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Using resources generated by the Seattle Structural Genomics Center for Infectious Disease (SSGCID) for training early career researchers

Julie V. Early,[a,b]* Craig L. Smith,[a,c]* Oluwatoyin A. Asojo[a,d]* and Peter J. Myler[a,b,e]*

[a]Seattle Structural Genomics Center for Infectious Diseases, Seattle, Washington, USA, [b]Center for Global Infectious Disease Research, Seattle Children's Research Institute, 1916 Boren Avenue, Seattle, WA 98101, USA, [c]Department of Biology, Washington University in St Louis School of Medicine, St Louis, MO 63114, USA, [d]Dartmouth Cancer Center, Dartmouth College, Lebanon, NH 03756, USA, and [e]Departments of Pediatrics, Biomedical Informatics and Medical Education, and Global Health, University of Washington, Seattle, WA 98195, USA. *Correspondence e-mail: julie.early@seattlechildrens.org, csmith22@wustl.edu, oluwatoyin.a.asojo@dartmouth.edu, peter.myler@seattlechildrens.org

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1. Introduction

This focused issue of *Acta Crystallographica Section F* entitled *Empowering education through structural genomics* contains 16 articles written by early career researchers, many of whom are undergraduates or high-school students. 15 of these were written using data provided by the Seattle Structural Genomics Center for Infectious Disease (SSGCID), a research consortium focused on determining the three-dimensional structures of targets important to infectious diseases (Stacy *et al.*, 2011). Since its inception in 2007, SSGCID has submitted over 1800 structures to the Protein Data Bank (PDB), but many of these structures lack a corresponding research article. A recent focus of SSGCID has been to use these data and materials as training tools for students to expand their research experience, as well as to develop better scientific writing and communication skills. We believe that the articles published in this focused issue demonstrate the success of this initiative in training the next generation of structural biology researchers.

2. Overview of SSGCID

Established in 2007, SSGCID is funded by a contract from the National Institute of Allergy and Infectious Diseases (NIAID) and currently includes scientists from the Seattle Children's Research Institute, the University of Washington, the University of Kansas, Washington State University, Dartmouth College and Washington University in St Louis. SSGCID operates a gene-to-structure pipeline and solves structures using X-ray crystallography, cryoEM and NMR. To date, SSGCID has worked on 15 853 unique targets, produced 13 690 clones, purified 4968 proteins and solved 1821 structures. SSGCID allows researchers to nominate new targets at https://targetstatus.ssgcid.org/CommunityRequest, and has so far accepted 10 821 target requests from 429 different researchers, leading to 1099 solved structures. In addition to its gene-to-structure pipeline, SSGCID applies structural biology expertise to various projects focused on determining the function of target proteins, developing preventative and therapeutic measures, and responding to outbreaks. SSGCID strives to be collaborative and shares all material and data that it generates with the research community. SSGCID has shared 2443 clones and 2398 proteins with external collaborators, at no charge other than shipping fees. SSGCID also provides protocols, models and structural biology advice to collaborators. All structures solved by SSGCID are deposited in the PDB, giving everyone in the scientific community unfettered access to the 3D shape of each target, as well as the underlying data. Finally, SSGCID has published 317 manuscripts describing 599 (33%) of the PDB structures solved by SSGCID.

3. SSGCID's training of early career researchers

Over the years, SSGCID has directly interacted with many early career researchers to provide training in structural biology by directly embedding them within the laboratories of consortium members. However, since the capacity for direct training is limited, SSGCID also works with educators who can leverage the SSGCID repository of clones,

proteins and structural data as teaching tools for students at various institutions. This gives early career researchers direct access to real-world materials and data, while also leading to more publications describing SSGCID structures. The process typically starts with a connection formed between SSGCID and an interested educator at an external institution. Once the connection is made, SSGCID and the educator select SSGCID targets according to mutually agreed-upon criteria (such as those with unpublished structures, unconstrained by legal agreements, without an active collaborator and/or unclaimed by others). Importantly, when the educator announces their intent to publish a manuscript, SSGCID places a hold on the target to ensure that no one else working at (or in collaboration with) SSGCID will write a manuscript describing the structure.

Most commonly, educators and students analyze structures already solved by SSGCID and write manuscripts describing the solved structure. For example, Dr Craig Smith at Washington University in St Louis developed 'Bio 4525: Structural Bioinformatics of Proteins', a Course-based Undergraduate Research Experience (CURE) where students work in groups and learn how to use structural biology software to analyze SSGCID structures. The students then draft a manuscript describing the structure, which is edited by the course instructor(s) to generate a final version for submission to a scientific journal. Importantly, this approach does not require access to a research laboratory (which is always in high demand), since SSGCID provides all of the data needed for writing the manuscript. Bio 4525 is currently taught in the Fall and Spring semesters and typically averages ∼18 students per semester. Three manuscripts in this focused issue were written by early career researchers in Bio 4525 (Agarwal *et al.*, 2025; Teng *et al.*, 2025; Baral *et al.*, 2025). Dr Krystle McLaughlin at Vassar College also runs a CURE where students analyze PDB structures generated by SSGCID. Early career researchers and undergraduates at Vassar College generated two publications for this focused issue (Nguyen, Fan *et al.*, 2025; Nguyen, Tramell *et al.*, 2025). In addition, early career researchers working with Dr Timothy J. Hagen at Northern Illinois University co-authored a publication based on multiple SSGCID structures in this issue (Grote *et al.*, 2025).

A publication in the focused issue (Belfon *et al.*, 2024) was generated by participants in the Molecular Interactions Virtual REU (MIV-REU), a ten-week NSF-funded virtual summer research experience for undergraduates. The three PIs, Dr Katherin Hicks (SUNY Cortland, New York), Dr Andrew Torelli (Ithaca College in Ithaca, New York) and Dr Jarrod French (University of Minnesota), worked with early career researchers from over 12 different institutions to co-author this manuscript with SSGCID.

During the COVID-19 pandemic, Dr Asojo at Hampton University ran several CUREs using SSGCID structures, allowing her to 'COVID-proof' her biochemistry research and generate several published manuscripts. As she prepared to transfer to Dartmouth in 2023, she recruited Dr Graham Chakafana, an Assistant Professor and protein chemist at Hampton University, to continue the CUREs. Early career researchers at Hampton co-authored three manuscripts in this focused issue with Drs Chakafana and Asojo (Bolling *et al.*, 2024; Chakafana *et al.*, 2024; Mendez *et al.*, 2025). Since leaving Hampton University, Dr Asojo has continued working with early career researchers (undergraduates) at Dartmouth, who authored two articles in this focus issue (Ayanlade *et al.*, 2025; Davis *et al.*, 2024) as part of their activities during their summer undergraduate research. Dr Asojo expanded virtual research experiences using SSGCID structures to include even younger early career researchers, as shown by the two manuscripts co-authored by high-school students (Kimble *et al.*, 2024; Srivastava *et al.*, 2024). She has also expanded the SSGCID collaboration globally to include early career researchers at Lagos State University, Nigeria (Ojuromi *et al.*, 2025).

Another approach (not illustrated in this focused issue) involves repeating all (or portions of) the gene-to-structure pipeline using materials provided by SSGCID. The educator requests the appropriate clones and/or proteins (from https://www.ssgcid.org/available-materials/) and, after processing a material transfer agreement, SSGCID provides the materials and protocols free of charge (except for shipping costs). This approach provides early career researchers from a wide variety of institutions access to hands-on structural biology learning opportunities (under the supervision of an educator) with a high probability of success, since they can use clones and/or proteins provided by SSGCID to proceed to the next step even if one step fails. The early career researchers then draft a manuscript describing the gene-to-structure process and analyzing the solved structure(s). They may also conduct additional biochemical, biophysical or other studies using SSGCID materials (Ran *et al.*, 2024). Educators who use this approach need a strong structural biology background and to be comfortable acting as a liaison between SSGCID and early career researchers. They must also provide research facilities to conduct any additional studies.

4. Impact on early career researchers at Hampton University

Access to SSGCID structural data has positively influenced the career trajectories of several early career researchers at Hampton University. Prior to 2020, students had limited opportunities for exposure to structural science research, since only about seven students could work in Dr Asojo's laboratory each year. However, during the shutdown caused by the COVID-19 pandemic, analysis of SSGCID structural data allowed 'virtual' biochemistry research for up to 27 early career researchers each academic year. This resulted in seven publications (Alenazi *et al.*, 2022; Beard, Subramanian *et al.*, 2022; Brooks *et al.*, 2022; Davidson *et al.*, 2022; Maddy *et al.*, 2022; Porter *et al.*, 2022; Beard, Bristol *et al.*, 2022), even before those in this focused issue. Co-authoring peer-reviewed manuscripts helped the students improve their confidence as scientists, and they all graduated with STEM degrees. Most of these early career researchers stayed in STEM or biomedical science, going on to graduate school at top research institu-

tions (such as Stanford, UCSF, UPenn, Vanderbilt, Johns Hopkins, Howard and Dartmouth), where several have already completed MS or MPH degrees. One has earned a PhD at UCSF, and another is an MD/PhD scholar at the University of Maryland. The number of Hampton University students conducting structural biology research during the academic year rose to over 100 in 2022 and remained at similar levels in 2023 and 2024. The transformative effect of collaborating with the SSGCID continues at Hampton University under the tutelage of Dr Chakafana.

5. Impact on early career researchers at Washington University

The collaboration with SSGCID has also had a transformative effect on early career researchers at Washington University in St Louis through Dr Smith's course, 'Bio 4525: Structural Bioinformatics of Proteins'. This CURE focuses on analyzing SSGCID-generated protein structures, and students prepare manuscripts for publication in peer-reviewed journals. Students consistently report that Bio 4525 provides valuable real-world research experience, with one student remarking that it was 'my favorite among all the classes that I have taken at WashU'. The course has had demonstrable impacts on the academic and career trajectories of numerous undergraduates. Multiple students have presented their work at regional and national conferences, and many Bio 4525 students have gone on to pursue postgraduate education (PhD, MD and MD/PhD) at the best universities in the country, producing work in high-impact journals (Varanese *et al.*, 2025). Student feedback highlights the value of working with authentic scientific data, with one student noting, 'I not only became more comfortable working with scientific literature, but also developed a variety of skills that I will use in my future career'. The problem-solving and analytical skills developed through structural analysis of SSGCID proteins are directly transferable to future scientific endeavors, empowering students to see careers in structural biology and related fields as viable options.

6. Win–win–win

This collaboration between SSGCID, educators and early career researchers represents a win–win–win for all three groups. Clones and proteins stored in the SSGCID's freezers are put to meaningful use, while educators can connect early career researchers with active researchers at SSGCID, fostering valuable mentorship opportunities. Early career researchers benefit by working with real-world materials and gaining hands-on experience that deepens their understanding of scientific research. They also learn how to write scientific manuscripts, contributing as co-authors to published work: an achievement that benefits the educators, their institutions and SSGCID alike. As a result, more SSGCID structures are published, students gain early exposure to the research process, and the entire scientific community benefits from this dynamic and productive partnership. We encourage other centers with large repositories of research materials or data to consider similar arrangements to broaden the participation and training of early career researchers in science.

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