Fogarty International Center

Division of International Epidemiology & Population Studies (DIEPS)

PROGRAM EVALUATION

Conducted November 2022

NIH Fogarty International Center
Advancing Science for Global Health

Division of International Epidemiology and Population Studies (DIEPS)

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Conducted November 21, 2022

I. EXECUTIVE SUMMARY

Reviewers: David Franz, Wondwossen Gebreyes, Bryan Grenfell (chair), Lee Hall, Maureen Lichtveld, Judith Wasserheit

The process: The review committee assessed the status and future trajectory of the Fogarty International Center (FIC) Division of International Epidemiology and Population Studies (DIEPS), based on an extended videoconference with DIEPS and FIC staff and reading of associated background papers and bibliometric analyses. Groups of reviewers then drafted assessments of the four individual programs and recommendations for future directions in research, training, and outreach. Below, we summarize the overall results of the review and the reports and recommendations for individual programs and for DIEPS as a whole.

Summary: Overall, DIEPS is internationally recognized for punching above its small size in research, training, and outreach. The research history is particularly long for the epidemiological modeling group; the three other programs, however, also make powerful, distinctive, and valuable contributions to this picture.

The review committee found that the current combined trajectories of the DIEPS programs both justify their excellent reputation and reflect a vibrant and unique contribution to the overall mission of FIC. The committee also made suggestions of areas for future development. These recommendations are summarized below for each individual program, grouped under the following headings: research directions; program size and networking; training, especially in low- and middle-income countries (LMICs).

COMPUTATIONAL EPIDEMIOLOGY AND MODELING OF INFECTIOUS DISEASES GROUP (MODELING GROUP)

Since its inception, the Computational Epidemiology and Modeling of Infectious Diseases Group at DIEPS has developed around a small but world-class group of senior scientists and postdocs, often productively leveraging much wider collaborative networks (see individual reports). The committee were unanimous that the current modeling group, centering on Cecile Viboud and Kaiyuan Sun, is generating a remarkable body of innovative work and technical developments on important questions in infectious disease dynamics and global health.

As well as their focus on influenza epidemiology and burden, there are many other research highlights, notably:

- innovative use of big data for infectious disease surveillance and modelling;
- landmark modeling networks and hubs for Ebola and COVID-19 epidemic forecasting. Related to this work, the DIEPS modeling group has led an influential body of research on pandemic mortality burden estimation; and

- pivotal modeling studies of the population impacts of alternative COVID-19 vaccination policies.

These achievements derive both from work within the group and a history of extremely effective research network building, e.g., the Multinational Influenza Seasonal Mortality Study (MISMS) and Research and Policy for Infectious Disease Dynamics (RAPIDD) programs and the COVID-19 Scenario Modeling Hub. Extensive training efforts in LMICs (notably, respiratory virus epidemiological modeling for the Computational Epidemiology and Modeling of Infectious Diseases Group and pathogen genomics with the Genomic Epidemiology and Evolution of Pathogens group) have been highly successful.

Recommendations

As summarized below, the committee made several recommendations, focused on further increasing the modeling group's impact:

Research directions

- Considering the technical strengths, and potential impact of the modeling and other groups in DIEPS, there are several opportunities to expand the significance of their work in alignment with Fogarty's priority focus areas. These include modeling studies and related methods development and training that integrate data across the One Health and AMR domains of animal/vector/ environment health and epidemiology, the intersection of infectious disease, and climate change.
- Further integration of the modeling and genomics groups could also yield powerful results (below).
- These developments could be a very important asset in U.S. and LMIC efforts to not only manage endemic infections but also prevent and prepare for future pandemics. Additional expertise in modeling of economic and behavioral impacts would also enhance the policy relevance of the work of this group and would align well with Fogarty's emphasis on implementation science.

Program size and networking

The committee appreciated that these proposed extensions would require a significant increase in the group's resources, if the focus on their current core (and world-class) research is also to be maintained. Network building is one solution in which the group has already proven to be extremely successful. Most of these networks (MISMS, RAPIDD, efforts supported by the Bill & Melinda Gates Foundation, etc.) have not focused on intra-NIH collaboration. The committee very strongly recommended increased collaboration and networking within NIH (see detailed report below); this is especially timely given increasing appreciation of the significance of this small, but world-class group, as well as the increasingly high profile of modeling. Networking within NIH would not only increase resources but would also leverage local expertise for model refinement.

That said, networking is only part of the picture; the committee concluded that a modest increase in FIC funded researchers would be necessary for the group to reach its full potential.

Training (especially in LMICs) and outreach

These networking developments could also help expand the group's already excellent efforts in training. The committee also recommended that an expanded sabbatical scheme, especially for scientists from LMIC universities, could yield powerful results across the whole of DIEPS.

GENOMIC EPIDEMIOLOGY AND EVOLUTION OF PATHOGENS GROUP (GEEP)

The Genomic Epidemiology and Evolution of Pathogens unit focuses on application of state-of-the-art genomic (and other molecular) technologies to address emergence and evolution of pathogens that cause epidemics at the human-animal interface, as well as endemic infections of public health significance. Current efforts of the unit include addressing important questions on the origin, evolution and transmission dynamics of influenza A, coronaviruses, RSV, HIV, and rabies viruses. GEEP has also been successful in leveraging its small size by networking within and outside NIH, fundraising and driving highly successful pathogen genomics training in LMICs (in collaboration with the Modeling Group).

Recommendations

To further accelerate the impact of this unit, reviewers recommended that DIEPS and GEEP leaders develop a strategic plan for the next few years, outlining how GEEP will address priority infectious agents with specific goals and implementation tactics. This exercise will be particularly useful if there are possibilities for increasing resources for GEEP.

Research directions

- GEEP currently does important work on a relatively small group of important infections. Contingent on availability of sufficient resources, there were strong recommendations to apply the group's skills to a broader list of pathogens (bearing in mind the importance of balancing research breadth and depth).
- Another key area for development for the unit is further enhancement of its already close integration with the world-class DIEPS Modeling Group. Specifically, developing phylodynamic models, mechanistically integrating pathogen genetic and host immunological data, would be a powerful and distinctive research thread.

Program size and networking

- As part of a proposed strategic plan, it would be great to clarify how GEEP complements or creates synergy with other platforms with similar activities, such as the Chan Zuckerberg Biohub, Sanger Institute, and other similar efforts.

- As with the Modeling Group, however, networking is only part of the picture. The committee therefore concluded that a modest increase in FIC funded researchers and financial support would be necessary for the group to begin to address the phylodynamics of an expanded array of pathogens.

IMPLEMENTATION SCIENCE AND CLIMATE CHANGE GROUP

Given the magnitude of adverse effects of home generated air pollution globally, the impact of the Clean Cooking Implementation Science Network and Household Air Pollution Intervention Network has been significant. The implementation science component is the most promising to achieve sustained impact.

The design of the NIH Climate Change and Health research framework and the partnership, impressively co-chaired by Josh Rosenthal, is fertile ground for implementation once dedicated congressional funding becomes available. The lifespan and transdisciplinary approaches naturally foster partnerships across funding agencies, the research continuum, and developed and LMIC states alike.

Both these programs reflect impressive networking, within and outside NIH, by Dr. Rosenthal and colleagues.

Recommendations

Program size and networking.

These programs address very important trans-disciplinary problems. Though networking to support them has been very adroit and successful, more internal resources could put DIEPS/FIC in a pivotal position to advance these programs, especially as more funding becomes available for research related to health impacts of climate change. A significant scientist and staff expansion is needed to support a comprehensive climate and health program. DIEPS/ FIC's leadership is pivotal to demonstrating the disproportionate burden of climate change on population health in LMICs and to forge partnerships to counter this public health threat.

Training and outreach

- Impressive for the clean cooking network.
- With the right resources, the program and FIC could make significant contributions towards training in the climate and health field.
- Partnerships with academic institutions and professional organizations are critical to support research workforce development, both qualitatively and quantitatively.

POPULATION STUDIES AND BIORISK MANAGEMENT CAPACITY BUILDING IN PAKISTAN GROUP

The success of FIC's long-term program in Pakistan is a great example of the power of science and public health to positively impact the culture of an entire science enterprise in a geopolitically important country in south Asia.

Zeba Rasmussen's program in Pakistan differs from most of the other DIEPS programs in focusing less on primary research and more on training, mentoring, leader development, and personal engagement at all levels of government and academia. The combination of deep, long-term involvement and regular communication makes the approach particularly powerful.

Reviewers noted the distinctness of the Pakistan program as a strength in the overall DIEPS portfolio and as the foundation for more research-related work. They also concluded that the program was well and diversely funded of late and very successful in establishing networks for training in Pakistan and the U.S.

Recommendations

Quality and extent of training are the main criteria of success. Reviewers recommended the opportunity of involving more young researchers from the US in the current very successful network of interactions. While this model is wonderful, it would be best to scale out to other priority LMIC countries in other continents and show similar long-term success.

OVERALL CONTRIBUTION OF DIEPS TO FIC

There were a number of detailed comments on the fit of DIEPS to FIC's mission (see individual reports). Overall, the committee concluded that DIEPS fits the FIC strategy extremely well in terms of global training and mentoring. It also brings a unique research flavor, in terms of modeling and genomics.

A recurring theme was how the very high productivity and worldwide reputation of DIEPS belies its small core size. This is partly due to highly successful network building. Another recurrent theme within the comments was the need to garner further financial and intellectual resources by increasing these links even more, especially within NIH. Notwithstanding this, a second theme was that an increase in DIEPS' core funding could further increase its impact.

II. COMPUTATIONAL EPIDEMIOLOGY AND MODELING OF INFECTIOUS DISEASES GROUP

Reviewers: Bryan Grenfell, Judith Wasserheit, Lee Hall

GENERAL REVIEW

1. **Significance**: Has the program addressed important problems? Are the aims of the project(s) being achieved? Is scientific knowledge being advanced and are the projects affecting the concepts or methods that drive this field?

   An emphatic yes to all these questions. Since its inception, the Computational Epidemiology and Modeling of Infectious Diseases Group at DIEPS has revolved around a small but world-class group of senior scientists and postdoctoral fellows, often productively leveraging much wider collaborative networks (see below). The current modeling group centers on Cecile Viboud and Kaiyuan Sun: they are generating a remarkable body of innovative work and technical developments on important questions in infectious disease dynamics and global health.

   Highlights include:

   - Key publications in the *use of big data for infectious disease surveillance and modelling*, including a *JID* supplement (Dec 2016). The group has been a key player in a large collaborative assessment of digital epidemiology, combining novel and traditional surveillance data to clarify and predict epidemic dynamics. They have produced influential publications on digital epidemiology for emerging infections (Mejia et al., Gates Open, 2019 and Aiken et al., 2020), and its application to early detection of COVID-19 (Sun et al., 2020). They have also led detailed studies of the immuno-epidemiology of COVID-19 and its direct and indirect impacts on mortality in the United States, as well as (latterly) seasonal influenza, based on synthesizing models with unique longitudinal cohort data from South Africa.

   - Landmark *modeling networks and hubs for epidemic forecasting*. This began with an influential Ebola modeling challenge, based on innovative use of synthetic test data and driven largely by DIEPS. Based on this experience, they've also been key players in the COVID-19 Scenario Modeling Hub, wherein Dr. Viboud has been highly influential, rooted in her scientific expertise, status, and diplomatic skills. Related to this work, the DIEPS modeling group has led an influential body of research on pandemic mortality burden estimation.

   - Pivotal modeling studies of the *population impacts of alternative COVID-19 vaccination policies* including, most recently, for the reformulated bivalent booster, which informed ACIP and FDA decisions during the pandemic.

   In light of the technical strengths and potential impact of this group, there are several opportunities to expand the significance of their work in alignment with Fogarty's priority focus areas. These include modeling studies; related methods development and training that integrate data across the One Health domains of

animal/vector health and epidemiology; and environmental parameters, such as weather and climate, as well as human health. This could be a very important asset in U.S. and LMIC efforts to prevent and prepare for future pandemics. Additional expertise in modeling of economic impacts would also enhance the policy relevance of the work of this group and would align well with Fogarty's emphasis on implementation science.

2. **Innovation**: Do the projects employ novel concepts, approaches, or methods? Are the aims original and innovative? Do the projects challenge existing paradigms or develop new methodologies or technologies?

   Many highly innovative threads, as described above.

3. **Collaborations**: Is the program taking advantage of the special features of the NIH scientific environment, Fogarty's international network and the broader scientific community to initiate collaborative arrangements inside and outside of NIH?

   This question is usefully considered under two headings:

   - *Collaborations beyond NIH*. The modeling group has an enviable record here—arguably uniquely successful for its size. First, the MISMS Program, initially focused on analysis of the epidemiology and evolution of influenza both globally and regionally, has been highly successful both in primary research and analytical training in LMICs. Second, the NIH FIC/DHS RAPIDD Program was highly influential in the broader field of infectious disease dynamics research, as well as training and mentoring via the successful postdoctoral fellows' program. (Disclosure: Reviewer Grenfell was co-director of RAPIDD).

     With the establishment of CDC's Center for Forecasting and Outbreak Analytics April 2022, and WHO's Hub for Pandemic and Epidemic Intelligence (the WHO Pandemic Hub) in September 2021, there is both a tremendous opportunity and a pressing need for particularly strong collaborations with these two units. Such collaborations could reap significant mutual benefits for both research and capacity building efforts (such as the expansion of modeling hubs in LMICs), as was highlighted in proposed future directions for this group.

   - *Collaborations across NIH*. There are a number of fruitful links within NIH and an increasing appreciation of the significance of this small, but world-class group, given the current high profile of modeling. However, we suggest that it would be highly beneficial, both to FIC and potential NIH collaborators, if these links (and associated resources for the DIEPS group) were multiplied and strengthened. Future interactions might include the Office of Data Sciences and Emerging Technologies at NIAID as well as the Office of Genomics and Advanced Technologies in the Division of Microbiology & Infectious Diseases (DMID), NIAID. In addition, NIAID supports a number of intramural and extramural programs and networks that might also be sources of future collaborative efforts. These include the Africa Centers of Excellence in Bioinformatics and Data Intensive Sciences facilitated by the NIAID Office of Cyberinfrastructure and Computational Biology; the Biostatistics Research Branch and programs funded through the Division of Clinical Research; the International Centers of Excellence in Research supported by the Division of Intramural Research; and the Tropical Medicine Research Centers, the International Centers of Excellence in Malaria Research, the Centers for Research on Emerging Infectious Diseases Network, and the

Centers of Excellence for Influenza Research and Response, all supported by DMID.

4. **Productivity**: How would you rate the program's overall research productivity and outputs?

   World-class by any standard; especially powerful given their collaborative and network building skills.

5. **Training and Mentoring**: Is the investigator providing appropriate training and mentoring for more junior investigators and the outside community?

   An excellent record, both for the global community (MISMS, RAPIDD and recent genomics and modeling workshops, plus training of summer interns and post baccalaureate researchers). In the future, the development of funded sabbatical opportunities for faculty from U.S. and international (especially LMIC) universities could provide training and mentoring to early and mid-career investigators and increase collaborations while simultaneously offering the Computational Epidemiology and Modeling of Infectious Diseases Group additional human resources flexibility. Sabbatical options would likely be enthusiastically received by the academic global health community and consistent with the "hybrid intramural model" presented during the review.

6. **Support**: Is the support the program received appropriate?

   The Computational Epidemiology and Modeling of Infectious Diseases Group has been remarkably successful at creating and leveraging collaborative networks to punch above their weight in advancing the application of computational modeling to epidemic dynamics and global health. This record is based on modest core funding, mainly in terms of salaries. Though maintaining this level of core support would allow this excellent work to continue, a modest increase in the core budget could yield even more powerful contributions. For example, a number of suggestions were made by the panel for broadening the excellent impact of the group (for example to STIs, AMR, vector-transmitted infections); this could be exciting but might necessitate some increase in core support to expand leadership, domain skills and collaborative networks into novel areas. In addition, it is worth noting that various emerging areas of interest, e.g., the interaction between climate change and health, will require mathematical modeling to prospectively assess potential impact. Exploration of such topics could benefit from increases in core funding to encourage recruitment of appropriate talent and lay the foundation to inform future adaptation and implementation science.

OVERALL PORTFOLIO

For all reviewers these questions refer to your assessment of the division overall.

1. How well does the DIEPS portfolio fit with the goals of FIC?

As stated on its Website, the "Fogarty International Center is dedicated to advancing the mission of the National Institutes of Health (NIH) by supporting and facilitating global health research conducted by U.S. and international investigators, building partnerships between health research institutions in the U.S. and abroad, and training the next generation of scientists to address global health needs." The DIEPS portfolio fits extremely well with all aspects of the stated mission. Of particular note, DIEPS programs bring a unique integrative perspective and approach in terms of modeling and genomics. This intellectual framework and integrative approach are critical to addressing future anticipated needs (e.g., emerging, and re-emerging infectious diseases, pandemic preparedness, and climate change and health interactions) and will be critical over the long term to developing human and intellectual capital to address these challenges.

2. What are recommendations for future DIEPS activities? Do you see gaps in the relevant research landscape and how could DIEPS address these gaps?

   A number of new research directions were raised by the panel (e.g., for the modeling group: focusing again on AMR, broadening the range of infections considered, increasing the focus on the power of immune surveillance). As above, though these can partly be achieved by expanding collaborative networks, they might also require more core resources. An important aspect for DIEPS to consider in the future is how to build on its significant intellectual capital and assets to better position FIC, NIH, and the broader biomedical and public health research communities for future transdisciplinary approaches such as adaptation science and implementation science. The Hubs for Modeling and Outbreak Analysis may provide a framework for such an effort.

   The major focus of discussion was integrating many components of DIEPS still further. A particular recommendation here was much more focus of research effort and network building at the intersection of modeling, pathogen genomics, pandemic disease preparedness and response, and climate change. This is a major area of development in NIH and more broadly (as described by Josh Rosenthal), and is a key area to expand, both in terms of vital scientific applications and accrual of resources for DIEPS.

III. GENOMIC EPIDEMIOLOGY AND EVOLUTION OF PATHOGENS GROUP

Reviewers: Wondwossen Gebreyes, Judith Wasserheit

GENERAL REVIEW

1. **Significance**: Has the program addressed important problems? Are the aims of the project(s) being achieved? Is scientific knowledge being advanced and are the projects affecting the concepts or methods that drive this field?

   The Genomic Epidemiology and Evolution of Pathogens (GEEP) unit focuses on application of state-of-the-art molecular technologies to address emergence and evolution of pathogens that cause epidemics at the human-animal interface. As more than two-thirds of emerging infectious diseases in humans are of animal origin, the unit addresses very important global problems. In light of the COVID-19 pandemic and other (re)emerging pandemic threats, understanding strain dissemination across the planet is a crucial component of global epidemiologic tracking. Therefore, the work of this unit on genomic sequencing and phylodynamic analysis of SARS-CoV-2 strains and other viral pathogens is highly relevant with great potential to inform development of biomedical countermeasures and other aspects of national pandemic response efforts.

   Current efforts of the unit include addressing origins, evolution and transmission dynamics of influenza A, coronaviruses, RSV, HIV, and rabies viruses. These are all very important pathogens with high consequence across the world. As such, the focus of the unit has the potential for significant impact in helping to guide development of large-scale programs and policies. For example, a recent study of the origins and evolution of the four seasonal human coronaviruses demonstrated shared amino acid substitutions in multiple proteins along the spillover path from non-human to human hosts, suggesting that sentinel surveillance of non-human coronavirus hosts may be a useful adjunct to pandemic preparedness and control strategies for human populations.

   A clearly articulated strategy that lays out a coherent approach for prioritization of pathogens, partners and activities would be likely to focus this group's efforts and enhance and accelerate its impact. We recommend that DIEPS and GEEP leaders develop a *strategic plan* for the next three to five years, with measurable goals and objectives, and an implementation plan that complements and strengthens collaborations and synergies with other platforms with similar activities, such as the Chan Zuckerberg Biohub, Sanger Institute, and other similar efforts. This exercise will be particularly useful if there are possibilities for increasing resources for GEEP. Indeed, such a strategic planning exercise should explore opportunities to leverage GEEP expertise, resources, and partnerships to identify additional external funds from diverse sources.

2. **Innovation**: Do the projects employ novel concepts, approaches, or methods? Are the aims original and innovative? Do the projects challenge existing paradigms or develop new methodologies or technologies?

   Collaborative studies on genomic epidemiology and evolution of pathogens in LMICs using samples from the respective partner countries are, broadly speaking, original or somewhat innovative in nature. This is because the majority of LMICs do not have access to such technologies within their own national systems and depend on partnerships, such as with GEEP and many other global partners, including Chan Zuckerberg Biohub and Sanger Institute. Historically, work on infectious disease transmission dynamics and source tracking depended on phenotypic approaches or non-genomic based genotyping approaches (amplification, fragment analysis, etc.). As such, GEEP work, including the phylodynamic analysis conducted by the unit, advances genomic epidemiology in the LMIC contexts in which they are collaborating. The questions addressed in the publications, while often not highly innovative, are original and address important issues in neglected geographical contexts.

   A key potential focus for this unit and one that we feel should be seriously considered as part of its future strategy is to identify technological gaps through needs assessment and address them through development of new methods, and/or platforms for genomic analysis. While we do not advise repeating the same, we believe there is a global need to focus on LMICs and address specific bottlenecks within the GEEP portfolio. Especially considering the National Center for Biotechnology Information (NCBI) is a unit based within the NIH, as it is the case for GEEP, we advise collaborative work with NCBI in this area. Such an approach will allow the units to be globally recognized players in the field.

   Another important step for the unit is further development of its already close integration with the world-class DIEPS Modeling Group. Specifically, developing phylodynamic models that mechanistically integrate pathogen genetic and host immunological data would be a powerful and distinctive research thread.

3. **Collaborations**: Is the program taking advantage of the special features of the NIH scientific environment, Fogarty's international network and the broader scientific community to initiate collaborative arrangements inside and outside of NIH?

   It is highly commendable that the unit has been part of a global network such as the COV-IRT (COVID-19 International Research Team) and NIAID's Centers of Excellence for Influenza Research and Response (CEIRR), among others. In addition, the unit has been partnering with many U.S. universities and federal government agencies nationally, as well as interacting with several collaborating institutes internationally, including from Belgium, China, Ghana, Ivory Coast, Mexico, Nigeria, Pakistan, Portugal, and United Kingdom. It is advisable to strengthen partnerships with federal agencies with similar genomic activities (such as CDC's Applied Genomics and FDA's GenomeTrakr Network groups) and also the World Health Organization. Such partnerships have the potential to accelerate the impact of the unit.

The unit has also been successful in collaborative funding. We encourage continued momentum as the unit will undoubtedly need robust financial resources to grow and maximize its impact. In addition, the unit served as a collaborator on NIH funded grants, including R03s and R21s. We recommend that, in the future, the unit continue to provide its wonderful computational talent to partner with diverse collaborators in higher level projects beyond R21 (such as R01s, U01s, D43s) as well as other program and center grants.

4. **Productivity**: How would you rate the program's overall research productivity and outputs?

   The unit has shown substantial success in terms of publication outputs. The unit published articles on SARS-CoV-2 strain dissemination and comparative analyses between different continents in high impact factor journals. High impact publications in the areas of origins and evolutions of seasonal human coronaviruses are also notable.

   The unit also produced manuscripts as a result of their genomic epidemiology training program, including from their activities in Africa, broadly, as well as specifically in Pakistan, Ghana, and Nigeria. This is significant because of its dual impact in terms of training as well as broader impact through the publication of research findings.

5. **Training and Mentoring**: Is the investigator providing appropriate training and mentoring for more junior investigators and the outside community?

   The unit, while small in size, is composed of highly capable professionals at different stages of their career. The unit regularly conducts in-house trainings and hosts visiting scholars, as well as conducts virtual mentorship. The unit reported in-house training to eight undergraduate, one masters and two Ph.D. students which is an impressive, win-win model as the students learn while also contributing towards the impactful work of the unit. GEEP staff mentored more than 30 masters or Ph.D. graduates from LMICs.

   This team is also providing outstanding capacity building activities to diverse partners, particularly in LMICs. The main emphasis of their capacity building program is on real-time genomic surveillance and phylodynamic analysis of emerging infectious diseases for low-resource settings. They have utilized a three-step approach that addresses the needs of trainees with diverse levels of knowledge (beginner to advanced). The training they provide also involves genomic epidemiology for public health laboratories with potential for large scale, direct impact. In response to the COVID-19 pandemic, the unit provided training to more than 460 participants from 35 countries and 60 institutes across the world.

6. **Support**: Is the support the program received appropriate?

   With the limited information available to us in terms of support to the unit, it is difficult to comment. However, since genomic work remains costly and FICs mission and activities focus on LMICs where resources to conduct genomic analyses are very

limited, the GEEP unit needs significant financial resources to conduct robust and impactful work across the world. Besides project funding, it appears the staff size is also very limited. We believe FIC, through intramural or extramural funds, needs to invest in this unit to expand the staff size significantly, as resources allow. The current staff size will not enable DIEPS/ GEEP to be a major player globally nor to launch platforms and technologies to conduct robust and impactful activities recommended in other sections of this review.

OVERALL PORTFOLIO

For all reviewers these questions refer to your assessment of the division overall.

1. How well does the DIEPS portfolio fit with the goals of FIC?

   DIEPS plays a critical role in the success of the mission of Fogarty International Center (FIC). Critical emphasis areas of the division, including mathematical modelling and genomic evolution, are of utmost global significance. This is very much in line with the FIC mission. Further, the division also provides the critical component of research and training capacity building. That is another major area of DIEPS very much aligned with the mission of the FIC.

   Considering our planet is in the midst of the COVID-19 pandemic, and DIEPS, particularly the Modeling and GEEP units have done much globally significant work in understanding the transmission dynamics of the SARS-CoV-2 strains across the world, the division plays an important role at FIC and its research is highly aligned with the mission of FIC. We believe DIEPS is an integrally important division that adds luster to the FIC mission and is a great asset to the Center.

2. What are recommendations for future DIEPS activities? Do you see gaps in the relevant research landscape and how could DIEPS address these gaps?

   We live on a planet where the interdependence of human health, animal health, and the environment are more and more recognized. The division has already been focusing on some of the key zoonotic viral pathogens. As a future strategy, we strongly suggest that the division position itself as the One Health division serving FIC as well as other NIH institutes. This will allow it to attract diverse partnerships and sponsors.

   Considering the critical role that the division plays, we believe its funding portfolio will need to be diversified with a more robust engagement across many of the centers, such as NIAID and NCI. Finally, while we have limited depth of understanding of the budget, we believe investing in this division could be very important.

   The main gap we see is that the unit has been focused on very few pathogens despite the state-of-the-art technologic implementation for genomic epidemiology. The state-of-the-art tools used by the group can be implemented to study diverse sets of highly important pathogens beyond the viral (such as highly multi-drug resistant bacterial

pathogens, etc.). Therefore, efforts to expand engagement in diverse projects and to align collaborations with academia and other NIH institutes would be key.

IV. IMPLEMENTATION SCIENCE AND CLIMATE CHANGE AND HEALTH GROUP

Reviewers: Maureen Lichtveld, Wondwossen Gebreyes

GENERAL REVIEW

1. **Significance**: Has the program addressed important problems? Are the aims of the project(s) being achieved? Is scientific knowledge being advanced and are the projects affecting the concepts or methods that drive this field?

   The impact of the Clean Cooking Implementation Science Network and Household Air Pollution Intervention Network have been significant, given the magnitude of the problem globally. The implementation science component is the most promising component to achieve sustained impact.*

   The design of the NIH Climate Change and Health research framework and partnership, impressively co-chaired by Josh Rosenthal, is fertile ground for implementation once dedicated congressional funding becomes available. The lifespan and transdisciplinary approaches naturally foster partnerships across funding agencies, the research continuum, and developed and LMIC states, alike.*

   Of particular importance are the following:

   Clean cooking and indoor air pollution

   - Continue to advance in-country interventions through locally designed and executed implementation science informed interventions.
   - An enterprise evaluation strategy, rather than a program-specific logic model, may assist in targeting community-driven goals.
   - Implementation research should include examining the viability of tailored adaptation strategies.
   - While tailoring increases the likelihood for uptake, the dissemination of replicable findings globally is a critical component of program sustainability.
   - The most impactful change is advancing policy; implementation science focused on policy development, implementation, and evaluation can be an important growth area.

   Climate and health

   - The core elements of a transdisciplinary research framework, if supported in an integrated fashion, will result in transformative change both in the U.S. and above all in LMICs.*
   - Specifically elevating health equity, intervention research, and training and capacity building in tandem with health effects research bolsters the yield, relevance, and sustainability of the investment.*

- As mentioned earlier, partnerships in funding, design, and community engagement are pivotal success pillars.*
- The focus on resilience provides an opportunity to holistically build resilience, considering both physical resilience as well as factors influencing health and wellbeing such as the Social Determinants of Health (SDH) and health equity.
- The ad hoc approach of funding, awaiting a dedicated funding stream, is a challenging way to build a sustainable science and knowledge base globally, especially in LIMCs.

3. **Innovation**: Do the projects employ novel concepts, approaches, or methods? Are the aims original and innovative? Do the projects challenge existing paradigms or develop new methodologies or technologies?

   The unit has been driving innovative activities. The concentration on implementation science focused on sustainable impact is an important component of the innovativeness of the unit. As household air pollution is a critical public health problem in LMICs, the unit's focus on implementation science will hopefully garner impactful results and should be commended. Another innovative nature of the unit's approach is bringing in diverse scientific disciplines towards a common goal. As indicated in one of the hallmark publications (Rosenthal et al., 2017), they incorporate epidemiology, behavioral science, medical anthropology, economics, systems science, and implementation science together in their work in various LMICs in Africa and Asia. *Several elements are indicated with a * above*.

4. **Collaborations**: Is the program taking advantage of the special features of the NIH scientific environment, Fogarty's international network and the broader scientific community to initiate collaborative arrangements inside and outside of NIH?

   Clean cooking and indoor air pollution

   - The program is exemplary with respect to coordination across NIH, as well as extramural collaborations. The success of the program is positively influenced by this approach.
   - Evidence of great collaborative effort is the steering committee that the unit established in partnership with several NIH centers and institutes and other federal agencies . In addition to FIC, these include EPA, CDC, USAID, other NIH institutes (NIEHS, NCI, NICHD, NHBLI) and the Clean Cooking Alliance.

   Climate and health

   - Core to the framework design is a diverse, trans-NIH and extramural partnership.
   - Research funded through the initial NOSIs and other funding mechanisms should be closely examined to evaluate the role of these partnerships in advancing the climate and health science base.
   - Partnerships with academic institutions and professional organizations will be critical to support research workforce development, both qualitatively and quantitatively.

- The lack of a dedicated funding stream hampers progress. Hopefully this will be addressed soon.
- FIC must continue to play a leadership role in demonstrating the disproportionate burden of climate change on population health in LMICs and forge partnerships to counter this public health threat.

5. **Productivity**: How would you rate the program's overall research productivity and outputs?
   - Extremely productive, despite, in the case of climate and health, the lack of dedicated funding.
   - Sustained collaborations significantly influence this level of productivity.
6. **Training and Mentoring**: Is the investigator providing appropriate training and mentoring for more junior investigators and the outside community?
   - Within the limits of existing personnel (one lead scientist and a postdoc).
   - The unit has been actively engaging with LMICs and conducting capacity building and outreach activities. For instance, through its 32 projects, the Cleaning Cooking Implementation Science network conducted workshops across 15 LMICs.
7. **Support**: Is the support the program received appropriate?
   - Since dedicated funding (other than ad hoc funding from the NIH Common Fund and other ICs) is absent, this is the highest priority gap for the program, the division, FIC, and NIH as a whole.
   - A significant scientist and staff expansion is needed to support a comprehensive climate and health program.
   - The recent extramural ambassador program as well as cross assignments of FIC staff may temporarily alleviate this challenge.
   - The Cleaning Cooking Implementation Science garnered $4M from the NIH Common Fund between 2016 and 2021. While this is a good amount, considering the magnitude of the indoor cooking pollution problem across the world, significant financial support may be needed in the future.

OVERALL PORTFOLIO

For all reviewers these questions refer to your assessment of the division overall.

1. How well does the DIEPS portfolio fit with the goals of FIC?
   - Fits well as a research anchor for other divisions within FIC.
2. What are recommendations for future DIEPS activities? Do you see gaps in the relevant research landscape and how could DIEPS address these gaps?
   - Climate modeling efforts can build on the existing modeling portfolio in the division.

- Integration of programs within DIEPS can advance the resources available at the division level and particularly strengthen portfolios such as climate and health.
- Intra-FIC collaboration can synergize resources at the Institute level as well, especially in the areas of implementation research and data science.
- LMICs in the South American and Caribbean regions are geographic areas in need of research and research training support. While the challenges are of great magnitude and are often commensurate with the opportunity to advance the science base, the research and research training opportunities are sparse. Given the limited health system resources in these countries, predictive modeling of infectious diseases and climate effects of flooding and drought could help target efforts to where they are most needed.
- DIEPS—through its wonderful and complementary units, including the Health and Environment Implementation Science and Climate Change as well as the Genomic Epidemiology and Evolution of Pathogens unit—could position itself as the One Health division and leader at the NIH. This could help refine its strategy and align it with the growing need and emphasis of the One Health approach at the federal level, by the G7/ G20, and other global players. This is an opportune time for DIEPS to consider this suggestion.

V. POPULATION STUDIES AND BIORISK MANAGEMENT CAPACITY BUILDING IN PAKISTAN GROUP

Reviewers: David Franz, Lee Hall

GENERAL REVIEW

1. **Significance**: Has the program addressed important problems? Are the aims of the project(s) being achieved? Is scientific knowledge being advanced and are the projects affecting the concepts or methods that drive this field?

   The success of FIC's long-term program in Pakistan is a great example of the power of science and public health to positively impact the culture of an entire science enterprise. Pakistan is an important geopolitical country in south Asia and, currently, their alternative to the U.S. is China, which is actively engaging Pakistani students and scientists through 'belt and road', education support and other powerful initiatives. Therefore, it is critical that we, the U.S., and the free world, stay engaged.

2. **Innovation**: Do the projects employ novel concepts, approaches, or methods? Are the aims original and innovative? Do the projects challenge existing paradigms or develop new methodologies or technologies?

   Zeba Rasmussen's program in Pakistan appears to differ from most of the other DIEPS programs in that it involves more training, mentoring, leader development, and personal engagement at all levels of government and academia. Other FIC programs, obviously, also engage individuals, but the focus appears to be mostly on epidemiology and health impacts; the Pakistan Collaborative Program also includes a real focus on human-to-human solutions. Dr. Rasmussen's program activities, in a sense, may keep the division 'grounded' in the all-important activity of human engagement and trust-building.

   The approach has been to build trusted relationships initially with a few senior leaders in the Pakistan Academy of Sciences, the Armed Forces Institute of Pathology, the NIH, and academia broadly, and then to jointly develop policy supporting safety/security in labs, transparency, collaboration, and the promotion of trust and trustworthiness. As it has matured, the staff has emphasized education, training of trainers, and developing next-generation leaders who will be critically important to ensuring sustainability and momentum as the current leadership ages. Furthermore, it is relatively rare for a USG program to be led by someone with as much history and knowledge of the engaged country as Dr. Rasmussen has with Pakistan; this approach is powerful and should be considered innovative among USG models. The credibility she and her expert staff bring to the program is extremely effective and leveraging.

   The other theme that has made this program a success is regular communication between Pakistani scientists and FIC implementors. Too often, in engagement

programs, the contract-implementors engage while there is funding and then disengage when the contract ends. This has been a hard lesson for many U.S. programs. FIC has been able to remain engaged steadily for extended periods of time, and individuals continue to communicate even during periods of no or very limited funding. It is clear that FIC understands that time on target is critical for the sustainability and long-term impact of such programs.

3. **Collaborations**: Is the program taking advantage of the special features of the NIH scientific environment, Fogarty's international network and the broader scientific community to initiate collaborative arrangements inside and outside of NIH?

   The team has been able to leverage experts, including NIH scientists, from across the U.S. Tim Trevan and Sean Kaufman bring excellent leadership and collaboration skills, tools, and understanding to the effort. They arrange hour-long semi-free-ranging discussions between three to four students in Pakistan and a collaborating expert in the U.S.; it is a fun hour for the collaborator on this end and appears to be enjoyable and a learning experience for the Pakistanis as well. We suggest they try to include a mix of young and more experienced people from the U.S. side in these efforts where possible. If they do, they are not just training Pakistanis but also training American scientists. Moreover, such shared experiences are beneficial in broadening partnerships over the long run and ensuring sustainability.

4. **Productivity**: How would you rate the program's overall research productivity and outputs?

   Research productivity isn't necessarily the only or even the correct measure of this program. Safety, security, knowledge of laboratory activities, joint publications and relationships of trust would be better markers. While the focus of FCI's mission is not national security, it does contribute significantly, and Dr. Rasmussen's program in Pakistan is about as good as it gets because of time on target and powerful personal relationships which regularly result. It has been productive because it is focused on people, relationships, and trust. It is also focused on the needs of Pakistan rather than transient political fashions.

   The close link that they have established with the Pakistani Biosafety Association (PBSA) is a smart insurance policy and can act as an anchor for the critically important principles of biosafety, biosecurity, and risk assessment—and even traditional clinical laboratory excellence—after formal engagement wanes or ceases. The efforts conducted with the PBSA and the plans for the future are excellent, involving International Biosafety Committees (IBCs), Personnel Reliability Systems, ISO for human and veterinary labs, responsible conduct in genomic sciences and informatics. For some counterintuitive, but effective, reason, the program has introduced the value of guidelines and sound leadership close to the bench rather than traditional box checking regulations from a bureaucracy that are often an unnecessary drag on the enterprise.

5. **Training and Mentoring**: Is the investigator providing appropriate training and mentoring for more junior investigators and the outside community?

   Training and mentoring, along with and related to building leaders, are the focus of the program at this stage of development. Training continues enthusiastically e and is ongoing at a more mature level than one might expect from a country like Pakistan. The Institutional Biosafety Committees (IBCs) (focused on 18 key universities) which have been established, are said, by Philippe Stroot, to be "at least as good and functional as the ones we have in our countries." Even the relatively new *WHO Risk Assessment* training package has been incorporated. This is not what the average outsider would expect from Pakistan. From 2014 to 2019, nearly 1000 scientists from 80 cities and 342 institutions have been trained, with a focus on regional leaders. That's the right thing to do.

6. **Support**: Is the support the program received appropriate?

   The support for the Pakistani program, generally, appears to have been fairly good, but they must continue to lay the groundwork for continued support and more funding.

OVERALL PORTFOLIO

For all reviewers these questions refer to your assessment of the division overall.

1. How well does the DIEPS portfolio fit with the goals of FIC?

   The epidemiology and modeling of infectious disease, population studies, and influenza work appear to be a good fit. The clean cooking and household air pollution appear to be 'next generation' epidemiologic studies that also fit under the overall support for global health research. It is also important, however, to recognize that part of FIC's mission is to "build partnerships" and train "the next generation of scientists to address global health needs." The work in Pakistan addresses these aspects of the FIC mission very well, while simultaneously serving as a foundation for more research-related work in both the near-term and long-term.

2. What are recommendations for future DIEPS activities? Do you see gaps in the relevant research landscape and how could DIEPS address these gaps?

   If it's not currently a focused effort, FIC might consider introducing more young people to the projects, both from the U.S. and from the engaged country, wherever possible. Note, however, that the Pakistanis have always included large numbers of young people in meetings and projects. We could do better on our end. Current generations move on quickly; it's important that we constantly think about mentoring, exposing, and introducing the next generation to these programs.

   Sticking with a focus on epidemiology, but not getting sucked into fixing all the problems described by it, seems the right strategic approach for this small division. There will be other government and non-government agencies which can be

influenced by the good work of DIEPS, helping them understand the problems so that they, with more and different resources, can then attempt to remedy them.

Given the potential public health threats that may arise from climate change and the recent experience with both devastating flooding and associated increases in dengue, Pakistan may represent an opportunity for future engagement in better understanding, assessing, mitigating, and managing the health risks and impacts associated with climate change. It may be possible to capitalize on the Pakistan program's track record of training and trust building to accelerate efforts to inform transdisciplinary initiatives in adaptation science and implementation science linked to climate change and health.

VI. EVALUATION COMMITTEE

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