grants were unique at NIGMS in that the Advisory Council received a summary of progress by each consortium every year. In most years, the Program Director submitted a two-page report to the Council describing progress. In the third year, however, the PIs were brought before Council to make brief reports in an open session.

"Administrative review" refers to a set of informal management procedures that may be invoked at the discretion of NIGMS staff or the Council to gather additional information about awards

while they are in progress. Council typically decides when such reviews should be conducted, but the details of how to conduct the reviews are generally decided by program staff.

At the time of the Process Evaluation, administrative review had been requested by the Council for each of the three active Glue consortia that had reached the midpoint between competitive renewal and the end of the ten year funding period. Administrative reviews of the CFG and Cell Migration consortium had been completed, and a review of the Inflammation consortium was still in progress. The Council's purpose in requesting these reviews, as described by interviewees, was to ensure that the consortia remained on track to meet their milestones as the end of their ten year funding period approaches.

Interviewees characterized the administrative review processes differently for each of the three consortia:

- The Cell Migration PI described the review as a multistage process. It began with the consortium submitting a document to a panel of reviewers that described the consortium's progress toward its milestones during the previous two years. Next, the consortium's annual meeting was held at NIH, and several of the reviewers attended the meeting and had the opportunity to interact with attendees. Afterward, the reviewers developed a set of questions for the consortium, and the consortium responded in writing. Finally, the reviewers made a report to the Council that included recommendations for the future.
- As described by the PI, the CFG administrative review process consisted of a panel of external reviewers extracting information from the consortium's annual reports and preparing a written evaluation for Council based on that evidence only. No input from the consortium was sought, and the PI stated that he was unaware that the process was underway until the panel's assessment was complete.
- The Inflammation consortium has not yet been completed, but the process as described by interviewees had so far been different from both of the other two. According to the PI, the NIGMS Council itself (rather than an outside review group) posed a set of questions to the consortium, and the consortium has responded in writing. Interviewees stated that the questions focused primarily on two milestone-related issues.

One program staff member suggested that administrative reviews of the three consortia were implemented differently because they were designed to meet different information needs on the part of NIGMS as well as to motivate different behaviors on the part of the awardees.

D. Program-Level Management and Coordination of the Glue Grants

Dr. Michael Rogers, the Director of PPBC, served as the coordinator for the Glue Grants program. Interviewees stated that Dr. Rogers stayed well informed about all of the Glue Grants and acted as a mentor for the program staff members involved in the program. Dr. Rogers also coordinated monthly meetings with the Glue program staff, commonly referred to as the "G6" meetings. The purpose of these meetings, according to interviewees, was to create an opportunity for program staff members to discuss issues that arose with particular Glue Grants consortia. Senior NIGMS staff members, including the current NIGMS Director, occasionally attended the "G6" meetings.

However, neither Dr. Rogers nor the "G6" group ever had authority to set or enforce policy across the program; consortium-level management decisions remained in the hands of the Program Director and/or more senior staff members in the Division to which the Glue Grant was assigned.

Dr. Rogers described his own role as primarily advisory, especially for the Glue Grants that do not fall within the PPBC portfolio.

However, an interesting example of limited program-level coordination occurred during the fourth year of the program, when a document referred to by interviewees as the "management matrix" was accepted by the program staff and approved by NIGMS leadership as Institute policy. The matrix actually consists of a list of possible changes that might be made to the consortia (e.g., implementing non-substantive scientific changes; proposing new scientific directions within the scope of the award or new scientific leadership; proposing significant changes in scale or new directions; and clear changes in project scope) that were to trigger specific actions on the part of program staff members. For each possible trigger event, the matrix describes appropriate actions to be taken by the program staff (e.g., requesting that the PI consult with the External Advisory Committee, seeking external input); it also lists parties to be notified as well as documentation to be obtained.

One interviewee appreciated that the matrix provided a general set of procedural guidelines for the program staff members responsible for the Glue Grants to fall back on, clarifying the events that the Institute believes should trigger action on the part of the staff as well as the immediate next steps to be taken. However, it was difficult to get a more general sense from interview responses of the role the matrix has played in actual management of the Glue consortia.

V. Findings

The following findings summarize conclusions drawn by the independent evaluators after careful consideration of the evidence collected during the Process Evaluation. Findings in three categories correspond to the original study questions:

- Program planning and design (Findings 1 and 2);
- Implementation and management at the level of the consortium (Finding 3);
- Implementation and management at the level of the program (Findings 4 through 7).

Finding 1: The program-level objectives of the Glue Grants were not clear.

Two program objectives were identified in the original (1999) Glue RFA: "to enable the solution of major problems in biomedical research" and "to facilitate the next evolutionary stage of integrative biomedical science." Of the two, problem solving is probably more straightforward, but the meanings of both "problem" and "solution" were never entirely clear in the context of the program. The four examples offered by the RFA in lieu of a more general description of the types of problems appropriate for the initiative suggested an emphasis on determining and/or modeling cellular processes, structures, and physiological pathways, but they did not set specific parameters and boundaries for the types of problems most amenable to solution via the Glue Grants. Most interviewees, including the PIs, seemed to recognize that the concept of solving a complex biological problem at all—let alone doing so in ten years—runs counter to how science is generally performed. In fact, although the Glue FOAs clearly emphasized problem solving as the ultimate goal of the consortia, interviews suggested that neither the Institute nor the awardees interpreted the language literally. One NIGMS staff member stated outright that the solution of a large-scale problem in 10 years was always more of an aspiration than an expectation, and the real purpose of the language was to encourage applicants to set ambitious goals for themselves.

The second objective ("to facilitate the next evolutionary stage of integrative biomedical science") is even more difficult to interpret as a program objective. Integrative activities were clearly important to program planners, but it was less clear what specific outcomes were to be achieved through integration. Discussions with interviewees suggested that the gluing concept was rooted in a particular set of assumptions made by NIGMS and its advisors about integrative biomedical science: (1) that many fields of interest to NIGMS have reached a point where integration is needed to take the next step forward; (2) that the scope and scale of the integration needed will require collaboration between multiple groups and across multiple disciplines; and (3) that traditional mechanisms are not adequate to support these activities. Given this context, it may be reasonable to understand the second objective in terms of filling perceived gaps by supporting activities that promote integration in order to move a field forward. Again, however, the FOA provided little guidance to help applicants, reviewers, or program managers identify the situations in which integration was most likely to promote progress. Also not specified explicitly by NIGMS—and apparently a key source of tension between NIGMS and several of the funded consortia—was what portion of the relevant scientific communities should be involved in integration efforts and at what level of intensity.

At least one interviewee suggested that the program-level objectives were deliberately left open to interpretation so that objectives could be self-defined by applicants. While this does appear to have been what occurred in practice (see Finding 3), sufficient evidence was not available to determine what the actual intent of the planners may have been. Regardless of intent, however, the Institute's decision to state program objectives that were open to interpretation had consequences for management at both the consortium and program levels.

Finding 2: The program design as implemented was not entirely consistent with either of the stated program objectives.

The structure of the program as implemented was not entirely consistent with either of the program objectives described in the solicitations, let alone both. With respect to problem solving, if NIGMS actually intended for the Glue consortia to be exclusively dedicated to solving research problems, the "gluing" approach was not obviously the most direct and efficient means of achieving the goal. Facilitating collaboration between groups of independently funded researchers does not guarantee that their goals and incentives will be aligned with any larger vision or overarching set of questions. In fact, if the goal had truly been to solve a complex biomedical research problem, it would likely have been more effective to provide dedicated research support so that the investigators working on the subcomponents would have been free to devote as much attention as possible to finding a solution.

On the other hand, if integration was the primary objective, it is likely that the program design could have been more effective if it had focused on a particular mechanism by which integrative activities were expected to result in progress for a particular field and/or the biomedical research enterprise as a whole. Examples of possible integrative mechanisms by which progress might be achieved include:

- Overcoming specific technical barriers or bottlenecks that impede progress;
- Identifying and filling gaps in strategic research agendas to reach common goals more quickly and efficiently;
- Adapting concepts, tools, and technologies from other fields to open new frontiers;
- Harmonizing methods, standards, and reporting practices and centralizing data collection to accommodate analysis of large-scale patterns; and
- Pooling the resources and expertise of multiple laboratories to address questions too large for a single group to tackle on its own.

Various components of the program as implemented appeared to be consistent with several of these mechanisms for achieving progress through integration, but the program design overall was not optimized for any of them. One example of a program component that was consistent with a particular mechanism was the bridging projects, which were used to overcome technical barriers and bottlenecks and, to a lesser extent, to adapt technologies and concepts from other fields. However, these structures represented only a minor component of the consortia that included them at all. Another example was the required information cores, which aimed to facilitate pooling of data. Similarly, the Inflammation consortium's efforts to develop consensus treatment protocols and the efforts by the CFG and LIPID MAPS to build consensus on nomenclature and taxonomy were also consistent with this strategy.

Finding 3: In the absence of clear program objectives, the Glue consortia were structured to meet needs and priorities as determined at the consortium level.

Awardees appear to have designed the Glue consortia to meet perceived need in their own fields. One PI stated that he had simply proposed to do as much to move his field forward as he felt could reasonably be accomplished for $5million dollars per year in direct costs, while another emphasized the ten year time frame as the most important constraint on consortium design. As might be expected, there were substantial differences in how the various consortia framed their objectives as well as how they organized and interpreted the structural elements of the program (e.g., cores and bridging projects). Some interviewees, particularly the PIs, identified the flexibility of the program with respect to both objectives and structure as a key strength. Some literature does suggest that flexibility can enhance a program's effectiveness in promoting collaboration under certain conditions.[32]

Finding 4: The Glue Grants functioned as a funding mechanism rather than a cohesive program or initiative.

As implemented by NIGMS, the Glue Grants functioned as a funding mechanism rather than a true program or initiative with its own vision, goals, and management structure. Interviews with individuals who participated in the planning stages made it clear that the original concept was motivated in part by a desire to experiment with alternatives to the R01 Research Project Grant, which, at the time, made it difficult to support collaborative projects. Instead of creating a unified management structure for the Glue Grants as a program, each cooperative agreement was placed into the portfolio of an existing NIGMS Division with relevant interests. The program staff members from different Divisions who were assigned to Glue Grants did meet regularly, and senior NIGMS leaders were involved in those discussions as needed. However, neither the "G6" group nor any central authority below the level of the Institute Director was authorized to set or enforce policy for the Glue Grants as a group. Instead, responsibility for decision-making was retained by the Program Directors and their respective Divisions.

It is not the intent of the evaluators to suggest that the Institute's decision to treat the Glue Grants as large cooperative agreements within the context of existing NIGMS Divisions and portfolios was unreasonable or inappropriate. However, some interview evidence suggests that stakeholders at NIGMS and in the extramural community may not have fully recognized the implications of this choice. Although they arose from a common solicitation, the Glue consortia functioned and were managed as five separate cooperative agreements.

Finding 5: The ten-year timeframe posed a variety of challenges.

Based on discussions with stakeholders involved in the design process for the Glue Grants, the original rationale for the ten year time frame was to ensure that the Glue consortia would not continue indefinitely. Interviewees stated that a five year initial award plus a single competing

[32] See E. Corley, C. Boardman, and B. Bozeman (2006). "Design and the Management of Multi-institutional Research Collaborations." *Research Policy* 35: 975-993; C. Boardman and B. Bozeman (2006). "The Emergence and Impact of 'Organic' Research Collaboration." *Economics of Innovation and New Technology* 15(1): 51-69.

renewal term should have been sufficient to address a complex biological problem. Several interviewees hinted that the sunset provision was also intended to allow the Institute to invest a portion of its newly expanded extramural budget without creating obligations over the long term.

Regardless of the rationale, however, it is clear that the ten year time frame had several important implications for program planning and implementation. First, experience demonstrated that collaborative efforts on the scale of the Glue consortia required substantial amounts of time to scale up to a point where they are fully functional. PIs stated that one to two years of "ramp-up" time were typically required to fully staff the consortia, build trust and productive communication between participants, overcome technological and methodological barriers, and otherwise begin operations. This ramp-up process had funding implications because the consortia were generally unable to spend their full budgets during the first year or two, resulting in carry-overs to future years. Some interviewees interpreted this circumstance as serendipitous, because the carry-over funds were used to support new projects or increase funding to initiatives that required additional resources. Several program staff members and PIs also anticipated a "ramp-down" period towards the end of the ten year funding period. The possibility of asymmetrical annual budgets was introduced with the 2004 solicitation specifically to address this problem.

Second, several interviewees expressed concern that the sunset provision reduced the amount of leverage that NIGMS had over the consortia after the competing renewal as well as the leverage the consortia had over participating investigators. With no possibility of continued funding, they reasoned, participating investigators had less incentive to prioritize the needs of the consortium over their own interests, such as obtaining new funding for their individual laboratories. As a partial solution, several NIGMS staff members suggested shorter intervals between reviews and/or instituting mandatory administrative review at the midpoint of each interval, with subsequent funding released upon a successful evaluation or identification of corrective steps needed.

Finally, post-award sustainability of resources and other consortium activities do not appear to have been adequately incorporated into the original program design. Since the Process Evaluation was initiated while four of the five consortia were still active, assessment of post-award sustainability is somewhat premature. However, interviewees described a variety of serious concerns about the fate of the Glue consortia and their data, resources, and networks after the funding period expires. All of the PIs interviewed were actively seeking options to sustain the most essential consortium resources, but in all cases the future looked uncertain, and several PIs expressed frustration that there was no obvious path at NIGMS through which to pursue continued funding. Evidence received after the interviews were complete indicated that the Institute was actively making plans to address the sustainability issue towards the end of 2009.

Finding 6: Significant challenges for peer review were encountered because of the size and scope of the Glue Grants.

Several serious challenges for review of the Glue Grant applications were described by interviewees. At Phase I, Special Emphasis Panels (SEPs) may have been asked to review multiple proposals and to evaluate the importance and plausibility of concepts without sufficient information. At all phases, review staff members had to expend considerable (and sometimes extraordinary) effort to recruit reviewers with appropriate expertise and seniority who were free of conflicts of interest with the applicants and willing to keep an open mind about the Glue Grants. Once assembled, the SEPs faced challenges in fairly assessing applications with an unusually large number of components. Competing renewal applications were even more difficult

to assess because there were no accepted standards for how much progress was reasonable to expect from the Glue consortia after only a few years of operating at full scale. After peer review, the Council faced challenges in deciding how to interpret all of the input it received regarding the merit of each application. These challenges were often made more daunting by the absence of the Council members with the most knowledge and experience in the relevant areas of science, because these individuals were most likely to have conflicts of interest with the application under consideration.

It is worth noting that the most serious challenges described above arose from the size, scope, and nature of the Glue Grant applications rather than from any inappropriate actions on the part of NIGMS staff members, the SEPs, or the Advisory Council. Evidence indicates that appropriate efforts were made by all participants to meet the unique needs of the Glue Grants while working within the confines of NIH requirements for peer review.

Finding 7: The Institute's approach to management of the Glue cooperative agreements was not adequately defined.

Two potential problems were identified in the Institute's approach to managing the Glue cooperative agreements. The first was that mechanisms for ensuring that the consortia and NIGMS developed and maintained a common vision for the objectives and strategic direction of the consortia were inadequate. Interviewees tended to raise this concern most often by observing that they received inconsistent feedback from NIGMS regarding whether the relative importance of creating resources for and involving the entire research community as opposed to solving a complex biological problem. In particular, several PIs commented that they were directed by NIGMS to divert funds to activities that they did not deem central to their goals, or, conversely, away from activities that they did deem critical. The PIs expressed some frustration with what they perceived as shifts in priorities that appeared to motivate these requests.

The second potential problem with the Institute's management approach was a lack of clarity surrounding the role for NIGMS in consortium management. Although the Institute clearly had the authority to involve itself to the extent it saw fit, truly active participation by program staff in directing extramural research is not the cultural norm at NIGMS. Interviewees suggested that they would have expected any attempts by individual program staff members to wield too much control without obvious justification to be met with strong resistance from the extramural community, and they would not necessarily have expected support from colleagues or superiors, either. As might be expected, therefore, the default approach to management of the Glue Grants program appears to have been mostly passive, with NIGMS program staff members providing advice and answering questions but leaving scientific direction and day-to-day management to the PIs and Steering Committees.

In the case of one consortium, however, an escalating series of disagreements after the competing renewal seems to have resulted in a shift from passive to increasingly active involvement in consortium management by program staff. It was beyond the scope of this evaluation to determine whether specific actions or positions taken by either party were justified by circumstances or who was at fault for the apparent breakdown in communication. However, it seemed clear from interview evidence at the time of the Process Evaluation that the consortium was not sure what level of involvement to expect from NIGMS moving forward.

VI. Recommendations

The first part of this section considers findings of the Process Evaluation in the context of strategic options available to NIGMS in order to make recommendations for how program processes might be improved in the future. The second part makes recommendations for future evaluation efforts.

A. Recommendations Based on Findings of the Process Evaluation

The Process Evaluation can offer little guidance to NIGMS in choosing among strategic options with respect to the future of the Glue Grants. However, once a strategic direction is chosen, certain findings of the Process Evaluation have implications that may be useful in planning how to move forward. In the subsections that follow, recommendations based on Process Evaluation findings have been made in the context of four strategic options that are presumably available to NIGMS. Other programs that the evaluators believe might serve as useful models have also been suggested where relevant. Please note, however, that the list of options and models considered is by no means exhaustive, and the options are discussed in no particular order.

Option 1: Allow the current Program Announcement to expire and do not fund any new Glue Grants.

The Process Evaluation can offer little insight into whether the Glue Grants are well aligned with current NIGMS priorities or what value would be lost if the program was to be discontinued.

Option 2: Continue to fund and manage the Glue Grants as individual cooperative agreements within the context of existing NIGMS research portfolios.

Specific improvements that might be considered within the existing program design and management model are described below.

> **Recommendation 2-1: Require the funded consortia to set achievable goals and consider requiring them to develop post-award strategic plans for approval by NIGMS.** If NIGMS decides to continue allowing goals to be set at the consortium level, it will be critical that those goals are clearly communicated and understood by all parties. One mechanism that is employed by some NSF Centers programs is to require development of a post-award strategic plan for approval by the agency.[33] The purpose of the strategic plan is to clarify and reach agreement on goals, routes to goals, and use of resources.
>
> **Recommendation 2-2: Formalize administrative review processes during Phase II.** Increasing the number of times a consortium can expect to undergo substantive review to justify continued support would almost certainly increase the leverage of NIGMS over the consortia, particularly after renewal. However, the current system of *ad hoc* administrative review procedures is inadequate to meet this need because neither the consortia nor the Institute can plan for them in advance. Again, NIGMS might look to

[33] One example of such a program is the third-generation Engineering Research Centers (Gen-3 ERCs). For more information about the Gen-3 ERCs, see http://www.nsf.gov/pubs/2009/nsf09545/nsf09545.pdf; accessed August 2009. For the section of the ERC Best Practices Manual that deals with strategic planning, see http://www.erc-assoc.org./manual/bp_ch2_2.htm; accessed August 2009.

various NSF Centers programs for models; NSF Centers programs typically rely on a combination of annual site visits and approval of updates to the Centers' strategic plans as preconditions for receiving the next year's funding and as mechanisms to ensure ongoing communication regarding priorities.

Recommendation 2-3: Re-think expectations and adjust budget limits as necessary during Phase I to reduce ramp-up time and unexpected technical difficulties during Phase II. For example, Phase I awardees might be expected to produce detailed plans for data management systems, prototypes of tools, standard operating procedures, more accurate yearly budgets, etc. Under this scenario, review guidelines for Phase I would have to be made more stringent to avoid investing in planning for consortia that are unlikely to be competitive for Phase II funding. Of possible interest with respect to this recommendation are the NSF Centers for Chemical Innovation. This relatively new program is intended to allow groups of investigators to collaboratively solve "big problems" in chemistry. Like the Glue Grants, the program is designed to operate in two phases. However, the larger Phase I award ($500K per year for three years) requires a group of investigators to form a team and management infrastructure, develop their grand challenge concept, and address technical barriers that have emerged early in the research. The Phase II funding model is a five year cooperative agreement (maximum of $4 million in funding) with the possibility of a single renewal.[34]

Recommendation 2-4: Consider lifting the sunset provision or providing an alternative means of continued support for collaborative efforts after the first ten years. The start-up costs associated with the consortia in terms of time, effort, and money are substantial. While decisions about future investment should not be made exclusively on the basis of sunk costs, it would seem to be in the interest of both NIGMS and the consortia to remain open to the possibility of continued support for the most successful consortia if they remain well positioned to continue addressing important research questions at the end of ten years. This might be accomplished through additional renewals for existing Glue Grants, acceptance of applications for new Glue Grants from the same groups or development of transitional mechanisms to support continued collaboration.

Recommendation 2-5: Address the issue of sustainability for consortium-developed resources. Regardless of whether a mechanism is developed for continued support of collaborative research, it is clear that the data and resources developed by the Glue consortia should remain available to the extramural community for as long as they remain useful and relevant. Evidence received after the formal period of evaluation data collection suggests that NIGMS is currently engaged in planning for how to sustain resources developed by the current Glue consortia. Ideally, sustainability of resources to be developed by any new consortia would be addressed before new awards are made.

Option 3: Take steps to transform the Glue Grants from a mechanism to a true initiative with clear goals and consistent, centralized management practices.

If NIGMS decides to transform the Glue Grants into an initiative with central coordination, it is strongly recommended that the Institute closely examine the various large-scale Centers

[34] For more information about the Centers for Chemical Innovation, see http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=9186; accessed August 2009.

programs run by the National Science Foundation. For example, the Science and Technology Centers (STCs) program supports research awards of approximately the same size and duration as the Glue Grants. Like the Glue Grants, the STCs are open to a wide variety of topics, requiring only that the research reflect an ambitious research vision or theme of national importance. However, unlike the Glue Grants, the STCs are overseen by a team of four program staff from the NSF Office of Integrative Activities who work closely with each award's program officer(s). There is also a common reporting framework and process for all STCs as well as a long-term contract for evaluation support. Finally, there is a network of participating centers described in the program solicitation as being "charged with addressing common goals, problems and opportunities, and facilitating personnel and resource exchanges." The program convenes an annual meeting for the STC Directors, and side meetings are convened as needed to discuss particular aspects of Center operations.[35]

Assuming that the Glue Grants continue to use the cooperative agreement mechanism, many of the recommendations described under the previous option would apply to this option as well. Additional changes recommended based on Process Evaluation findings include the following:

Recommendation 3-1: Articulate a rationale, clear program goals, and a theory of action for the Glue Grants. To optimize design of the Glue Grants as a program, it will likely be necessary to clarify what it means to "glue" and what specific outcomes NIGMS hopes to achieve through "gluing."

Recommendation 3-2: Centralize leadership, management, and oversight. Under the current arrangement, no individual or group below the level of the Institute Director appears to have true authority over the Glue Grants as a portfolio. Managing the Glue Grants as a program would likely require dedicated management resources with a more centralized structure.

Recommendation 3-3: Encourage formation of a "network" of funded consortia. Encouraging interaction between the Glue consortia might serve several purposes: (1) it would allow for sharing of best practices on issues such as consortium management, data management, reporting, information dissemination, etc.; (2) it might encourage collaboration between consortia working in related areas of science; and (3) it would help to create a sense of identity for the program as a whole and investment in making progress towards program goals. Common mechanisms for network formation include annual "all hands" meetings (especially for programs where awardees' research is similar enough that such meetings are likely to facilitate collaboration), PI meetings (to share management practices), online networking, and electronic newsletters.

Recommendation 3-4: Implement mechanisms for collecting data sufficient to monitor progress towards program goals. To track progress towards program goals, it would be useful to collect relevant information prospectively. The types of information to be collected and appropriate mechanisms would depend on the vision and goals articulated and the management philosophy espoused by the program.

[35] For more information about the STCs, see http://nsf.gov/funding/pgm_summ.jsp?pims_id=5541&org=OIA; accessed August 2009.

Option 4: Identify the components of core functionality provided by the Glue Grants that are priorities for NIGMS and build smaller programs around each component.

A fourth option, possibly useful on its own or in combination with any of the previous three, would be to identify the most important core functionalities provided by the Glue Grants and design a series of smaller programs around the various components. Some existing mechanisms that might replace components of "gluing" functionality include:

- R13/U13 Conference Grant awards for coordination of research agendas and strategic planning;
- R24/U24 Resource-Related Research awards for building research resources to benefit a community;
- Collaborative R01 Research Project Grant awards to support collaborative research projects involving multiple laboratories and/or institutions.

Smaller programs would almost certainly be easier for the Institute to administer and review, and they would also give NIGMS more flexibility with respect to its commitments. However, a "gluing" approach composed of several small programs would not necessarily encourage synergies within a single field as the Glue consortia were intended to do.

A variation on this option that NIGMS might also consider would be to create a more modular structure for the Glue consortia based around a smaller cooperative agreement to which additional awards could be linked based on demonstrated needs of a particular research community. The Roadmap Interdisciplinary Research Consortia (IRCs) may be a useful model for this type of structure. The IRCs consist of a U54 cooperative agreement as the central component to support scientific cohesion and operational coordination of the consortium. Additional components, including research projects, resource development, and training programs, are funded as separate but linked awards.[36]

B. Recommendations for Future Evaluation Efforts

The size, scope, and visibility of the Glue Grants suggest that an Outcome Evaluation is almost certainly warranted to assess the value provided by the program to NIGMS and the extramural community. However, the Process Evaluation identified a number of factors that are likely to pose significant challenges for the feasibility of a program-level Outcome Evaluation of the Glue Grants. These include:

- The small number of funded consortia (five) relative to the high degree of heterogeneity with respect to consortium organization, goals, activities, and outputs;
- The apparent absence of a common set of objectives or theory of action across the program;
- The lack of standards or suitable comparison groups against which to measure progress.

While a Feasibility Study would be required to explore these issues in detail, the sense of the evaluators who conducted the Process Evaluation is that program-level evaluation of Glue Grant

[36] For more information, see PAR 06-122/RFA-RM 06-008.

outcomes would be an extremely difficult undertaking, and there is a high risk that any results would be misleading.

As an alternative to analytical assessment of outcomes at the program level, therefore, it is recommended that NIGMS consider attempting to document outcomes for each of the Glue consortia individually. One option available to NIGMS would be for the program staff members to work with the awardees to expand upon Appendix C of this report. Although somewhat anecdotal, a list of accomplishments considered important by the awardees would likely be informative regarding Glue Grant outcomes. Alternatively, NIGMS could opt for a more systematic approach, hiring a contractor or other neutral observer to develop outcome-focused case studies for each of the funded Glue consortia.

Either of these descriptive options could potentially be combined with some form of evaluative assessment based on expert judgment, but the logistics would be challenging. Any panel seeking to evaluate the Glue Grants as a group would face many of the same difficulties described previously for an analytic approach—especially the lack of a common set of standards against which to measure progress. Alternatively, a separate panel could be convened to render a judgment about the value of each funded consortium relative to its costs, but there is a risk that such a process would be perceived as second-guessing the peer reviewers with the benefit of hindsight. As was true of every stage of peer review for the Glue Grant applications, recruiting expert panel members with sufficient expertise and seniority to be credible who are also free of both direct conflicts of interest and preconceived opinions about the Glue consortia is also likely to be challenging.

Furthermore, it must be noted that the range of questions that could potentially be addressed by any retrospective effort to assess outcomes of the Glue Grants would mainly be of historical interest, with limited relevance to the strategic decisions faced by NIGMS regarding the future of the Glue Grants. Certain key circumstances, including the budget situation, have changed for NIGMS since the Glue Grants were launched in 1999. NIH-wide, new mechanisms such as the collaborative R01 and the Roadmap initiatives have also been introduced that offer new alternatives for support of collaborative activities. In the interest of looking forward, therefore, the most logical next step might be for NIGMS to consider a Needs Assessment to assess current needs and priorities of the Institute with respect to large-scale problem solving and collaborative research. Such an effort might take the shape of a formal research effort, as described in the NIH Guide to Evaluation, or relatively informal discussions among key stakeholders.

Appendix A: Glue Grants Logic Model

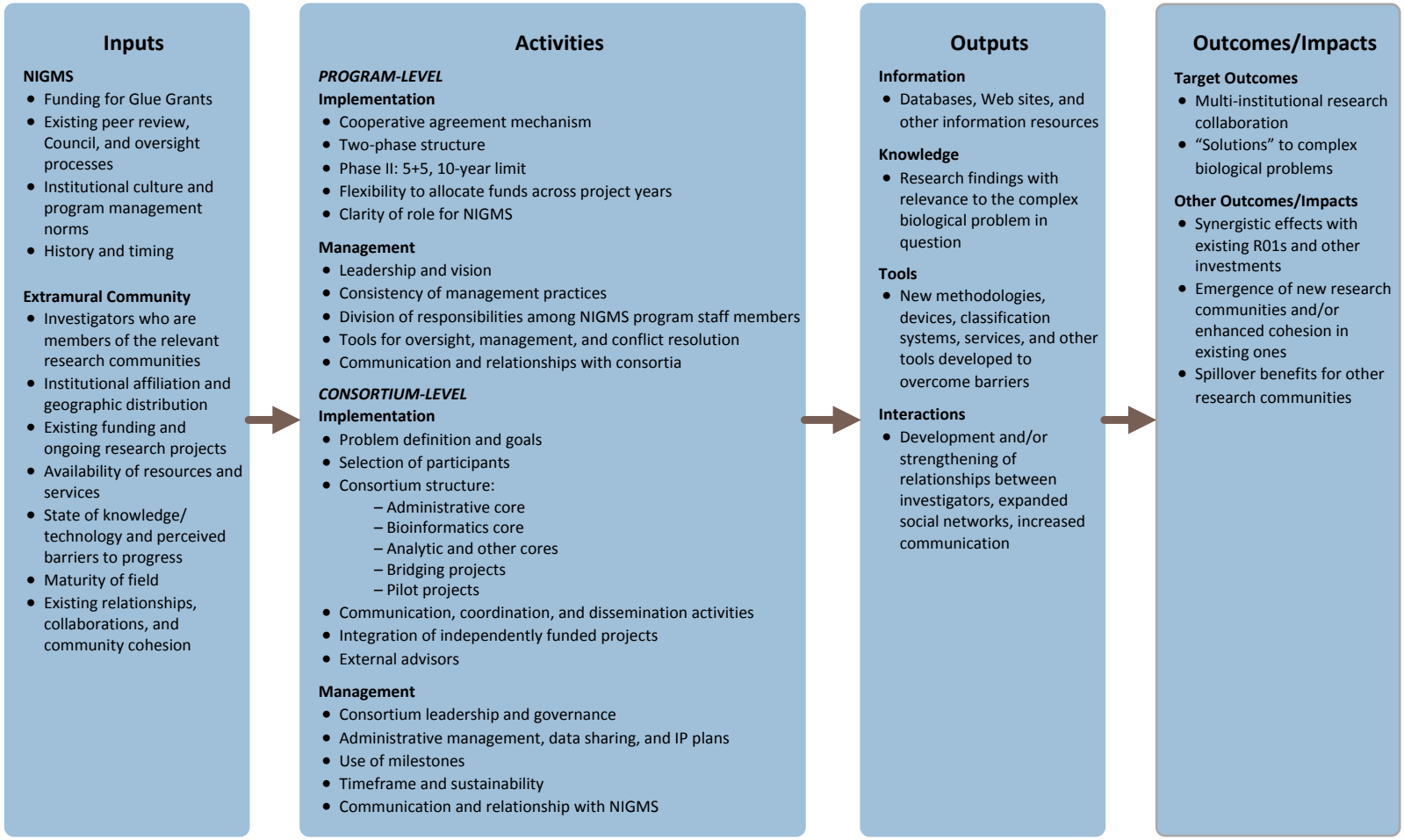
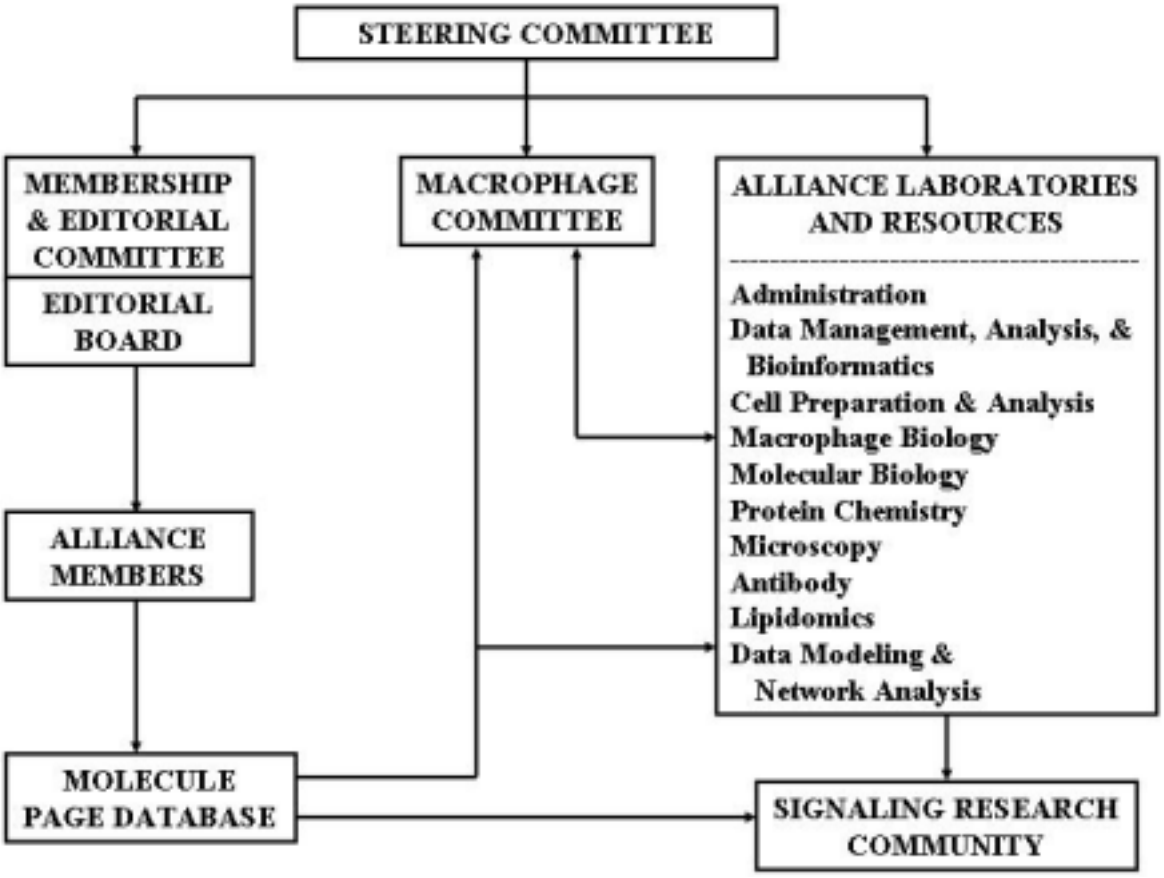


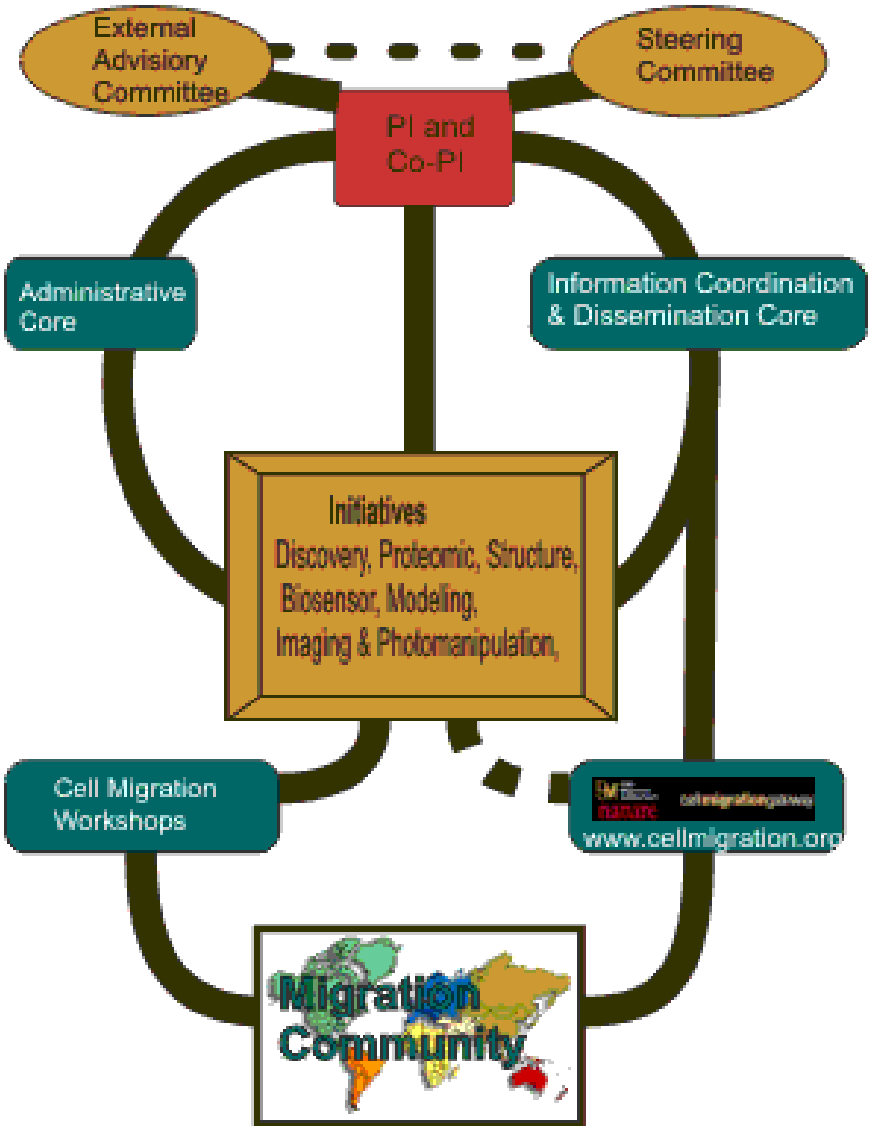
Figure A-1: Glue Grants Logic Model

Appendix B: Organizational Structures of Glue Consortia



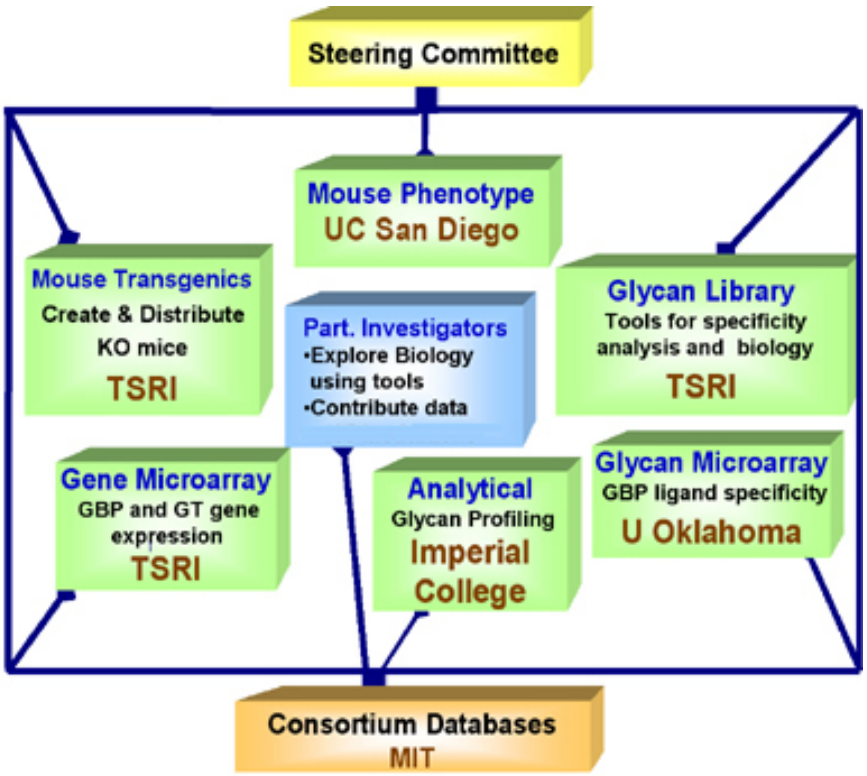
Source: AfCS application for funding.

Figure B-1: AfCS Structure



Source: Cell Migration Gateway, http://www.cellmigration.org/consortium/con_management.shtml, accessed 6/28/10).

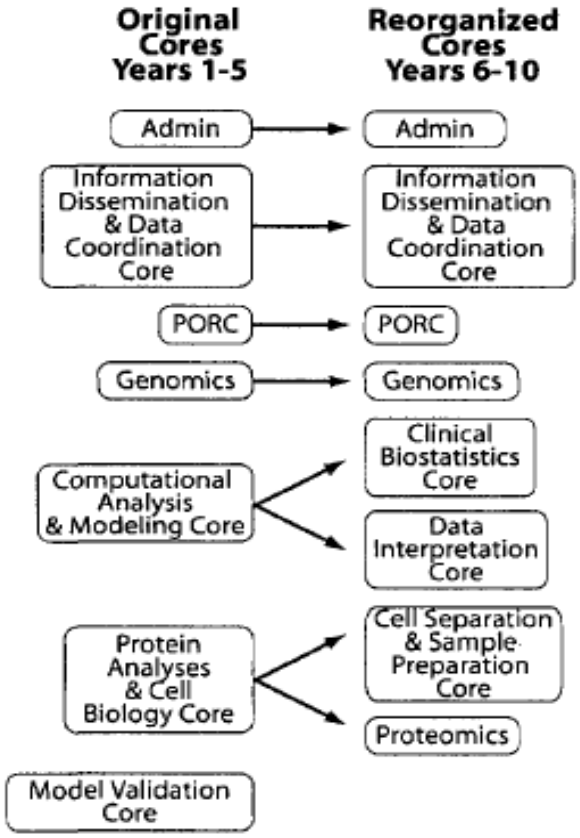
Figure B-2: Cell Migration Consortium Structure



Source: Functional Glycomics Gateway, http://www.functionalglycomics.org/static/consortium/organization.shtml, accessed 6/28/10).

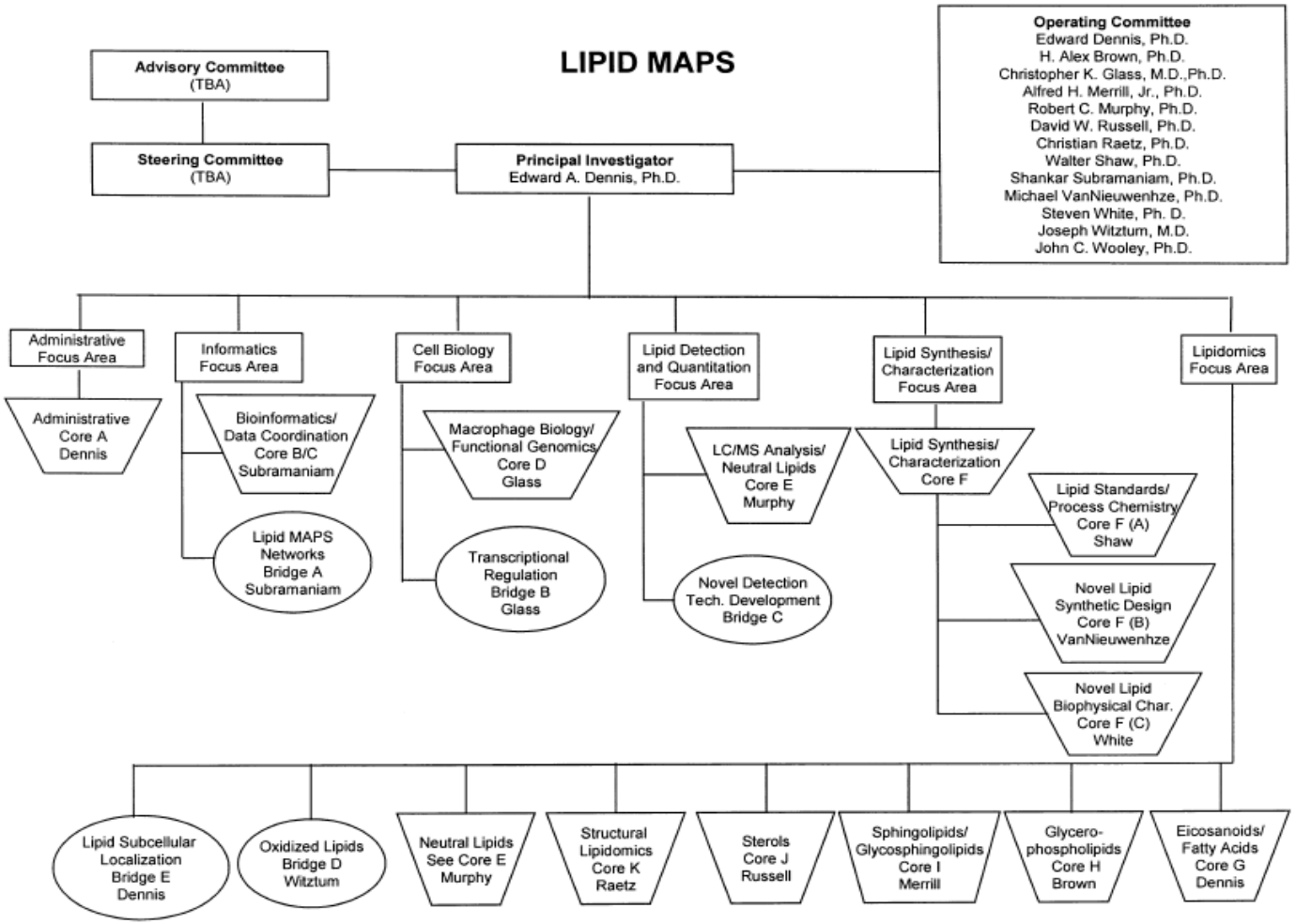
Note: The Glycan Microarray Core has moved from the University of Oklahoma to Emory University.

Figure B-3: CFG Structure



Source: Inflammation and Injury application for funding.

Figure B-4: Inflammation and Injury Consortium Structure



Source: LIPID MAPS application for funding.

Note: Figure describes consortium structure during the first five years; some cores were re-organized after the competitive renewal.

Figure B-5: LIPID MAPS Structure

Appendix C: Preliminary Outcomes of Glue Consortia as Identified by Interviewees, Administrative Data, and Consortium Web Sites

Note: Publication counts include only PubMed-indexed journal articles and are based on information compiled from progress reports and consortium Web sites as of March 2009. Advances and accomplishments listed are drawn from points made during interview discussions with PIs and program staff members; the lists are not exhaustive and have been included for illustrative purposes only.

Consortium Name	Number of Publications	Key Scientific Advances and Other Notable Accomplishments Identified by Interviewees
Alliance for Cellular Signaling (AfCS)	34	• Archived data sets from multiple ligand screens in B cells, WEHI cells, and RAW264.7 macrophages. • Database of quality control information on commercially available antibodies from CST. • Clones in plasmid vectors now commercially available at ATCC. • Other datasets (yeast 2-hybrid, microarray, lipid profiles), image files, and protocols. • Molecule Pages effort at Signaling Gateway (with ongoing support independent of AfCS). • Negative finding that studies of this kind cannot be done using the cell types originally proposed.
Cell Migration	239	• Identified the migration genome by genetic and RNAi screens. • Determined the phosphoproteome of a set of key migration molecules. • Determined the structural basis of integrin activation and the structure of dendritic actin. • Developed models for component processes that drive migration and started integrating into a comprehensive model. • Developed toolbox of biosensors, novel photomanipulation and imaging modalities, transgenic knockout mice, and suite of protocols and reagents. • Involvement with the consortium appears to have attracted researchers to cell migration who likely would have pursued other research directions—examples include a researcher who had previously focused on cancer and another who works on RNA screening.
Consortium for Functional Glycomics (CFG)	258	• Developed glycan array for high-throughput screening and library of 400+ glycans as the most visible and widely appreciated product of the consortium to date. • Using these tools to process and analyze approximately 50 samples per quarter at the request of participating investigators. • Used glycan array to identify proteins responsible for the shift of avian influenza virus to humans. • Spearheaded a worldwide effort to create a GeneBank-like resource for carbohydrates. • Developed 26 new strains of knockout mice. • Up to 90 requests per quarter processed by gene microarray core. • Produced and distributed synthetic glycans as well as standards and other reagents. • As part of the Functional Glycomics Gateway (http://www.functionalglycomics.org), developed a set of "Molecule Pages" for various proteins that attempts to integrate everything that is known about the molecule, including information from the CFG as well as other sources.

Consortium Name	Number of Publications	Key Scientific Advances and Other Notable Accomplishments Identified by Interviewees
Inflammation and Injury	91	• Developed consensus clinical treatment protocols and standards of care for trauma patients that have been adopted widely—NHLBI and DOD have both required use of consortium protocols for all relevant funded studies. • Because the commercially available Affymetrix microarray chip was based on information current as of ten years ago, a new microarray chip was designed, constructed, and validated to take advantage of recently acquired knowledge about the human genome and provide information of greater breadth and depth that previously possible. • Developed a microfluidic device for drawing blood from children that required a much smaller volume of blood than the standard 20mL. The cassette developed by the consortium requires only 0.1mL and speeds up the extraction process from two hours to 20 minutes. In combination with the SOP developed by the consortium, it is also suitable for use by nurses and technicians in standard clinical settings and may be conducive to use in rodent studies. • Developed a set of computational tools for dealing with time-related microarray data that was described in a 2005 paper in *PNAS* and has since been downloaded at least 7000 times (according to the PI). • A 2005 paper in *Nature* described use of a structured network knowledge-base approach to analyze blood leukocyte gene expression patterns in human subjects stimulated with bacterial endotoxin.
LIPID MAPS	118	• Forged international consensus on a lipid classification scheme. • Developed mass spectrometry protocols, standards, and reagents for lipid researchers that have been made available through the Avanti Polar Lipids catalog. • Developed a software tool that helps to draw structures for unknown lipids • Discovered several novel lipids. • Inspired similar efforts to support lipidomics communities in Europe and Japan.

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

PLEASE DO NOT RETURN YOUR FORM TO THE ABOVE ADDRESS.

1. REPORT DATE *(DD-MM-YYYY)*	2. REPORT TYPE	3. DATES COVERED *(From - To)*
XX-07-2010	Final	Aug 2008 - Jul 2010

4. TITLE AND SUBTITLE

Process Evaluation of the Large-Scale Collaborative Project Awards (Glue Grants) of the National Institute of General Medical Sciences (NIGMS)

5a. CONTRACT NUMBER

OIA-0408601

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)

Zuckerman, Brian
Srivastava, Christina Viola

5d. PROJECT NUMBER

5e. TASK NUMBER

OSTP-20-0002.46

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

Science and Technology Policy Institute
1899 Pennsylvania Avenue, NW, Suite 520
Washington, DC 20006-3602

8. PERFORMING ORGANIZATION REPORT NUMBER

IDA Document NS D-4051

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

Office of Program Analysis and Evaluation
National Institute of General Medical Sciences, National Institutes of Health
Building 45 - Natcher Building, 2AN32F
45 Center Drive
Bethesda, MD 20892

10. SPONSOR/MONITOR'S ACRONYM(S)

NIGMS

11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT

Approved for public release; distribution is unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT

The Large-Scale Collaborative Project Awards initiative of the National Institute of General Medical Sciences (NIGMS), commonly known as the Glue Grants program, was launched in 1999. Its purpose was to facilitate collaboration among independently funded investigators to solve complex biomedical research problems through the funding of consortia for a ten-year period. Beginning in 2008, STPI conducted a Process Evaluation of the Glue Grants program. The evaluation focused specifically on three main areas of interest: (1) program planning and design; (2) consortium-level implementation and management; and (3) program-level implementation and management. Key findings included: the program-level objectives of the Glue Grants were not clear; the program design as implemented was not entirely consistent with either of the stated program objectives; in the absence of clear program objectives, the Glue consortia were structured to meet needs and priorities as determined at the consortium level; the Glue Grants functioned as a funding mechanism rather than a cohesive program or initiative; the ten-year timeframe posed a variety of challenges; significant challenges for peer review were encountered because of the size and scope of the Glue Grants; and the Institute's approach to management of the Glue cooperative agreements was not clearly defined.

15. SUBJECT TERMS

Keywords: National Institutes of Health, Process Evaluation, Program Design, Program Implementation, Large-Scale Collaborative Project Awards, Glue Grants Program

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			Blome, Juliana M.
Unclassified	Unclassified	Unclassified	Same as Report	63	19b. TELEPHONE NUMBER *(Include area code)* 302-594-2762

Reset

Standard Form 298 (Rev. 8/98)
Prescribed by ANSI Std. Z39.18