The Value of Building an Interdisciplinary Scientific Workforce—A Call to Philanthropy

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INTERDISCIPLINARY SCIENCE DRIVES INNOVATION

Across our work at CSP, we routinely observe that at the point where two scientific fields must converge to advance ideas and solutions, systemic struggles make progress difficult. Scientific fields go far and go fast, using common language, designated funding sources, central convenings, and a sense of community. However, these same factors drive exclusion and prevent the incorporation of methods or advances from other research disciplines. While science has been going far, fast, societal advancement could go even further, faster, if researchers worked across disciplines to achieve common goals. Here we explore the benefits of interdisciplinary science and the ways private funders can incorporate specific initiatives, such as implementing research fellowships, to foster greater collaboration across scientific disciplines to address society's most complex issues.

What Is Interdisciplinary Science?

Science allows society to link seemingly isolated facts and findings into a comprehensive conceptualization of the world. The challenges that science strives to solve are increasingly complex, ranging from entrenched problems such as developing cures for cancer to emerging problems, such as the yet-to-be-discovered zoonotic diseases. These problems are usually multi-dimensional and thus require scientific study across disciplines. This approach is commonly referred to as **interdisciplinary research**, defined by the National Academies of Sciences, Engineering, and Medicine as research that "integrates information, data, techniques, tools, perspectives, concepts, and/or theories from two or more disciplines or bodies of specialized knowledge" to address a problem or improve our understanding of the world (National Academies of Sciences, Engineering, and Medicine 2005).

Over the past decade, the number of undergraduate science students participating in interdisciplinary studies has increased by 50 percent, from 34,000 in 2008 to 52,000 in 2018 (Digest of Education Statistics 2019). However, this proportion represents only 10 percent of the total STEM undergraduate population. Interdisciplinary degrees significantly decrease at the doctoral level, with only 850 degrees conferred in 2018 (Digest of Education Statistics 2019).

Real-World Problems Require Comprehensive Solutions

Scientists have identified the importance of integrating multiple disciplines as a strategy to solve the world's toughest problems. A 2015 special issue of Nature was dedicated to interdisciplinary research, emphasizing that complex, real-world problems, such as climate change and the development of new health treatments, can only be solved if scientists from multiple disciplines come together. Interdisciplinary research has led to entirely new fields of science and technology (*Nature News* 2015). For example, our modern understanding of genetics originated with the discovery of the structure of DNA by Francis Crick, a physicist and crystallographer, and James Watson, a biologist, with data from Rosalind Franklin, a chemist and crystallographer. In 1953, they decoded the structure of DNA and inferred how it functioned. Other examples from the past century include artificial intelligence, computer software engineering, immunotoxicology, nanotechnology, and spectroscopy.

Developing a novel medical drug or device also requires expertise from disparate disciplines. New drugs require biologists, chemists, and physicists to examine mechanisms underlying a disorder to identify what biological target might be contributing to a disease. Medicinal chemists develop compounds that can affect these mechanisms. Many other experts must work together to optimize drug delivery and clinical protocol.

For medical devices, engineers manufacture a physical device to engage the biological mechanism, often working with material scientists to identify or develop new materials with unique properties that are safe in humans. Surgeons are critical collaborators because they place the device in a patient and develop a clinical protocol. Finally, data scientists are typically involved throughout the process to analyze the considerable amounts of data.

Case Study Part 1:
Addressing the Challenges of Alzheimer's Research

The direct costs of treating Alzheimer's disease and related dementias will exceed $1 trillion in the United States alone within the next 30 years unless we find new treatments or change the way dementia care is currently delivered. In response to the growing crisis, CSP partnered with a family foundation to better understand the needs of the Alzheimer's research community and how its philanthropic resources could best be deployed to advance the field, resulting in the "Giving Smarter Guide" for Alzheimer's (Keller, Briggs, and Riley 2018).

One key barrier that we noted was the increasing availability of large health and biological datasets that were untapped in the exploration of Alzheimer's. Furthermore, we learned that the integration of data science and biology, more broadly, remained difficult to achieve because the educational trajectories were generally non-overlapping. However, data scientists play a crucial role in analyzing the complex interplay of biological, environmental, and social determinants that impact the risk, management, and progression of neurological diseases.

BARRIERS IMPEDING INTERDISCIPLINARY SCIENCE

Although there are well-known examples of interdisciplinary collaboration that have led to major advancements, overcoming barriers is never easy—a concerted effort from major stakeholders is required. These barriers include insufficient education and training programs, structural impediments to funding success, and the absence of established and supportive scientific communities (Bromham, Dinnage, and Hua 2016; Gill et al. 2015; Lyall et al. 2013; Tripp and Shortlidge 2019). Overcoming these barriers requires researchers, academic leadership, and government and private funders to change their approach.

Insufficient Education and Training

Scientific education at the graduate and undergraduate levels predominantly occurs within academic departments focused on a specific scientific discipline (for example, biochemistry or ecology). This structure clarifies the requirements for educational programs, undergraduate majors/minors, and graduation requirements. However, students report that the system also creates rigid curriculum requirements that prevent their participation in cross-department courses (Tripp and Shortlidge 2019). These structures persist throughout the research enterprise, creating cohesive disciplines where researchers work on common topics, publish in field-specific journals, and collaborate easily across institutions within their specific field. However, these structures contribute to bureaucratic constraints that prevent scientists from engaging in studies across disciplines, learning from adjacent fields, and sparking innovative thinking and collaboration that can propel whole communities forward (Gill et al. 2015; Tripp and Shortlidge 2019).

Inadequate Funding for Interdisciplinary Science

A vast majority of scientific funding undergoes rigorous peer review. Assessing and prioritizing proposed research projects to fund is notoriously difficult, and input from specific experts is required to evaluate the quality of proposed methods and hypotheses. The peer-review process has been routinely criticized for favoring dominant research and entrenched hypotheses over interdisciplinary work (Lyall et al. 2013; Tripp and Shortlidge 2019). Therefore, a preponderance of funding is rewarded to scientists with a long history in the field, and individuals newer to the discipline usually do not fare as well. This effect is so severe that research administrators have expressed concern that scientists are dissuaded from developing and submitting innovative research. In turn, the entire research enterprise stagnates (Bromham, Dinnage, and Hua 2016).

Lack of Community

A critical challenge to promoting interdisciplinary research is the lack of community required to support students, faculty, and staff who pursue interdisciplinary science (Gill et al. 2015). Researchers working across disciplines or at the border of a traditional discipline may not find peers who can discuss and challenge new hypotheses. Students co-mentored by faculty from two separate fields may lack a supportive network of peers with similar experiences or feel torn between the priorities of multiple mentors from different disciplines. In addition, scientific conferences that serve as a social and idea exchange platform are generally targeted to specific communities, decreasing the opportunity to attend, present, and network for students who may not fit into these traditional disciplines. The absence of physical and digital forums lead to a gap in collaboration, knowledge, and data shared within the science community.

Case Study Part 2:
Strengthening Alzheimer's Research via Interdisciplinary Science

Based on our landscape analysis of the Alzheimer's research community, we found that few programs could successfully retain and integrate data scientists in the Alzheimer's field. Identified challenges included disparities in compensation between communities, incentive structures that drive data scientists away from biological research, as well as insufficient community and training for interdisciplinary scientists. In partnership with a family foundation, CSP addressed these issues by developing a competitive training program that encapsulates learnings from other fields and incentivizes collaboration between PhD data scientists and neuroscientists.

PHILANTHROPIC OPPORTUNITY: FELLOWSHIPS FOR INTERDISCIPLINARY SCIENCE

Private funders can foster meaningful interdisciplinary science and fund fellowships as a mechanism to cross-pollinate novel methods and ideas.

What is a Research Fellowship?

Research fellowships are avenues for trainees to transition and integrate into new disciplines. With creative and flexible structures that allow new and varied opportunities for trainees, they are typically short-term, lasting from several months to a few years, and are focused on professional development and training. Programs range from undergraduate to postdoctoral levels and can be designed to support an array of studies or a specific topic to advance knowledge gaps within a field.

Benefits of a Research Fellowship

With a fellowship focused on interdisciplinary studies, early-career scientists can cross fields and access new knowledge and training (Jones 2010). The trainee can better advance their educational and professional goals and gain invaluable interdisciplinary research experience (Yarris, Jordan, and Coates 2016). Institutions also benefit from offering fellowships because they can be used as a tool to recruit and retain diverse candidates while building new communities on their campuses.

Receiving a fellowship is an honor and can increase the probability of receiving future federal funding (Picket 2019). In addition, the National Bureau of Economic Research reported that fellowships promote scientists' retention in the workforce pipeline (Heggeness et al. 2018). National Institutes of Health (NIH) fellowship recipients are awarded a larger percentage of NIH grants and represent an increasing fraction of faculty positions in academic research institutions (Picket 2019). Research fellowships can be an effective strategy to encourage scientists to join a field and build a career pipeline to help grow specific disciplines.

Key Components of Successful Interdisciplinary Fellowships

Based on discussions with fellowship directors, mentors, and trainees, we found that the drivers of success for an interdisciplinary fellowship rely on multiple components, which include the following:

1. **Cross-discipline co-mentorship** that balances time and effort among multiple mentors, which requires clear guidelines and expectations for mentors and fellowship recipients.

2. Facilitation of appropriate interdisciplinary **education and training** through mentorship and a range of courses, trainings, and professional development opportunities.

3. Creation of a **culture and community** that supports interdisciplinary work by providing physical and virtual resources and rewarding innovative research.

4. Hiring and rewarding **faculty who have experience in interdisciplinary science** to provide meaningful mentorship and guidance to trainees and can advocate to the department and university for additional support.

5. Development of **interdisciplinary career pipelines** in academia, government, industry, and other fields that align with the unique needs and talents of an interdisciplinary scientist.

Case Study Part 3:
A Bespoke Alzheimer's Data Science Fellowship

Building on its assessment of challenges facing interdisciplinary science, CSP identified best practices to design a postdoctoral fellowship program that promotes cross-institutional, cross-disciplinary research. To ensure that each fellow can receive the necessary scientific support, fellows and mentors will create a clear and focused training plan. In addition, the program is designed to create cohorts of fellows so that a community of like-minded scientists might form, fostering greater collaboration and belonging. Finally, the fellowship program will support institutional staff time to ensure that fellows have support in the exploration of career steps. In summary, the specific features of this program were developed to specifically promote interdisciplinary research between these communities.

INTERDISCIPLINARY FELLOWSHIP PROGRAM GOVERNANCE

By necessity, creating an interdisciplinary program requires a union of multiple communities and key stakeholders. Because priorities and incentives vary across scientific fields, programs at the nexus of disciplines must develop clear expectations that incentivize scientists to build partnerships with others outside of their areas. Philanthropic funders must carefully select partners that are capable of shepherding a vision of interdisciplinary science.

Partnership Selection

There are many ways to create fruitful partnerships between different disciplines through science fellowship programs. Fellowship programs that utilize the expertise of multiple departments or institutions could help funders to develop a program that best aligns with their scientific vision. Opportunities are as follows:

1. **Create Partnerships between Multiple Departments within One Institution**

   A fellowship program within one institution, such as a university or think tank, can encourage two centers or departments to better integrate their science, community, and culture. This option could allow research fellows to use laboratory resources, convene with experts, and attend seminars and classes from multiple departments. It is particularly beneficial because researchers are often in closer proximity and aligned in broader institutional priorities and culture.

   Example: Gladstone Institutes' four institutes frequently collaborate. External funding could support and facilitate further collaboration through a fellowship program that supports trainees who are jointly mentored from multiple centers.

2. **Build Partnerships between Multiple Institutions**

   Fellowships can involve multiple institutions that allow fellows to combine many types of expertise and methodologies and promote innovative thinking beyond the traditional boundaries of geography and discipline. With two or more partners, community can be built across a vast cross-disciplinary network.

   Example: The philanthropically-funded Weill Neurohub partnership created a vast multi-institutional network that includes the University of California (UC) San Francisco, UC Berkeley, and the University of Washington to accelerate the advancements in neuroscience.

3. **Promote Community Building through Scientific Associations**

Larger partnerships could be built by involving scientific associations or societies and various institutional collaborators. This type of partnership would expand the community element needed for interdisciplinary studies and streamline the integration of multiple disciplines across the globe. In addition, it could harness well-established science-specific communities, leverage their convening power to advance professional networks, and highlight the fellows' work through various annual meetings or conferences.

> **Example:** The American Association of Immunologists is a nonprofit scientific society that offers multiple grants, awards, fellowships, and educational programs to promote interdisciplinary research.

Assembling a Guiding Executive Committee

Engaging key cross-discipline stakeholders is vital to understanding and overcoming barriers. An executive committee composed of key decision makers from the relevant parts of the partner organizations and potentially the philanthropic funder is critical to driving programmatic progress. Additional executive committee members could include experts within collaborating disciplines and funding partners or external advisors that can aid in decision-making processes, milestone development, and the program's design.

Case Study Part 4:
Structuring the Alzheimer’s Data Science Fellowship

In partnership with a family foundation, CSP determined that a multi-organizational partnership would be the most fitting strategy to execute a data-science fellowship program focused on Alzheimer’s disease.

The partnership included a nonprofit research organization specializing in neuroscience and an academic institution department with an outstanding biomedical data science program. The partnership depends on the engagement of executive leaders and experts who collaborate to ensure that fellows can access the best resources and mentors across institutions. CSP continues to work with the family foundation to launch the Neuro-Data Science Fellowship Program in fall 2021.

CONCLUSION

The world has already seen glimpses of what is possible when experts from different fields come together. How much more discovery could be possible through the integration of different disciplines? Philanthropy could be the catalyst for that change.

Philanthropists, working with nonprofits and other sectors, can break barriers and promote scientific knowledge in various fields. Although changing a well-established single-discipline education and research system is complex, any movement forward requires dedicated support from funders and institutions to take a proactive, research-driven approach.

Interdisciplinary fellowships are just one way to promote cross-cutting scientific research that integrates multiple disciplines. Creating grant programs that target interdisciplinary science teams and funding existing graduate programs or departments that promote interdisciplinary research are other ways to support interdisciplinary thinking that can lead to innovative solutions to address the challenges of our world.

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