IDA | SCIENCE AND TECHNOLOGY POLICY INSTITUTE

MEMORANDUM November 11, 2020

**To:** Hannah Dueck
National Cancer Institute (NCI)

**From:** Carly S. Cox
Science and Technology Policy Institute (STPI)

**Through:** Bill Brykczynski
Acting Director, STPI

**CC:** Amana Abdurrezak and Brian Zuckerman
STPI

**Subject:** Expert Panel Report of the Cancer Systems Biology Consortium Program Evaluation

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The National Cancer Institute (NCI) Division of Cancer Biology (DCB) asked the Science and Technology Policy Institute (STPI) to facilitate an expert panel to evaluate the Cancer Systems Biolgoy Consortium (CSBC) ahead of its 2020 renewal request. To fulfill this request, STPI selected panelists, issued invitations, convened the panel for meetings to discuss program evaluation materials, facilitated a meeting between CSBC investigators and panelists, and supported the panel in its deliberations. Based on the NCI provided program information, conversations with CSBC resources, and information gathered at the CSBC Annual Meeting, the panel formulated answers to the five program evaluation questions charged to them by NCI. STPI summarized the panel's answers to these questions in a draft document and completed a round of revisions with the panel and NCI. A finalized summary of the panel's response to the program evaluation questions is provided in the attached document.

**Attachment:** "Expert Panel Report of the Cancer Systems Biology Consortium Program Evaluation"

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# Expert Panel Report of the Cancer Systems Biology Consortium Program Evaluation

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October 2020

**This document is under review and is subject to modification or withdrawal. It should not be cited in other publications.**

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## A. Introduction

The Cancer Systems Biology Consortium (CSBC) is a network of research institutions and principal investigators working to "advance the mechanistic understanding of cancer using systems biology approaches that build and test predictive models of disease initiation, progression, and response to treatment."[1] CSBC was launched in September of 2016 and supports the following:

- 17 Individual U01 Research Projects
- 13 U54 CSBC Research Centers
- 1 U24 Coordinating Center

In support of the 2020 CSBC renewal request, The National Cancer Institute (NCI) requested an independent analysis of the program. NCI chose to convene an expert panel to provide insight into the CSBC program evaluation. As part of the process, NCI charged the panel with five questions:

1. Should NCI continue to support a dedicated program in cancer systems biology?
2. What impact is CSBC having on the field of cancer biology?
3. What is the role of CSBC in supporting a strong and stable research community?
4. Are the current funding mechanisms (U24, U54, and U01) appropriate to achieve the program goals?
5. Are there additional training and outreach activities that should be pursued to achieve program goals?

The panel identified an additional question to answer as a component of Question 1: What should a dedicated systems biology program look like moving forward?

NCI asked the Science and Technology Policy Institute (STPI) to facilitate the panel and its evaluation process. To fulfill this request, STPI selected panelists, issued invitations, convened the panel for meetings to discuss program evaluation materials, facilitated a meeting between CSBC investigators and panelists, and supported the panel in its deliberations. The panel is composed of five members with backgrounds in a mixture of cancer and systems biology fields. Short biographies of the panelists are provided in Appendix A.

NCI provided the panel with summary CSBC program information, but not individual grant applications or review documents. To collect information important to their charge, the panelists met and interacted with CSBC investigators during a virtual Investigator Panel

[1] Dueck, H. and Hughes, S. Communication to Panel. June 22, 2020.



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on August 31, 2020 and during the online CSBC Annual Meeting on September 16–17, 2020. During the Annual Meeting, panelists attended sessions presenting CSBC funded research and showcasing training and education initiatives at U54 centers. The panel met during the latter part of the Annual Meeting on September 17, 2020 to develop answers to the evaluation questions. A summary of the observed strengths of the Consortium and recommendations for the program in the future is provided below.

## B. Summary of Evaluation Questions

### 1. Question 1: Should NCI continue to support a dedicated program in cancer systems biology? Panel Identified Sub-Question: What is the expectation or impact of a dedicated program for systems biology research?

The panel recognizes the success of the CSBC program given its short period of operations. The panel agrees that the CSBC fosters a productive research community that is actively generating important data, resources, and computational tools that are of great value to the field. The panel also considers the CSBC to have enormous potential to produce clinically relevant models and data to inform cancer treatment and prevention. To date, however, its optimal impact has not yet been realized. In the next iteration of the CSBC, the panel recommends increased collaboration and outreach with clinical and biological researchers to translate CSBC resources into human impact. This will require specific mechanisms to encourage formal interactions toward concrete translational goals, but done in a way that will not dilute efforts to expand fundamental knowledge of the disease. The NCI should consider opportunities to expand the Consortium, bringing in new ideas and new innovators.

### 2. Question 2: What impact is CSBC having on the field of cancer biology?

The panel recognizes that the CSBC has created a productive platform for the cancer systems biology community to make collective action that is having significant impact in the field. The panel agreed that the CSBC is producing high-impact publications, tools, and resources that otherwise would not have been generated. The panel observed, however, that the interoperability and usability of these data and tools are suboptimal. Therefore, the panel recommends that the U54 centers and especially the U24 coordinating hub develop data and tool standards for harmonizing and integrating data produced by CSBC.

Despite its relatively short lifespan, the panel also recognizes the potential of future CSBC research to have clinical and translational applications. As such, the panel recommends the next iteration of the U54 Request for Application (RFA) and U01 Program Announcement with Receipt/Referral and/or Review (PAR) more effectively implement the incorporation of experimentation into cycles of computational modeling with the explicit goal of developing predictive disease models.

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3. **Question 3: What is the role of CSBC in supporting a strong and stable research community?**

The panel observed that the CSBC is generating a stable research community that is making great strides to train future generations of cancer systems biology researchers. However, the panel considered interconnectedness to be a critical component of a strong research community, which they did not observe to be sufficiently present across the Consortium. The panel suggested that the U24 Collaboration and Pilot Projects Hub focus on a defined set of research questions that could be used to promote collaboration within the Consortium. Additional competitive funding mechanisms were suggested to engage systems biology researchers outside of the Consortium and to expand the CSBC community.

4. **Question 4: Are the current funding mechanisms (U24, U54, and U01) appropriate to achieve the program goals?**

The panel finds that the U54 CSBC Research Centers and U01 Research Project – Cooperative Agreements are appropriate mechanisms for pursuing large-scale systems biology research. The panel further finds that while the U24 Coordinating Center mechanism is appropriate to achieve the Consortium's goals of data sharing and collaboration formation, there are weaknesses in how it has operated to organize and disseminate data. The panel recommends that the U24 Coordinating Center do more to harmonize and organize the data and tools generated by the Consortium, as detailed in the panel's response to Question 2.

Additionally, although the panel agreed that the Consortium is building a community of cancer systems biology researchers, the panel recognized that additional funding mechanisms are needed to foster new collaborations between Consortium members and researchers conducting systems biology research not funded by the Consortium. These collaborations could be fostered through new independent solicitations or program supplements and would allow the Consortium to expand its expertise and further disseminate CSBC resources and tools.

5. **Question 5: Are there additional training and outreach activities that should be pursued to achieve program goals?**

The panel recognizes the thoughtful mechanisms CSBC employs to train new leaders in cancer systems biology and generate a sustainable mechanism for future growth. The panel also applauds the Consortium for its community outreach to the public and local communities. To further increase its outreach, the program recommends that additional training courses be used to educate external researchers on how to maximize the utility of these resources and the tools that have been developed. This will augment the usefulness of the data generated by the CSBC and promote the adoption of the group's methods to the larger research community.

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## C. Panel Responses to Evaluation Questions

### 1. Question 1: Should NCI continue to support a dedicated program in cancer systems biology?

**Panel Identified Sub-Question - What is the expectation or impact of a dedicated program for systems biology research?**

The panel unanimously agreed that the NCI should continue to fund the CSBC program given the Consortium's positive contributions to the field and the continued need to build the systems biology community in cancer research. The panel noted that the Consortium has done well to stimulate this growing field and begin facilitating a cadre of people, ranging from early career to senior levels, who are willing to connect and collaborate on a host of systems biology topics.

As part of the identified sub-question, "What is the expectation or impact of a dedicated program for systems biology research?" the panel found it important to consider "What is the unique importance of systems biology to cancer research?". It was the opinion of the expert panel that cancer, as a complex system, can be best deconvoluted using tools tailored for modeling. These systems tools—many of which are mathematical and quantitative with roots in computer science and in the physical and engineering sciences—are only now applicable in biology. Systems biology as defined by the CSBC seeks to formalize the application of such tools in the dissection of cancer, and to then construct models that can be predictive of biological behavior. This goal is the cornerstone of predictive cancer medicine, as evidence grows that individual genes and mutations do not alone determine cancer risk, cancer development, or response to therapy. Thus, for cancer science to move forward, a systems approach is imperative. As with all new disciplines, an orderly discourse is necessary to provide the grounding framework for a community to grow. The CSBC has been an important first step in helping to crystallize a cancer systems biology community. The goal for the future should be to expand the systems biology community and to seek avenues toward clinical impact.

The panel identified the following as expectations of a dedicated program for systems biology in the future (and further enunciated in this document).

- **A dedicated program plays a coordinating role and leadership role in enunciating experimental principles in systems biology and establishing standards and quality control measures for systems biology resources.** The panel strongly recommends that the CSBC reexamine how data are developed, organized, managed, and disseminated to the community. In addition, attention to how wet lab experimentation is optimally coordinated with computational modeling will be important.

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- **A dedicated program develops processes and tools that facilitate effective collaboration between researchers within the Consortium and outside the CSBC.** The panel reaffirms that the Consortium has a responsibility to ensure investigators communicate and collaborate beyond the Consortium. To make further progress in answering systems biology's fundamental questions, the panel recommends that the CSBC work to make data and open source implementations of their software easier to obtain by those outside of the community. Additionally, the panel recommends that more be done to standardize resources and to close the experimental loop.
- **A dedicated program has impact.** Though the Consortium is in its early stages, the panel agrees that CSBC's research has already increased understanding of cancer and has the potential to produce clinical impact. The panel emphasizes that future research should be coordinated with clinical studies to increase options for cancer treatment, prevention, and survivability.

## 2. Question 2: What impact is CSBC having on the field of cancer biology?

The panel unanimously agree that CSBC is having significant impact on the field of cancer biology and noted that CSBC is producing numerous publications of high impact and significance to the field. The panel found that CSBC has created a productive research community and that the Consortium is producing data resources and computational tools that otherwise would not have been generated. It was also appreciated that the CSBC has provided a powerful platform for leading systems biology scientists to discuss and plan collective action that is having an impact in the field. The panel firmly believes that the CSBC concept of supporting a community of scholars in systems sciences to work together toward common goals should continue.

Although the panel recognizes that CSBC is producing many datasets, tools, and resources, they find that the interoperability and usability of these datasets and tools are suboptimal. Specifically, the panel found that data and tools are not adequately organized for integration and interoperability across the individual units within the CSBC. Moreover, the data generated were not translatable across cancer types. Interoperable datasets are important to building cell and organismal models that can accurately represent biological systems and contribute to the prevention, treatment, and survivability of disease. Similarly, easily transportable, open source software is essential for both reproducible research and for broad application of the methods developed.

The panel also noted that challenges exist with sharing data and resources generated by CSBC. The panel acknowledges that these resources and data are being used within the CSBC community (but often only by a small group of researchers), but the accessibility and usability of these resources to researchers external to CSBC is not mature. The panel agrees that standardized and quality-controlled data and resources should be made

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available to researchers in an accessible manner. The National Institutes of Health (NIH)-supported Encyclopedia of DNA Elements (ENCODE) Consortium was identified as a program after which CSBC could model data and tool integration, visualization, and dissemination. It is acknowledged that the data output of the CSBC is more complex and heterogeneous. However, if done correctly, the value of these data in creating predictive models of cancer biology is great. Currently, the panel observed that many of the datasets presented appeared to be stand-alone units derived from the work of individual investigators. Since the CSBC was launched in 2016, data harmonization and integration of these individual datasets may be limited, but for the CSBC to reach its full potential, such harmonization will be essential for systems biology to be truly engaged by the wider scientific community. To prevent the risk of overinterpretation of disseminated data and tools, training efforts could educate the future users about how these data and tools were generated and what could constitute appropriate use. Additional details about recommended training mechanisms may be found in the panel's response to Question 5.

***Recommendation: The panel recommends that the CSBC U24 Resource Coordinating Hub develop data and tool standards for harmonizing and integrating heterogeneous data and that mechanisms to share these resources (similar to NIH ENCODE) be established so researchers outside CSBC can readily use these data and tools.***

While the U54 RFA[2] uses language in describing research objectives that requires both modeling and experimentation[3] and the U01 PAR uses similar language, the panel observed that current research is focused on data and computational analysis with limited biological validation. The important future direction will be to create predictive models whose capabilities can be validated in experimentation. At the CSBC Investigators Symposium, only three presentations focused on predictive models: drug prediction from Ideker lab, Andrea Clifano's modular master regulator, and that of Nataly Karchenko with Forest White. There was some biological and clinical validation with these models that is modest perhaps because of the relatively short lifespan of the CSBC.

Incorporating iterative cycles of computation and experimentation is needed to progressively refine any *in silico* models arising from CSBC work. The panel, therefore, recommends that CSBC investigators develop formal work-flows and study designs that engage clinical and experimental biologists to validate models and to demonstrate human health relevance. The panel specifically recommends that predictive models be developed

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2 Department of Health and Human Services. "Research Centers for Cancer Systems Biology Consortium (U54)."

3 "CSBC Research Centers proposed in response to this FOA must demonstrate explicit integration of experimental biology and computational modeling to test and validate novel hypotheses or ideas of high importance in cancer research."



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with the goal of answering biologically and clinically relevant questions from the beginning of the research proposal.

***Recommendation: The next iteration of the U54 RFA and U01 PAR should more effectively implement the incorporation of experimentation as a complement to modeling and predictive efforts through future solicitation language, instructions to reviewers, and direction by NCI staff participating in the management of the Consortium.***

The panel further notes the potential for results from the Consortium (and its U54 research centers especially) to have clinical impact. The panel acknowledges that CSBC is still in its early stages, so it is reasonable that the program does not have clinical or therapeutic applications at this time. However, the research centers' research objectives include language specifying the goal of clinically relevant research results[4]. Translating those results into clinical testing should be an important next goal to prove system biology's impact on cancer prevention, treatment, and survivorship. The panel understands that the CSBC does not fund clinical research itself as it is currently constituted. However, some NCI networks (e.g., the Drug Resistance and Sensitivity Network [DRSN]) incorporate interactions with NCI-supported clinical trials networks into their activities to facilitate translation of results into clinical testing.

NCI could similarly provide supplements to CSBC awardees for the design of clinical trials of Consortium-generated hypotheses that could be carried out by NCI-supported cancer centers or clinical research networks such as the Experimental Therapeutics Clinical Trials Network (ETCTN), National Clinical Trials Network (NCTN), or the NCI Community Oncology Research Program (NCORP), potentially to validate predictive models (e.g., of metastasis, of drug treatment efficacy). Conversely, supplements could be provided to these clinical programs to encourage introduction of systems biology paradigms into their research activities. To this end, clinical researchers could be invited to propose problems in prediction that would engage CSBC investigators.

***Recommendation: NCI should create a supplemental mechanism that would facilitate collaboration between the CSBC and clinical researchers (e.g., in cancer centers and NCI-supported clinical research networks) both to advance CSBC-developed concepts toward clinical testing and to incorporate systems biology modeling and validation efforts into ongoing NCI-supported clinical research.***

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[4] "Dynamic, predictive models that provide a robust and actionable understanding of the effect of multiple biological interactions and/or incorporate multi-scale, spatial analysis over varying resolution scales to describe cancer initiation, progression and metastasis" and "*In silico* modeling to predict effective treatment."

### 3. Question 3: What is the role of CSBC in supporting a strong and stable research community?

Throughout conversations with investigators, graduate students, and post-doctoral researchers at these centers, the panelists identified "family trees of researchers," suggesting that CSBC is establishing a stable research community and training future generations of researchers in the field. However, the panel considered interconnectedness to be a critical component in the development of a strong community, which the panel did not observe to be sufficiently present across U54 centers and U01 projects.

Although CSBC U54 centers are organized around common themes in systems cancer biology research that can be organized to include "(a) the role of tumor heterogeneity and evolution in cancer; (b) biological mechanisms of therapeutic sensitivity and resistance; (c) tumor-immune interactions in cancer progression and treatment; (d) cell-cell interactions and complexities of the tumor microenvironment; and (e) systems analysis of metastatic disease,"[5] these themes are not explicitly solicited. The panel suggested that targeted research solicitations be used to focus the research community on a defined set of questions to increase the interconnectedness of the community and their data output. This will be important for the assembly of data resources that will be useful to the wider cancer research community.

***Recommendation: The panel recommends that U24 Collaboration and Pilot Projects Hub focus on a defined set of research questions to promote collaboration within the Consortium. One option would be to designate a percentage of pilot projects toward promoting new collaborations between Consortium awardees. Additionally, in a new FOA, consortia focused on specific systems questions such as the comprehensive understanding of a cancer process, the role of the tumor microenvironment in therapeutic response, or cellular mechanisms of therapeutic resistance within or between cancer types could be solicited.***

### 4. Question 4: Are the current funding mechanisms (U24, U54, and U01) appropriate to achieve the program goals?

The CSBC includes three types of awards, each using a different NIH activity code. The largest awards are the CSBC Research Centers, funded through the U54 Specialized Center – Cooperative Agreements activity code. These awards support interdisciplinary teams of investigators organized around a common theme intending to address fundamental cancer research questions. U54s include a minimum of 2–3 research projects; an administrative core that manages interactions with NCI and the Consortium as well as supports pilot projects; an outreach core that coordinates scientific outreach activities; working with the U24 Coordinating Center; and optional shared resource cores. The

[5] Dueck, H. and Hughes, S. Communication to Panel. June 22, 2020.



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Consortium supports research projects through the U01 Research Project – Cooperative Agreements activity code. These projects must comprise interdisciplinary teams explicitly constituted to conduct research that integrates experimental biology and computational modeling intended to test and validate novel hypotheses in cancer research. Finally, the Consortium includes a Coordinating Center funded through the U24 Resource-Related Research Projects – Cooperative Agreements activity code. The U24 supports a Resource Coordinating Hub that serves as a repository for curated datasets, models, and computational tools. The U24 also is intended to facilitate collaboration across the Consortium (through a Collaboration and Pilot Projects Hub) and to support an Outreach Hub intended to coordinate dissemination of research advances, working with the U54s' Outreach Cores. The paragraphs below assess the research and collaboration promotion aspects of the Consortium awards, while discussion of outreach and training activities are addressed in the response to Question 5.

The panel finds that the U54 CSBC Research Centers and U01 Research Project – Cooperative Agreements are appropriate mechanisms for pursuing large-scale systems biology research. The panel further finds that while the U24 Coordinating Center mechanism is appropriate to achieve the Consortium's goals of data sharing and collaboration formation, there are weaknesses in how it has operated. One concern noted by the panel is that data resources are not adequately organized and shared so that they can be used broadly by the field; there are many data centers and resources, but they are not well integrated. Moreover, the panel is concerned that in the current construction, resources are mainly useful to Consortium members. Additional information about recommendations to standardize, organize, and share data are identified in the panel's response to Question 2. The U24 should be doing more to ensure that data collected by breast cancer researchers that touch tumor microenvironment and tumor evolution, for example, are integrated. The CSBC could model efforts after the ENCODE Consortium.

***Recommendation: The panel recommends that the CSBC, operating through the U24 Resource Coordinating Hub, should develop standards for harmonizing and integrating data collected by CSBC members so that data sets become interoperable and more readily usable by CSBC members and other cancer researchers.***

A second concern noted by the panel is that the CSBC may not be fully inclusive—the Consortium structure carries the risk of hardening the formation of a relatively small cadre of experts that will prematurely define the field and thus could potentially enforce orthodoxies. There are many groups doing exceptional work in cancer systems biology that are not part of the CSBC but could help the existing Consortium expand its expertise. The panel finds need for a networked structure that brings in new members and allows incumbents to pass on the knowledge and the good work that the Consortium has been doing. Other NCI-supported networks, such as the DRSN, incorporate competitive supplements as a mechanism for fostering collaboration. Others, such as the Informatics

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Technology for Cancer Research (ITCR), continually solicit applications to bring new members into the Consortium program.

***Recommendation: NCI should create a competitive mechanism, whether supplements to Consortium awards, supplements to other NCI programs, or through an independent solicitation (e.g., R21 Exploratory/Developmental Research Grant Awards) to foster new collaborations between Consortium members and researchers conducting systems biology research not funded by the Consortium. A potential role for the core U54 centers would be to provide training to cooperating R21s so that these outside investigators can gain expertise in using these data resources.***

Finally, the panel discussed whether investigator-initiated systems biology research would best be reviewed by a standing study section devoted to the topic. The panel finds that it would not be appropriate to have a separate study section for systems biology research at this time. The panel noted that a single study section can actually reduce the total amount of resources for that discipline. Moreover, systems biology is not sufficiently distinct as a discipline to circumscribe an appropriate triaging strategy. Finally, there is a concern that a study section for cancer systems biology might encourage orthodoxy in an emerging field where there is a need for rapid evolution of new ways of problem solving. The continuation of the U54 mechanism in systems biology seems appropriate for the near future. It is also suggested that certain cancer study sections recruit systems biology investigators in the study sections to provide some expertise in the field and to encourage discussion and potential funding of new and innovative research approaches. Since creating a new study section is an NIH-wide decision rather than an NCI-specific one, the panel did not consider a recommendation for action by NCI to be necessary.

## 5. Question 5: Are there additional training and outreach activities that should be pursued to achieve program goals?

The CSBC's training and outreach activities vary across research institutions and support the education and professional development of current and prospective members of the field of cancer systems biology. Many CSBC research institutions have developed educational programs that aim to 1) engage the public and their local communities on science and cancer issues; 2) support young students interested in biology, cancer, and computing; and 3) sustain young and senior professionals ranging from the undergraduate to professional level in their research and professional development. Activities differ across research institutions in the Consortium, but many have developed programs and activities that a) offer hands-on education for high school and undergraduate students interested in systems biology, modeling, and oncology; b) provide research and training support for graduate and doctorate students; and c) support professionals interested in participating in workshops, conferences, trans-consortium collaborative projects, and public lectures.

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The panel finds that the CSBC's mechanism for training and outreach is well thought out, noting that current efforts to educate and train a range of audiences help to sustain the network and subsequently enable the field of systems biology. They also agree that the way in which the Consortium is handling its internal trainees is notable and demonstrates the Consortium's value for early career researchers.

However, the panel finds that the CSBC can work to improve training and outreach beyond the Consortium, namely by improving the dissemination of resources outside of traditional funding mechanisms (e.g., U54s). Specifically, the panel recommends the NCI create a training program that can engage researchers outside of the Consortium and train external researchers (of all career stages) in data and tools developed by the CSBC. This new training system could be modeled after the Jackson Laboratory's Human and Mammalian Genetics and Genomics course[6] and would facilitate the use of data and modeling across the Consortium and the larger biology community, rather than restricting use of CSBC resources to CSBC researchers. Additionally, R25 ("A Short Course in Cancer Systems Biology"[7]) and T32 ("Proteogenomics of Cancer Training Program"[8]) awards have been used to train researchers in cancer biology and bioinformatics-relevant topics, both of which could serve as models for future training programs.

***Recommendation: The panel recommends that the Consortium disseminate its resources more broadly outside of traditional funding mechanisms and develop a training system that encourages non-experts and individuals outside of the Consortium to use data resources developed by CSBC researchers.***

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6 The Jackson Laboratory. Human and Mammalian Genetics and Genomics course. https://www.jax.org/education-and-learning/education-calendar/2021/07-july/62nd-mckusick-short-course

7 Waterman Marian. A Short Course In Cancer Systems Biology.

8 Nesvizhskii, Alexey I. Proteogenomics of Cancer Training Program.

# Appendix A. Expert Panel Biographies

This appendix contains a short biography of each CSBC expert panelist.

## Edison T. Liu, Chair

Edison T. Liu, M.D. is the president and CEO of the Jackson Laboratory. From 1997–2001, Dr. Liu was the Scientific Director of the National Cancer Institute's Division of Clinical Sciences, where he led the intramural clinical translational science programs. He later went on to become the Founding Executive Director of the Genome Institute of Singapore from 2001–2011, and led the Human Genome Organization (HUGO) as president from 2007–2013. Dr. Liu is an international expert in cancer biology, genomics, human genetics, molecular epidemiology and translational medicine. His scientific research has focused on the functional genomics of breast cancers, uncovering new oncogenes, and deciphering the dynamics of gene regulation that modulate cancer biology. He has authored over 300 scientific papers and co-authored two books.

## Ken Buetow

Ken Buetow, Ph.D. is a human genetics and genomics researcher who leverages computational tools to understand complex traits such as cancer, liver disease, and obesity. He currently serves as Director of the Center for Evolution at Arizona State University (ASU), is a professor in the School of Life Sciences (SoLS) in ASU's College of Liberal Arts and Sciences, and Co-Director of the SoLS Computational Life Sciences Program. Dr. Buetow is also director of bioinformatics and data management for the National Biomarker Development Alliance. Dr. Buetow previously served as the Founding Director of the Center for Biomedical Informatics and Information Technology within the National Institutes of Health's National Cancer Institute.

## Teresa Przytycka

Teresa Przytycka, Ph.D. is a senior investigator in Computational Biology Branch at National Library of Medicine, NIH. She is developing novel algorithms for Computational and Systems Biology focusing on gene regulation, cancer network biology, and methods for analysis of new high throughput experimental data. She is specifically interested in the dynamic properties of biological systems including spatial, temporal and/or contextual variation, and how such variations impact gene expression, network topology, and organism phenotype. Dr. Przytycka is a recipient of the I.W. Killam Memorial Predoctoral

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Fellowship and the Sloan & U.S. Department of Energy Fellowship in Computational Biology. She serves as associate editor of several journals including PloS Computational Biology and Bioinformatics and is a member of the steering committee of the International Conference on Research in Computational Molecular Biology (RECOMB).

## John Quackenbush

John Quackenbush, Ph.D. is the Henry Pickering Walcott Professor of Computational Biology and Bioinformatics and Chair of the Department of Biostatistics at the Harvard T.H. Chan School of Public Health. Dr. Quackenbush's research involves developing integrative methods in computational and systems biology and their application to the study of human diseases, including cancer and pulmonary disease. He has long been an advocate of open science and reproducible research; among his honors is recognition in 2013 as a White House Open Science Champion of Change. In 2012, he founded Genospace, a precision medicine software company providing data platforms to hospitals, diagnostic testing labs, and other groups; the company was purchased by the Hospital Corporation of America in 2017. He serves on numerous advisory boards, including those of Merck KGaA, Caris Life Sciences, and RenalytixAI.

## Cynthia Reinhart-King

Cynthia Reinhart-King is a Cornelius Vanderbilt Professor of Engineering and the Director of Graduate Studies in Biomedical Engineering. Her research uses approaches from tissue engineering, biomaterials, cellular engineering, and mechanobiology to understand the role of the tissue microenvironment in disease with a focus on cancer metastasis, blood vessel growth, atherosclerosis, and diabetes. Dr. Reinhart-King is a fellow of the Biomedical Engineering Society and the American Institute for Medical and Biological Engineering, and she is a New Voices Fellow of the National Academies of Science, Engineering and Medicine. Dr. Reinhart-King is currently a standing member of the NIH Cellular and Molecular Technologies (CMT) study section panel and Secretary of the Biomedical Engineering Society. Dr. Reinhart-King has received the Rita Schaffer Young Investigator Award in 2010, the Mid-Career Award in 2018 from the Biomedical Engineering Society, an NSF CAREER Award, and the 2010 Sonny Yau '72 Excellence in Teaching Award.

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# Abbreviations

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| CSBC | Cancer Systems Biology Consortium |
| DRSN | Drug Resistance and Sensitivity Network |
| ENCODE | Encyclopedia of DNA Elements Consortium |
| ETCTN | Experimental Therapeutics Clinical Trials Network |
| FOA | Funding Opportunity Announcement |
| IDA | Institute for Defense Analyses |
| NCI | National Cancer Institute |
| NCORP | National Cancer Institute Community Oncology Research Program |
| NCTN | National Clinical Trials Network |
| NIH | National Institutes of Health |
| OSTP | Office of Science and Technology Policy |
| PAR | Program Announcement with Receipt/Referral and/or Review |
| RFA | Request for Application |
| STPI | Science and Technology Policy Institute |

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